SEDAR
Southeast Data, Assessment, and Review

SEDAR 46
Stock Assessment Report

Caribbean Data-Limited Species

April 2016

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

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Southeast Data, Assessment, and Review

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U.S. Caribbean Data-limited Species

SECTION I: Introduction

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EXECUTIVE SUMMARY

SEDAR 46 addressed the stock assessments of six U.S. Caribbean data-limited species using data-limited techniques. Those species were: yellowtail snapper and hogfish from Puerto Rico, spiny lobster and queen triggerfish from St. Thomas, and spiny lobster and stoplight parrotfish from St. Croix. One in-person workshop was held November 2-6, 2015 in San Juan, Puerto Rico. During that workshop a review of the available data for 36 species was conducted, and the Panel selected the six species listed above for further analysis. In addition to the in-person workshop, two webinars were held to complete the assessment. The Review Workshop took place February 22-25, 2016 in Miami, FL.

The Stock Assessment Report is organized into 5 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/Assessment Workshop Report can be found in Section II. It documents the discussions and data recommendations from the in-person Workshop Panel. This section also details the assessment model. Consolidated Research Recommendations from all three stages of the process (data, assessment, and review) can be found in Section III for easy reference. Section IV documents the discussions and findings of the Review Workshop (RW). Finally, Section V– Addenda and Post-Review Workshop Documentation consists of any analyses conducted during or after the RW to address reviewer concerns or requests. It may also contain documentation of the final RW-recommended base model, should it differ from the model put forward in the Assessment Report for review.

The final Stock Assessment Reports (SAR) for Caribbean Data-limited Species was disseminated to the public in April 2016. The Council's Scientific and Statistical Committee (SSC) will review the SAR for these stocks. 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 Fishery Management Council's SSC will review the assessment at its April 2016 meeting, followed by the Council receiving that information at its June 2016 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 of Mexico, 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

Summary of Management History for the Fishery Management Plan (FMP) for the Corals and Reef Associated Plants and Invertebrates of Puerto Rico and the U.S. Virgin Islands (USVI) (Coral FMP)

The following table summarizes actions in the Coral FMP and each of the amendments to the Coral FMP, as well as some events not covered in amendment actions. Not all details are included in the table. Please refer to the Proposed and Final Rules to obtain more information.

Fishery Management Plan or Amendment	Effective Date	Proposed Rule (PR) Final Rule (FR)	Major Actions
Coral FMP (1994)	Effective 12/27/1995, except for §670.23(b) (Restrictions on sale or purchase), which became effective 3/1/1996	PR: 60 FR 46806 FR: 60 FR 58221	- Prohibited the take or possession, whether dead or alive, of gorgonians, stony corals, and any species in the fishery management unit (FMU) if attached or existing upon live rock; - Prohibited the sale or possession of any prohibited coral unless fully documented as to point of origin; - Prohibited the use of chemicals, plants, or plant-derived toxins, and explosives to take species in the coral FMU; - Required that dip nets, slurp guns, hands, and other non-habitat destructive gear types be used to harvest allowable corals; - Required that harvesters of allowable corals obtain a permit from the local or federal government; - Framework measures allowed NMFS Southeast Regional Administrator (RA) to modify management measures, including the establishment of marine conservation districts, changes to the list of prohibited species, changes to the FMU, harvest limitations, including quotas, trip or daily landing limits, and gear restrictions.
Amendment #1 to the Coral FMP establishing a Marine Conservation District (MCD) (1999)	12/6/1999	PR: 64 FR 42068 FR: 64 FR 60132	Established a no-take MCD in the U.S. exclusive economic zone (EEZ) southwest of St. Thomas, USVI, including: - No anchoring by fishing vessels, no fishing of any kind (including no bottom fishing and no spear fishing), and no removal of any organism in the MCD (including, but not limited to, those organisms listed in the FMUs of the Coral FMP, Reef Fish FMP, Queen Conch FMP, and Spiny Lobster FMP). - Scientific research would be allowed as long as it fits under the proper definition and guidance of "scientific research" under the Magnuson Stevens

Fishery Management Plan or Amendment	Effective Date	Proposed Rule (PR) Final Rule (FR)	Major Actions
			Act.
Amendment #2 to the Coral FMP (2005) (Part of the Caribbean Sustainable Fisheries Act Amendment)	11/28/2005	PR: 70 FR 53979 FR: 70 FR 62073	- Moved the aquarium trade species in both the Reef Fish and Coral FMPs into a 'data collection only' category. Inclusion in the data collection only category resulted in no specification of maximum sustainable yield (MSY), optimum yield (OY), or other stock status determination criteria (i.e., fishing mortality, biomass, minimum stock size threshold, maximum fishing mortality threshold) for these species due to no real need for federal conservation and management of these species. Consequently, existing regulations defining a marine aquarium fish as "a Caribbean reef fish that is smaller than 5.5 inches (14.0 cm) total length" and restricting the harvest of a marine aquarium fish to hand-held dip nets or hand-held slurp guns (50 CFR 622.41§(b)) were eliminated. - Described and identified essential fish habitat (EFH) according to functional relationships between life history stages of federally managed species and Caribbean marine and estuarine habitats. The EFH for the coral fishery in the U.S. Caribbean consists of all waters from mean low water to the outer boundary of the EEZ – habitats used by larvae – and coral and hard bottom substrates from mean low water to 100 fathoms depth – used by other life stages.
Amendment #3 to the Coral FMP (2011) (Part of the 2011	1/30/2012	PR: 76 FR 68711 FR: 76 FR 82414	- Established management reference points, ACLs, and accountability measures (AMs) for species in the Coral FMP, including aquarium trade species, which were not determined to be undergoing overfishing. The ACL for

Fishery Management Plan or Amendment	Effective Date	Proposed Rule (PR) Final Rule (FR)	Major Actions
Caribbean Annual Catch Limit [ACL] Amendment)			aquarium trade species is a U.S. Caribbean-wide ACL. The U.S. Caribbean-wide ACL for the aquarium trade species was established using landings data from the Puerto Rico commercial and recreational sectors. - Established framework measures for species in the Coral FMP.
Amendment #4 to the Coral FMP: Seagrass Management (2013)	7/5/2013	PR: 78 FR 14503 FR: 78 FR 33255	- Removed seagrass species from the Coral FMP as there was no known targeted or indirect harvest of any seagrass species from the EEZ or from Puerto Rico or USVI state waters, and future harvest was not anticipated.

3 ASSESSMENT HISTORY AND REVIEW

Previous stock assessments of US Caribbean resources have attempted to quantify stock status and condition using traditional stock assessment procedures (e.g., yield per recruit (YPR), stock production analyses (ASPIC), catch curve analyses, length frequency examinations). Table X. presents summary information on historical stock assessments of the six species island units evaluated in SEDAR 46. However, nearly all of these evaluations have resulted in an unsatisfactory determation of stock status due to the lack of sufficient data with which to parameterize the models. The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), National Standard 1 (NSA) Guidelines require that “conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry (Section 301(a)(1)”. This mandate led to the establishment of annual catch limits (ACLs) by 2010 for all “stocks in the fishery”, including data-limited stocks.

In the absence of sufficient information to conduct traditional stock assessments, managers have implemented various procedures such as scalars of landings history (e.g., median catch, Carruthers et al. 2014) or Only Reliable Catch Series [ORCS] (Berkson et al. 2011). In light of the challenges imposed in using traditional fisheries models to assess US Caribbean data-limited stocks, the SEDAR 46 stock evaluation explored the use of a data-limited modeling framework to provide management advice for US Caribbean resources. The intent was to explore the use of multiple data-limited models in an analytical framework that would provide an objective comparison across a variety of methods and provide diagnostics that could be used to compare performance.

Table 1. Summary of previous stock assessments of US Caribbean resources for selected species.

Species unit assessed	**Assessment method**	**Assessment reference**
Puerto Rico hogfish dive fishery	• NA	None
Puerto Rico yellowtail snapper handline fishery	• CPUE trends, examination of changes in length frequency • Length frequency analyses	SEDAR (2005b) Appeldoorn et al. (1992)
St. Thomas queen triggerfish trap fishery	• Length frequency analysis from the pot and trap fishery (Puerto Rico), Gedamke - Hoenig mean length estimator	SEDAR (2013)
St. Thomas spiny lobster trap fishery	• Stock production model, CPUE examinations, yield per recruit • CPUE and landings trends • Landings and length frequency • CPUE	SEDAR (2005a) Matos-Caraballo (1999) Bolden (2001) Bohnsack et al. (1991)
St. Croix spiny lobster dive fishery	• Stock production model, CPUE examinations, yield per recruit • CPUE and landings trends • Landings and length frequency • Production model • CPUE	SEDAR (2005a) Matos-Caraballo (1999) Bolden (2001) Mateo and Tobias (2002) Bohnsack et al. (1991)
St. Croix stoplight parrotfish trap fishery	• NA	None

Southeast Data Assessment and Review (SEDAR). 2005a. SEDAR 08 Stock Assessment Report, Caribbean Spiny Lobster. SEDAR, North Charleston, SC. Available from http://sedarweb.org/docs/sar/S8SAR2_CaribLobFinal.pdf

Southeast Data Assessment and Review (SEDAR). 2005b. SEDAR 08 Stock Assessment Report, Caribbean Yellowtail Snapper. SEDAR, North Charleston, SC. Available from http://sedarweb.org/docs/sar/S8SAR1_CaribYTSfinal.pdf

Appeldoorn, R. S., Beets, J., Bohnsack, J., Bolden, S., Matos, D., Meyers, S., Rosario, A., Sadovy, Y., and Tobias, W. 1992. Shallow water reef fish stock assessment for the US Caribbean, volume 304. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center.

Southeast Data Assessment and Review (SEDAR). 2013. SEDAR 30 stock assessment report, US Caribbean Queen Triggerfish. SEDAR, North Charleston, SC. Available from http://sedarweb.org/docs/sar/S30_Queen_trigger_SAR.pdf

Bolden, S. 2001. Status of the US Caribbean spiny lobster fishery 1980–1999. NOAA/SEFSC Lab. Contrib. No. PRD-99/00-17

Bohnsack, J., Meyers, S., Appledoorn, R., Beets, J., Matos-Caraballo, D., and Sadovy, Y. 1991. Stock assessment of spiny lobster, *Panulirus argus*, in the United States Caribbean. Miami Laboratory Contribution No. MIA-9C91-49, National Marine Fisheries Service, Southeast Fisheries Science Center

Matos-Caraballo, D. 1999. Comparison of Size of Capture by Gear and by Sex of Spiny Lobster (*Panulirus argus*) during 1989–91. Proceedings of the Gulf and Caribbean Fisheries Institute 45: 809–820

4 REGIONAL MAPS

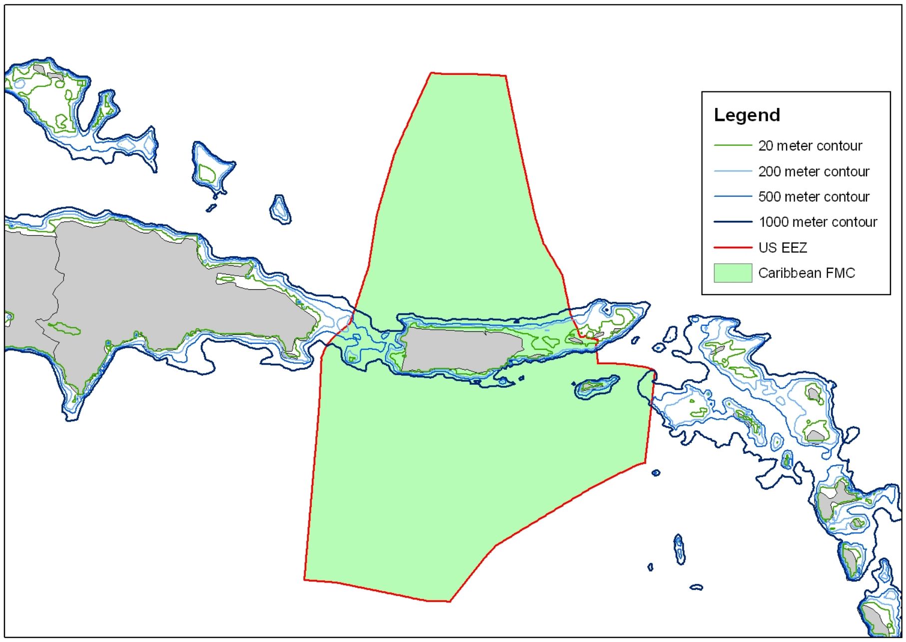

Figure 4.1 Caribbean management region including Council and EEZ Boundaries.

5 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
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
BAM	Beaufort Assessment Model
BMSY	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FMSY	fishing mortality to produce MSY under equilibrium conditions
FOY	fishing mortality rate to produce Optimum Yield under equilibrium
FXX% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
FMAX	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) 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)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources

MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey
MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a 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
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
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	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

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Southeast Data, Assessment, and Review

SEDAR 46

U.S. Caribbean Data-Limited Species

SECTION II: Data and Assessment Workshop Report

February 2016

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1. Workshop Proceedings

1.1 Introduction

1.1.1 Workshop time and place

The SEDAR 46 Caribbean data-limited species data/assessment workshop was held November 2-6, 2015 in San Juan, Puerto Rico. In addition to the workshop, several additional webinars were conducted between December 2015 and January 2016 to finalize the assessment.

1.1.2 Terms of reference

i. Review the results of the Data Triage conducted by the SEFSC, documenting available data sources for US Caribbean species managed by the Caribbean Fishery Management Council.
ii. Discuss and recommend which species have data suitable for evaluation using data-limited stock assessment modeling techniques.
iii. Apply various data-limited modeling techniques, as appropriate, to the recommended species in order to provide management advice.
iv. Prepare Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines.

1.1.3 List of participants

Workshop Panel

Nancie Cummings (co-lead analyst)	NMFS Miami
Skyler Sagarese (co-lead analyst)	NMFS Miami
Richard Appeldoorn	SSC/UPRM
Bill Arnold	NOAA SERO
Jonathan Brown	DPNR – St. Thomas
Daniel Matos Caraballo	PR DNER
Tom Carruthers	UBC
Shannon Cass-Calay	NMFS Miami
Jorge Garcia- Sais	SSC/UPRM
Eric Hoffmayer	NMFS Pascagoula
Walter Ingram	NFS Pascagoula
Michael Larkin	NOAA SERO
Winston Ledee	Industry Representative - St. Thomas
Vivian Matter	NMFS Miami
Kevin McCarthy	NMFS Miami
Noemi Peña	PR DNER-FRL
Adyan Rios	NMFS Miami
Aida Rosario	PR DNER
Michelle Scharer	University of Puerto Rico
Roberto Silva	DAP Puerto Rico
William Tobias	STX-DAP

Attendees

Molly Adams	RSMAS
Helena Antoun	CFMC-DNER
Carlos Farchette	CFMC
Bill Hartford	NMFS Miami
John Hoenig	VIMS
Quang Huynh	VIMS
Yasmin Velez-Sancher	Pew Charitable Trust
Edgardo Ojeda Serrano	PR Sea Grant
Nathan Vanghan	RSMAS

Staff

Julie Neer	SEDAR
Iris Oliveras	CFMC
Graciela Garcia-Moliner	CFMC

Additional Participants via Webinars

Jerry Ault	RSMAS
Meaghan Bryan	NMFS Miami
Josh Bennet	NMFS Miami
Dave Gloeckner	NMFS Miami
Clay Porch	NMFS Miami
Steve Turner	NMFS Miami

1.1.4 List of assessment workshop working papers

Document #	Title	Authors	Date Submitted
Documents Prepared for the SEDAR 46 Data and Assessment Workshop			
SEDAR46-WP-01	A comparison of data-rich versus data-limited methods in estimating overfishing limits	Skyler R. Sagarese, John F. Walter, J. Jeffery Isely, Meaghan D. Bryan, Nancie Cummings	19 Oct 2015
SEDAR46-WP-02	Enhancing tools for data-limited management strategy evaluation within the South Atlantic, Gulf of Mexico, and U.S. Caribbean: An introduction	Skyler Sagarese, William Harford, Mandy Karnauskas, John F. Walter, Elizabeth A. Babcock, Nancie J. Cummings, Meaghan Bryan, Shannon Calay	19 Oct 2015
SEDAR46-WP-03	Probabilistic assessment of fishery status using data-limited methods	William Harford, Meaghan Bryan, Elizabeth A. Babcock	16 Oct 2015
SEDAR46-WP-04	Overfishing limits (OFLs) for Greater Amberjack from the Stock Synthesis (SS) population model and from several data limited methods with a preliminary	Nancie Cummings and Skyler R. Sagarese	26 Oct 2015

	review of varying assumptions on natural mortality and current abundance on OFL results		
SEDAR46-WP-05	Summary of the Trip Interview Program data from the US Caribbean	Meaghan D. Bryan	29 Oct 2015
SEDAR46-WP-06	A summary of commercial fishing reporting compliance for Puerto Rico and the U.S. Virgin Islands for calendar years 2013 and 2014	Josh Bennett	3 Nov 2015
SEDAR46-WP-07	Recreational Survey Data for Puerto Rico from the Marine Recreational Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP)	Vivian M. Matter	4 Feb 2016
Reference Documents			
SEDAR46-RD01	Fisheries Technical Workshop #1: “Length-Based Stock Assessment of Puerto Rico Reef Fishes & Computer-based Tools Laboratory”	Jerald S. Ault, Steven G. Smith, Nathan R. Vaughan, Marc O. Nadon, Natalia Zurcher	
SEDAR46-RD02	Fisheries Technical Workshop #1 and #2 “Length-Based Stock Assessment of Puerto Rico Reef Fishes & Computer-based Tools Laboratory” and Fisheries Technical Workshop #3 “Building Fisheries Information Systems for Sustaining Coral Reef Fisheries of Puerto Rico	Jerald S. Ault, Steven G. Smith, Nathan R. Vaughan, Natalia Zurcher	
SEDAR46-RD03	Report of the U.S. Caribbean Fishery-Independent Survey Workshop	Shannon L. Cass-Calay, William S. Arnold, Meaghan Bryan, Jennifer Schull	

1.2 Panel recommendations and comment on terms of reference

1.2.1 Term of Reference 1

Review the results of the Data Triage conducted by the SEFSC, documenting available data sources for US Caribbean species managed by the Caribbean Fishery Management Council.

Section 2, Data Review, documents the data sources that were available for the SEDAR 46 US Caribbean stock evaluation. The data reviewed included life history information (Section 2.2), fishery statistics (Section 2.3), measures of catch per unit effort (Section 2.4), measures of fishing effort (Section 2.5), and length frequency data (Section 2.6). An overview at the beginning of each subsection summarizes the data recommended for use in SEDAR 46 (Sections 2.2.1, 2.3.1, 2.4.1, 2.5.1, and 2.6.1).

Research recommendations for improving the available data are included at the end of each subsection (Sections 2.2.4, 2.3.5, 2.4.4, 2.5.5, and 2.6.2).

1.2.2 Term of Reference 2

Discuss and recommend which species have data suitable for evaluation using data-limited stock assessment modeling techniques.

Section 2.1, Species Selection, provides a list of the species in the US Caribbean considered for evaluation using data-limited methods (Table 2.1.1). Species selection criteria and decisions were described in Section 2.1.1.

The SEDAR 46 DW/AW Panel restricted the evaluations to six species (Section 2.1) due to time constraints for the available analytical work. Two species were selected for each of the three island units (Puerto Rico, St. Thomas/St. John, and St. Croix.). These species included yellowtail snapper (*Ocyurus chrysurus*) and hogfish (*Lachnolaimus maximus*) in Puerto Rico, Caribbean spiny lobster (*Panulirus argus*) and queen triggerfish (*Balistes vetula*) in St. Thomas, and Caribbean spiny lobster and stoplight parrotfish (*Sparisoma viride*) in St. Croix.

Research recommendations for identifying suitable species for future data-limited stock evaluations in the US Caribbean are documented in Section 2.1.3.

1.2.3 Term of Reference 3

Apply various data-limited modeling techniques, as appropriate, to the recommended species in order to provide management advice.

1.2.3.1 Application of data-limited modeling techniques

The species-island units recommended for stock evaluation are discussed within TOR 2. Figures 3.1.1 – 3.1.6 provide graphical summaries of the available data for the primary components (landings and effort trends, length frequency, abundance measures, life history characterizations and relevant management measures) used in the SEDAR 46 evaluations for each species-island unit.

Section 3 provides the basis for the primary analytical method applied in the SEDAR 46 evaluation. Both Table 3.0 and Figure 3.0 provide the assessment history for each of the six species-island units. The Data-Limited Methods Toolkit (DLMtool) (Carruthers et al. 2015; Carruthers 2015a; Carruthers 2015b) was the primary analytical framework used in the SEDAR 46 stock evaluation to assess the use of data-limited stock assessment models or management procedures in developing management advice for the six US Caribbean species-island units. Section 3.1 provides an overview of the data available for the SEDAR 46 stock assessment evaluations for the six species-island units under consideration.

A supplemental mean length estimation analysis, using length frequency observations, was also used in SEDAR 46 and is described in Huynh (2016 unpublished).

Sections 3.2.1 and 3.2.2 provide a brief overview of the application of the DLMtool through management strategy evaluation (MSE). Table 3.1 provides a glossary of key terms used in the DLMtool and discussed herein. Appendix 4.3 provides the data inputs used in DLMtool calculations of total allowable catches for each of the six species-island units. Appendix 4.4 provides a comprehensive summary and description of all the management procedures (MPs) available in the DLMtool applicable to the SEDAR 46 evaluation.

Table 3.2.2 provides an abridged summary including assumptions for all the DLMtool MPs used in the SEDAR 46 evaluations. Appendix 4.5 provides the relevant R code for the DLMtool functions used in the SEDAR 46 evaluation.

Sections 3.2.2 – 3.2.3 describe the specifications of each subcomponent of the base operating models and alternative operating models for sensitivity examinations within the MSE: stock subclass (3.2.2.1), fleet subclass (3.2.2.2), and observation subclass (3.2.2.3), respectively. Tables 3.2.3 – 3.2.4 provide base and sensitivity operating model inputs for the stock subclass component for each of the six species-island units. Tables 3.2.5 – 3.2.6 provide base and sensitivity operating model inputs for the fleet subclass component for each of the six species-island units. Tables 3.2.7 – 3.2.8 provides base and sensitivity operating model inputs for the observation model subclass for each of the six species, which is used to assess the impact of imprecise and biased data inputs on MSE results.

Section 3.2.4 describes performance evaluation between management procedures and examination of data inputs. Section 3.2.5 summarizes the procedure of calculating total allowable catch (TAC) using the DLMtool procedure and data in a real world context.

1.2.3.2 Results of data-limited modeling techniques (Section 3.3)

Results of the DLMtool application are provided in Sections 3.3.1 (Puerto Rico hogfish), 3.3.2 (Puerto Rico yellowtail snapper), 3.3.3 (St. Thomas queen triggerfish), 3.3.4 (St. Thomas spiny lobster), 3.3.5 (St. Croix spiny lobster), and 3.3.6 (St. Croix stoplight parrotfish). The following table identifies the Sections summarizing results of the application of the DLMtool to each species-island unit for evaluating various management procedures through MSE and the application of the DLMtool to the 'real world data'.

Component	**Puerto Rico hogfish**	**Puerto Rico yellowtail snapper**	**St. Thomas queen triggerfish**	**St. Thomas spiny lobster**	**St. Croix spiny lobster**	**St. Croix stoplight parrotfish**
MSE: overall	Section 3.3.1	Section 3.3.2	Section 3.3.3	Section 3.3.4	Section 3.3.5	Section 3.3.6
Model stability	Section 3.3.1.1	Section 3.3.2.1	Section 3.3.3.1	Section 3.3.4.1	Section 3.3.5.1	Section 3.3.6.1
OM sensitivity	Section 3.3.1.2	Section 3.3.2.2	Section 3.3.3.2	Section 3.3.4.2	Section 3.3.5.2	Section 3.3.6.2
Value of Information	Section 3.3.1.2	Section 3.3.2.2	Section 3.3.3.2	Section 3.3.4.2	Section 3.3.5.2	Section 3.3.6.2
Performance evaluation	Section 3.3.1.3	Section 3.3.2.3	Section 3.3.3.3	Section 3.3.4.3	Section 3.3.5.3	Section 3.3.6.3
Real world TACs and sensitivity to data inputs	Section 3.3.1.4	Section 3.3.2.4	Section 3.3.3.4	Section 3.3.4.4	Section 3.3.5.4	Section 3.3.6.4
Interpretation of Results and	Table 3.3.1.7	Table 3.3.2.7	Table 3.3.3.7	Table 3.3.4.7	Table 3.3.5.7	Table 3.3.6.7

Guidance						

Results of the supplemental stock evaluation procedure utilizing the mean length estimator are provided in Section 3.4 and Huynh (2016 unpublished).

1.2.4 Term of Reference 4

Prepare Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines.

A report was prepared documenting the available data including recommended parameter estimates for life history characterizations, historical removals, indices of abundance, landings and effort trends in both Section 2 (Data Review) and Section 3.1 (Data Update Review). Recommendations from the DW/AW Panel regarding species selection for the SEDAR 46 assessment are provided in Section 2.1. Section 2 (Data Review) documents the data available for use in SEDAR 46 evaluations. Section 3 (Stock Assessment models and results) documents the application of the data-limited methods in the SEDAR 46 evaluation. Section 3.2 described the data-limited modeling process, the 'DLMtool' selected for use in the SEDAR 46. Sections 3.2.2 – 3.2.4 (MSE) and 3.2.5 (application to real world data) describe the application of the tool within the management strategy evaluation framework for the six species under consideration. Evaluation results are described for Puerto Rico hogfish (Section 3.3.1), Puerto Rico yellowtail snapper (Section 3.3.2), St. Thomas/St. John queen triggerfish (Section 3.3.3), St. Thomas/St. John spiny lobster (Section 3.3.4), St. Croix spiny lobster (Section 3.3.5), and St. Croix stoplight parrotfish (Section 3.3.6). Supplemental information on guidance and interpretation of the DLMtool results are provided in each results section for each species-island unit (Sections 3.3.1 – 3.3.6). Section 3.4 provided research recommendations by the analytical team. Appendices 4.1 through 4.5 provided details on the data and data-limited analytical framework applied in the SEDAR 46 stock assessment evaluations.

Results of the length frequency analysis are provided in Section 3.4 and Huynh (2016 unpublished).

2 Data review

The SEDAR 46 stock assessment for US Caribbean Data-limited Species was conducted through a Data and Assessment Workshop (DW/AW) held November 2 − 6, 2015 in San Juan, Puerto Rico and two webinars, held on December 14th, 2015 and January 11th, 2016. At the DW/AW workshop and during the webinars, the DW/AW panel discussed the data reported herein. The data include species selection criteria (Section 2.1), life history information (Section 2.2), fishery statistics (Section 2.3), measures of catch per unit effort (Section 2.4), measures of fishing effort (Section 2.5), and length frequency data (Section 2.6).

2.1 Species selection

Due to time constraints, the DW/AW Panel restricted the evaluations to six species selected based on the sufficiency of available data. Two species were selected for each of the three island units: Puerto Rico, St. Thomas/St. John, and St. Croix. These species included yellowtail snapper (*Ocyurus chrysurus*) and hogfish (*Lachnolaimus maximus*) in Puerto Rico, queen triggerfish (*Balistes vetula*) and Caribbean spiny lobster (*Panulirus argus*) in St. Thomas, and Caribbean spiny lobster and stoplight parrotfish (*Sparisoma viride*) in St. Croix (Figure 2.1.1).

2.1.1 Species selection method

Thirty-six species-island units were identified as potential candidates for assessment (Table 2.1.1). The candidate species list was developed by enumerating the frequency (number of years reported and average landings per year) of each reported species in the commercial landings and logbook data, the Marine Recreational Intercept Program (MRIP) recreational landings and interview data (Puerto Rico only), and the Trip Interview Program (TIP) length data. The selection criteria defining “species that were frequently reported” were intended to identify all species-island units for which at least one data-limited management procedure could be attempted (if a species was highly ranked in one dataset but not the others it was still retained). Further discussion on the quantity and quality of available life history information as well as the regional importance of each species contributed to the DW/AW Panel’s consensus to assess six species-island units that were best-suited for the SEDAR 46 stock evaluation.

The panel discussions that contributed to the final list of species-island units selected for evaluation initially considered queen conch as a candidate species. However, the life history, particularly growth, of queen conch does not lend itself well to existing length based methods or the alternative assessment techniques available in the DLM toolkit.

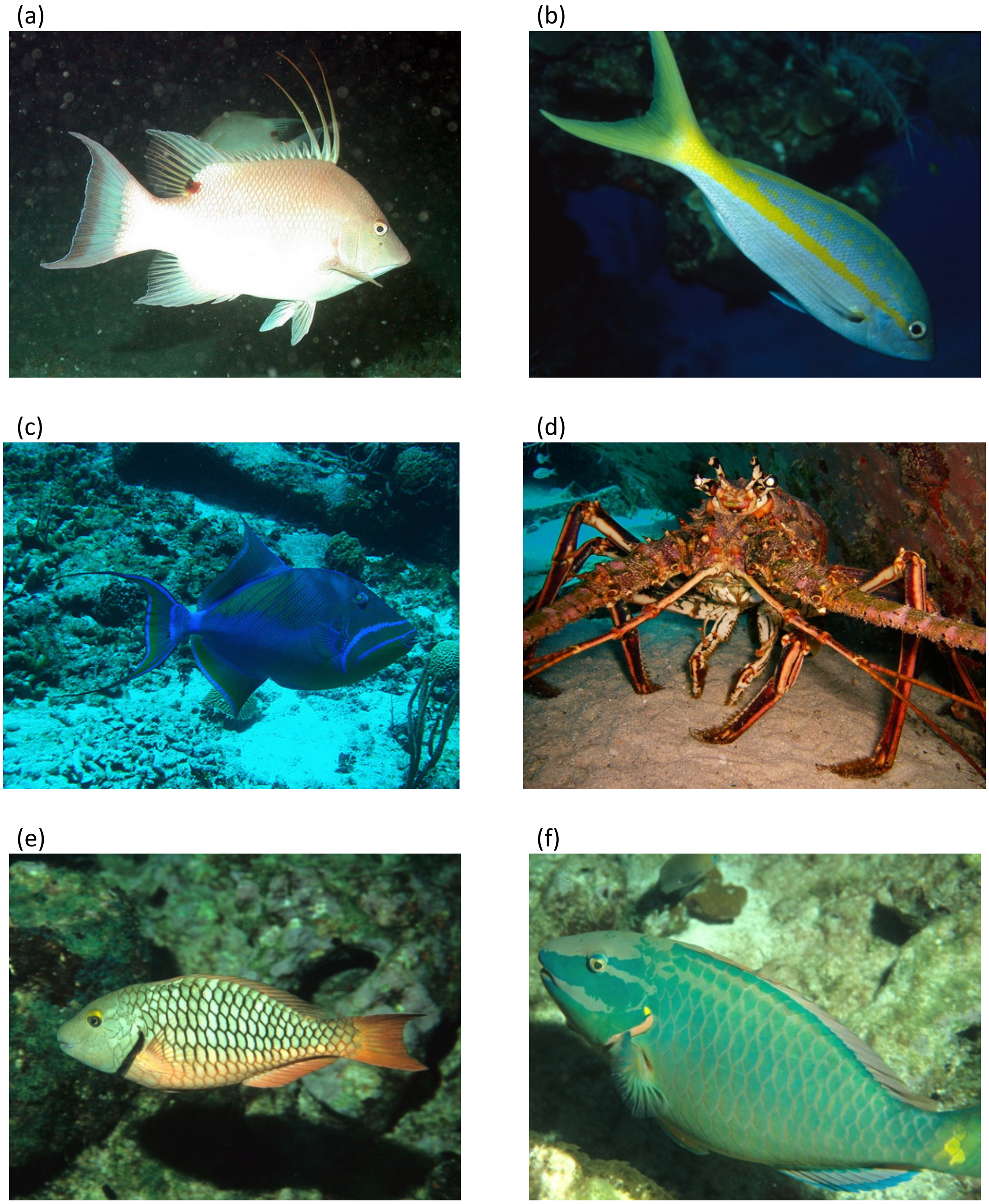


Figure 2.1.1 Photos of a) hogfish (*Lachnolaimus maximus*), b) yellowtail snapper (*Ocyurus chrysurus*), c) queen triggerfish (*Balistes vetula*), d) Caribbean spiny lobster (*Panulirus argus*), e) stoplight parrotfish (*Sparisoma viride*) primary phase and f) stoplight parrotfish secondary super-male phase. Photos from NOAA Photo Library (http://www.photolib.noaa.gov/).

Table 2.1.1 Species-specific summary of commercial landings, recreational landings, and length frequency data for the initial thirty-six species-island units identified as potential candidates for exploration in the SEDAR 46 stock evaluation. Selected species-island units are highlighted in gray. Species are ranked by average annual commercial landings for each island unit.

		Commercial Landings		Recreational Landings		Trip Interview Program (TIP) Length Frequency				
Species	Island	No of Years	Average Lbs	No of Years	Average Lbs	No of Years	Average Trips	Total Number of Trips	No of Average Lengths	Total Lengths
Yellowtail snapper	PR	32	287,164	15	21,285	31	144	4,478	3,039	94,218
Spiny lobster	PR	32	359,940	NA	NA	32	158	5,058	1,341	42,920
Silk snapper	PR	32	341,251	15	75,196	31	51	1,567	896	27,782
Queen conch	PR	32	328,407	NA	NA	NA	NA	NA	NA	NA
Lane snapper	PR	32	212,214	15	22,707	31	110	3,416	1,368	42,402
White grunt	PR	32	197,815	15	2,821	31	133	4,135	1,642	50,894
King mackerel	PR	32	145,351	15	93,939	30	38	1,149	300	8,997
Dolphin	PR	32	139,961	15	1,078,815	28	16	448	128	3,571
Queen snapper	PR	28	121,935	15	23,097	30	17	522	220	6,602
Mutton snapper	PR	32	75,974	15	30,723	31	69	2,131	251	7,780
Queen triggerfish	PR	32	71,428	15	10,258	31	62	1,921	288	8,924
Hogfish	PR	32	68,132	15	5,338	31	58	1,801	184	5,695
Red hind	PR	29	62,585	15	30,053	31	120	3,733	802	24,864
Cero	PR	28	50,913	15	29,468	31	24	743	168	5,223
Blackfin tuna	PR	28	25,134	15	3,207	28	15	411	94	2,639
Vermilion	PR	28	17,108	15	8,465	31	32	996	420	13,008
Coney	PR	28	11,638	15	12,533	31	83	2,577	579	17,958
Wahoo	PR	28	6,289	15	139,627	24	6	151	28	675
Great barracuda	PR	7	683	15	80,969	11	2	25	3	34
Tripletail	PR	6	317	15	30,301	12	2	25	22	263
Stoplight parrotfish	PR	5	144	15	9,053	28	53	1,475	601	16,828
Crevalle jack	PR	NA	NA	15	39,127	18	3	56	13	242
Spiny lobster	STT	15	107,534	NA	NA	24	21	509	467	11,205
Queen triggerfish	STT	4	44,235	NA	NA	23	31	721	365	8,394
Red hind	STT	4	33,494	NA	NA	23	31	712	309	7,104
Yellowtail snapper	STT	4	29,263	NA	NA	23	30	679	490	11,277
White grunt	STT	4	11,152	NA	NA	22	20	449	168	3,700
Blue tang	STT	3	965	NA	NA	22	19	414	139	3,054
Spiny lobster	STX	16	110,978	NA	NA	31	47	1,468	598	18,531
Queen conch	STX	16	96,498	NA	NA	NA	NA	NA	NA	NA
Dolphin	STX	16	55,381	NA	NA	17	12	206	55	930
Stoplight parrotfish	STX	4	32,464	NA	NA	27	33	899	1,009	27,231
Queen parrotfish	STX	4	14,894	NA	NA	25	8	200	32	807
Queen triggerfish	STX	4	14,858	NA	NA	28	34	965	314	8,790
Redtail parrotfish	STX	4	12,488	NA	NA	27	37	999	1,365	36,845
White grunt	STX	4	7,297	NA	NA	29	35	1,006	751	21,788

2.1.2 Additional considerations for species selection

2.1.2.1 Hogfish (*Lachnolaimus maximus*) in Puerto Rico

In addition to considering species in the US Caribbean with the most data available for evaluation in SEDAR 46, the DW/AW Panel also considered species with a moderate amount of available data. Compared to other candidate species (Table 2.1.1), hogfish is one such species. Additional considerations that led to the selection of hogfish as a species and the diving fleet as the most representative fishery in tracking their abundance included:

- Hogfish landings were reported from more commercial diving trips than any other finfish in Puerto Rico
- diving has been the most reported fishing gear in the self-reported commercial logbook data in Puerto Rico since 2007

2.1.2.2 Yellowtail snapper (*Ocyurus chrysurus*) in Puerto Rico

In Puerto Rico, yellowtail snapper was the finfish with the most length measurements in TIP and the second largest average annual commercial landings (Table 2.1.1). Additional considerations that led to the selection of yellowtail snapper as a species and the handline fleet as the most representative fishery in tracking their abundance included:

- Yellowtail snapper landings were reported from more handline fishing trips than any other species in Puerto Rico
- Throughout the time series, handline has been either the first or second most reported fishing gear in the self-reported commercial logbook data in Puerto Rico

2.1.2.3 Queen triggerfish (*Balistes vetula*) in St. Thomas

In St. Thomas, queen triggerfish was the finfish with the most length measurements in TIP and the largest average annual commercial landings (Table 2.1.1). Additional considerations that led to the selection of queen triggerfish as a species and the pots and traps fleet as the most representative fishery in tracking their abundance included:

- Queen triggerfish landings were reported from more trap fishing trips in St. Thomas than any other species since species-specific reporting started in 2011
- Fishing with pots and traps has been the most reported fishing gear in the self-reported commercial logbook data in St. Thomas since 2000

2.1.2.4 Caribbean spiny lobster (*Panulirus argus*) in St. Thomas

In St. Thomas, Caribbean spiny lobster was the species with the second most length measurements in TIP and the largest average annual commercial landings (Table 2.1.1). Additional considerations that led to the selection of spiny lobster as a species and the pots and traps fleet as the most representative fishery in tracking their abundance included:

- Caribbean spiny lobster landings were reported from more trap fishing trips than any other species in St. Thomas
- Fishing with pots and traps has been the most reported fishing gear in the self-reported commercial logbook data in St. Thomas since 2000

2.1.2.5 Caribbean spiny lobster (*Panulirus argus*) in St. Croix

In St. Croix, Caribbean spiny lobster was the species with the fourth most length measurements in TIP and the largest average annual commercial landings (Table 2.1.1). Additional considerations that led to the selection of spiny lobster as a species and the diving fleet as the most representative fishery in tracking their abundance included:

- Caribbean spiny lobster landings were reported from more diving trips than any other species in St. Croix
- Diving has been the most reported fishing gear in the self-reported commercial logbook data in St. Croix since 2003

2.1.2.6 Stoplight parrotfish (*Sparisoma viride*) in St. Croix

In St. Croix, stoplight parrotfish was the finfish with both the second most total measured lengths and the second highest average annual commercial landings (Table 2.1.1). Additional considerations that led to the selection of stoplight parrotfish as a species and the diving fleet as the most representative fishery in tracking their abundance included:

- Stoplight parrotfish landings were reported from more diving trips in St. Croix than any other finfish since species-specific reporting started in 2011
- Diving has been the most reported fishing gear in the self-reported commercial logbook data in St. Croix since 2003

2.1.3 Species descriptions

Species descriptions for the selected species included in the SEDAR 46 stock assessment evaluations are provided by the Comprehensive Amendment to the Fishery Management Plans of the US Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act (CFMC 2005). Information from the CAFMP US Caribbean is included below.

2.1.3.1 Hogfish, *Lachnolaimus maximus*

Hogfish occur in the Caribbean Sea, the Gulf of Mexico, and the Western Atlantic from Nova Scotia (Canada) to northern South America (Robins and Ray 1986). They are found from 3–30 meters depth, over open bottoms or coral reef habitats. Hogfish are often encountered where gorgonians are abundant. Mollusks constitute the primary prey item, although this species also feeds on crabs and sea urchins (Robins and Ray 1986).

2.1.3.2 Yellowtail snapper, *Ocyurus chrysurus*

Yellowtail snapper occur in the Caribbean Sea, the Gulf of Mexico, and the Western Atlantic from Massachusetts (USA) to southeastern Brazil. This species is most common in the Bahamas, off south Florida, and throughout the Caribbean. They inhabit waters up to 180 meters in depth and usually occur well above the bottom (Allen 1985). In Jamaica, this species was most abundant at depths of 20‒40 meters near the edges of shelves and banks (Thompson and Munro 1974). Early juveniles are usually found over seagrass beds whereas later juveniles inhabit shallow reef areas (Allen 1985; Thompson and Munro 1974). Adults tend to inhabit deeper reefs (Thompson and Munro 1974). Yellowtail snapper is a schooling species (Thompson and Munro 1974) and tends to be more mobile than other snapper species, however, the extent of its movement is unknown (SAFMC 1999). Yellowtail snapper feed upon zooplankton, nekton, and benthic organisms (McEachran and Fechhelm 2005).

2.1.3.3 Queen triggerfish, *Balistes vetula*

Queen triggerfish occur in the Caribbean Sea, the Gulf of Mexico, and both the Eastern and Western Atlantic. In the Western Atlantic, their range extends from Massachusetts (USA) to southeastern Brazil (Robins and Ray 1986). This species is generally found over rocky or coral areas, from depths of 2‒275 meters but has also been observed over sand and grassy areas (Robins and Ray 1986). There is some evidence that juveniles inhabit shallower waters and move into deeper waters as they mature (Aiken 1975). Queen triggerfish may remain solitary, aggregate in small groups, or form schools (Aiken 1975; Robins and Ray 1986). Food for queen triggerfish consists of sea urchins and other invertebrates (McEachran and Fechhelm 2005).

2.1.3.4 Caribbean spiny lobster, *Panulirus argus*

The Caribbean spiny lobster (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).

2.1.3.5 Stoplight parrotfish, *Sparisoma viride*

The stoplight parrotfish occurs throughout the Caribbean Sea and the western Atlantic from southern Florida to Brazil (Cervigón et al. 1992). This species inhabits coral reefs, occurring from 3‒49 meters in depth. Juveniles are found in seagrass beds and other heavily vegetated bottoms. This species is strictly diurnal, and spends the night resting on the sea bottom. Stoplight parrotfish can remain solitary or occur in small groups. Food for stoplight parrotfish consists of benthic vegetation (McEachran and Fechhelm 2005).

2.1.4 Identifying representative fleets

The data-limited methods used in the SEDAR 46 US Caribbean stock evaluations were limited to modeling a single fishing fleet. Thus, a fleet considered to best represent stock dynamics was identified for each species. The DW/AW Panel determined the fleets by examining the percentage of reported commercial fishing trips by gear group (Figure 2.1.2),

The selected fleets were associated with the largest percentage of commercial fishing trips that reported landings of each species. The handline fleet was selected for Yellowtail Snapper in Puerto Rico. The diving fleet was selected for Hogfish in Puerto Rico and for both Caribbean spiny lobster and Stoplight parrotfish in St. Croix. The trap fleet was selected for both queen triggerfish and Caribbean spiny lobster in St. Thomas.

2.1.5 Research recommendations

Investigate additional data sets and re-evaluate species selection criteria for future stock evaluations, including:

- The information available for queen conch (*Strombus gigas*) in the National Ocean Service's Biogeography visual surveys (Menza et al. 2006) and in data collected by universities in the region.
- Mesophotic reef surveys in western Puerto Rico (García-Sais et al. 2012), visual surveys and passive acoustic monitoring in western Puerto Rico and Mona Island (Scharer-Umpierre et al., 2014), and SEAMAP-C (Pagan 2002, Ingram 2014).

To the extent possible, these (and any other datasets) should be integrated and comprehensively summarized to facilitate comparisons and explorations in future analyses.

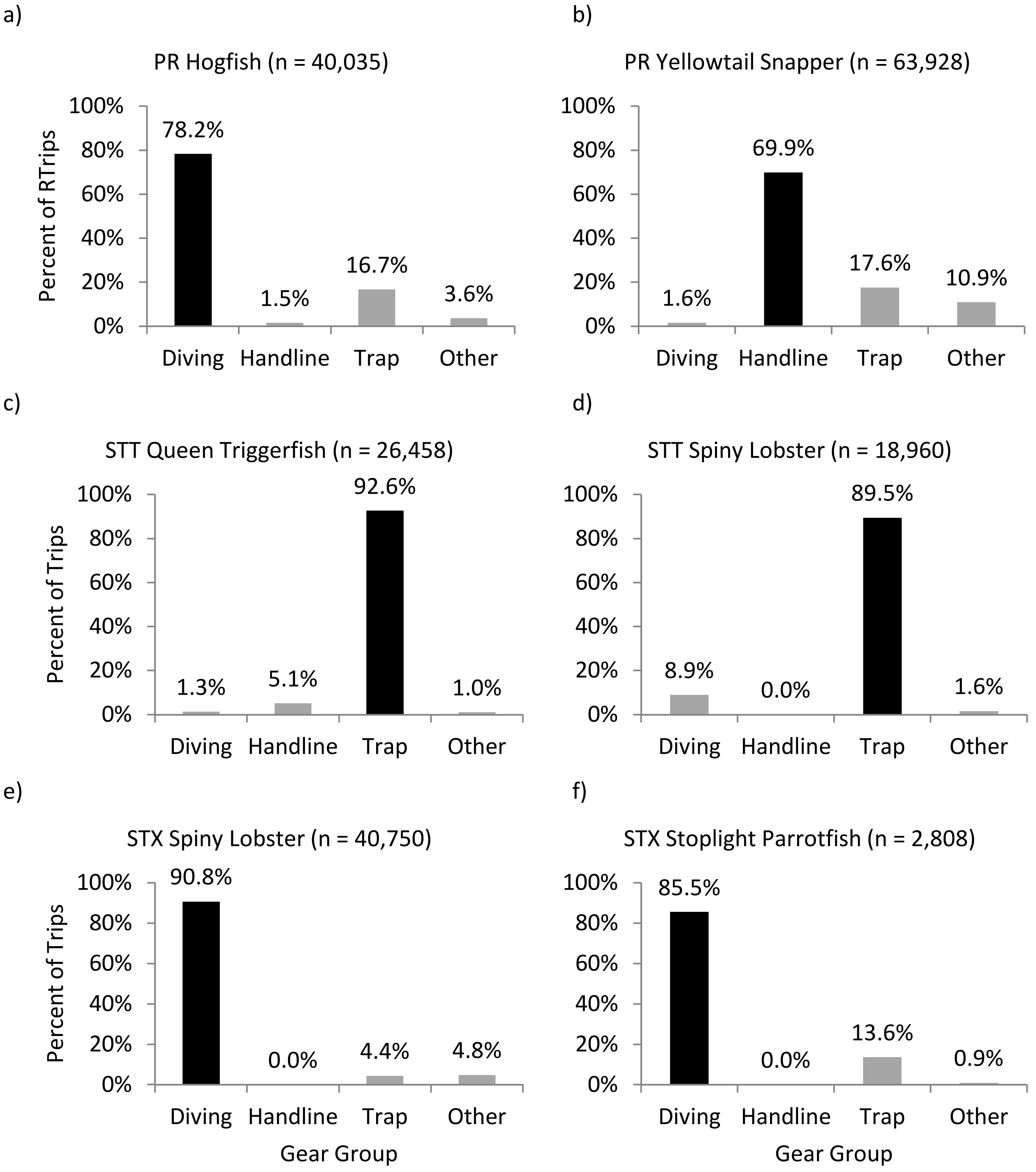


Figure 2.1.2 Total number of reported logbook trips and the percentage of trips by gear group for each species considered in the SEDAR 46 stock evaluation. The black bars identify the gear that the DW/AW Panel selected as representative of the stock dynamics. The filtering methods applied to the commercial logbook data prior to summarizing the number of trips by gear group are described in Section 4.4.2.

2.2 Life history

2.2.1 Overview

Table 2.2.1 provides a summary of parameters, definitions, nomenclature, and units for the life history parameters included within this report. The life history variables and parameter estimates are summarized in Table 2.2.2. The demographic functions and species-specific justifications for each parameter estimate are provided in the text. A summary list of the study area and source of life history inputs for each species-island unit is provided in Table 2.2.3.

The analytical framework used in the SEDAR 46 evaluations, the 'Data-limited Methods toolkit' (Carruthers 2015) requires measures of uncertainty to be specified along with point estimates of life history parameters. In instances where point estimates obtained from the literature were not accompanied by estimates of uncertainty, the Life History Working Group (LHWG) provided input on plausible levels of uncertainty.

2.2.1.1 Life history working group members

Members - Molly Adams (Leader, University of Miami - Rosenstiel School of Marine and Atmospheric Science), Richard Appeldoorn (SSC Representative/University of Puerto Rico), William Harford (NOAA Fisheries, Southeast Fisheries Science Center - Miami), Eric Hoffmayer (NOAA Fisheries, Southeast Fisheries Science Center - Pascagoula), Noemi Pena (PR Department of Natural and Environmental Resources), Michelle Scharer (University of Puerto Rico), Nathan Vaughan (University of Miami - Rosenstiel School of Marine and Atmospheric Science).

Table 2.2.1 Summary of parameters, definitions, Data-Limited Method Toolkit DLMtool) nomenclature (Carruthers 2015) and units for model parameters included within this report.

Parameter	Definition	DLMtool		Units
		Management strategy evaluation stock input	Real world data input	
L_∞	Asymptotic length	Linf	vbLinf	mm FL (lobster CL)
K	Brody growth coefficient	K	vbK	year $^{-1}$
t_0	Theoretical age at length 0	t0	vbt0	years
α	Weight-length scalar	a	wla	dimensionless
β	Weight-length power	b	wlb	dimensionless
W_∞	Asymptotic weight	--	--	g
L_m	Length at maturity	L50	L50	mm FL
t_m	Age at maturity	--	--	years
t_λ	Maximum age	maxage	MaxAge	years
L_λ	Mean length of maxage	--	--	mm FL
M	Natural mortality	M	Mort	year $^{-1}$
S_λ	Survivorship to maxage	--	--	dimensionless

Table 2.2.2 Recommended life history parameter values for hogfish, yellowtail snapper, queen triggerfish, spiny lobster, and stoplight parrotfish. Values provided include the mean and CVs. Units are defined in Table 2.2.1. Asterisks denote values where the CV was not reported in the literature and instead imputed by the LHWG.

Parameter	Hogfish	Yellowtail snapper	Queen triggerfish	Caribbean spiny lobster	Stoplight parrotfish
vbLinf	849.0 (0.06)	502.5 (0.05)	605.3* (0.12*)	183.0 (0.08*)	631.6* (0.12*)
vbK	0.106 (0.24)	0.139 (0.16)	0.214* (0.35*)	0.240 (0.21*)	0.250* (0.30*)
vbt0	−1.33 (0.38)	−0.96 (0.45)	0.00* (0.50*)	0.440 (1.14*)	0.00* (0.50*)
wla	9.50E-05 (0.05*)	3.45E-05 (0.05*)	8.64E-05 (0.05*)	9.21E-03 (0.05*)	3.70E-05 (0.05*)
wlb	2.745 (0.05*)	2.859 (0.05*)	2.784 (0.05*)	2.480 (0.05*)	2.905 (0.05*)
W_∞	10,430	1,870	4,800*	3,770	5,060*
L50	176.8 (0.113*)	248 (0.15*)	215* (0.20*)	65.79 (0.15*)	205 (0.20*)
t_m	0.878 (0.25*)	3.939 (0.25*)	2.050* (0.25*)	2.296 (0.25*)	1.572* (0.25*)
L_λ	784.3	471.1	575.0*	181.3	600.0*
MaxAge	23	19	14*	20	12*
Mort (M)	0.156 (0.082*)	0.189 (0.083*)	0.257* (0.083*)	0.350 (0.071*)	0.300* (0.084*)
S_λ	0.0278	0.0276	0.0275*	0.00091	0.0274*

Table 2.2.3 Source and study area of the life history inputs for hogfish, yellowtail snapper, queen triggerfish, spiny lobster, and stoplight parrotfish.

Species-Island Unit	Life History Input	Source	Study Area
Hogfish - Puerto Rico	Weight-length	McBride and Richardson (2007)	South Atlantic, eastern GOM
	Growth	McBride and Richardson (2007), Claro et al. (1989)	South Atlantic, eastern GOM, Cuba
	Maximum age	McBride and Richardson (2007)	South Atlantic, eastern GOM
	Maturity	McBride and Richardson (2007)	South Atlantic, eastern GOM
	Mortality	Inferred from Ault et al. (1998) and Hoenig (1983)	South Atlantic, eastern GOM
Yellowtail Snapper-Puerto Rico	Weight-length	SEAMAP (Pena unpublished)	Puerto Rico
	Growth	SEDAR 46 LHWG	Caribbean wide
	Maximum age	Araujo et al. (2002)	Brazil, Central
	Maturity	Figuerola et al. (1998)	Puerto Rico
	Mortality	Inferred from data of Araujo et al. (2002)	Brazil, Central
Queen Triggerfish - St. Thomas	Weight-length	Bohnsack and Harper (1988)	St. Thomas
	Growth	Inferred from maximum sizes using Rothschild et al. (1994)	Puerto Rico, Jamaica, Brazil
	Maximum age	Albuquerque et al. (2011)	Brazil-Gulf of Mexico
	Maturity	Aiken (1975)	Jamaica
	Mortality	Inferred from Ault et al. (1998) and Hoenig (1983)	Brazil-Gulf of Mexico
Caribbean Spiny Lobster - St. Thomas and St. Croix	Weight-length	Chormanski et al. (2005)	Puerto Rico
	Growth	Leon et al. (1995) cited in SEDAR 08	Puerto Rico
	Maximum age	Die (2005)	Southeastern US and Caribbean
	Maturity	Die (2005)	Southeastern US and Caribbean
	Mortality	Inferred from Ault et al. (1998), Hoenig (1983) and FAO (2001), SEDAR 2005; Babcock et al. 2014	Caribbean wide
Stoplight Parrotfish - St. Croix	Weight-length	Bohnsack and Harper (1988)	Puerto Rico
	Growth	Inferred from Ault et al. (1998), Hoenig (1983) and FAO (2001)	Puerto Rico
	Maximum age	Expert opinion and SEDAR 46 LHWG	Puerto Rico, south Florida, Bahamas
	Maturity	Figuerola et al. (1998)	Puerto Rico
	Mortality	Inferred from Ault et al. (1998) and Hoenig (1983)	Puerto Rico

2.2.2 General demographic functions

2.2.2.1 Lifetime growth

The von Bertalanffy model (von Bertalanffy 1938) was used to describe growth as:

$$L(t) = L_\infty \left(1 - e^{-K(t - t_0)}\right) \qquad \text{Eq. 2.2.1}$$

where,

$L(t)$ = fork length at age t,
L_∞ = asymptotic length,
K = Brody growth coefficient, and
t_0 = theoretical age at which length equals zero.

Parameter estimates for L_∞, K, and t_0 were based upon the available literature and supplemental information (i.e., maximum observed lengths) from the NOAA SEFSC Trip Interview Program (TIP) for Puerto Rico and from the multi-agency (National Oceanic and Atmospheric Administration Southeast Fisheries Science Center, Florida Fish and Wildlife Conservation Commission's Florida Fish and Wildlife Research Institute, the University of Miami's Rosenstiel School of Marine and Atmospheric Science, and the National Park Service) Reef Visual Census (RVC) of the Florida Keys and Dry Tortugas regions. The TIP sampling program provides two types of information - size frequency data and age at length data (see Section 2.6 for further details). In addition, this program also provides catch per unit effort data and information on the composition of the species being caught and landed (NOAA 2015). The RVC employs a stratified random sampling design that uses environmental features correlated with the spatial distribution of reef fishes to partition the survey area into strata (Smith et al. 2011). A probabilistic approach to sampling effort allocation is implemented that focuses on precise estimation of population and community metrics that can be estimated for principal species of the exploited reef fish complex (Smith et al. 2011). Closely-spaced pairs of SCUBA divers conduct a standardized observation process and report all observed fish species during five minute sampling periods before recording abundance and fork length information (Smith et al. 2011).

2.2.2.2 Weight-length relationship

The allometric weight dependent on length function was:

$$\mathrm{W} = \alpha \mathrm{L}^{\beta} \qquad \text{Eq. 2.2.2}$$

where,

W = whole weight in grams,
L = fork length in millimeters,
α = the scalar coefficient, and
β = the power coefficient.

The exception to length type was spiny lobster where size was reported in carapace length (mm CL).

2.2.2.3 Natural mortality

Natural mortality rates (Mort) were determined using two estimation methods:

(1) assuming 5% of a cohort survives to the maximum age based on the following relationship:

$$S_{\lambda} = 0.05 = e^{-\mathrm{Mort}\, t_{\lambda}}$$ (Ault et al. 1998, Nadon et al. 2015)Eq. 2.2.3

And, (2) assuming 1.5% survivorship to the maximum age (S_λ = 0.015; *inter alia* Hoenig 1983):

$$\mathrm{Mort} = e^{(1.46 - 1.01 \ln(t_{\lambda}))}$$ Eq. 2.2.4

The mean Mort rate from these two estimates was considered most representative for each species. The coefficient of variation (CV) for Mort was assigned based on the range of the two mortality estimators.

2.2.2.4 Maturity

Size at 50% maturity (L_m = L_{50}) for females was reported in cases of sexual dimorphism (i.e., gonochoristic separate sexes) and protogynous hermaphroditism. All values of age at 50% maturity (t_m = t_{50}) were determined by converting length at 50% maturity (L_m) to age using the recommended von Bertalanffy growth parameters.

2.2.3 Species parameterizations

2.2.3.1 Hogfish (Puerto Rico)

Von Bertalanffy growth parameters for Gulf of Mexico and South Atlantic hogfish populations were estimated in SEDAR 37 (SEDAR 2013) utilizing a synthesis of length at age data for hogfish collected from the West Florida Shelf (n=1,063). The Von Bertalanffy parameter values reported by SEDAR 37 were similar to those reported by Claro et al. (1989) from Cuban waters (L_∞ = 849.0 vs 850.0 mm FL; K = 0.106 vs. 0.098 yr^{-1}; t_0 = −1.329 vs. −1.382 yrs). The estimates of L_∞ also aligned with the largest hogfish sampled from Puerto Rico in the TIP port sampling database (870 mm FL).

SEDAR 37 weight-length parameter estimates were used to represent hogfish allometric growth (α = 9.50E-05, β =2.745, n=3,919). Parameter uncertainty was not provided with these point estimates and, thus, CVs of 0.05 were assigned by the LHWG. McBride and Richardson (2007) used sectioned otoliths to age hogfish and found a maximum age of t_λ = 23 years from the eastern Gulf of Mexico, although a maximum age of 25 years was used in SEDAR 37 (SEDAR 2013). In all analyses, a maximum age of 23 was used to calculate Mort. Mort estimates for the Hoenig 1983) estimator and the 5% survival estimator were 0.18 and 0.13, respectively, which resulted in a mean Mort of 0.15 and a 95% confidence envelope between 0.13 and 0.18.

Accurately defining maturity for this species is difficult as they are protogynous hermaphrodites and maturation often occurs in response to sexual cues within localized harems. McBride (2001) estimated female length at 50% maturity (L_m = 176.8 mm FL) for the eastern Gulf of Mexico and south Florida. The LHWG recommends a sensitivity run for length at 50% maturity.

2.2.3.2 Yellowtail snapper (Puerto Rico)

Von Bertalanffy growth parameters as reported by Manooch and Drennon (1987) in USVI and Puerto Rico were recommended for use by the LHWG (L_∞ = 502.5 mm FL, K = 0.139 yr^{-1}, t_0= −0.955 yrs; Table 2.2.2). Standard errors from the Manooch and Drennon (1987) Von Bertalanffy estimates were used as uncertainty measures (Table 2.2.2). These parameters were derived from a data set which covered a range of ages (1−17) and sizes (117−504 mm FL), and comprised a sample size of 654. A maximum age (t_λ) of 19 years was reported by Araujo et al. (2002) in central Brazil, which corresponded to a Mort of 0.22 and 0.16 for the Hoenig (1983) and 5% survival estimators, respectively, and a mean Mort of 0.19. As a statistical estimate of uncertainty around the mean Mort was unavailable, the range of 0.16 to 0.22 was used as an approximate 95% confidence envelope.

Allometric weight dependent on length (α =3.54E-05, β=2.859, n = 645) parameters were calculated from data collected by the SEAMAP survey in Puerto Rico waters provided by Noemi Pena (unpublished). Parameter uncertainty was not provided with these point estimates, thus, CVs of 0.05 were assigned by the LHWG. Because these data were obtained from Puerto Rico waters, they were considered the best available information for use in the assessment. In addition, these values were similar to those reported by Garcia et al. (2003) from south Florida (α =4.14E-05, β=2.83, n=1,263).

Length at 50% maturity (248 mm FL) as reported by Figuerola et al. (1998) was used in this assessment and in the prior Caribbean yellowtail snapper SEDAR 8 assessment (SEDAR 2005b).

2.2.3.3 Queen triggerfish (St. Thomas)

Within the Caribbean region, length frequency analysis by Menezes (1979) suggests that queen triggerfish reach a maximum age of 7 years. In contrast, maximum ages of queen triggerfish outside of the Caribbean region have been reported up to 14 years in Brazil (Albuquerque et al. 2011). A congener, the gray triggerfish (Balistes capriscus), has been aged to a maximum of 14 years in the Gulf of Mexico whereas the Picasso triggerfish (Rhinecanthus aculeatus) has reached 14 years in Okinawa, Japan (Künzli and Tachihara 2012). Consequently, the LHWG was concerned that: (1) age compression due to exploitation may have limited collection of larger/older specimens (Ault et al. 1998); and (2) age estimates obtained using dorsal spines may not be accurate for older age classes. The LHWG examined maximum lengths reported in the Puerto Rico TIP database, finding maximum reported sizes in the Caribbean region of: 722 mm FL in Puerto Rico (TIP database); 546 mm FL in Puerto Rico (Bohnsack and Harper 1988); and 572 mm FL in USVI (Randall 1968). When compared to estimates of L_∞, which ranged from 415−450 mm FL, (Aiken 1975, Manooch and Drennon 1987), the LHWG felt that the Von Bertalanffy growth curves may not be representative of the older ages and maximum sizes that have been observed in TIP and elsewhere. Thus, across the family Balistidae, a maximum age of 14 years was deemed reasonable by the LHWG and was used to calculate Mort. Mort was estimated at 0.30 and 0.21 for the Hoenig (1983) and 5% survival estimators, respectively, with a mean Mort of 0.26. The range of 0.21 to 0.30 was used as a 95% confidence envelope.

Given the range of the largest reported sizes across the Caribbean region (546 – 722 mm FL), the size at maximum age, L_λ, was specified to be 575 mm FL. Assuming that L_λ is 95% of L_∞ (L_∞ = 605.3 mm FL), Rothschild et al. (1994) developed a mathematical expression to estimate K when the age at L_λ is known, and assuming t_0 equals zero,

$$K = \frac{1}{t_\lambda - t_0} \ln\left(\frac{L_\infty - L_0}{L_\infty - L_\lambda}\right) \qquad \text{Eq. 2.2.5}$$

which results in a K = 0.214. A CV of 0.12 was assigned for L_∞ to allow the 95% confidence interval to encompass 755 mm FL (approximately what is reported in the Virgin Islands TIP data), down to 455 mm FL (approximately what is reported in the literature).

Length-weight parameters for St. Thomas and St. John were obtained from Bohnsack and Harper (1988) (α = 8.64E-05, β =2.784, n=509), which were intermediate to Bohnsack and Harper (1988) from Puerto Rico (α = 6.57E-05, β = 2.829, n=339) and Manooch and Drennon (1987) from USVI and Puerto Rico (α = 1.01E-04, β = 2.750, n=151). Parameter uncertainty was not provided with these point estimates, thus, CVs of 0.05 were assigned by the LHWG.

The maturity at size relationship was inferred from the proportion of ripe females reported by Aiken (1975). Since running ripe females occurred approximately half of the time, and the data appeared to reach an asymptotic percentage of about 50% ripe, it was assumed that 50% of ripe females sampled throughout the year meant that 100% of the females within this length class were mature, at 280 mm FL. This assumption was extended to length at 50% maturity, 215 mm FL, which was approximated by the reported value of 25% ripe females.

2.2.3.4 Caribbean spiny lobster (St. Thomas and St. Croix)

Molt-based models may be more realistic characterizations of spiny lobster growth patterns, although, these models have rigorous empirical data requirements (Ehrhardt 2008). Hoenig and Restrepo (1989) found that, given the intrinsic variability of inter-molt times between individuals, a continuous growth function may be a reasonable approximation of molt-based functions. The Von Bertalanffy growth model was used to approximate molt-based growth in the present assessment since DLMtool, the analytical procedure applied in this evaluation, requires estimates in the form of the Von Bertalanffy equation.

The Von Bertalanffy growth parameters were derived from Leon et al. (1995) and have been used elsewhere in assessing Caribbean spiny lobster (Gongora 2010; Babcock et al. 2014). Point estimates from Leon et al. (1995) were compared to the extensive length-frequency analysis conducted by Leon et al. (2005) as a means to specify Von Bertalanffy growth parameter ranges and use these ranges as coarse measures of variation around each growth parameter (L_∞ = 183.0 mm CL, K = 0.240 yr^{-1}, t_0 = 0.44 yrs; Table 2.2.2).

Tagging studies have provided Mort (i.e., natural Mortality (M)) estimates 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, calculated from a variant of Pauly's equation, is also widely reported (Cruz et al. 1981). Point estimates based upon longevity require maximum age observations, which are difficult to obtain for lobsters (Kanciruk 1980). By establishing an inverse relationship between neurolipofuscin accumulation and longevity in arthropods, the potential lifespan for spiny lobster has been estimated as 20 years (Maxwell et al. 2007). The recommended Von Bertalanffy growth parameters suggest that spiny lobster could reach 99% of this theoretical maximum length at age 19. Longevity-based point estimates of Mort using a 20 year maximum age are 0.22 year^{-1} using Hoenig (1983), 0.27 year^{-1} using the updated linear Hoenig estimator from Then et al. (2014), and 0.31 year^{-1} using the nonlinear estimator recommended by Then et al. (2014). The range of Mort estimates (0.3 to 0.4) and the range of longevity-based point estimates of Mort (0.22 to 0.31) overlap at the lower end of the tagging-based mortality estimates. Several spiny lobster stock assessments in the broader Caribbean region have used 0.34 to 0.36 year^{-1} in base model runs (Cruz 2001; Gongora 2010; SEDAR 2005a; Babcock et al. 2014). In the absence of new information about spiny lobster natural mortality, a value of 0.35 was recommended as the median of the 0.3 – 0.4 range and is similar to the values 0.34 and 0.36 used in previous Southeastern US and US Caribbean spiny lobster assessments, respectively (SEDAR 2005a, Ehrhardt 2005). The range of 0.30 to 0.40 was used as a 95% confidence envelope for defining uncertainty in M. The Mort point estimate of 0.35 translates to 0.091% survivorship to the age of 20 years old. If spiny lobster live longer, this Mort estimate could be too high, and may inadvertently lead to overestimates of resilience to exploitation. A sensitivity analysis is recommended using alternative values of Mort including 0.22 and 0.44 yr^{-1}, which are similar to the sensitivity runs recommended during SEDAR 08 (SEDAR 2005a).

Length-weight parameters from Chormanski et al. (2005), who used Puerto Rican TIP data from 1986–2003, were chosen as most representative for spiny lobster (α = 9.21E-03, β= 2.4804). These estimates were also utilized in the SEDAR 8 Caribbean spiny lobster assessment. Parameter uncertainty was not provided with these point estimates, thus, CVs of 0.05 were assigned by the LHWG. Die (2005) reanalyzed maturity schedules for US Caribbean spiny lobster from the data of Bohnsack et al. (1992). These maturity schedules were estimated using lengths in inches and were converted to mm for use with DLMtool (L_m = 65.8 mm CL).

2.2.3.5 Stoplight parrotfish (St. Croix)

Multiple growth curves have been estimated for stoplight parrotfish in the Bahamas, Panama, Venezuela, Barbardos, and the Florida Keys (Choat and Robertson 2002, Choat et al. 2003, Paddack et al. 2009). However, maximum lengths included in these studies have ranged between 303 – 379 mm SL (approx. 365–456 mm FL) with a maximum age of 9 years identified based on otolith ageing. Problematically, observed maximum sizes in fishery-independent and fishery-dependent sampling are much larger than any of the largest sizes included in growth curve fitting. Observations from the TIP database for Puerto Rico report stoplight parrotfish to 678 mm FL, and observations from the Reef Visual Census (RVC) in south Florida report lengths up to 750 mm TL. Thus, the growth model parameter estimates for stoplight parrotfish could be unreliable. Given this information, a maximum age of 12 was assigned to this species based on the expert opinion of the LHWG. The Hoenig estimate (1983) of Mort was 0.35 and the 5% survival estimate was 0.25. The range of 0.25 to 0.35 was used as an approximate 95% confidence envelope.

The mathematical expression of Rothschild et al. (1994) was used to calculate K because observed lengths in the Caribbean region exceeded maximum lengths included in growth curve fitting. L_λ was specified as 600 mm FL (Puerto Rico TIP, South Florida RVC). Assuming that L_λ is 95% of L_∞ (L_∞= 631.6 mm FL), K = 0.249 when t_0 is assumed to equal zero (Equation 2.2.5; Rothschild et al. 1994).

Length-weight relationships reported by Bohnsack and Harper (1988) were selected for stoplight parrotfish (α =3.70E-05, β =2.91, n=1,693). Parameter uncertainty was not provided with these point estimates, thus, CVs of 0.05 were assigned by the LHWG.

Length at maturity estimates from Figuerola et al. (1998) were considered most representative (L_m= 205 mm FL) and corresponded well with those reported by Robertson and Warner (1978) from Panama (note: values were reported in SL, and when converted to FL using Choat et al.'s (2003) conversion factor, they were approximately equal).

2.2.4 Research recommendations

The LHWG research recommendations were:

- Representative sampling across size/age spectra for under-sampled US Caribbean stocks.
- Updated studies of life history and demographic characteristics are needed that focus on sampling under-represented size classes, particularly large (old) fishes to provide more accurate estimates of asymptotic length, and small (young) fishes to more accurately estimate the rate at which fishes approach asymptotic length. This recommendation stems from a concern that maximum lengths were too often considerably longer than L_∞ estimates. This observation could stem from inadequate sampling of the largest length classes, region-specific differences in asymptotic growth (where parameters were borrowed from other regions), or where exploitation has dramatically modified stock structure.
- Additional sampling is also necessary for improving stock-specific maturity schedules, and these data should be fit via logistic regressions methods to obtain the most robust estimates of length at maturity.
- Research efforts into compilation of various datasets of life history demographic parameters for all exploited species in the tropical western Atlantic, through a Regional Expert Demographic Workshop are recommended.

2.3 Fisheries statistics

2.3.1 Overview

Tables 2.3.1 and 2.3.2 summarize the time series of annual landings and discards available for the six species-island units identified for analysis under SEDAR 46. The data sources and methods used to characterize estimates of landings and discards are described below.

Table 2.3.1 Summarized annual total landings (whole weight, pounds) for species evaluated in the SEDAR 46 stock evaluation. Landings from Puerto Rico include commercial and recreational data. Landings for St. Thomas and St. Croix include commercial landings data only. Landings reported as triggerfish in St. Thomas were considered queen triggerfish for the assessment because nearly all triggerfish landings consist of queen triggerfish (See Section 2.3.3.1).

Year	**Puerto Rico**		**St. Thomas**			**St. Croix**	
	Hogfish	**Yellowtail snapper**	**Queen triggerfish**	**Unspecified triggerfish**	**Spiny lobster**	**Spiny lobster**	**Stoplight parrotfish**
1975					6,796	2,169	
1976					6,742	2,218	
1977					19,462	8,166	
1978					58,432	4,981	
1979					29,385	3,078	
1980					36,088	1,288	
1981					38,068	2,104	
1982					36,661	2,692	
1983	119,075	274,597			36,141	4,480	
1984	120,254	227,422			35,979	7,564	
1985	74,668	250,598			30,141	4,426	
1986	49,999	124,996			23,637	5,970	
1987	48,647	122,999			40,667	13,032	
1988	53,827	137,918			54,682	8,012	
1989	50,096	178,461			58,858	2,207	
1990	42,514	209,873			77,837	19,472	
1991	60,712	291,165			54,800	37,246	
1992	35,297	248,488			86,451	21,132	
1993	35,308	304,925			83,261	37,176	
1994	50,341	291,047			61,773	29,790	
1995	69,687	409,607			67,390	25,029	
1996	84,051	383,049			88,037	28,843	
1997	87,610	349,869			95,097	35,949	
1998	62,968	322,532		47,932	74,077	42,718	
1999	58,854	356,577		68,618	75,828	53,329	
2000	107,364	663,675		72,090	76,153	89,020	
2001	108,000	498,566		82,688	89,711	116,619	
2002	79,591	363,681		97,543	115,972	116,273	
2003	71,163	341,668		101,523	135,292	106,039	
2004	87,343	381,243		87,420	133,982	125,415	
2005	131,073	688,908		76,462	124,643	120,929	
2006	52,455	281,022		70,120	136,027	146,592	
2007	57,814	231,993		72,642	119,641	168,005	
2008	79,819	393,731		84,131	110,465	148,003	
2009	77,217	239,705		79,469	115,762	149,908	
2010	68,540	225,039		79,555	114,577	139,685	
2011	56,177	159,830	26,364	30,703	84,302	109,751	20,152
2012	71,732	225,201	44,835	1,205	83,157	86,997	41,869
2013	49,537	134,502	43,762	1,272	84,233	59,398	33,773
2014	58,569	200,667	44,107	1,556	89,092	39,681	21,750

Table 2.3.2 Estimates of discards in numbers for species considered in the SEDAR 46 stock evaluation. Discards from Puerto Rico are from recreational data only. No discard data were presented at the DW/AW workshop for St. Thomas or St. Croix.

	Puerto Rico	
Year	**Hogfish**	**Yellowtail snapper**
2000	0	3,085
2001	4,290	8,666
2002		6,626
2003	0	5,319
2004		7,632
2005		6,209
2006		9,735
2007	0	22,121
2008	0	11,737
2009	0	9,215
2010	455	8,853
2011	0	1,142
2012	0	2,044
2013	0	6,537
2014	0	13,072

2.3.2 Puerto Rico

2.3.2.1 Commercial landings

Commercial fishery landings data for Puerto Rico were available from self-reported fisher logbooks (2012-current) and sales receipts for the years 1983–2011. Data were reported by species (during most years), fishing gear, and fishing center where the catch was landed. Puerto Rico commercial landings have been incompletely reported and thus required use of correction/expansion factors to estimate total landings (SEDAR 2009). For the years 2003 to 2014, correction/expansion factors have been coast-specific (north, south, east, west). Estimation of commercial fishery landings for years prior to 2003 used a single, island-wide, expansion factor.

Puerto Rico expanded landings were estimated for each reported trip as:

*trip-specific reported landings*year-specific expansion factor* Eq. 2.3.1

Yearly total landings were estimated as the sum of all trip-specific expanded landings within each year. Estimation of landings for the most recent years (2003–2014) included year and coast-specific expansion factors. Reported landings were assigned to coast based upon the fishing center reported for a trip and total landings were estimated using the appropriate correction/expansion factor.

Landings of all species and species-groups reported during the years 1983–2014 are provided in Appendix 4.1.1. Species/species-groups are ordered by total expanded landings from highest to lowest. Also provided are the average landings per year (average over all years 1983–2014), the number of years the species/species-group was reported (not all species were included on the reporting form during all years), average landings per year (average over years the species was reported), percent of total landings accounted for by the landings of each species, and cumulative percentage of the total landings. The species/species-group with the highest total landings was spiny lobster.

Commercial landings data for hogfish and yellowtail snapper from Puerto Rico are provided by year in Table 2.3.3. Yellowtail snapper landings data for the years 1983–1989 should be used with caution. During the years 1983–1989, landings of yellowtail snapper were reported along with queen snapper (*Etelis oculatus*), vermilion snapper (*Rhomboplites aurorubens*), and silk snapper (*Lutjanus vivanus*) as a single entry on the commercial fishery reporting forms. During that period, species-specific landings are available (the species landed was indicated by the reporting fisher; Garcia-Moliner, pers. comm.); however, it is uncertain how individual trips with landings of multiple species (e.g., vermilion snapper and yellowtail snapper) reported those landings on the single line provided on the reporting form.

2.3.2.2 Commercial discards

Self-reported commercial discard information available from commercial logbooks is restricted to the number of fish discarded dead, the number of fish discarded alive, the number of lobster discarded dead, and the number of lobster discarded alive. The limited self-reported commercial discard information was available for the period 2011–2014. No commercial discard information was presented at the SEDAR 46 DW/AW Workshop.

2.3.2.3 Recreational landings

Recreational fishery landings data for Puerto Rico were available from the Marine Recreational Fisheries Statistics Survey (MRFSS) and the Marine Recreational Information Program (MRIP). The MRFSS/MRIP survey provides estimates of recreational landings from 2000–2014. In summary, the survey combines catch rates from dockside intercept surveys with estimates of effort from telephone interviews to estimate total landings and discards by two month wave, fishing mode (shore-based fishing, private and rental boat fishing, or for-hire charter and guide fishing), and area fished (inland, state, or federal waters). The survey design and tables of the data available for all species/species-groups are described in SEDAR 46-WP-7.

Recreational landings data in numbers and in pounds for hogfish and yellowtail snapper from Puerto Rico are provided by year in Table 2.3.4.

2.3.2.4 Recreational discards

Recreational fishery discards data for Puerto Rico were available from MRFSS/MRIP surveys (SEDAR 46-WP-7). Total estimates of discards (B2s) are derived from angler-reported discards recorded during the intercept portion of the survey. The discard data in number for hogfish and yellowtail snapper from Puerto Rico are provided by year in Table 2.3.4.

Table 2.3.3 Puerto Rico annual commercial landings (whole weight, pounds) for hogfish and yellowtail snapper. Yellowtail landings for the years 1983–1989 should be used with caution (See Section 2.3.2.1 for explanation of specific concerns regarding how multiple species were reported).

Year	**Puerto Rico**	
	Hogfish	**Yellowtail snapper**
1983	119,075	274,597
1984	120,254	227,422
1985	74,668	250,598
1986	49,999	124,996
1987	48,647	122,999
1988	53,827	137,918
1989	50,096	178,461
1990	42,514	209,873
1991	60,712	291,165
1992	35,297	248,488
1993	35,308	304,925
1994	50,341	291,047
1995	69,687	409,607
1996	84,051	383,049
1997	87,610	349,869
1998	62,968	322,532
1999	58,854	356,577
2000	100,995	632,061
2001	99,794	465,165
2002	79,591	338,151
2003	67,709	282,114
2004	87,343	344,448
2005	131,073	670,719
2006	52,455	274,653
2007	55,022	206,470
2008	54,539	373,529
2009	66,737	222,670
2010	59,270	214,892
2011	53,162	150,487
2012	68,495	207,952
2013	48,930	131,254
2014	51,205	190,574

Table 2.3.4 Puerto Rico annual recreational landings and discards for hogfish and yellowtail snapper. Landings are provided in number and in pounds (whole weight). Estimates of discards were provided only in numbers.

	Hogfish			**Yellowtail snapper**		
YEAR	**Landings (num)**	**Landings (lbs)**	**Discards (num)**	**Landings (num)**	**Landings (lbs)**	**Discards (num)**
2000	2,453	6,369	0	35,044	26,603	3,085
2001	1,912	8,206	4,290	29,143	33,402	8,666
2002	0	0	0	21,250	25,530	6,626
2003	1,099	3,454	0	57,940	59,554	5,319
2004	0	0	0	33,281	36,795	7,632
2005	0	0	0	20,040	18,189	6,209
2006	0	0	0	18,237	6,369	9,735
2007	352	2,792	0	41,633	25,523	22,121
2008	6,086	25,280	0	24,546	20,202	11,737
2009	2,523	10,480	0	18,102	17,035	9,215
2010	1,761	9,270	455	10,251	10,147	8,853
2011	384	3,015	0	27,947	9,343	1,142
2012	978	3,237	0	18,435	17,249	2,044
2013	787	607	0	5,859	3,247	6,537
2014	9,357	7,365	0	10,936	10,092	13,072

2.3.3 St. Thomas

2.3.3.1 Commercial landings

In the US Virgin Islands, commercial logbook landings data from the islands of St. Thomas and St. John were compiled separately from St. Croix. Logbook reporting began in July, 1974; however, landings were initially reported by gear type combined over species/species-groups (e.g., net fish, hook fish, pot fish, and spear fish) and later as either 'snapper/grouper' or reported as 'other fin fish' during the period 1974‒1995. Beginning in 1997 in St. Thomas/St. John, some landings data were reported by species-group (e.g., snappers, groupers, parrotfishes, surgeon fishes, etc.) and by gear (hook and line, gill net, SCUBA, trap, etc.). All commercial fishery data reports in St. Thomas/St. John included only species-group reporting beginning in 2000 for the SEDAR 46 DW/AW Panel. Species-specific data were initially reported in the US Virgin Islands during the 2011‒2012 fishing year. Spiny lobster landings have been consistently reported by species throughout the period 1975 (first full year of reporting) through 2014 (terminal year for the stock assessment).

The self-reported logbook records from commercial fishers make up the available statistics for calculating annual total commercial landings in St. Thomas and St. John. In the US Virgin Islands, landings have been assumed to be fully reported and no correction/expansion factors have been used (CFMC, 2009; J.Brown USVI DFW Chief of Fisheries, personal communication). Landings of all species/species-groups reported during the years 2000‒2014 are provided in Appendix 4.1.2. Species/species-groups are ordered by total expanded landings from highest to lowest. Also provided are the average landings per year (average over all years 2000‒2014), the number of years during which the species/species-group was reported (not all species were included on the reporting form during all years), average landings per year (average over years the species was reported), percent of total landings accounted for by the landings of each species/species-group, and the cumulative percentage of the total landings.

The species/species-group in St. Thomas/St. John accounting for the highest total landings was unspecified snapper. The species/species-groups that accounted for the highest 50 percent of the landings included unspecified snapper, spiny lobster, unspecified triggerfish, and unspecified grouper. Appendix 4.1.3 includes landings totals, primarily by species-group, for the period July, 1974 to December, 1999. Landings reported by gear (e.g., pot fish, hook fish) are not included; therefore, landings of most species-groups are incomplete by necessity as no method exists to convert landings by gear to landings by species-group. Landings of spiny lobster and queen conch, however, have been consistently reported by species since 1974.

Commercial landings data for queen triggerfish and spiny lobster from St. Thomas are provided by year in Table 2.3.5. Spiny lobster landings were available beginning in 1975 (first full year of reported landings). During the years 1998–1999, two commercial landings forms with different reporting requirements were in use. Landings by species-group, including triggerfish, were required for one form while landings by gear (e.g., pot fish, hook fish) were required when reporting using the second form. Landings data of triggerfish for the years 1998–1999 should be used with caution due to incomplete reporting by species group. Beginning in July, 2011 landings reporting was species-specific. The SEDAR 46 DW/AW Panel recommended treating the landings reported as triggerfish (2000–July, 2011) as queen triggerfish for the assessment because the percentage of queen triggerfish ranged from 96.6–97.4 percent of total triggerfish landings during 2012–2014 (available complete years of species-specific landings reported).

2.3.3.2 Commercial discards

Self-reported commercial discard information available from commercial logbooks is restricted to the number of fish discarded dead, the number of fish discarded alive, the number of lobster discarded dead, and the number of lobster discarded alive. The limited self-reported commercial discard information was available for the period July, 2011–2014. No commercial discard information was presented at the SEDAR 46 DW/AW Workshop.

Table 2.3.5 St. Thomas annual commercial landings (whole weight, pounds) for queen triggerfish and spiny lobster. Unspecified triggerfish was not included on commercial fisheries logbook forms until July, 1997. Complete landings for the triggerfish species-group cannot be determined during the years 1997–1999 (see Section 2.3.3.1 for concerns regarding use of multiple forms in these years). During 2011, queen triggerfish landings were reported as "triggerfish" from January-June; species-specific landings began in July.

Year	Queen triggerfish	Unspecified triggerfish	Spiny lobster
1975			6,796
1976			6,742
1977			19,462
1978			58,432
1979			29,385
1980			36,088
1981			38,068
1982			36,661
1983			36,141
1984			35,979
1985			30,141
1986			23,637
1987			40,667
1988			54,682
1989			58,858
1990			77,837
1991			54,800
1992			86,451
1993			83,261
1994			61,773
1995			67,390
1996			88,037
1997			95,097
1998		47,932	74,077
1999		68,618	75,828
2000		72,090	76,153
2001		82,688	89,711
2002		97,543	115,972
2003		101,523	135,292
2004		87,420	133,982
2005		76,462	124,643
2006		70,120	136,027
2007		72,642	119,641
2008		84,131	110,465
2009		79,469	115,762
2010		79,555	114,577
2011	26,364	30,703	84,302
2012	44,835	1,205	83,157
2013	43,762	1,272	84,233
2014	44,107	1,556	89,092

2.3.4 St. Croix

2.3.4.1 Commercial landings

In St. Croix, landings have been available from lobbooks, reported by species-group since 1998. Logbook landings data by species/species-group for the years 1998–2014 are provided in Appendix 4.1.4. Species/species-groups are ordered by total expanded landings from highest to lowest. Also provided are the average landings per year (average over all years 1998–2014), the number of years during which the species/species-group was reported (not all species were included on the reporting form during all years), average landings per year (average over years the species was reported), percent of total landings accounted for by the landings of each species, and the cumulative percentage of the total landings.

The species/species-group with the highest total landings was unspecified parrotfish. The species/species-groups that accounted for the highest 50 percent of the landings included unspecified parrotfish, spiny lobster, and queen conch. Appendix 4.1.5 includes landings totals, primarily by species-group, for the years July, 1975 to December, 1997. Landings reported by gear (e.g., pot fish, hook fish) are not included; therefore, landings of most species-groups are incomplete by necessity as no method exists to convert landings by gear to landings by species-group. Landings of spiny lobster and queen conch, however, have been consistently reported by species since 1975 and may be considered complete as reported.

Commercial landings data for spiny lobster and stoplight parrotfish are provided by year in Table 2.3.6. Spiny lobster landings were available beginning in 1976 (first full year of reporting). Beginning in July, 2011 landings reporting was species-specific.

Parrotfish landings are available for all species combined for the years 1996-2011. Species-specific landings are only available for 2012 – 2014, during which time stoplight parrotfish comprised approximately 32 percent of the total parrotfish reported landings. Other species recorded included princess parrotfish (*Scarus taeniopterus*), queen parrotfish (*Scarus vetula*), redband parrotfish (*Sparisoma aurofrenatum*), redfin parrotfish (*Sparisoma rubripinne*), redtail parrotfish (*Sparisoma chrysopterum*) and unspecified parrotfish; Table 2.3.7). The SEDAR 46 DW/AW Panel recommended using the proportion of stoplight parrotfish reported from the Trip Interview Program (~38%) to partition landings of stoplight parrotfish from the landings reported as parrotfish during the period 1996 to July, 2011.

2.3.4.2 Commercial discards

Self-reported commercial discard information available from commercial logbooks is restricted to the number of fish discarded dead, the number of fish discarded alive, the number of lobster discarded dead, and the number of lobster discarded alive. The limited self-reported commercial discard information was available for the period July, 2011–2014. No commercial discard information was presented at the SEDAR 46 DW/AW Workshop.

Table 2.3.6 St. Croix commercial landings (whole weight, pounds) for spiny lobster and stoplight parrotfish. Unspecified parrotfish was not on commercial fisheries logbook forms until July, 1995. Complete landings for the parrotfish species-group cannot be determined during the years 1997–1999 (see Section 2.3.4.1 text for concerns regarding use of multiple forms in these years). During 2011, all parrotfish landings were reported as "parrotfish" from January-June; species-specific landings began in July.

Year	**Spiny lobster**	**Stoplight parrotfish**	**Unspecified parrotfish**	**Other Parrotfish Species**				
				Princess parrotfish	**Queen parrotfish**	**Redband parrotfish**	**Redfin parrotfish**	**Redtail parrotfish**
1976	2,218							
1977	8,166							
1978	4,981							
1979	3,078							
1980	1,288							
1981	2,104							
1982	2,692							
1983	4,480							
1984	7,564							
1985	4,426							
1986	5,970							
1987	13,032							
1988	8,012							
1989	2,207							
1990	19,472							
1991	37,246							
1992	21,132							
1993	37,176							
1994	29,790							
1995	25,029							
1996	28,843		65,678					
1997	35,949		181,670					
1998	42,718		213,544					
1999	53,329		235,861					
2000	89,020		260,474					
2001	116,619		290,499					
2002	116,273		307,591					
2003	106,039		262,473					
2004	125,415		319,250					
2005	120,929		376,389					
2006	146,592		433,096					
2007	168,005		414,901					
2008	148,003		354,997					
2009	149,908		316,094					
2010	139,685		162,623					
2011	109,751	20,152	98,350	7,992	8,411	5,149	6,242	8,235
2012	86,997	41,869	98	18,140	17,475	13,264	15,337	12,684
2013	59,398	33,773	36	15,265	14,958	12,964	16,264	14,176
2014	39,681	21,750	19	11,068	12,248	9,166	10,481	10,605

Table 2.3.7 Percent of total parrotfish landings by species reported from the St. Croix commercial fishery.

Species	**Percent of 2012 parrotfish landings**	**Percent of 2013 parrotfish landings**	**Percent of 2014 parrotfish landings**	**Mean percent of total**
Princess parrotfish	15.26	14.21	14.69	14.72
Queen parrotfish	14.70	13.92	16.26	14.96
Redband parrotfish	11.16	12.07	12.17	11.80
Redfin parrotfish	12.90	15.14	13.91	13.98
Redtail parrotfish	10.67	13.19	14.08	12.65
Stoplight parrotfish	35.22	31.44	28.87	31.84
Unspecified parrotfish	0.08	0.03	0.03	0.05

2.3.5 Research recommendations

2.3.5.1 Commercial research recommendations

- Evaluate the efficacy of existing commercial landings expansion factors used in Puerto Rico; provide recommendations for improved methods to calculate expansion factors; examine the impact on landings estimates due to methodological changes implemented in 2003 for calculating expansion factors
- Verify, using port samplers or other appropriate methods, self-reported landings in the US Virgin Islands and Puerto Rico
- Obtain species-specific estimates of discards from the commercial sector in Puerto Rico and in the US Virgin Islands
- Quantify the sizes and discard conditions of fish discarded by commercial fisheries in Puerto Rico and in the US Virgin Islands

2.3.5.2 Recreational research recommendations

- Increase representative sampling of the recreational sector in Puerto Rico and expand to collect recreational data in the US Virgin Islands
- Include spiny lobster and conch in the MRIP in order to estimate recreational catch for these important Caribbean species
- Explore changes in the Puerto Rico recreational catch estimates as a result of the change in intercept protocols and estimation methodologies from MRFSS to MRIP in 2014

2.4 Measures of catch per unit of effort (CPUE)

2.4.1 Overview

The recommended nominal measures of catch per unit of effort (CPUE) are provided in Table 2.4.1.

Nominal and standardized estimates of CPUE were developed from fishery dependent data for the six island-species units identified for the SEDAR 46 stock evaluation (see Section 2.4.2). Generally, standardized indices are preferred when available. However, the DW/AW Panel recommended using the nominal indices until the standardization methods are improved or further investigated. The DW/AW Panel was concerned with the standardized indices developed for SEDAR 46 because there were few explanatory factors examined (year and month in USVI; year, month and coast in PR). While inclusion of few explanatory factors cannot justify the rejection of standardized indices, the diagnostic plots and estimates of dispersion in most of the standardizations suggested that variability in CPUE was not being model appropriately. Recommendations for improving the standardization methods are provided in Section 2.4.4.

Nominal and standardized estimates of CPUE were developed from fishery independent data for two of the species-island units identified for evaluation in SEDAR 46 (Section 2.4.3). The fishery independent indices were characterized by low numbers of positive stations and the results of a power analysis (described in Appendix 4.2) suggested a larger number of survey stations would be needed to detect a change in cpue over he period analyzed (5 or 10 years). Therefore, the DW/AW panel did not recommend the fishery independent data for use in SEDAR 46.

Table 2.4.1 Nominal measures of catch per unit of effort for the species considered in the SEDAR 46 stock evaluation.

	Puerto Rico		**St. Thomas**		**St. Croix**	
Year	**Hogfish diving**	**Yellowtail snapper handline**	**Queen triggerfish trap**	**Spiny lobster trap**	**Spiny lobster diving**	**Stoplight parrotfish diving**
1990	1.1053	1.5733				
1991	1.2284	1.1795				
1992	1.8357	0.9297				
1993	0.3479	0.9933				
1994	1.2756	1.1704				
1995	1.1161	1.4826				
1996	1.0002	1.1508				
1997	0.8982	1.1235				
1998	1.4381	1.2236				
1999	1.0749	1.1259				
2000	1.1739	1.1788	1.0495	0.6360	0.6937	
2001	1.0313	1.3280	1.0206	0.6168	0.7053	
2002	0.9704	1.1044	1.1288	0.8007	0.6987	
2003	0.7236	0.7797	1.0418	0.9686	0.7348	
2004	0.7377	0.8425	0.8730	0.9242	0.8766	
2005	0.8175	0.7178	1.0719	0.8757	0.8288	
2006	0.8229	0.7219	1.0586	1.0948	0.7827	
2007	0.7289	0.8569	0.9564	1.1008	1.2959	
2008	0.8539	0.6936	0.9390	1.2045	1.4462	
2009	0.8098	0.6101	0.9376	1.1086	1.4396	
2010	0.8697	0.6329	1.3975	1.2727	1.6383	
2011	0.9280	0.7539	0.9088	0.9556	1.4294	
2012	1.0649	0.8663	0.9751	0.9905	0.7906	1.1993
2013	1.0756	0.9501	0.7948	1.1055	0.7933	1.1241
2014	1.0716	1.0105	0.8465	1.3450	0.8461	0.6766

2.4.2 Fishery-dependent measures of abundance

Observations of catch and effort from self-reported commercial fisher catch reports (also called logbooks/sales receipts) were used to develop nominal and standardized indices of abundance for use in the SEDAR 46 stock evaluations. These data were collected by The Division of Fish and Wildlife in the US Virgin Islands (USVI) and by the Department of Natural and Environmental Resources in Puerto Rico (PR).

In both the USVI and PR, the DW/AW panel recommended combining observations across gears assumed to have similar selectivitioes. The diving gear group included (1) Diving Gear by Hand, (2) No Diving Gear by Hand and (3) Spears. The handline gear group included (1) Handline, (2) Hook and Line and (3) Bottom Hook and Line. The Trap gear included (1) Fish Pots and Traps, (2) Spiny Lobster Pots and Traps and (3) Pots and Traps.

The following data filtering techniques were applied to both the USVI and PR logbook data to identify data records suitable for use in the development of nominal and standardized CPUE abundance trends:

- Trips that reported more than one gear type were excluded
- Trips associated with more than one value or with no value for number of gear fished were excluded (USVI catch report data only)
- Trips associated with more than one value or with no value for number of hours fished were excluded (PR catch report data only)
- Records associated with more than one trip were excluded (PR catch report data only)
- Trips with effort outliers (reported effort values above the 99% quantile of values reported for a given gear and island unit)
- Outliers were removed from the data by examining the number of gear fished and the number of hours fished by gear type and removing trips where values in at least one of these variables fell above the 99.5th percentile.
- Analyses were were restricted to the gear group associated with the most representative fishing fleet (e.g., the gear with the most reported commercial logbook trips for a given species, Section 2.1.4)

Generalized linear models (GLM) were used to estimate relative indices of abundance. Specifically, the delta-lognormal modeling approach was used. This approach combines a binomial analysis of the proportion of successful trips (trips that landed a given species) and a lognormal analysis of the catch rates on successful trips to construct a single standardized CPUE index (Lo et al. 1992, Hinton and Maunder 2004, Maunder and Punt 2004). A stepwise approach was used to quantify the relative importance of the explanatory factors. The factors year, month, and coast were screened and added to the models until the reduction in deviance per degree of freedom was less than one percent. The years of data included, the factors considered, the parameters tested and retained in the delta-lognormal model, and a summary table of the nominal and standardized indices are provided within each species-island unit below.

2.4.2.1 Hogfish, Puerto Rico diving fishery

- Catch rate units: pounds per hour fished
- Years of data used: 1990–2014
- Variables tested: year, month, coast (north, south, east, west)
- Binomial submodel: year, coast
- Lognormal submodel: year, coast

Table 2.4.2 summarizes, by year, the number of total trips, the proportion of positive trips, the nominal catch rate, and the standardized index of abundance. Figure 2.4.1 provides plots of the nominal and standardized indices and standard diagnostic plots.

Table 2.4.2 Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for hogfish from the diving fishery in Puerto Rico.

Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
1990	435	0.28	1.0989	1.1053	0.1777	0.7768	1.5726
1991	1251	0.23	1.4841	1.2284	0.1189	0.9692	1.5570
1992	1199	0.27	1.4805	1.8357	0.1078	1.4807	2.2757
1993	1478	0.08	0.3258	0.3479	0.1781	0.2443	0.4955
1994	1984	0.20	1.1230	1.2756	0.0984	1.0482	1.5522
1995	2899	0.18	1.0552	1.1161	0.0878	0.9367	1.3300
1996	1976	0.19	1.1236	1.0002	0.1005	0.8185	1.2221
1997	2167	0.20	1.0963	0.8982	0.0942	0.7442	1.0839
1998	2102	0.31	1.3858	1.4381	0.0739	1.2408	1.6667
1999	2801	0.25	1.3663	1.0749	0.0744	0.9264	1.2471
2000	3092	0.27	1.6886	1.1739	0.0698	1.0211	1.3496
2001	6317	0.29	1.2247	1.0313	0.0492	0.9346	1.1379
2002	6310	0.29	1.2526	0.9704	0.0495	0.8790	1.0714
2003	8030	0.26	0.7620	0.7236	0.0476	0.6579	0.7958
2004	7809	0.23	0.6760	0.7377	0.0484	0.6696	0.8127
2005	7171	0.24	0.6485	0.8175	0.0492	0.7410	0.9020
2006	6936	0.28	0.7320	0.8229	0.0460	0.7505	0.9021
2007	7298	0.26	0.7429	0.7289	0.0483	0.6619	0.8027
2008	6876	0.26	0.7618	0.8539	0.0483	0.7753	0.9406
2009	7773	0.28	0.6958	0.8098	0.0451	0.7400	0.8861
2010	5339	0.25	0.6882	0.8697	0.0538	0.7810	0.9684
2011	6311	0.25	0.7243	0.9280	0.0497	0.8402	1.0249
2012	6762	0.25	0.9040	1.0649	0.0480	0.9676	1.1721
2013	6971	0.27	0.9649	1.0756	0.0460	0.9812	1.1792
2014	7310	0.26	0.9942	1.0716	0.0464	0.9768	1.1756

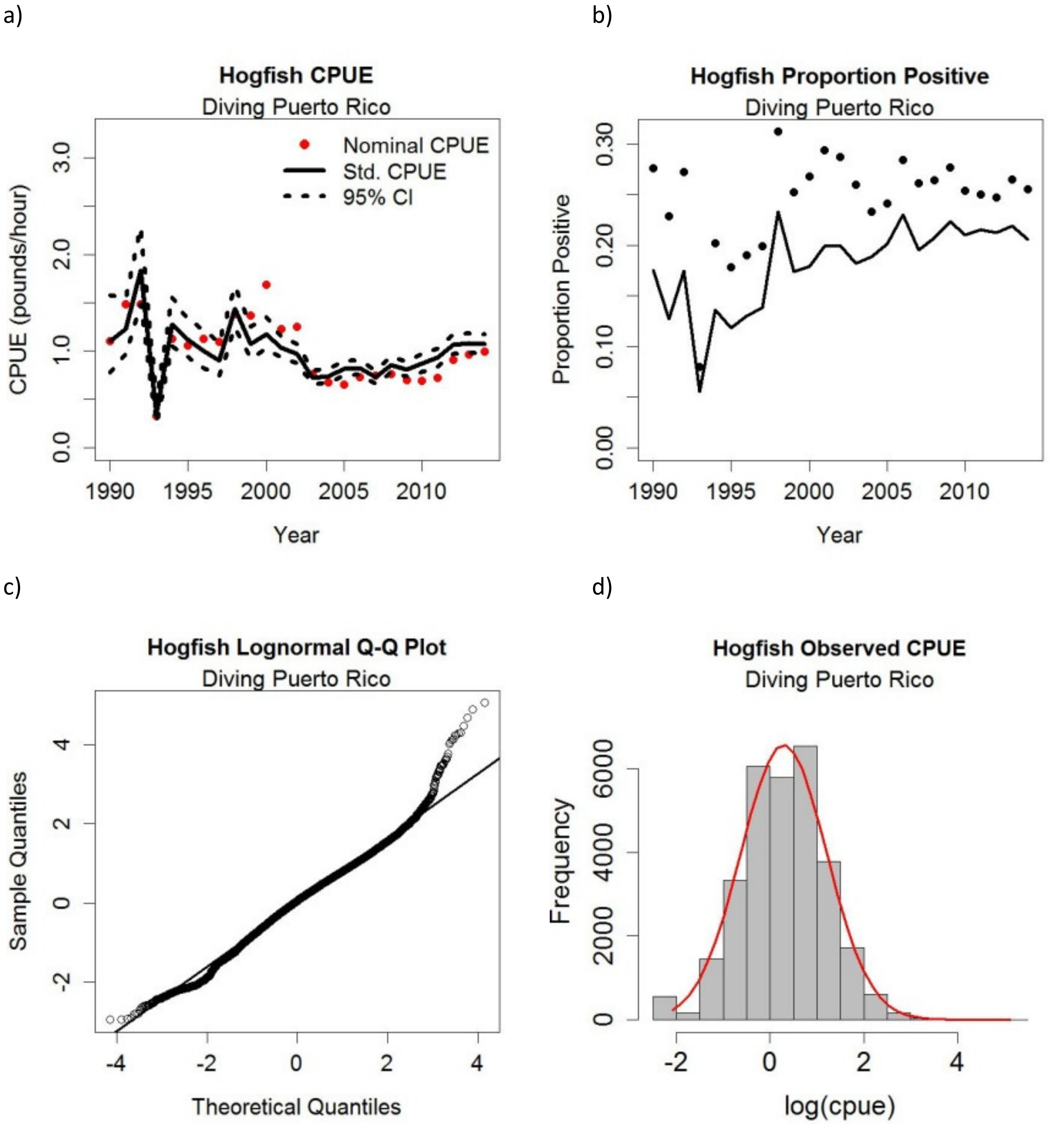


Figure 2.4.1 Nominal CPUE and diagnostics for the standardized index for hogfish from the diving fishery in Puerto Rico. a) Nominal CPUE, standardized index, and the 95% confidence intervals. b) Fit of the binomial proportion positive model to the observed proportion positive values. c) QQ-Plot of CPUE. d) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution.

2.4.2.2 Yellowtail snapper, Puerto Rico diving fishery

Catch rate units:	pounds per hour fished
Years of data used:	1990–2014
Variables tested:	year, month, coast (north, south, east, west)
Binomial submodel:	year, coast, month
Lognormal submodel:	year, coast, month

Table 2.4.3 summarizes, by year, the number of total trips, the proportion of positive trips, the nominal catch rate, and the standardized index of abundance. Figure 2.4.2 provides plots of the nominal and standardized indices and standard diagnostic plots.

Table 2.4.3 Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for yellowtail snapper from the handline fishery in Puerto Rico.

Year	**Trips**	**PPT**	**Nominal CPUE**	**Standardized Index**	**CV**	**Lower 95% CI**	**Upper 95% CI**
1990	1020	0.38	1.5733	1.4408	0.2481	0.8837	2.3491
1991	2680	0.33	1.1795	1.0879	0.1762	0.7668	1.5434
1992	2580	0.32	0.9297	0.8387	0.1827	0.5837	1.2051
1993	3779	0.30	0.9933	0.9185	0.1577	0.6713	1.2566
1994	3094	0.31	1.1704	0.9523	0.1743	0.6738	1.3459
1995	4950	0.35	1.4826	1.1722	0.1251	0.9136	1.5041
1996	4791	0.34	1.1508	0.9894	0.1304	0.7632	1.2827
1997	4493	0.35	1.1235	1.0036	0.1313	0.7726	1.3035
1998	4454	0.36	1.2236	1.0575	0.1276	0.8201	1.3636
1999	4421	0.36	1.1259	0.9401	0.1334	0.7208	1.2261
2000	4448	0.36	1.1788	0.9383	0.1312	0.7225	1.2185
2001	7852	0.38	1.3280	1.1061	0.0934	0.9180	1.3328
2002	8242	0.37	1.1044	1.0576	0.0904	0.8830	1.2667
2003	11348	0.29	0.7797	0.8456	0.0884	0.7088	1.0088
2004	9173	0.29	0.8425	1.0170	0.0952	0.8410	1.2298
2005	8822	0.26	0.7178	0.9062	0.1023	0.7390	1.1113
2006	8134	0.27	0.7219	0.9188	0.1027	0.7486	1.1277
2007	6951	0.27	0.8569	1.0790	0.1113	0.8642	1.3471
2008	6641	0.23	0.6936	0.8862	0.1263	0.6891	1.1397
2009	6080	0.24	0.6101	0.8118	0.1267	0.6307	1.0448
2010	5129	0.25	0.6329	0.8562	0.1370	0.6519	1.1246
2011	5285	0.28	0.7539	0.9842	0.1266	0.7647	1.2666
2012	4833	0.31	0.8663	1.0416	0.1294	0.8050	1.3477
2013	5128	0.32	0.9501	1.0157	0.1269	0.7888	1.3080
2014	6326	0.32	1.0105	1.1347	0.1111	0.9093	1.4160

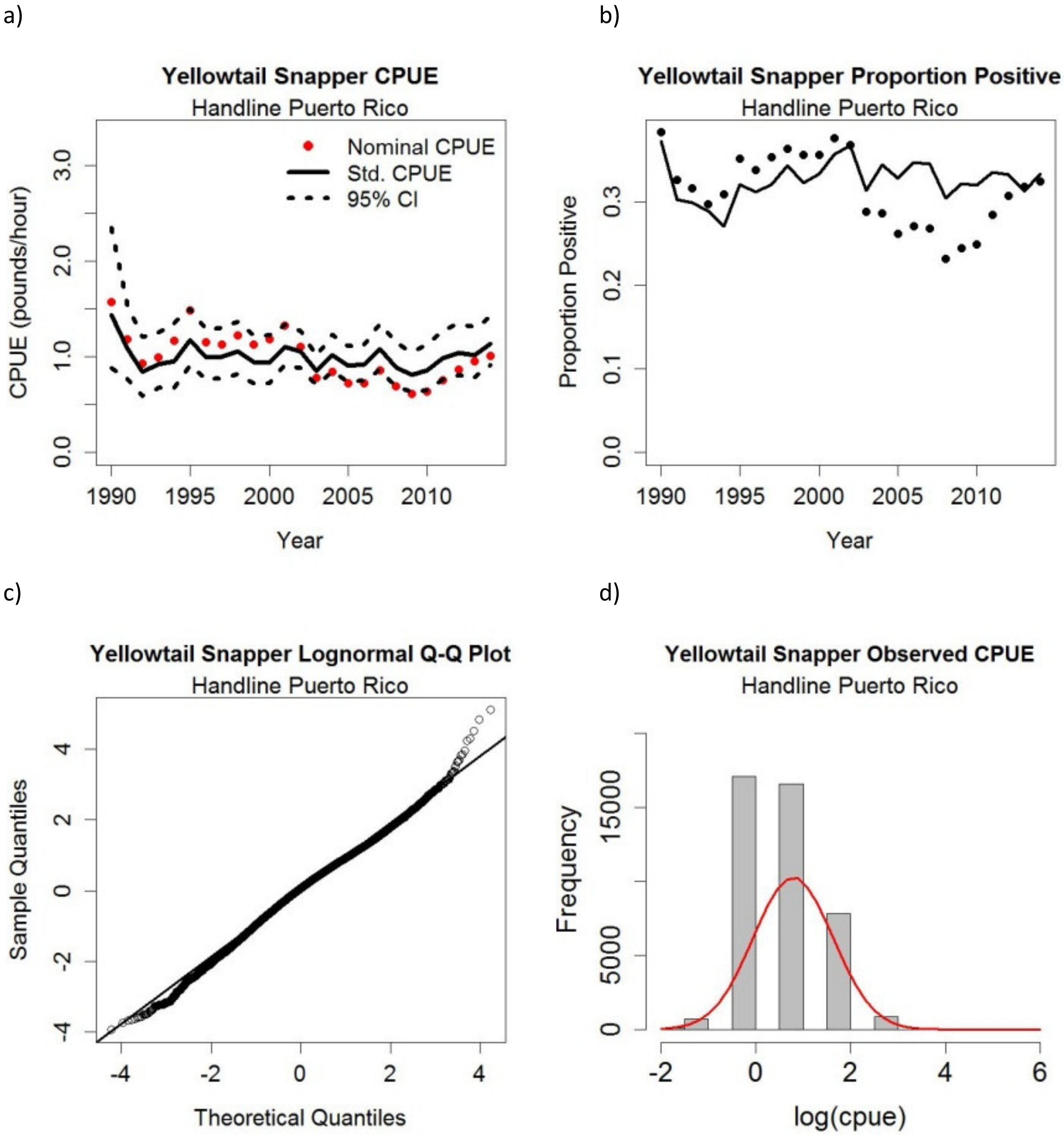


Figure 2.4.2 Nominal CPUE and diagnostics for the standardized index for yellowtail snapper from the handline fishery in Puerto Rico. a) Nominal CPUE, standardized index, and the 95% confidence intervals. b) Fit of the binomial proportion positive model to the observed proportion positive values. c) QQ-Plot of CPUE. d) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution.

2.4.2.3 Queen triggerfish and triggerfish unspecified, St. Thomas traps

Catch rate units:	pounds per trap fished
Years of data used:	2000–2014
Variables tested:	year, month
Binomial submodel:	year
Lognormal submodel:	year
Caveats:	no significant explanatory variables

Table 2.4.4 summarizes, by year, the number of total trips, the proportion of positive trips, the nominal catch rate, and the standardized index of abundance. Figure 2.4.4 provides plots of the nominal and standardized indices and standard diagnostic plots.

Table 2.4.4 Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for queen triggerfish and unspecified triggerfish from the trap fishery in St. Thomas.

Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
2000	2483	0.80	1.0495	1.1167	0.0200	1.0730	1.1621
2001	2572	0.78	1.0206	1.0654	0.0198	1.0240	1.1085
2002	2587	0.78	1.1288	1.1768	0.0198	1.1311	1.2243
2003	2646	0.76	1.0418	1.0643	0.0198	1.0230	1.1072
2004	2586	0.78	0.8730	0.9577	0.0198	0.9204	0.9965
2005	2559	0.73	1.0719	0.9267	0.0205	0.8894	0.9655
2006	2488	0.72	1.0586	0.9362	0.0209	0.8979	0.9762
2007	2397	0.72	0.9564	1.0145	0.0214	0.9720	1.0589
2008	2495	0.75	0.9390	1.0171	0.0206	0.9761	1.0599
2009	2325	0.75	0.9376	1.0308	0.0212	0.9879	1.0755
2010	2065	0.75	1.3975	1.0208	0.0225	0.9760	1.0677
2011	1526	0.73	0.9088	0.9936	0.0264	0.9425	1.0475
2012	1383	0.71	0.9751	0.8782	0.0280	0.8303	0.9289
2013	1242	0.73	0.7948	0.8761	0.0293	0.8263	0.9290
2014	1165	0.72	0.8465	0.9250	0.0305	0.8704	0.9831

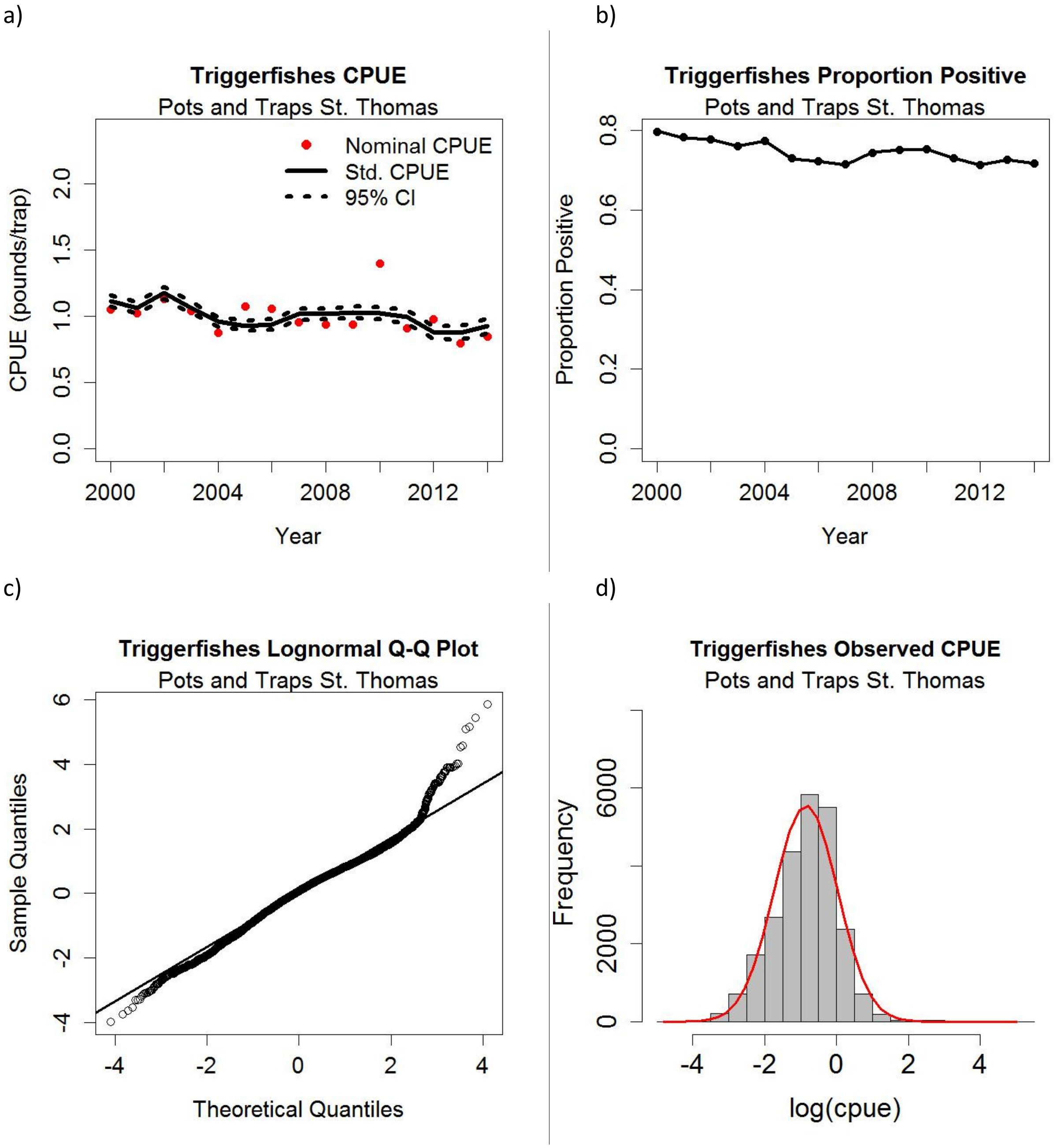


Figure 2.4.3 Nominal CPUE and diagnostics for the standardized index for triggerfishes from the trap fishery in St. Thomas. a) Nominal CPUE, standardized index, and the 95% confidence intervals. b) Fit of the binomial proportion positive model to the observed proportion positive values. c) QQ-Plot of CPUE. d) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution.

2.4.2.4 Caribbean spiny lobster, St. Thomas traps

Catch rate units:	pounds per trap fished
Years of data used:	2000–2014
Variables tested:	year, month
Binomial submodel:	year
Lognormal submodel:	year, month

Table 2.4.5 summarizes, by year, the number of total trips, the proportion of positive trips, the nominal catch rate, and the standardized index of abundance. Figure 2.4.4 provides plots of the nominal and standardized indices and standard diagnostic plots.

Table 2.4.5 Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for spiny lobster from the trap fishery in St. Thomas.

Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
2000	2483	0.40	0.6360	0.6245	0.0295	0.5887	0.6624
2001	2572	0.41	0.6168	0.6343	0.0287	0.5989	0.6718
2002	2587	0.47	0.8007	0.8228	0.0269	0.7798	0.8682
2003	2646	0.51	0.9686	1.0260	0.0255	0.9749	1.0797
2004	2586	0.56	0.9242	1.0140	0.0247	0.9652	1.0654
2005	2559	0.53	0.8757	0.9963	0.0256	0.9466	1.0486
2006	2488	0.49	1.0948	1.0418	0.0270	0.9871	1.0995
2007	2397	0.50	1.1008	0.9740	0.0271	0.9226	1.0283
2008	2495	0.53	1.2045	1.1136	0.0258	1.0577	1.1724
2009	2325	0.53	1.1086	1.0822	0.0268	1.0257	1.1418
2010	2065	0.54	1.2727	1.1717	0.0282	1.1076	1.2396
2011	1526	0.55	0.9556	0.9286	0.0323	0.8705	0.9906
2012	1383	0.62	0.9905	1.0096	0.0318	0.9473	1.0760
2013	1242	0.68	1.1055	1.1527	0.0321	1.0811	1.2291
2014	1165	0.69	1.3450	1.4079	0.0328	1.3185	1.5034

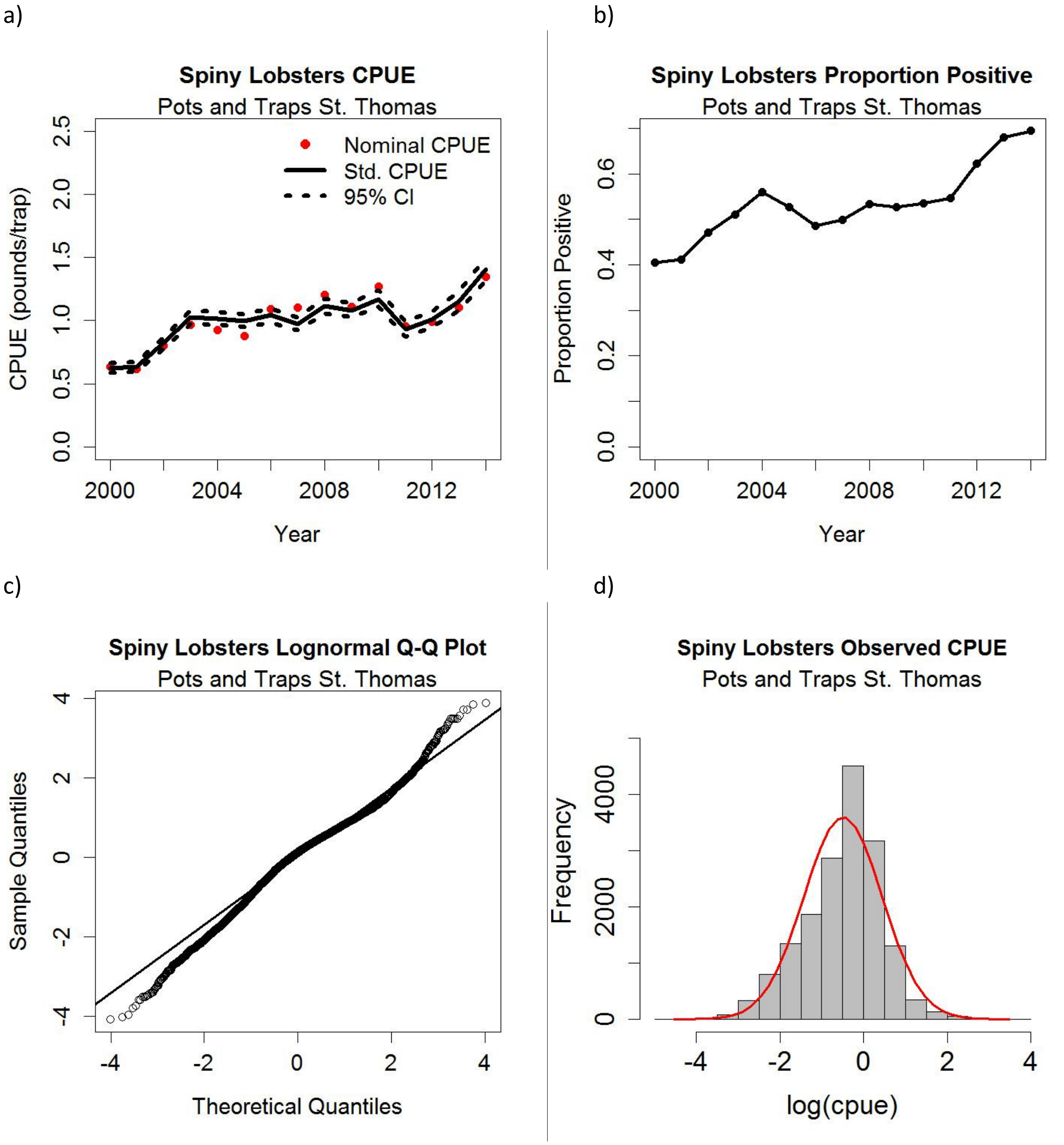


Figure 2.4.4 Nominal CPUE and diagnostics for the standardized index for spiny lobster from the trap fishery in St. Thomas. a) Nominal CPUE, standardized index, and the 95% confidence intervals. b) Fit of the binomial proportion positive model to the observed proportion positive values. c) QQ-Plot of CPUE. d) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution.

2.4.2.5 Caribbean spiny lobster, St. Croix diving

Catch rate units:	pounds per dive
Years of data used:	2000–2014
Variables tested:	year, month
Binomial submodel:	year, month
Lognormal submodel:	year

Table 2.4.6 summarizes, by year, the number of total trips, the proportion of positive trips, the nominal catch rate, and the standardized index of abundance. Figure 2.4.5 provides plots of the nominal and standardized indices and standard diagnostic plots.

Table 2.4.6 Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for spiny lobster from the diving fishery in St. Croix.

Year	**Trips**	**PPT**	**Nominal CPUE**	**Standardized Index**	**CV**	**Lower 95% CI**	**Upper 95% CI**
2000	3216	0.63	0.6937	0.6359	0.0452	0.5811	0.6960
2001	4097	0.65	0.7053	0.6796	0.0383	0.6296	0.7337
2002	4479	0.67	0.6987	0.6942	0.0343	0.6481	0.7435
2003	4392	0.69	0.7348	0.6600	0.0342	0.6164	0.7068
2004	4740	0.65	0.8766	0.8630	0.0333	0.8075	0.9224
2005	4626	0.59	0.8288	0.7899	0.0411	0.7276	0.8575
2006	5163	0.58	0.7827	0.7618	0.0386	0.7052	0.8228
2007	4802	0.69	1.2959	1.2614	0.0312	1.1851	1.3425
2008	4695	0.67	1.4462	1.5041	0.0338	1.4057	1.6094
2009	4669	0.73	1.4396	1.4461	0.0294	1.3636	1.5337
2010	3537	0.73	1.6383	1.6548	0.0326	1.5505	1.7661
2011	2051	0.72	1.4294	1.3546	0.0415	1.2467	1.4717
2012	1317	0.80	0.7906	0.8555	0.0455	0.7810	0.9370
2013	1150	0.80	0.7933	0.8666	0.0478	0.7877	0.9535
2014	855	0.73	0.8461	0.9725	0.0616	0.8598	1.1000

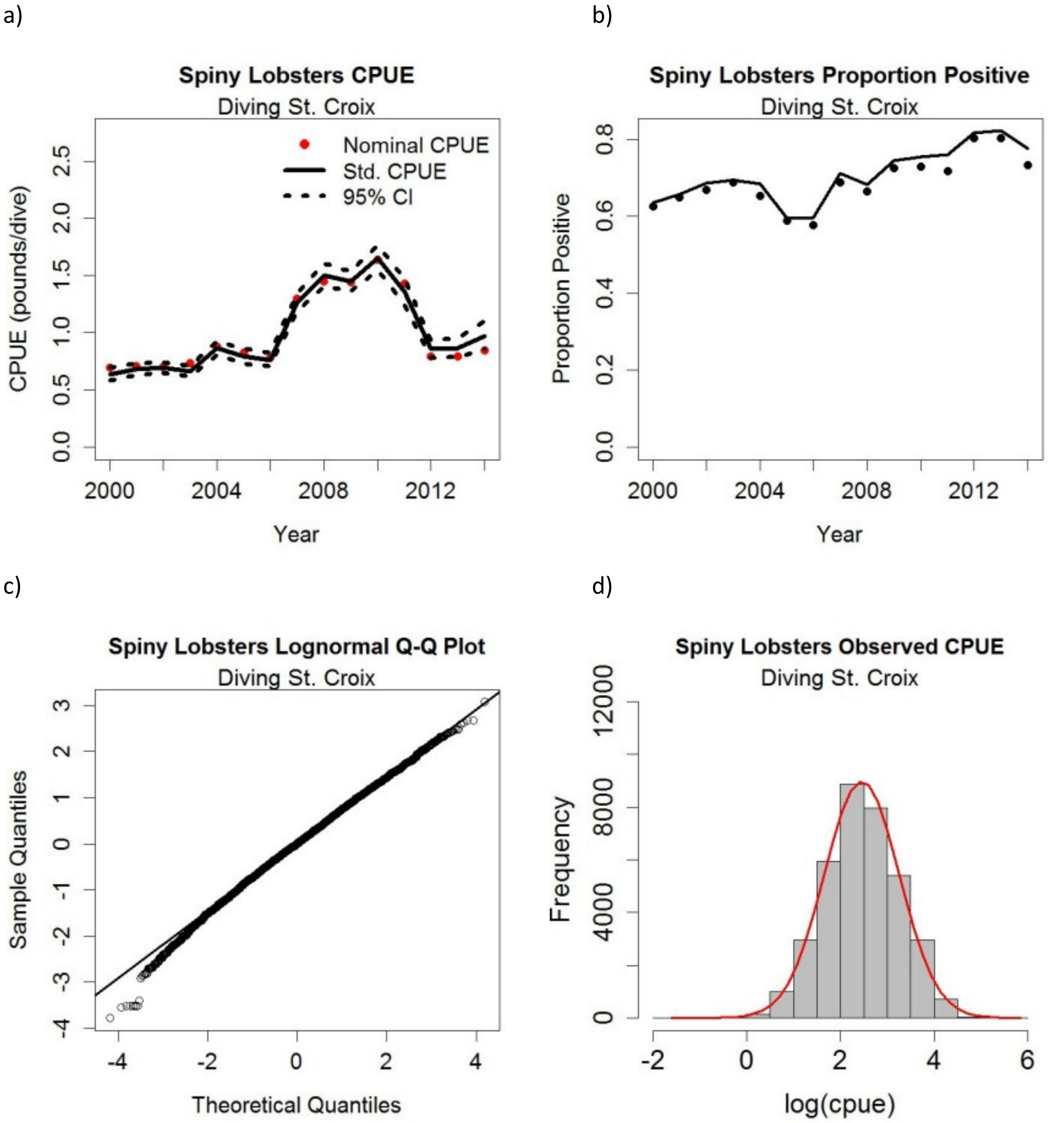


Figure 2.4.5 Nominal CPUE and diagnostics for the standardized index for spiny lobster from the diving fishery in St. Croix. a) Nominal CPUE, standardized index, and the 95% confidence intervals. b) Fit of the binomial proportion positive model to the observed proportion positive values. c) QQ-Plot of CPUE. d) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution.

2.4.2.6 Stoplight parrotfish, St. Croix diving

Catch rate units:	pounds per dive
Years of data used:	2012–2014
Variables tested:	year, month
Binomial submodel:	year, month
Lognormal submodel:	year, month
Caveats:	short time series

Table 2.4.7 summarizes, by year, the number of total trips, the proportion of positive trips, the nominal catch rate, and the standardized index of abundance. Figure 2.4.6 provides plots of the nominal and standardized indices and standard diagnostic plots.

Table 2.4.7 Number of trips, proportion of positive trips (PPT), nominal CPUE, standardized index of abundance and index statistics for stoplight parrotfish from the diving fishery in St. Croix.

Year	Trips	PPT	Nominal CPUE	Standardized Index	CV	Lower 95% CI	Upper 95% CI
2012	1317	0.62	1.1993	1.2270	0.0504	1.1094	1.3570
2013	1150	0.58	1.1241	1.0658	0.0580	0.9491	1.1969
2014	855	0.40	0.6766	0.7072	0.0967	0.5831	0.8577

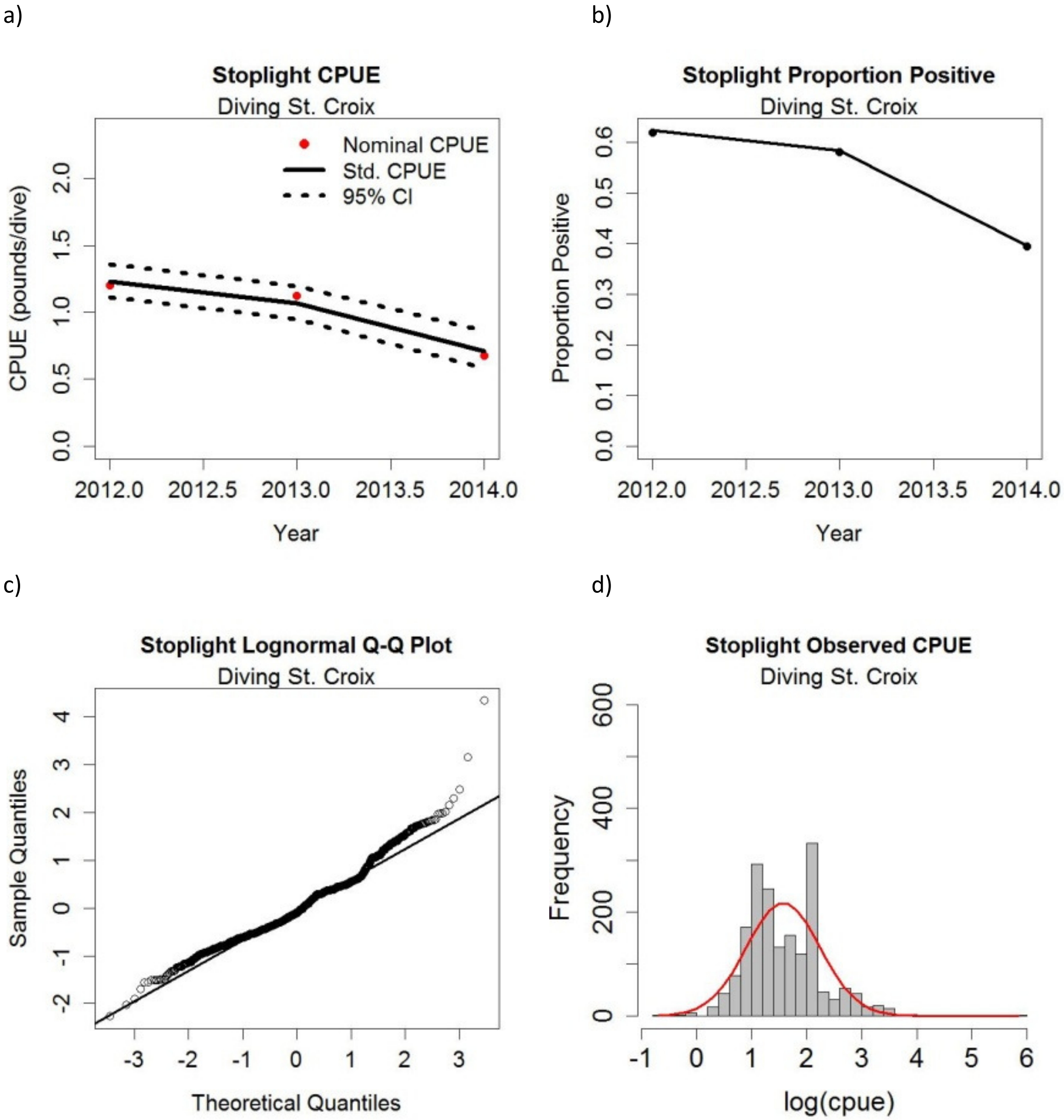


Figure 2.4.6 Nominal CPUE and diagnostics for the standardized index for stoplight parrotfish from the diving fishery in St. Croix. a) Nominal CPUE, standardized index, and the 95% confidence intervals. b) Fit of the binomial proportion positive model to the observed proportion positive values. c) QQ-Plot of CPUE. d) Frequency distribution of catch rates on positive trips. The solid line is the expected normal distribution.

2.4.3 Fishery-independent measures of abundance

Fishery independent observations were examined for use in developing abundance indices for SEDAR 46 evaluation but were not recommended at this time due to low sample sizes. Appendix 4.2 includes a summary of fishery-independent indices derived from SEAMAP-C data (Walter Ingram, unpublished data, personal communication). Reproduced here are the sections that relate to the species and gears in the SEDAR 46 stock evaluations. Within each section is a list of the years of data included, the number of survey stations, the parameters tested and retained in the delta-lognormal (D-L) model based on a backward selection procedure, a table of indices, and the results of power analyses.

2.4.3.1 Yellowtail snapper, Puerto Rico handline west

- Years of data used: 1991–1995, 1997–2001, 2004–2006, 2009–2010
- Total number of stations: 1949
- Parameters used in delta-lognormal model: year, bottom type, depth, closed area (i.e., are the stations located in a marine closed area or not)
- Binomial submodel: year
- Lognormal submodel: year
- Caveats: Numerous gaps in the time series

Year	Nominal Frequency	N	Index	Scaled Index	CV	LCL	UCL
1991	0.00000	94	.	.	.	.	.
1992	0.00962	312	0.001905	0.23512	0.59162	0.07860	0.7033
1993	0.01972	355	0.004319	0.53301	0.38551	0.25317	1.1222
1994	0.01311	305	0.003086	0.38076	0.51153	0.14518	0.9986
1995	0.00000	18	.	.	.	.	.
1997	0.00535	187	0.001070	0.13198	1.02643	0.02419	0.7200
1998	0.00000	82	.	.	.	.	.
1999	0.01235	162	0.002598	0.32066	0.72355	0.08759	1.1739
2000	0.03333	90	0.008689	1.07217	0.58485	0.36236	3.1724
2001	0.02439	82	0.005682	0.70111	0.71935	0.19269	2.5510
2004	0.00000	45	.	.	.	.	.
2005	0.02632	152	0.006713	0.82836	0.50827	0.31758	2.1607
2006	0.04444	45	0.011261	1.38966	0.71230	0.38591	5.0041
2009	0.07692	13	.	.	.	.	.
2010	0.14286	7	0.035714	4.40718	0.95664	0.87900	22.0969

Power analyses indicated that much more than 150 stations are needed annually to detect a 25% annual change in abundance over a ten-year time series.

2.4.3.2 Yellowtail snapper, Puerto Rico handline east

- Years of data used: 2009–2011
- Total number of stations: 88
- Parameters used in D-L model: year, depth
- Binomial submodel: year
- Lognormal submodel: year, depth
- Caveats: Short time series

Year	Nominal Frequency	N	Index	Scaled Index	CV	LCL	UCL
2009	0.15385	26	0.042409	1.12646	0.47101	0.46016	2.75751
2010	0.12245	49	0.032887	0.87354	0.39220	0.40996	1.86137
2011	0.00000	13	.	.	.	.	.

Power analyses indicated that at least 83 stations are needed annually to detect a 10% annual change in abundance over a five-year time series.

2.4.3.3 Queen triggerfish, St. Thomas trap

- Years of data used: 1992–1994, 1999–2000
- Total number of stations: 357
- Parameters used in delta-lognormal model: year, depth
- Binomial submodel: year
- Lognormal submodel: year
- Caveats: Gap in the time series

Year	Nominal Frequency	N	Index	Scaled Index	CV	LCL	UCL
1992	0.10000	60	0.13094	0.58710	0.45492	0.24660	1.39772
1993	0.00000	36	.	.	.	.	.
1994	0.04167	72	0.18982	0.85114	0.65555	0.25743	2.81408
1999	0.13699	73	0.22957	1.02935	0.34830	0.52318	2.02522
2000	0.17241	116	0.34176	1.53242	0.24437	0.94665	2.48064

Power analyses indicated that at least 81 stations are needed annually to detect a 20% annual change in abundance over a five-year time series.

2.4.4 Research recommendations

- Conduct additional examinations to identify auxiliary variables that could be informative in standardization
- Begin the spiny lobster nominal and standardized index further back in time
- Invest in regional scale fisheries-independent surveys to estimate relative (or absolute) abundance
- Investigate methods for subsetting to trips targeting the target species
- Account for change in regulations that may affect CPUE
- Obtain supplementary information and evaluate the use of aggregation of data over gears. The recommendation for SEDAR 46 was to group gear types that were assumed to have similar selectivity's. Additional efforts could help determine when it is or is not appropriate to use gear groups.

2.5 Measures of fishing effort

2.5.1 Overview

Trends in total effort were estimated using the self-reported logbook data. The logbook data are described previously in Section 2.4.2. The total reported logbook effort was adjusted to account for trips that did not report any effort data.

$$\text{Annual adjusted effort} = \\ \text{Annual number of kept trips} * \frac{\text{Total reported annual effort from kept trips}}{\text{Annual number of kept trips that reported effort}}$$

Eq. 2.5.1

where number of kept trips represents the number of trips that were retained after initial data filtering discussed in Section 2.4.2. The units of reported effort were hours fished in Puerto Rico and number of gear in the US Virgin Islands. The estimates of adjusted effort are summarized in Table 2.5.1.

Table 2.5.1 Adjusted effort trends for the four gear-island units identified for analysis during SEDAR 46.

	Puerto Rico (Total hours fishing)		**St. Thomas/St. John (Total number of traps)**	**St. Croix (Total number of dives)**
Year	**Handline**	**Diving**	**Traps**	**Diving**
1990	51,083	21,746		
1991	78,392	34,666		
1992	73,008	25,112		
1993	99,185	40,042		
1994	82,973	51,156		
1995	135,457	67,373		
1996	154,261	59,238		
1997	149,761	58,946		
1998	110,450	70,662		
1999	118,228	75,630		
2000	131,467	68,772	174,231	11,472
2001	131,066	71,722	180,852	16,213
2002	118,151	72,952	192,188	17,381
2003	94,719	60,695	218,618	16,726
2004	74,426	59,926	230,341	16,674
2005	71,076	50,634	224,696	17,663
2006	66,354	52,838	210,898	20,971
2007	56,177	51,213	195,611	15,478
2008	52,990	50,827	222,161	10,962
2009	48,842	56,470	208,180	11,103
2010	51,312	46,611	192,369	9,480
2011	58,911	63,447	156,738	8,851
2012	51,670	61,349	142,769	9,310
2013	54,178	65,932	132,201	6,355
2014	63,511	62,675	119,992	4,494

2.5.2 Puerto Rico handline and diving

There are two auxiliary variables used to report effort on the catch forms in Puerto Rico. The first variable is gear hours and the second is gear quantity. Since 2003, for both the handline and diving gears, the number of hours fished has been reported on the majority of trips, but few trips report the quantity of gear fished (Figures 2.5.1a and 2.5.2a). As such, the trend for effort was estimated using hours fished. Note that in recent years, for both gears, the proportion of trips that do not report hours fished has been increasing while the proportion of trips that report gear quantity has been increasing.

Figures 2.5.1b and 2.5.2b show mean annual hours per trip from trips that reported effort. Figures 2.5.1c and 2.5.2c show the difference between reported effort and the effort adjusted to account for trips that did not report effort.

a)

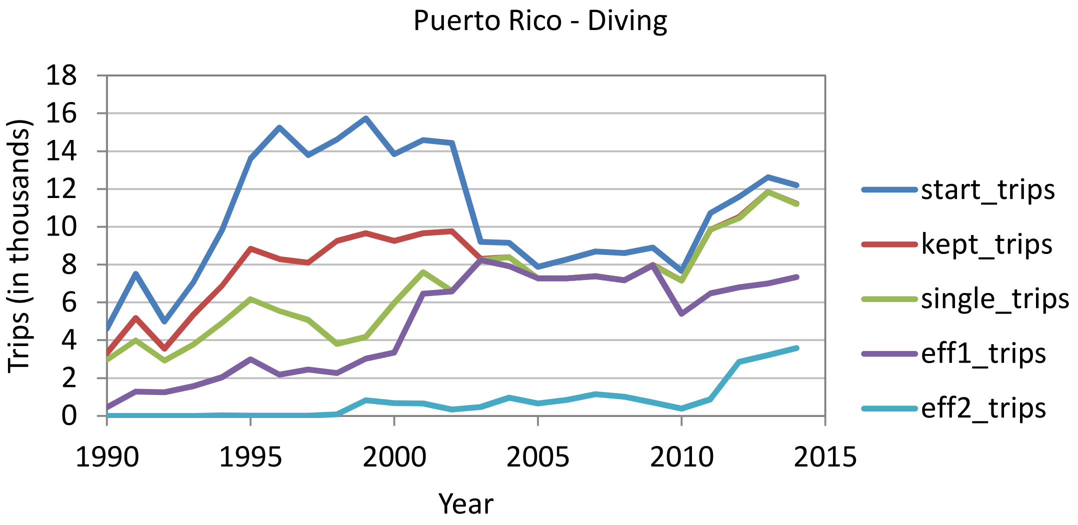
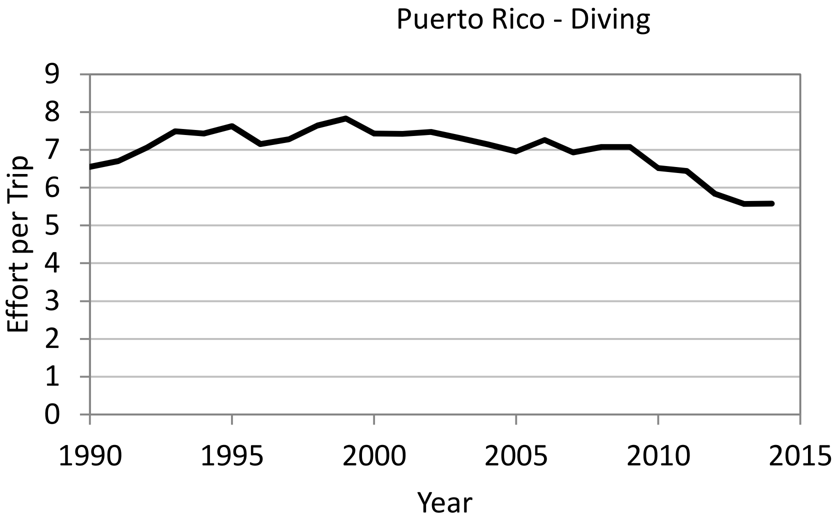


Figure 2.5.1 Effort plots for the diving fishery in Puerto Rico (1990–2014) a) Total trips (blue line) were calculated as the sum of reported trips across all of the data. The number of kept trips (red line) was calculated as the sum of reported trips across the data that remained after removing records associated with multiple gear groups or with inconsistent effort data. The number of single trips (green line) was calculated from the number of unique trips after further removing catch reports associated with more than one trip. Eff1_trips (purple line) and Eff2_trips (teal line) show the number of single retained trips that reported hours fished and quantity of trap gear, respectively.

b)



c)

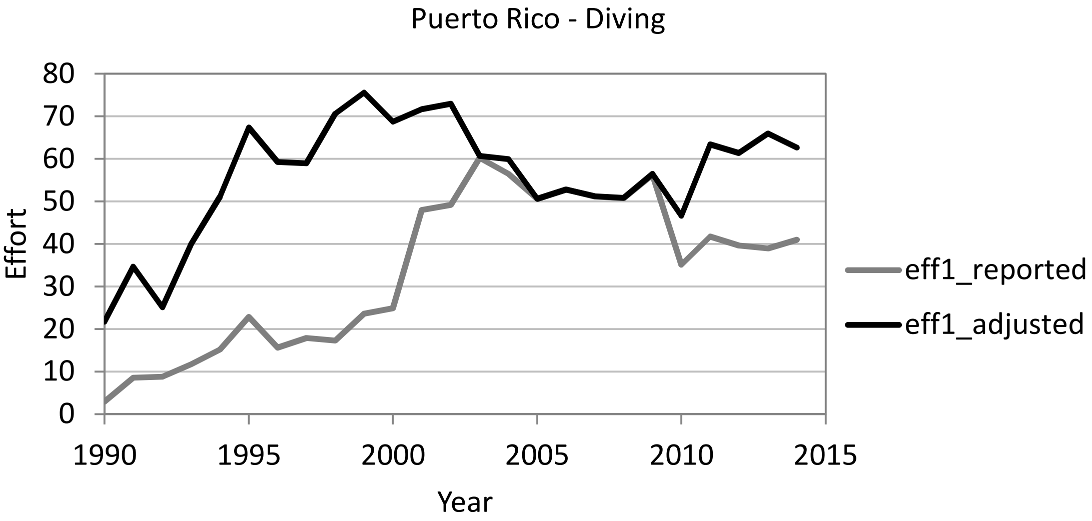


Figure 2.5.1 Continued. Effort plots for the diving fishery in Puerto Rico (1990–2014) b) Annual mean hours per trip from trips that reported hours fished. c) Total reported effort (gray line) compared to the total adjusted effort (black line).

a)

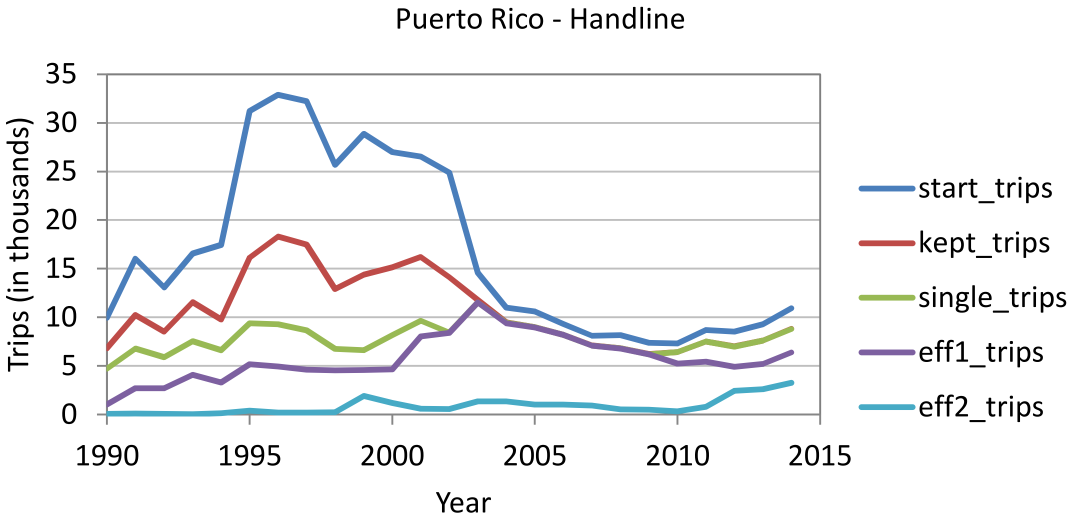
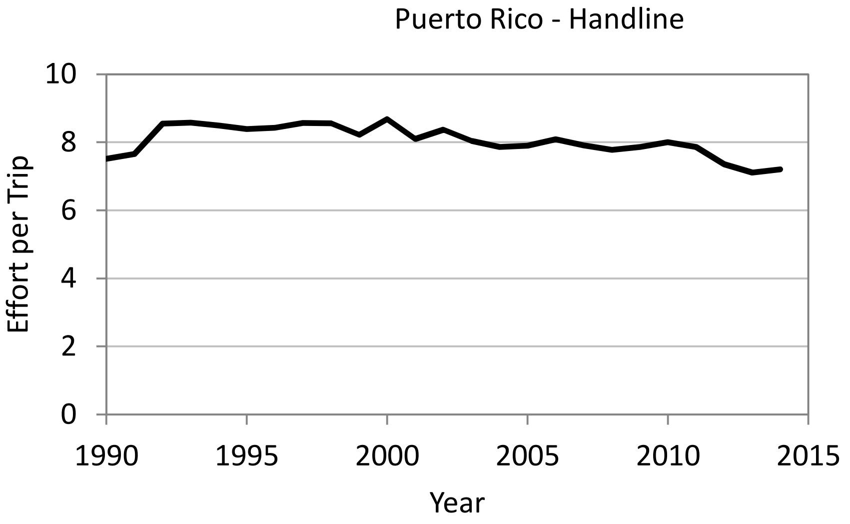


Figure 2.5.2 Effort plots for the trap fishery in Puerto Rico (1990–2014) a) Total trips (blue line) were calculated as the sum of reported trips across all of the data. The number of kept trips (red line) was calculated as the sum of reported trips across the data that remained after removing records associated with multiple gear groups or with inconsistent effort data. The number of single trips (green line) was calculated from the number of unique trips after further removing catch reports associated with more than one trip. Eff1_trips (purple line) and Eff2_trips (teal line) show the number of single retained trips that reported hours fished and quantity of trap gear, respectively.

b)



c)

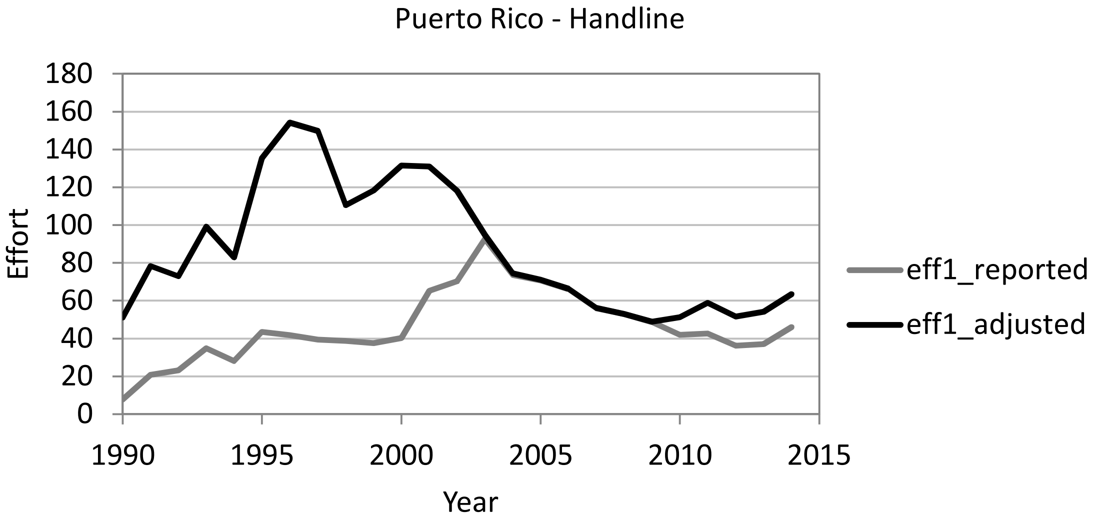


Figure 2.5.2 Continued. Effort plots for the handline fishery in Puerto Rico (1990–2014). b) Annual mean hours per trip from trips that reported hours fished. c) Total reported effort (gray line) compared to the total adjusted effort (black line).

2.5.3 St. Thomas traps

Gear number is the variable used to report effort on the catch forms in the Virgin Islands. For the trap gear in St. Thomas, it is the number of traps fished. A majority of the reported trap fishing trips reported the number of traps. Thus, the adjusted trend in effort is nearly identical to the reported trend in effort (Figure 2.5.3c).

a)

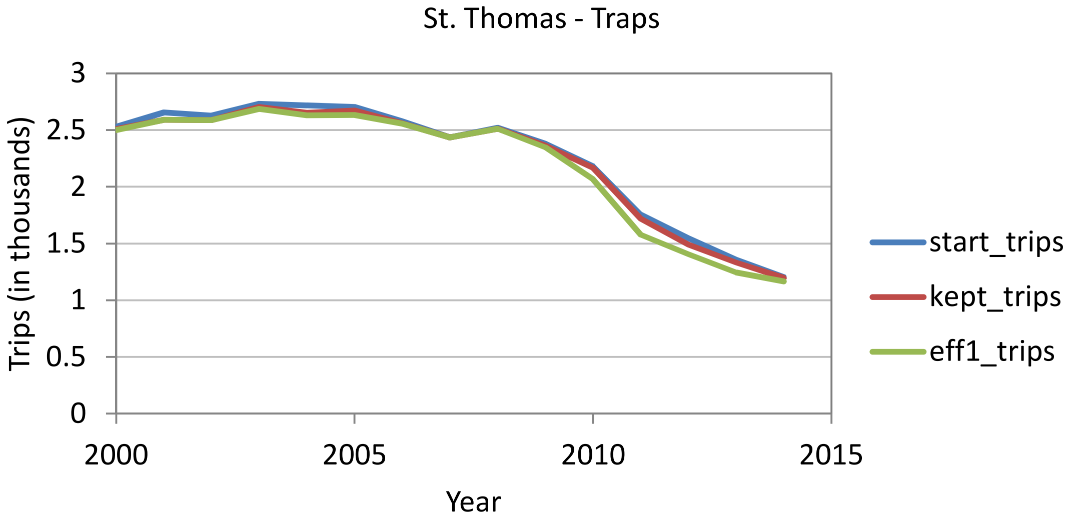
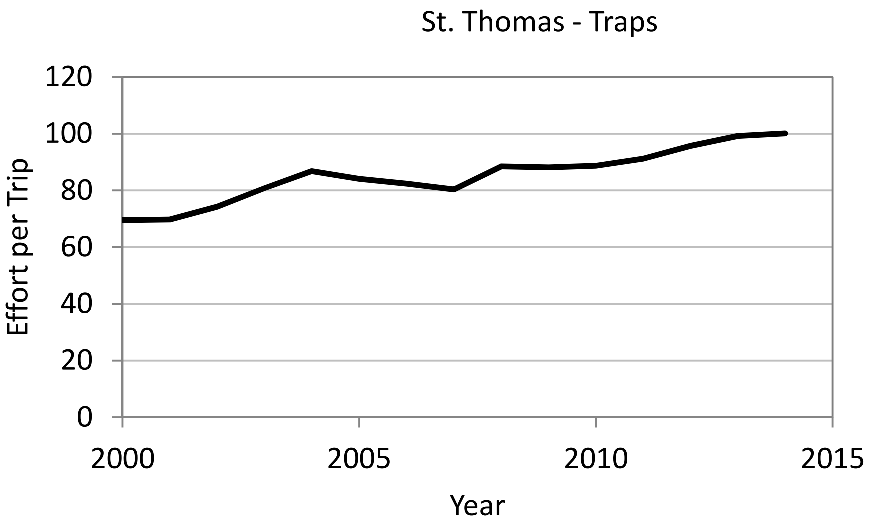


Figure 2.5.3 Effort plots for the trap fishery in St. Thomas (2000–2014) a) Total trips (blue line) were calculated as the number of unique trips across all of the data. The number of kept trips (red line) was calculated as the number of unique trips in the data after removing records associated with multiple gear groups or with inconsistent effort data. Eff1_trips (green line) shows the number of retained trips that reported the number of traps fished.

b)



c)

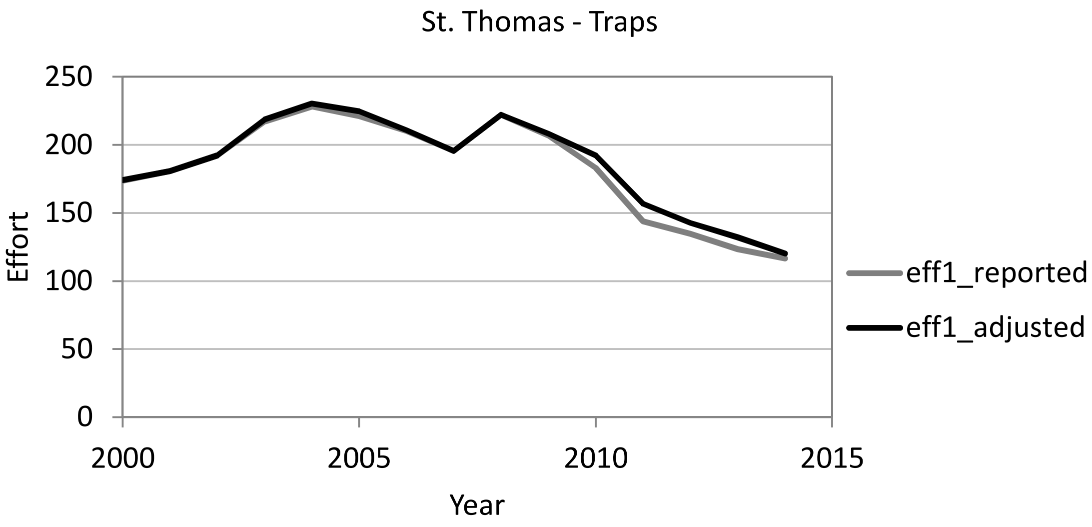


Figure 2.5.4 Continued. Effort plots for the trap fishery in St. Thomas (2000–2014). b) Annual mean number of traps fished per trip from retained trips that reported the number of traps fished. c) Total reported effort (gray line) compared to the total adjusted effort (black line).

2.5.4 St. Croix diving

For the diving gear in the St. Croix, it is believed that gear number is the number of dives made on a trip. A majority of the reported diving trips provide the number of dives. However, the proportion of trips that do not provide this information has been increasing in recent years (Figure 2.5.4a).

Figure 2.5.4b shows the mean annual dives per trip from trips that reported effort. Figures 2.5.4c shows the difference between reported effort and the effort adjusted to account for trips that did not report effort.

a)

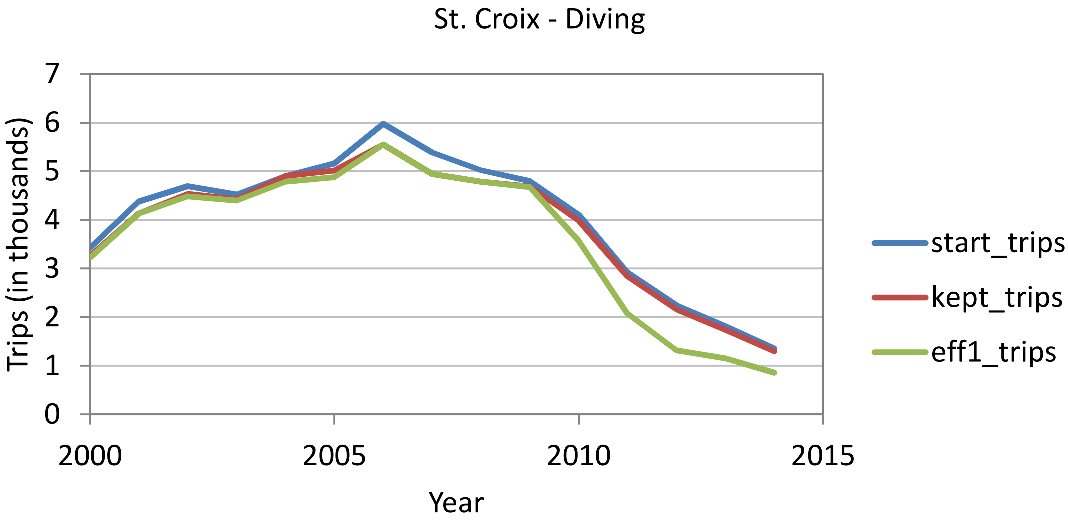
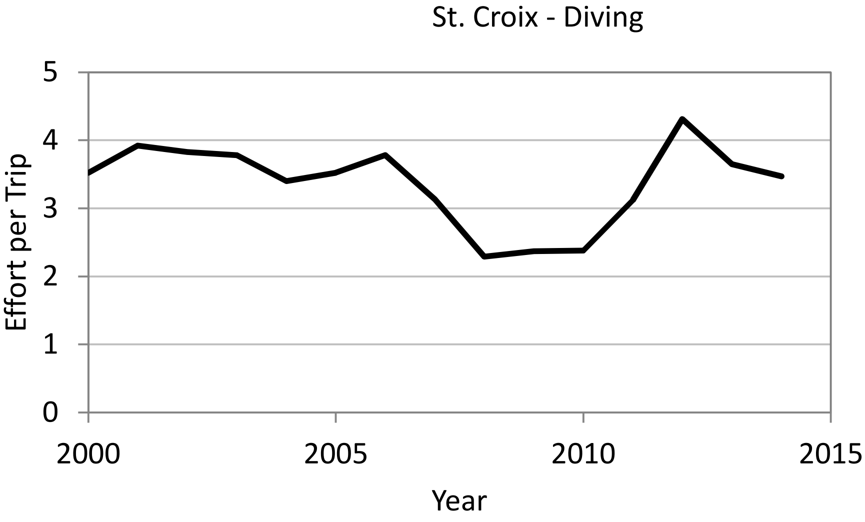


Figure 2.5.4 Effort plots for the diving fishery in St. Croix (2000–2014) a) Total trips (red line) were calculated as the number of unique trips across all of the data. The number of kept trips (green line) was calculated as the number of unique trips in the data after removing records associated with multiple gear groups or with inconsistent effort data. Eff1_trips (blue line) shows the number of retained trips that reported the number of gear fished

b)



c)

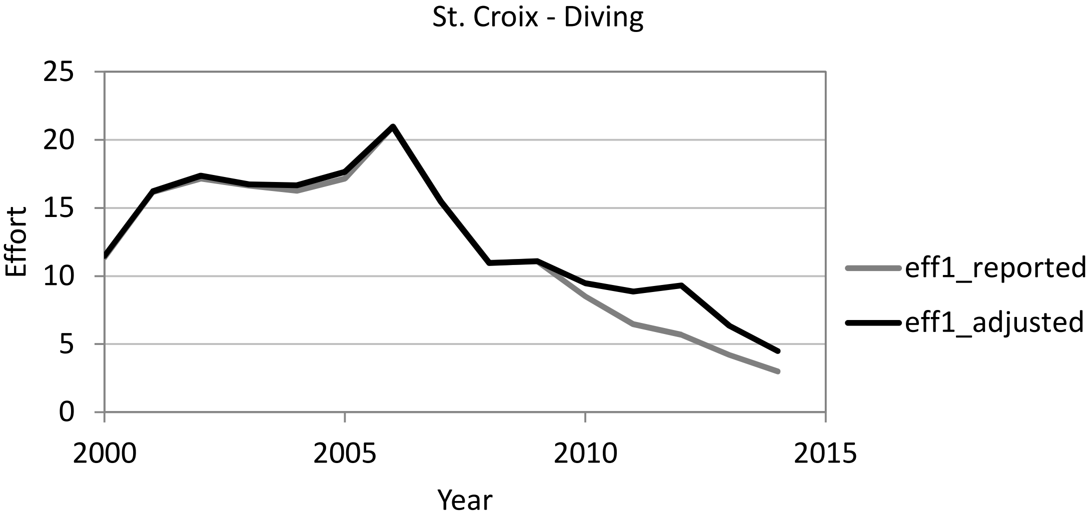


Figure 2.5.3 Continued. Effort plots for the diving fishery in St. Croix (2000–2014). b) Annual mean number of dives per trip from retained trips that reported the number of dives. c) Total reported effort (gray line) compared to the total adjusted effort (black line).

2.5.5 Research recommendations

- Investigate issue associated with fishers not reporting effort information in St. Croix
- Review any caveats/concerns such as species having more than one dominant fishery or noted changes in fishing behavior
- Extend the data-limited approaches to allow two fisheries, or a single fishery with two distinct types of selectivity/catchability

2.6 Length frequency data

2.6.1 Overview

The NOAA Fisheries, Southeast Fisheries Science Center Trip Interview Program (TIP) is a port sampling program that collects data on individual size and weight, to complement information that is collected through the logbook reporting. Size frequency data, species composition information, and sometimes other biological information are collected. Information about fishing area, fishing gear, etc., is collected. A description of the sampling program, as well as plots of the length frequency data available for various species, is included in Bryan (2015).

Figures 2.6.1 to 2.6.6 provide a summary of the length frequency data available from the predominant gear associated with each of the six species-island units identified for the SEDAR 46 stock evaluation: hogfish from diving gear in Puerto Rico, yellowtail snapper from handline gear in Puerto Rico, spiny lobster and queen triggerfish from trap gear in St. Thomas, and spiny lobster and stoplight parrotfish from diving gear in St. Croix.

For each species and gear, a logistic model was fit to the cumulative distribution function of the length data to provide some insight about the selectivity at length. This information can be used to inform decisions about the critical length (Lc) parameter that is a required input of mean length estimators, or the length at first capture (LFC) and length at full selection (LFS) required as a data input for DLMtool. This information along with summary statistics of the annual length frequency data, was used to identify the most appropriate Lc for each stratum being considered. Figures 2.6.7 to 2.6.12 provide results of the logistic models fit to the length data from the predominate gear associated with each of the six species-island units.

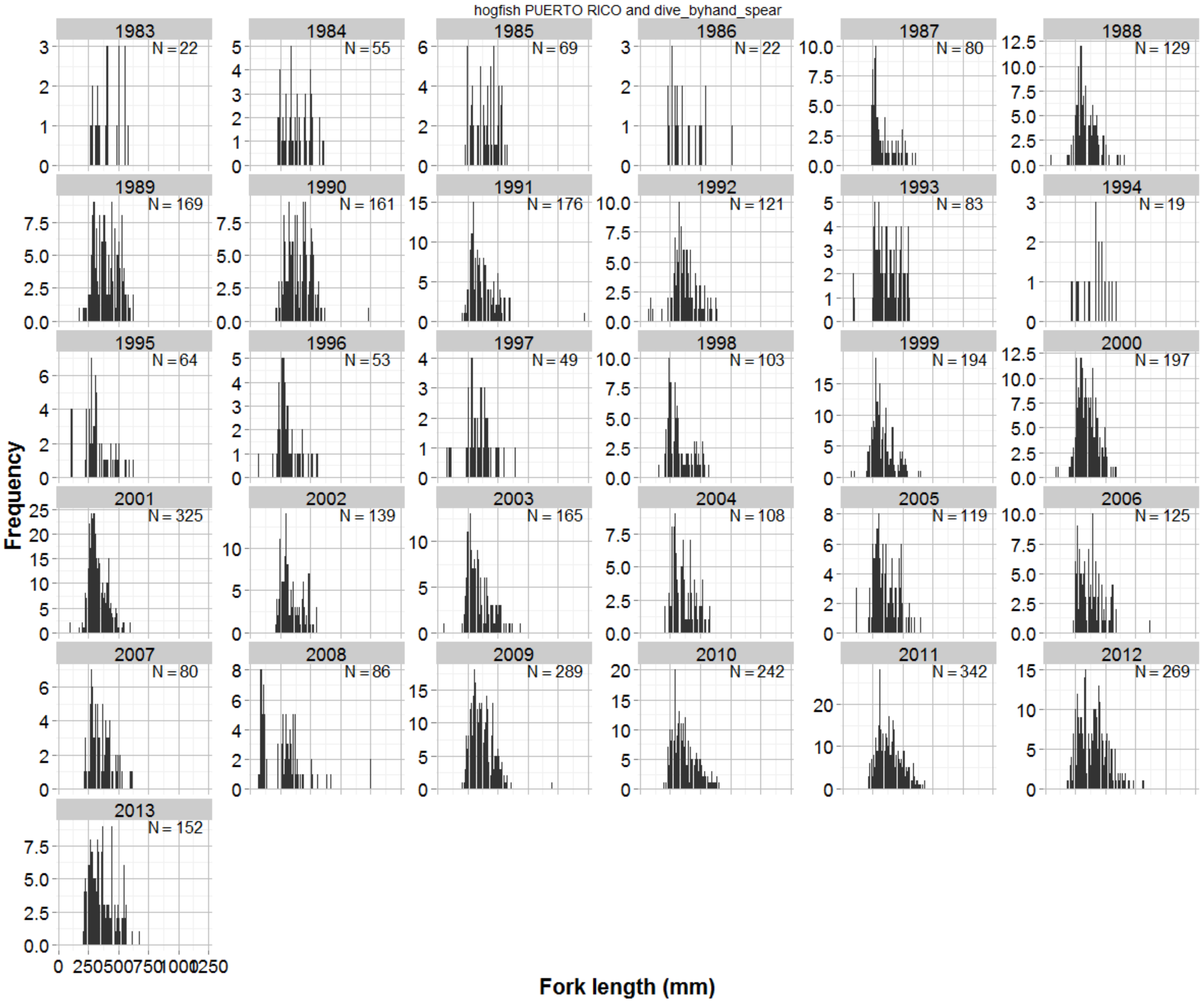


Figure 2.6.1 Annual length frequency histograms for hogfish caught by diving gears in Puerto Rico. N indicates the number of lengths per year. Each bar represents a 10mm length bin.

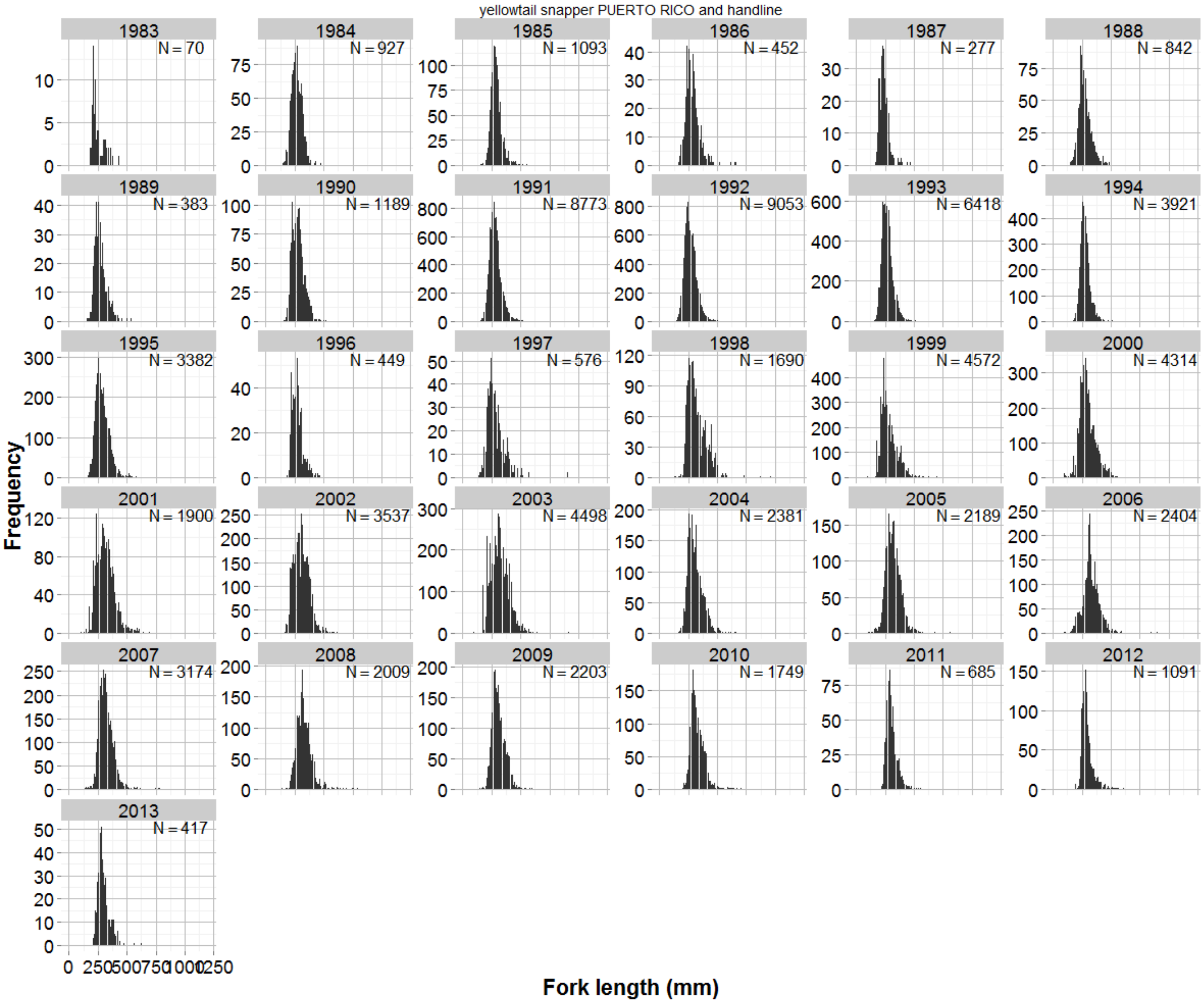


Figure 2.6.2 Annual length frequency histograms for yellowtail snapper caught by handline gears in Puerto Rico. N indicates the number of lengths per year. Each bar represents a 10mm length bin.

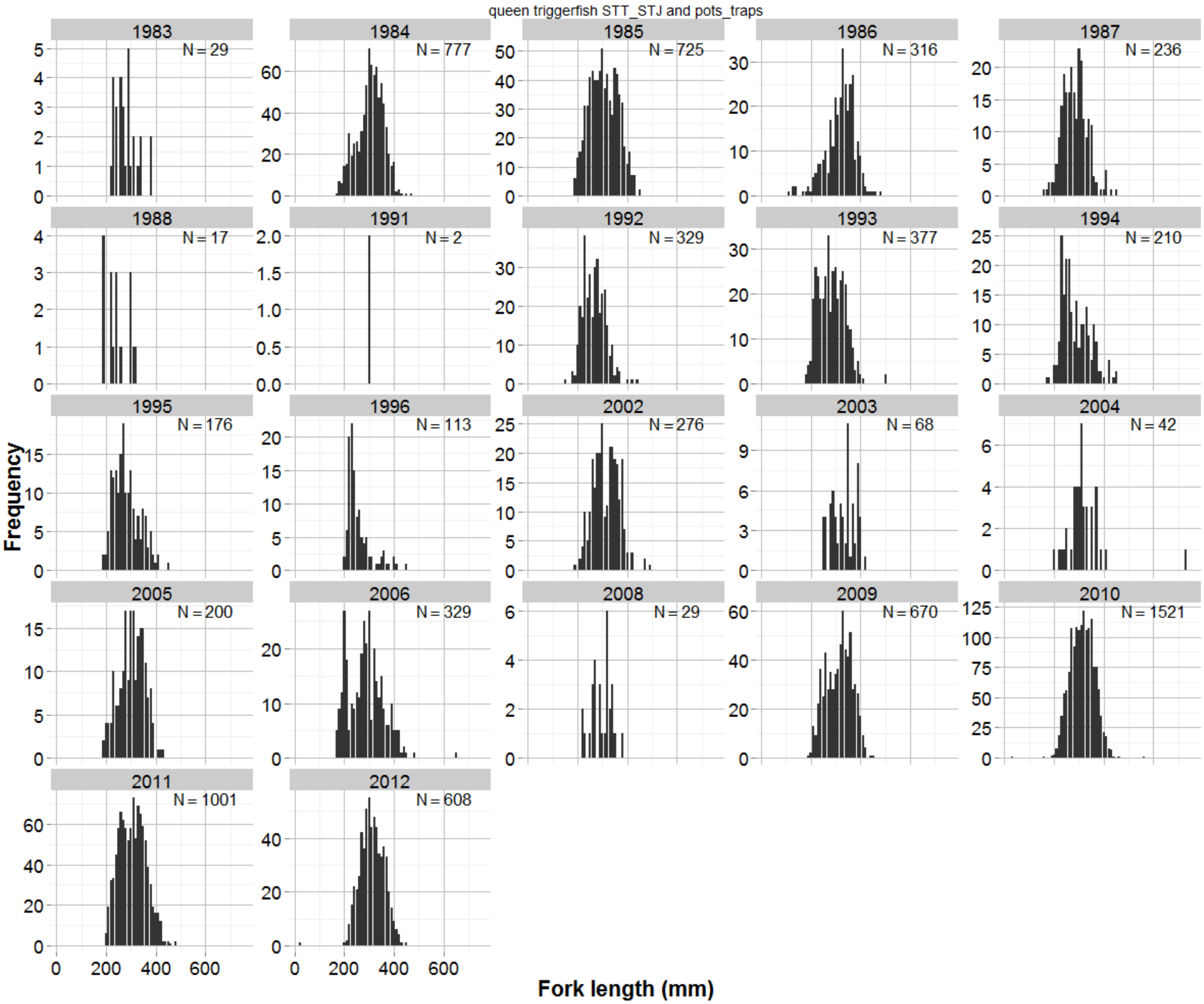


Figure 2.6.3 Annual length frequency histograms for queen triggerfish caught by trap gears in St. Thomas. N indicates the number of lengths per year. Each bar represents a 10mm length bin.

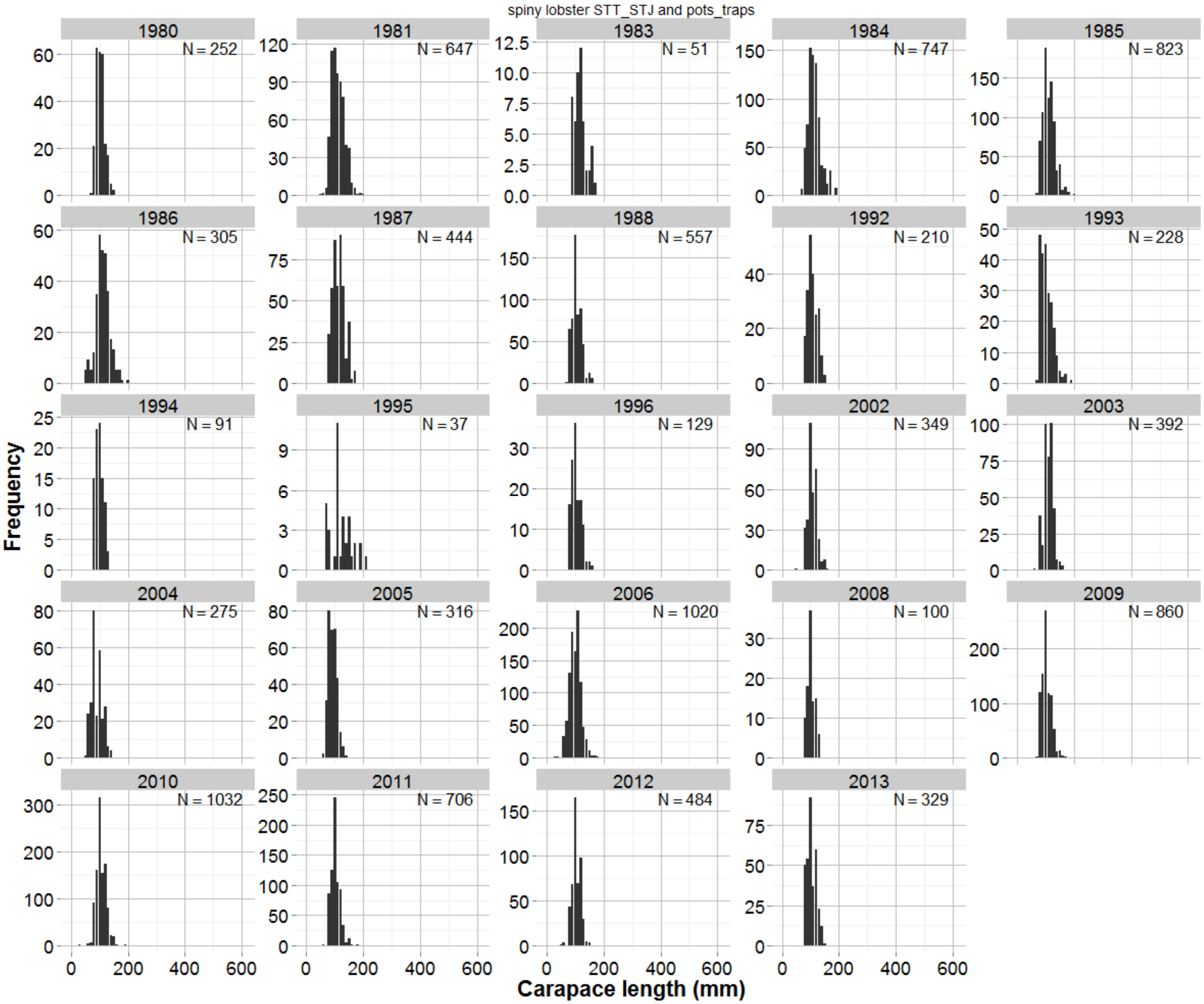


Figure 2.6.4 Annual length frequency histograms for spiny lobster caught by trap gears in St. Thomas. N indicates the number of lengths per year. Each bar represents a 10mm length bin.

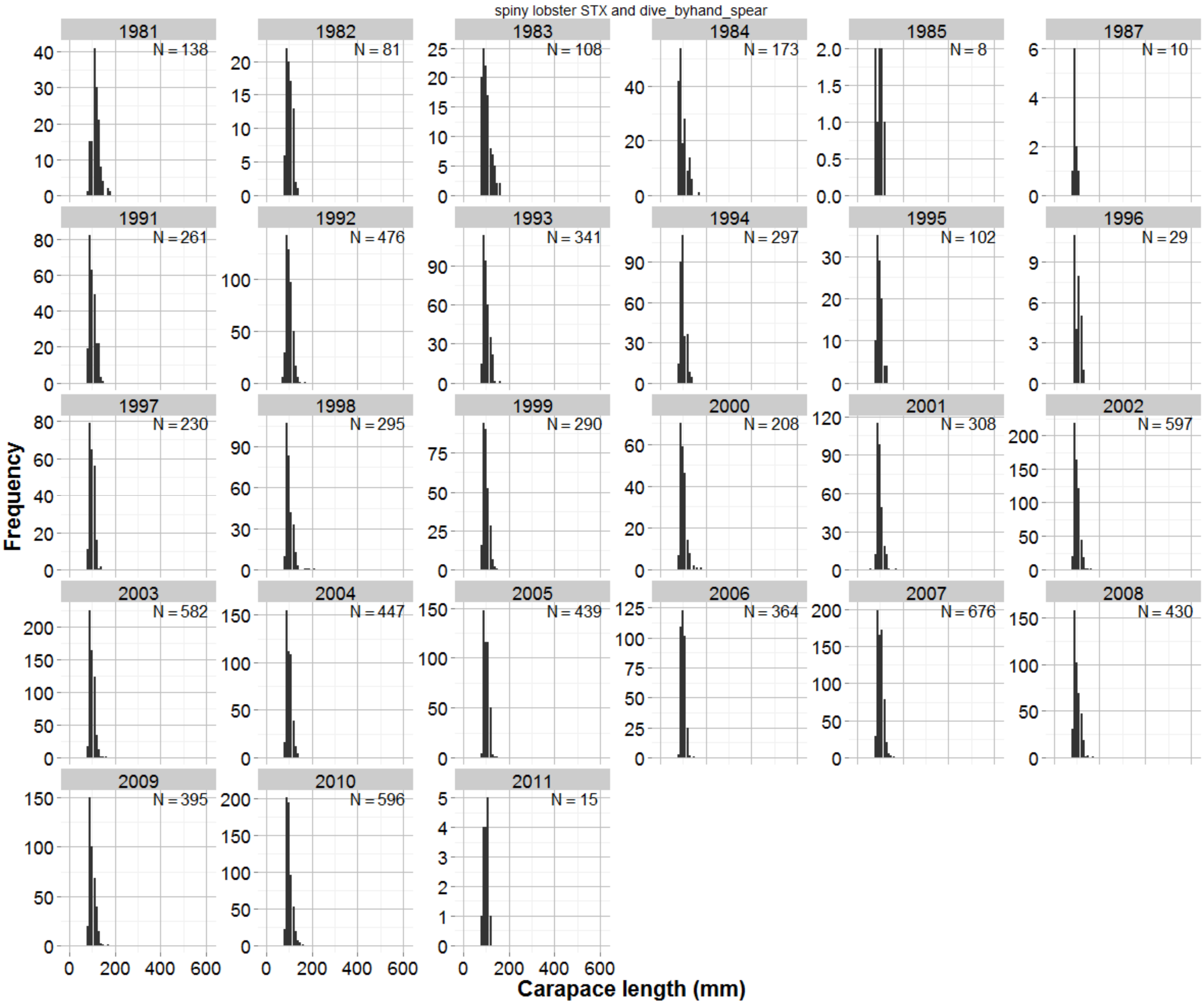


Figure 2.6.5 Annual length frequency histograms for spiny lobster caught by diving gears in St. Croix. N indicates the number of lengths per year. Each bar represents a 10mm length bin.

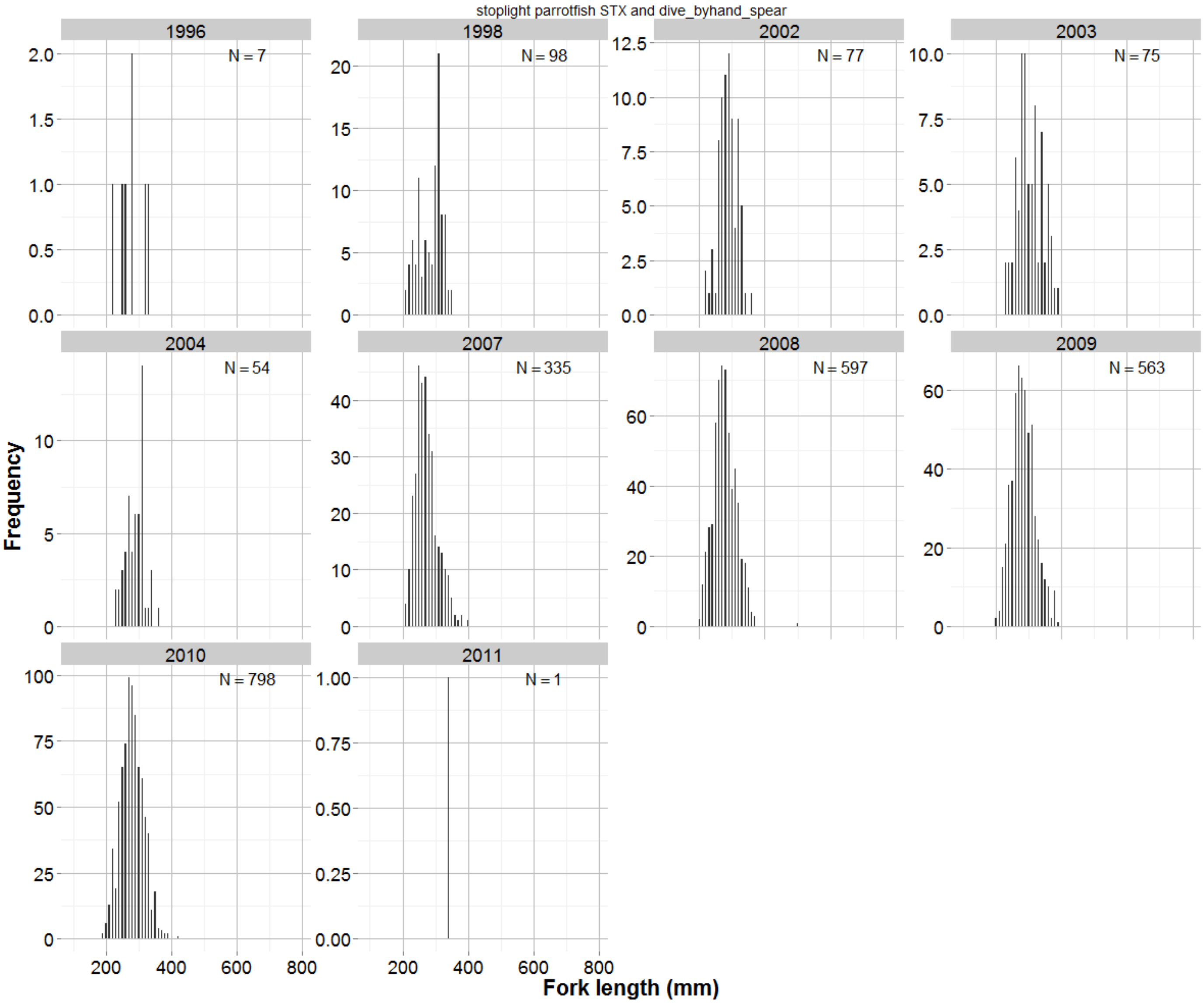


Figure 2.6.6 Annual length frequency histograms for stoplight parrotfish caught by diving gears in St. Croix. N indicates the number of lengths per year. Each bar represents a 10mm length bin.

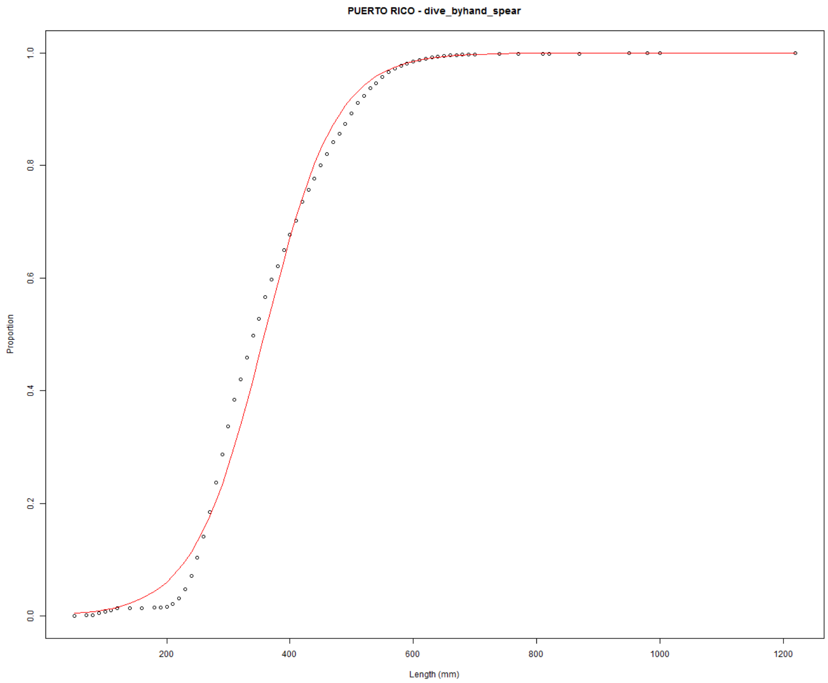


Figure 2.6.7 Logistic fit to the observed cumulative proportions of hogfish caught by diving gears in Puerto Rico. Source: Trip Interview Program.

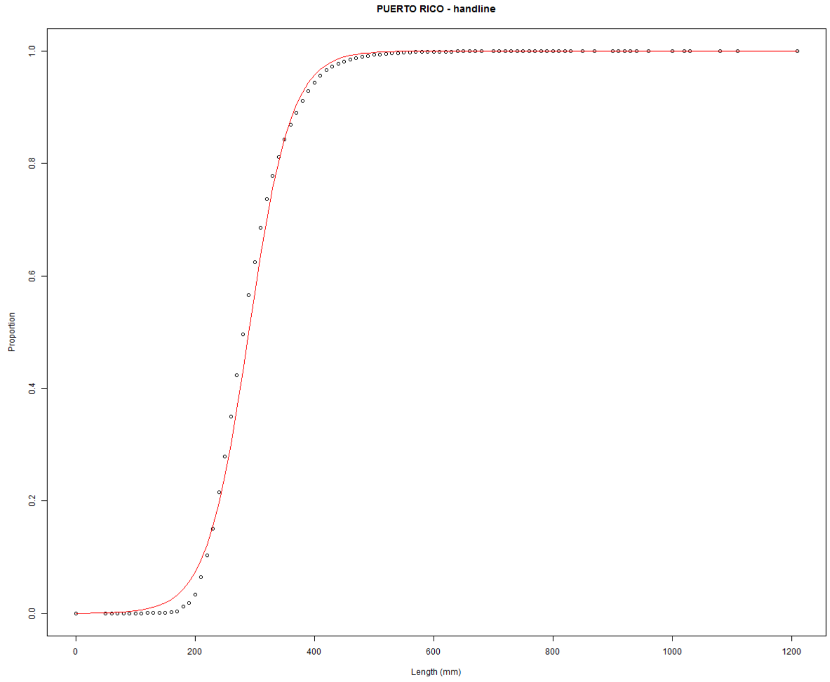


Figure 2.6.8 Logistic fit to the observed cumulative proportions of yellowtail snapper caught by handline gears in Puerto Rico. Source: Trip Interview Program.

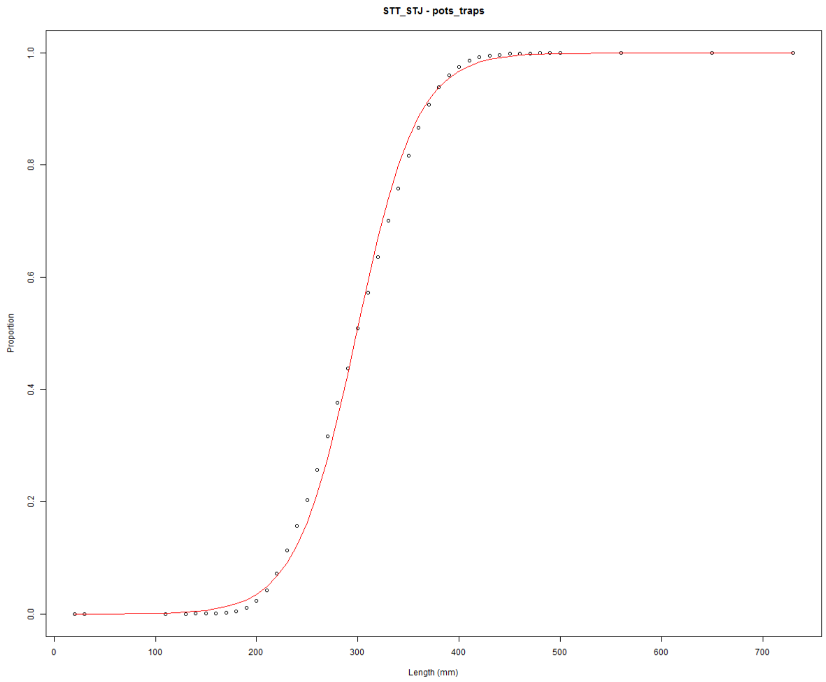


Figure 2.6.9 Logistic fit to the observed cumulative proportions of queen triggerfish caught by trap gears in St. Thomas. Source: Trip Interview Program.

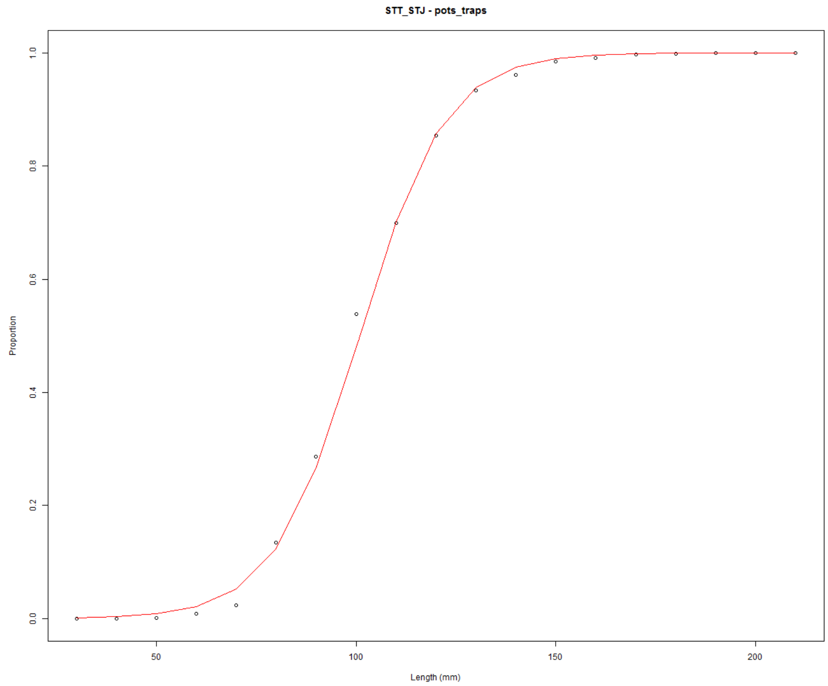


Figure 2.6.10 Logistic fit to the observed cumulative proportions of spiny lobster caught by trap gears in St. Thomas. Source: Trip Interview Program.

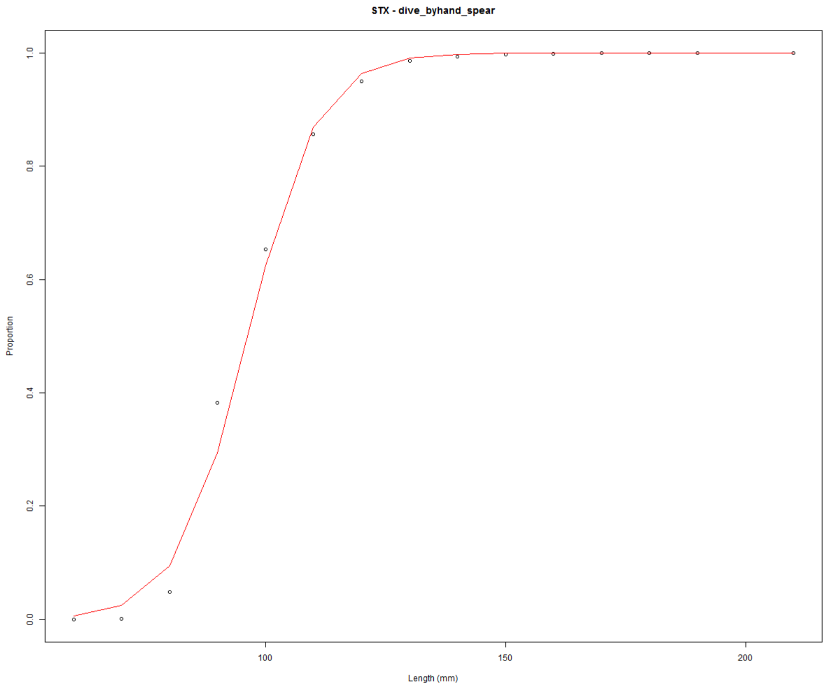


Figure 2.6.11 Logistic fit to the observed cumulative proportions of spiny lobster caught by diving gears in St. Croix. Source: Trip Interview Program.

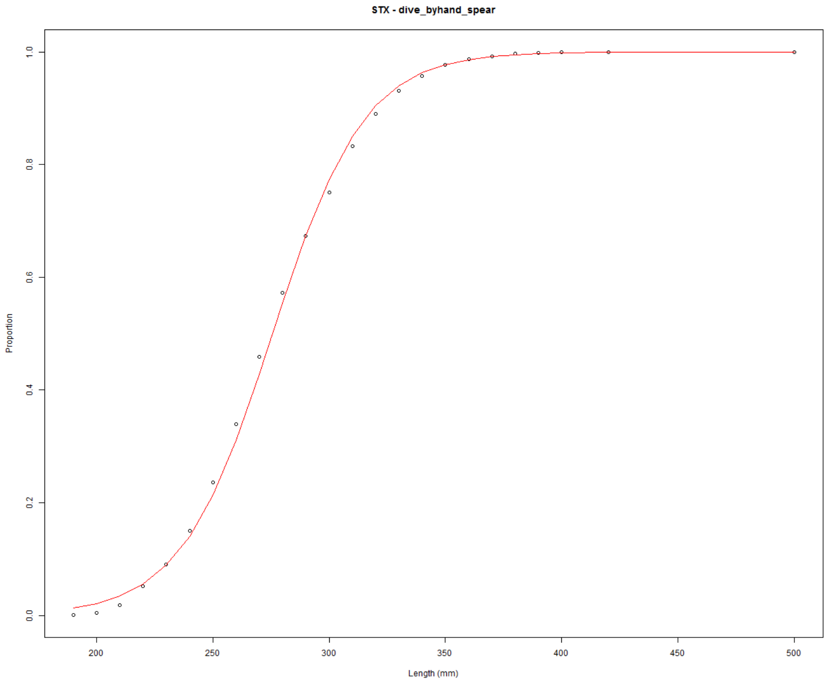


Figure 2.6.12 Logistic fit to the observed cumulative proportions of stoplight parrotfish caught by diving gears in St. Croix. Source: Trip Interview Program.

2.6.2 Research recommendations

- The TIP sampling operational framework in Puerto Rico and in the USVI should be reviewed to ensure sampling is representative of the primary fisheries.
- Conduct review of supplemental information on size from data series not readily available for these evaluations.
- Evaluate the use of aggregation of length samples over gears. The recommendation by the SEDAR 46 DW Panel was to group gear types that were assumed to have similar selectivities.
- Address difficulty in assigning the fishing areas to develop a continuous series for the USVI. Develop a consistent time series of area assignments for St. Thomas and St. John. Consider if alternative approaches to aggregating the fishing area information in the TIP data may be feasible.

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3. SEDAR 46 Stock assessment evaluation

Previous stock assessments of US Caribbean resources have attempted to quantify stock status and condition using traditional stock assessment procedures (Table 3.0). However, nearly all of these evaluations have resulted in an unsatisfactory determation of stock status due to the lack of sufficient data with which to parameterize the models. The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), National Standard 1 (NSA) Guidelines require that "conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry (Section 301(a)(1)". This mandate led to the establishment of annual catch limits (ACLs) by 2010 for all "stocks in the fishery", including data-limited stocks.

In the absence of sufficient information to conduct traditional stock assessments, managers have implemented various procedures such as scalars of landings history (e.g., median catch, Carruthers et al. 2014) or Only Reliable Catch Series [ORCS] (Berkson et al. 2011). Figure 3.0 provides a graphical illustration of how ACLs are established for data-limited fisheries stocks in the US including the Caribbean. In light of the challenges imposed in using traditional fisheries models to assess US Caribbean data-limited stocks, the SEDAR 46 stock evaluation explored the use of a data-limited modeling framework to provide management advice for US Caribbean resources. The intent was to explore the use of multiple data-limited models in an analytical framework that would provide an objective comparison across a variety of methods and provide diagnostics that could be used to compare performance.

3.1 Data review update

The SEDAR 46 stock evaluations were carried out using the data presented and reviewed at the November 2 − 6 San Juan (Puerto, Rico) Data and Assessment (DW/AW) Workshop. Six species-island units (i.e., stocks) were considered as defined in Section 2.1 and included: (1) Puerto Rico (PR) hogfish, (2) PR yellowtail snapper, (3) St. Thomas (STT) queen triggerfish, (4) STT spiny lobster, (5) St. Croix (STX) spiny lobster, and (6) STX stoplight parrotfish. Subsequent to the DW/AW Workshop, all relevant data were reviewed for completeness. No revisions to the commercial or recreational landings data or the length frequency analyses were identified. Additional analyses were conducted on the indices of abundance in an attempt to develop standardized abundance indices. In addition, updated time series of representative effort were developed for each representative island-fleet for each of the six species-island units considered in the SEDAR 46 stock evaluation. Life history demographic characterizations provided at the DW/AW Workshop were finalized and distributed to the analytical team. Section 2 contains detailed information on all information available to the analytical team for the stock assessment, including life history characterizations, landings, indices of abundance, effort time series, and length frequency data.

Figures 3.1.1 − 3.1.6 provide single-page graphical summaries of the data reviewed and available for use in the stock assessment evaluations.

Table 3.0 Summary of previous stock assessments of US Caribbean resources for selected species.

Species unit assessed	**Assessment method**	**Assessment reference**
Puerto Rico hogfish dive fishery	• NA	None
Puerto Rico yellowtail snapper handline fishery	• CPUE trends, examination of changes in length frequency • Length frequency analyses	SEDAR (2005b) Appeldoorn et al. (1992)
St. Thomas queen triggerfish trap fishery	• Length frequency analysis from the pot and trap fishery (Puerto Rico), Gedamke - Hoenig mean length estimator	SEDAR (2013)
St. Thomas spiny lobster trap fishery	• Stock production model, CPUE examinations, yield per recruit • CPUE and landings trends • Landings and length frequency • CPUE	SEDAR (2005a) Matos-Caraballo (1999) Bolden (2001) Bohnsack et al. (1991)
St. Croix spiny lobster dive fishery	• Stock production model, CPUE examinations, yield per recruit • CPUE and landings trends • Landings and length frequency • Production model • CPUE	SEDAR (2005a) Matos-Caraballo (1999) Bolden (2001) Mateo and Tobias (2002) Bohnsack et al. (1991)
St. Croix stoplight parrotfish trap fishery	• NA	None

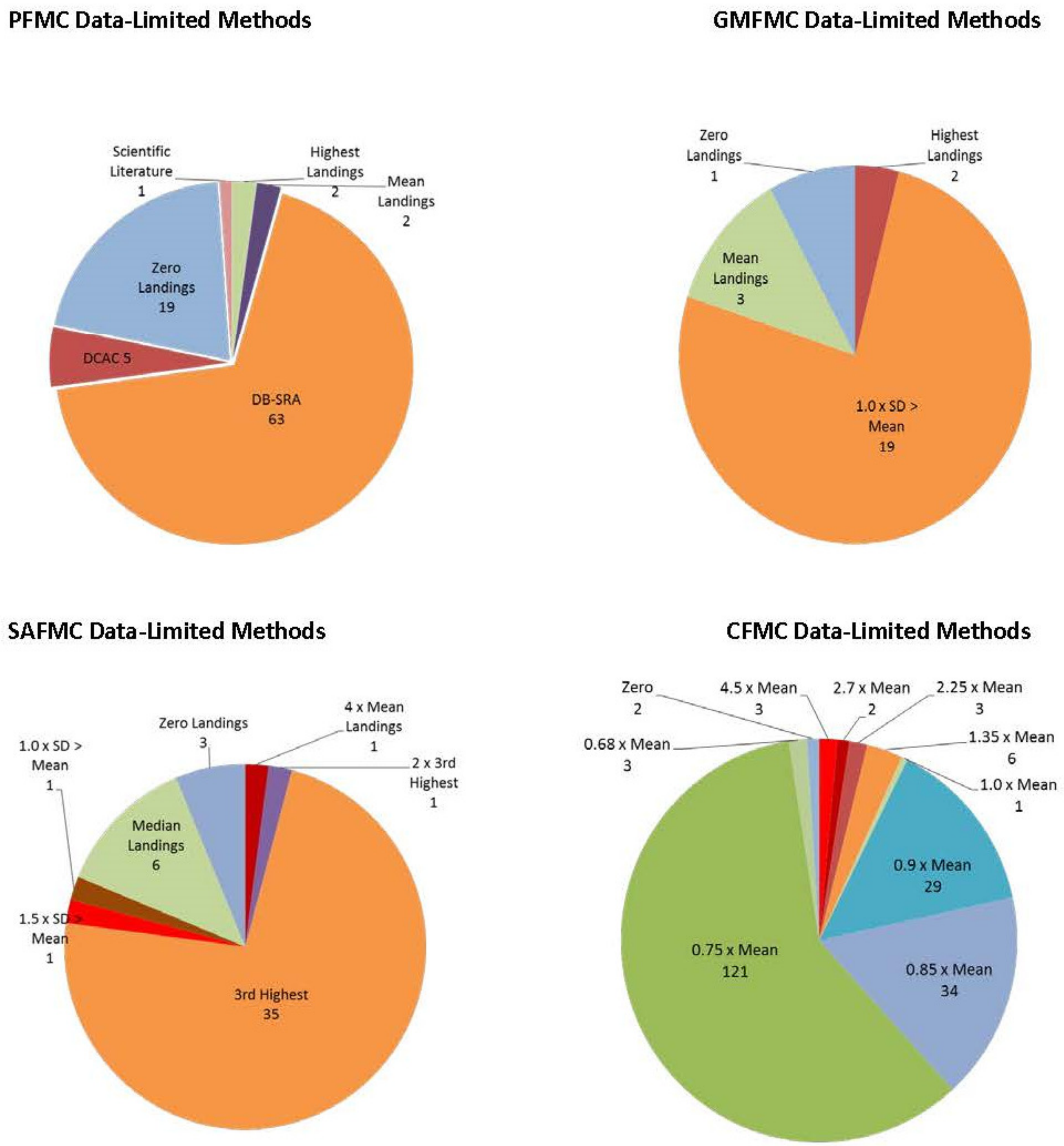
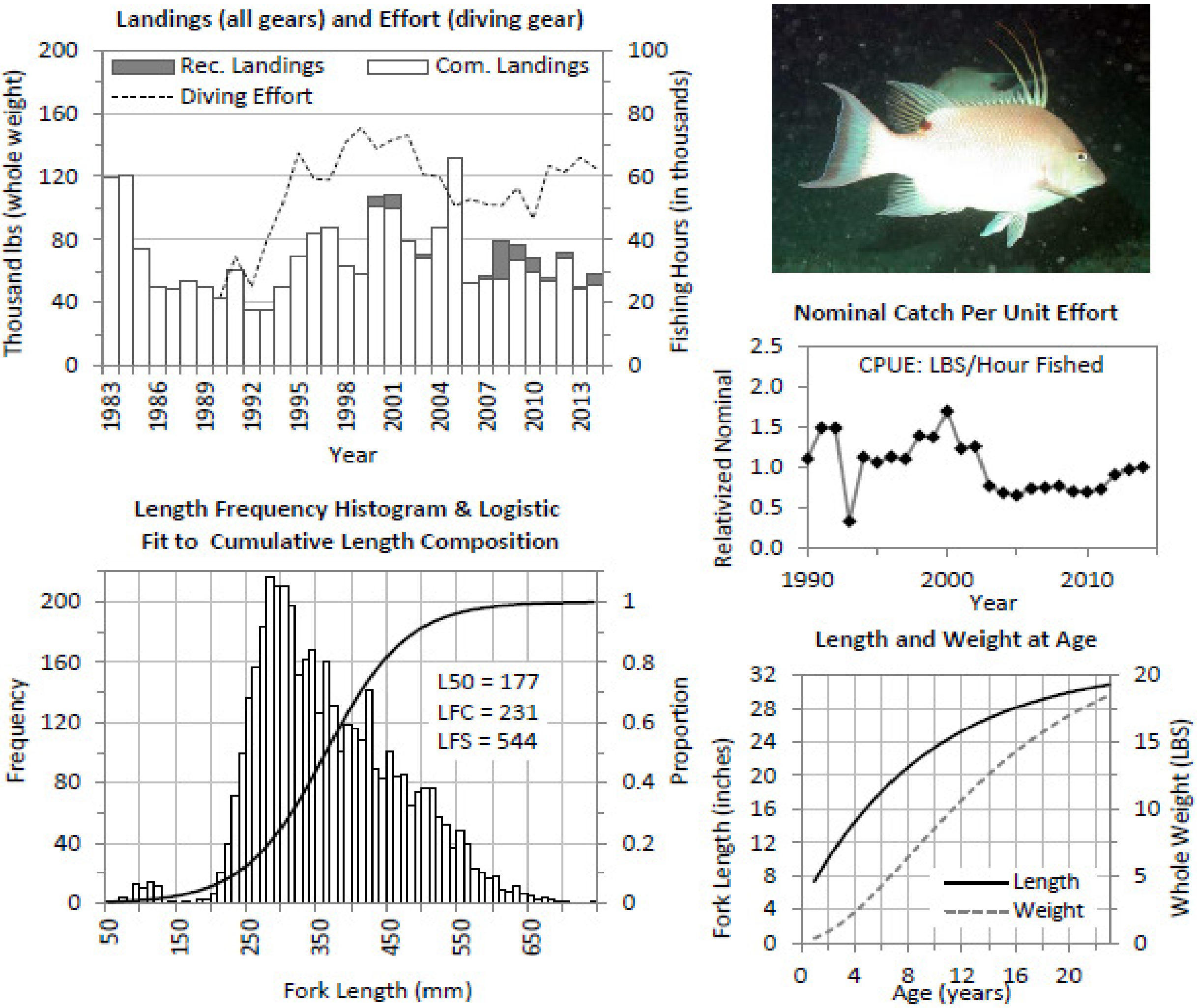


Figure 3.0 Methods used in the US for determination of Annual catch limits (ACLs) by the Pacific Fishery Management Council (PFMC), the Gulf of Mexico Fishery Maangement Council (GMFMC), the South Atlantic Fishery Management Council (SAFMC), and the Caribbean Fishery Management Council (CFMC) (Source: Newman et al. 2014).

Hogfish (*Lachnolaimus maximus*)

Puerto Rico Diving



Life History and Selectivity

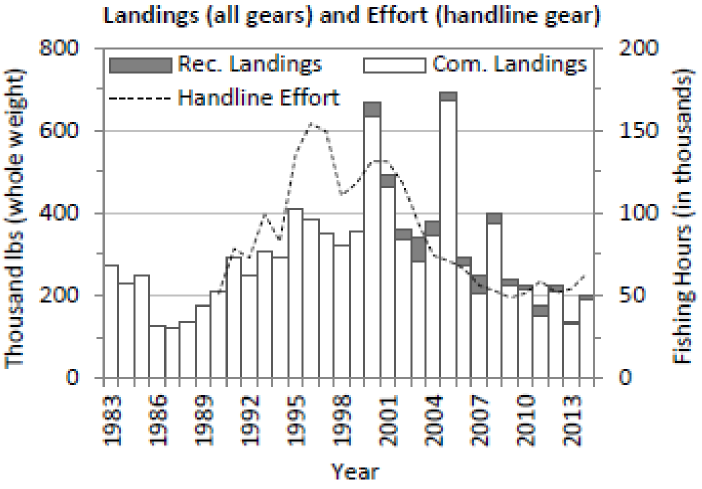
	vbLinf	vbK	vbt0	wla	wlb	L50	AM	Mort	LFC	LFS
	Asymptotic Len.	Growth Coeff.	Age at Len. 0	Wt-Len scalar	Wt-Len power	Len. at maturity	Age at maturity	Natural Mortality	Len. 1st Capture	Len. Full Selection
Parameter	849.0	0.106	-1.33	9.5E-5	2.745	176.8	0.878	0.156	231	544
CV	(0.06)	(0.024)	(0.38)	(0.05)	(0.05)	(0.113)	(0.25)	(0.082)	--	--
Units	mm FL	yr^{-1}	years	--	--	mm FL	years	yr^{-1}	mm FL	mm FL

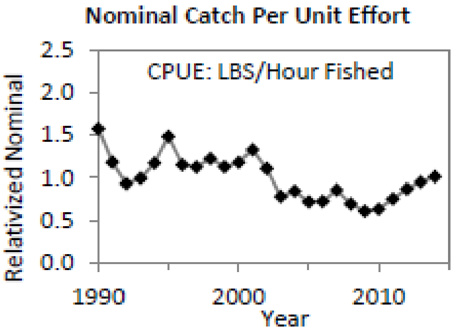
Relevant federal regulations

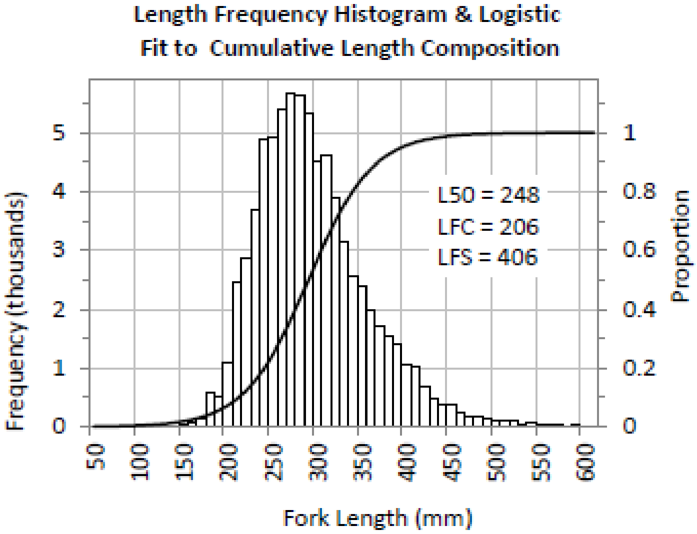
http://sero.nmfs.noaa.gov/sustainable_fisheries/policy_branch/	*Start Date*	*End Date*
Reef fish bag limit (5 per person, 15 per vessel)	30 Jan 2012	ongoing
Recreational closed season (Puerto Rico EEZ)	21 Oct 2013	31 Dec 2013
Commercial closed season (Puerto Rico EEZ)	20 Oct 2014	31 Dec 2014

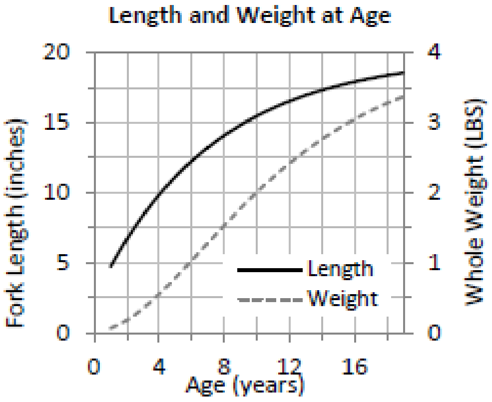
Figure 3.1.1 Summarized information available for stock evaluation of Puerto Rico hogfish using the DLMtool modeling framework.

Yellowtail Snapper (*Ocyurus chrysurus*)
Puerto Rico Handline


Landings (all gears) and Effort (handline gear)


Nominal Catch Per Unit Effort


Length Frequency Histogram & Logistic Fit to Cumulative Length Composition


Length and Weight at Age

Life History and Selectivity

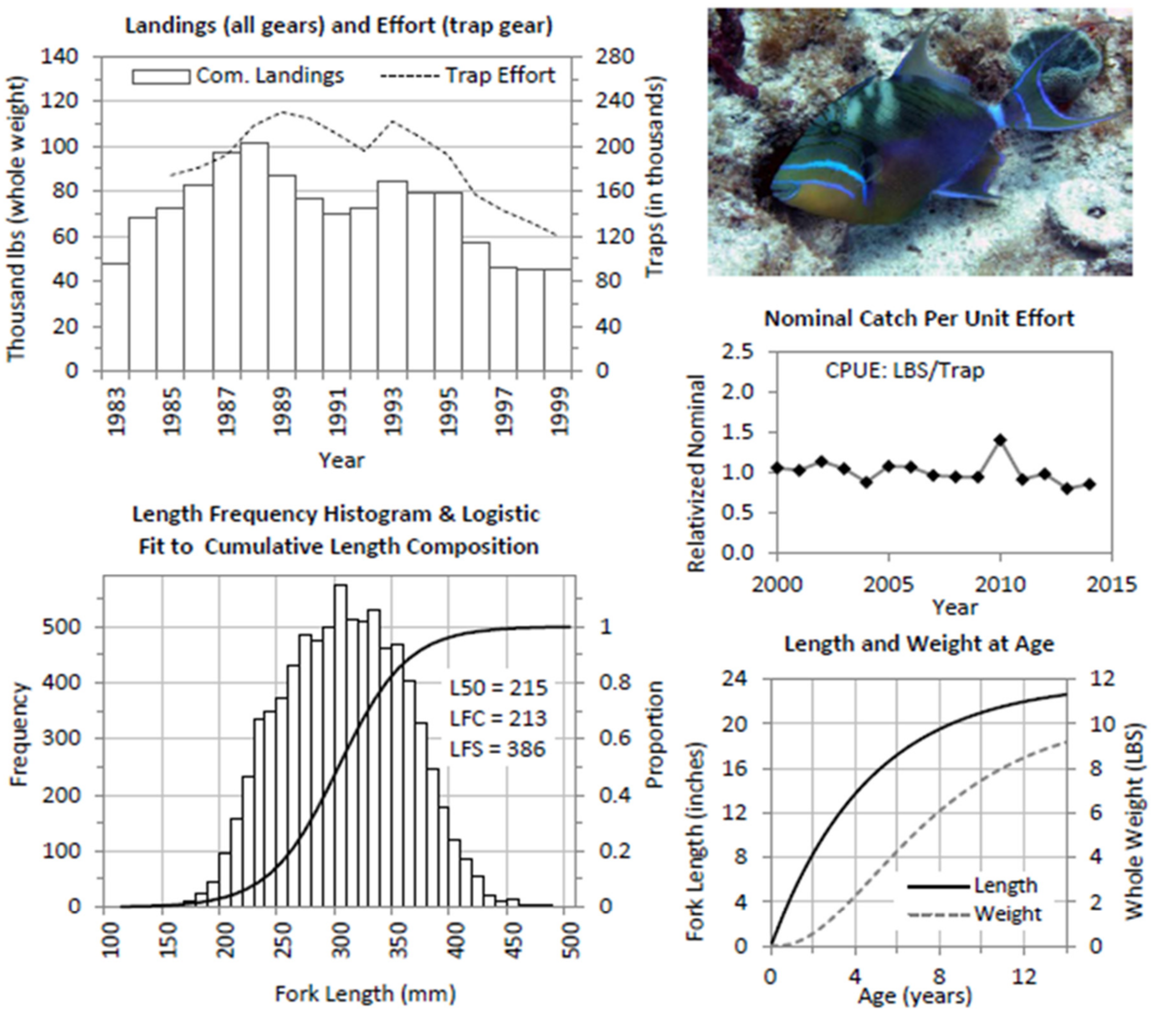
	vbLinf	vbK	vbt0	wla	wlb	L50	AM	Mort	LFC	LFS
	Asympt-otic Len.	Growth Coeff.	Age at Len. 0	Wt-Len scalar	Wt-Len power	Len. at maturity	Age at maturity	Natural Mortality	Len. 1st Capture	Len. Full Selection
Parameter	502.5	0.139	-0.96	3.45E-5	2.859	248	3.939	0.189	206	406
CV	(0.05)	(0.16)	(0.45)	(0.05)	(0.05)	(0.15)	(0.25)	(0.083)	--	--
Units	mm FL	yr^{-1}	years	--	--	mm FL	years	yr^{-1}	mm FL	mm FL

Relevant federal regulations

http://sero.nmfs.noaa.gov/sustainable_fisheries/policy_branch/	*Start Date*	*End Date*
Snapper, grouper, parrotfish bag limit (5 per person, 15 per vessel)	30 Jan 2012	ongoing
12 inches total length size limit (304.8 mm TL)	01 Jan 1989	ongoing

Figure 3.1.2 Summarized information available for stock evaluation of Puerto Rico yellowtail snapper using the DLMtool modeling framework.

Queen Triggerfish (*Balistes vetula*)
St. Thomas Trap


Landings (all gears) and Effort (trap gear)

Nominal Catch Per Unit Effort

Length Frequency Histogram & Logistic Fit to Cumulative Length Composition

Length and Weight at Age

Life History and Selectivity

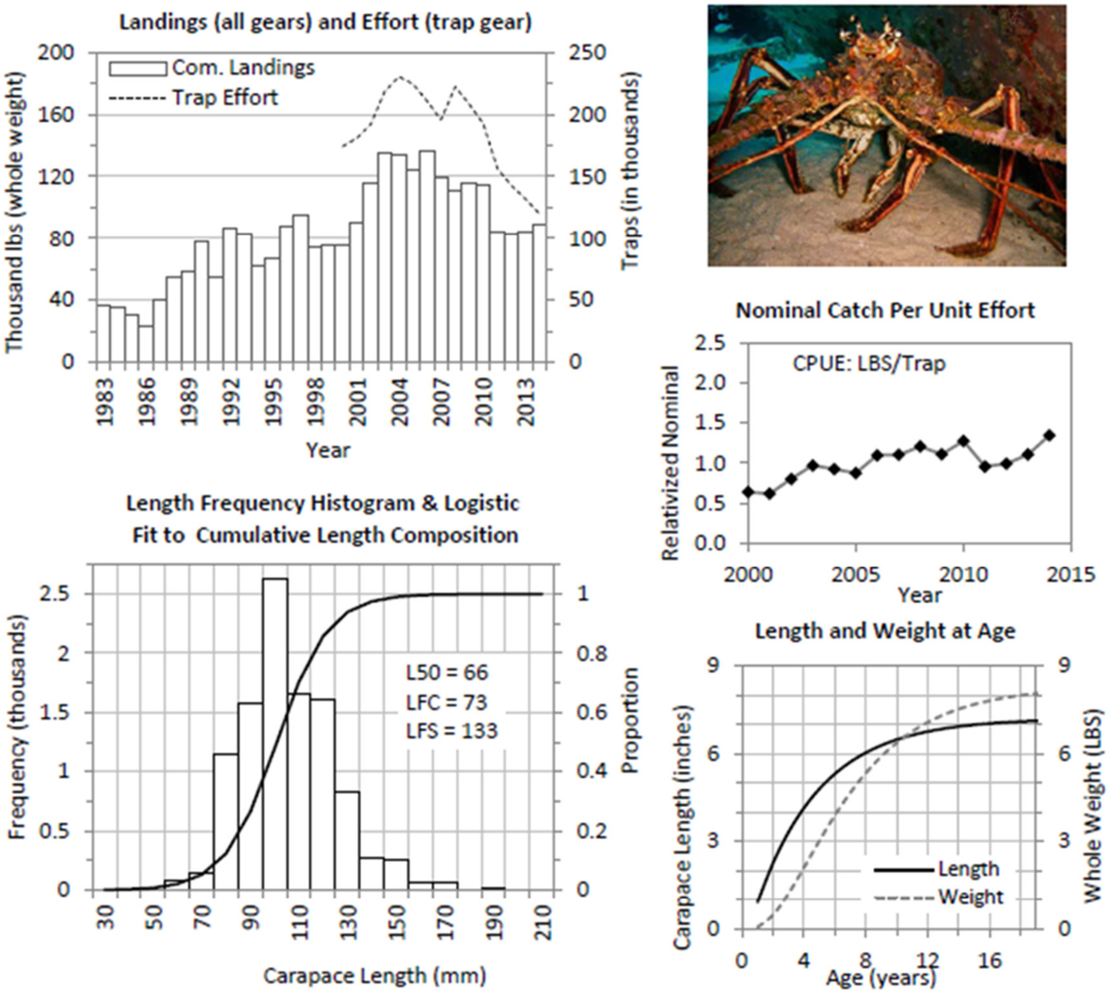
	vbLinf Asympt-otic Len.	vbK Growth Coeff.	vbt0 Age at Len. 0	wla Wt-Len scalar	wlb Wt-Len power	L50 Len. at maturity	AM Age at maturity	Mort Natural Mortality	LFC Len. 1st Capture	LFS Len. Full Selection
Parameter	605.3	0.214	0	8.64E-5	2.784	215	2.05	0.257	213	386
CV	(0.12)	(0.35)	(0.50)	(0.05)	(0.05)	(0.20)	(0.25)	(0.083)	--	--
Units	mm FL	yr^{-1}	years	--	--	mm FL	years	yr^{-1}	mm FL	mm FL

Relevant federal regulations

http://sero.nmfs.noaa.gov/sustainable_fisheries/policy_branch/	*Start Date*	*End Date*
Reef fish bag limit (5 per person, 15 per vessel)	30 Jan 2012	ongoing
Closed season (St. Croix EEZ)	21 Nov 2013	31 Dec 2013

Figure 3.1.3 Summarized information available for stock evaluation of St. Thomas queen triggerfish using the DLMtool modeling framework.

Caribbean Spiny Lobster (*Panulirus argus*)
St. Thomas Trap



Life History and Selectivity

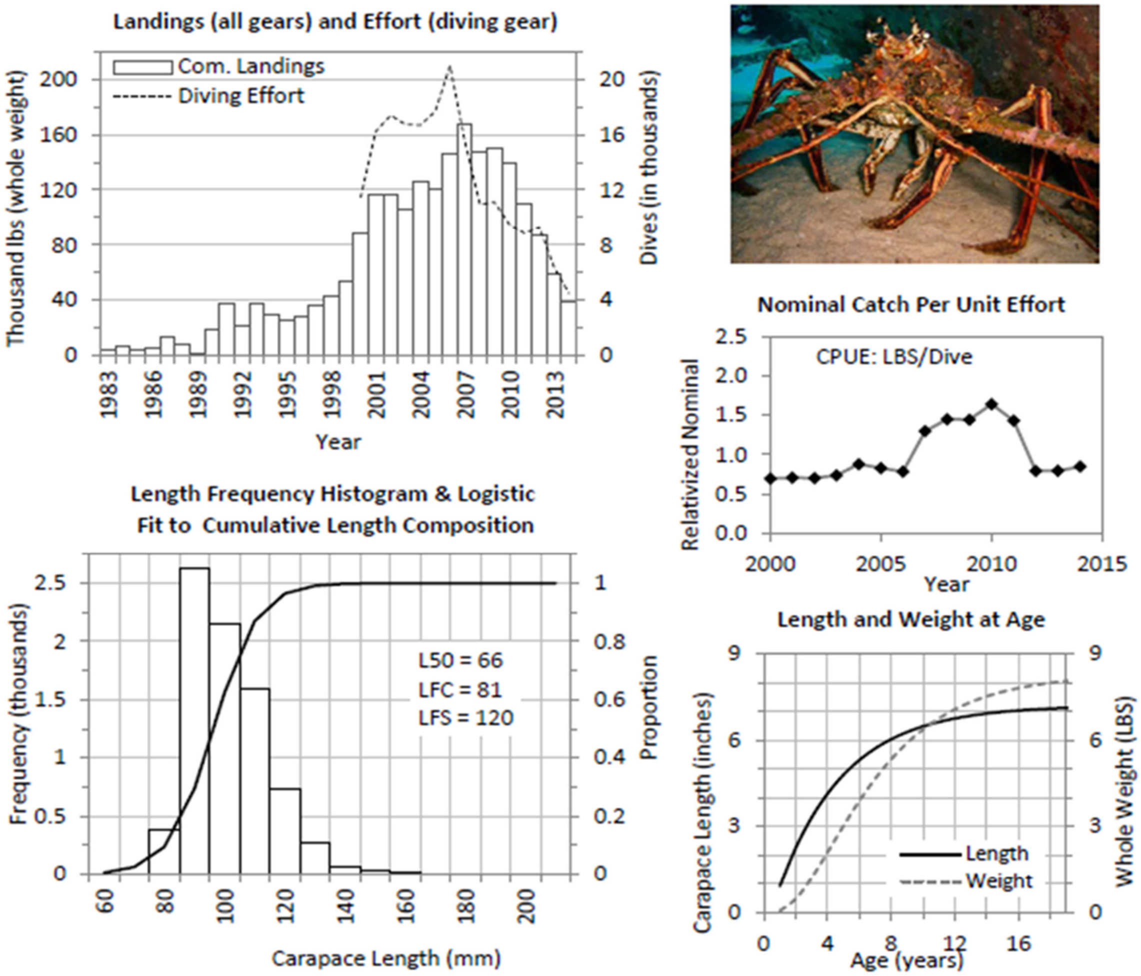
	vbLinf Asymptotic Len.	vbK Growth Coeff.	vbt0 Age at Len. 0	wla Wt-Len scalar	wlb Wt-Len power	L50 Len. at maturity	AM Age at maturity	Mort Natural Mortality	LFC Len. 1st Capture	LFS Len. Full Selection
Parameter	183	0.24	0.44	9.21E-3	2.48	65.79	2.296	0.35	73	133
CV	(0.08)	(0.21)	(1.14)	(0.05)	(0.05)	(0.15)	(0.25)	(0.071)	--	--
Units	mm CL	yr^{-1}	years	--	--	mm CL	years	yr^{-1}	mm CL	mm CL

Relevant federal regulations

http://sero.nmfs.noaa.gov/sustainable_fisheries/policy_branch/	*Start Date*	*End Date*
3.5 inches carapace length size limit (88.9 mm CL)	01 Jan 1985	ongoing
Recreational bag limit (5 per person, 10 per vessel)	01 Jan 2012	ongoing
Closed season (St. Croix EEZ)	19 Dec 2013	31 Dec 2013

Figure 3.1.4 Summarized information available for stock evaluation of St. Thomas spiny lobster using the DLMtool modeling framework.

Caribbean Spiny Lobster (*Panulirus argus*)
St. Croix Diving



Life History and Selectivity

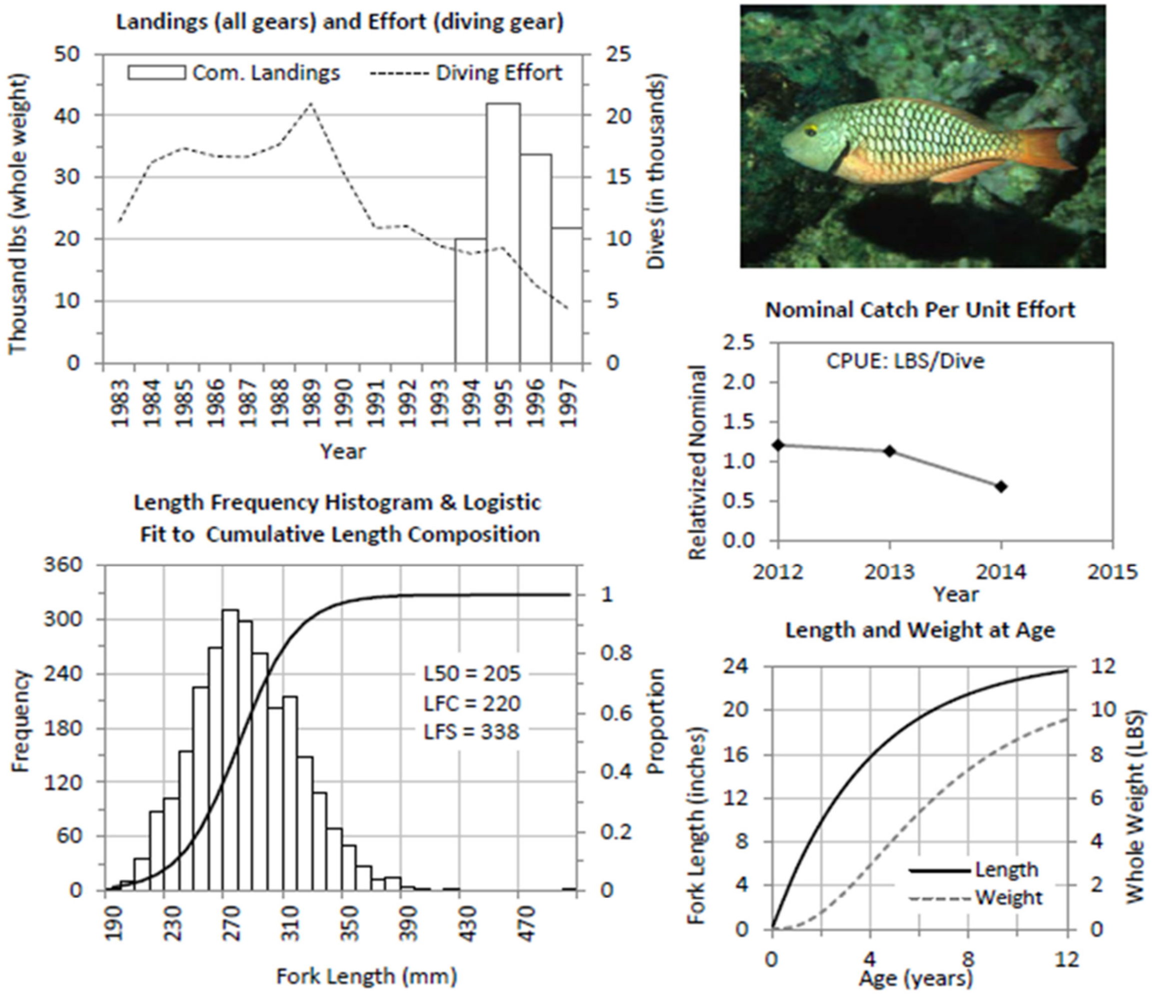
	vbLinf Asympt-otic Len.	vbK Growth Coeff.	vbt0 Age at Len. 0	wla Wt-Len scalar	wlb Wt-Len power	L50 Len. at maturity	AM Age at maturity	Mort Natural Mortality	LFC Len. 1st Capture	LFS Len. Full Selection
Parameter	183	0.24	0.44	9.21E-3	2.48	65.79	2.296	0.35	81	120
CV	(0.08)	(0.21)	(1.14)	(0.05)	(0.05)	(0.15)	(0.25)	(0.071)	--	--
Units	mm CL	yr^{-1}	years	--	--	mm CL	years	yr^{-1}	mm CL	mm CL

Relevant federal regulations

http://sero.nmfs.noaa.gov/sustainable_fisheries/policy_branch/	*Start Date*	*End Date*
3.5 inches carapace length size limit (88.9 mm CL)	01 Jan 1985	ongoing
Recreational bag limit (5 per person, 10 per vessel)	01 Jan 2012	ongoing
Closed season (St. Croix EEZ)	19 Dec 2013	31 Dec 2013

Figure 3.1.5 Summarized information available for stock evaluation of St. Croix spiny lobster using the DLMtool modeling framework.

Stoplight Parrotfish (*Sparisoma viride*)
St. Croix Diving



Life History and Selectivity	vbLinf Asympt-otic Len.	vbK Growth Coeff.	vbt0 Age at Len. 0	wla Wt-Len scalar	wlb Wt-Len power	L50 Len. at maturity	AM Age at maturity	Mort Natural Mortality	LFC Len. 1st Capture	LFS Len. Full Selection
Parameter	361.6	0.25	0	3.70E-5	2.905	205	1.572	0.3	220	338
CV	(0.12)	(0.30)	(0.50)	(0.05)	(0.05)	(0.20)	(0.25)	(0.084)	--	--
Units	mm FL	yr^{-1}	years	--	--	mm FL	years	yr^{-1}	mm FL	mm FL

Relevant federal regulations http://sero.nmfs.noaa.gov/sustainable_fisheries/policy_branch/	*Start Date*	*End Date*
Parrotfish bag limit (2 per person, 6 per vessel)	30 Jan 2012	ongoing
9 inches fork length size limit in St. Coix EEZ (228.6 mm FL)	29 Aug 2013	ongoing

Figure 3.1.6 Summarized information available for stock evaluation of St. Croix stoplight parrotfish using the DLMtool modeling framework.

3.2 Analytical tool - DLMtool

The stock evaluations conducted for SEDAR 46 explored the use of a relatively new analytical process, the Data-Limited Methods Toolkit (DLMtool) (Carruthers et al. 2015; Carruthers 2015a; Carruthers 2015b). The DLMtool focuses on the development of management advice for data-limited fisheries stocks through the application of data-limited stock assessment models and management procedures (herein referred to as MPs). Table 3.1 provides a glossary of key terms used in the DLMtool and discussed herein.The DLMtool provides a framework that can aid in streamlining the assessment process and enhance the capacity of scientists and managers through simulation capabilities and sensitivity examinations (Carruthers et al. 2015). Application of the DLMtool was discussed at the 2014 Workshop convened by the Natural Resources Defense Council (NRDC) Workshop on the "Science and Management of Data-Limited fisheries" (Newman et al. 2014). The DLMtool procedure is developed under the R programming language and is freely available for download through the CRAN-R repository at http://cran.rproject.org/web/packages/DLMtool/index.html.

3.2.1 DLMtool background

The DLMtool fisheries analysis package exhibits a number of beneficial properties outlined in Newman et al. (2014), including:

- Application of a set of peer reviewed data-limited assessment models and management procedures which could greatly enhance the efficacy and throughput of data-limited assessments;
- Powerful diagnostic tools for testing methods;
- Pre-tested computer code;
- Facilitated simulation testing and direct comparison of methods;
- Incorporation of a closed-loop management strategy evaluation procedure that allows for testing of the performance of any method with side-by-side comparisons of performance metrics;
- Sensitivity testing to identify the impact of certain data inputs on the accuracy and precision of method outputs;
- Output products which provide guidance on prioritizing data collection and assessment methods in a cost-effective manner; and
- Open architecture, simple data input form, and user-friendly graphical outputs which promote transparency, credibility, and increased buy in from fishery managers and stakeholders.

Currently (version 2.1.2, release November 2015), 63 data-limited methods are included in DLMtool (Table 3.2.1). Additional methods and diagnostic tools may easily be added by users. Newman et al. (2014) provide information on the evaluation of DLMtool for use in providing guidance to managers for data-limited fisheries.

The accessibility and user-friendly design of the DLMtool has introduced some concern regarding potential abuse of its utility, a topic discussed at the 30th Lowell Wakefield Fisheries Symposium on Tools and Strategies for Assessment and Management of Data-Limited Fish Stocks held in May 2015. Rather than apply all possible data-limited methods to real world data and select a total allowable catch (TAC) considered most desirable (e.g., highest catch), a structured procedure must be followed (Carruthers 2015a). Responsible application of DLMtool consists of two steps:

1. Management strategy evaluation to identify viable methods based on the stock and fleet dynamics of interest as parameterized in the operating model (see Sections 3.2.2 – 3.2.4); and
2. Application of viable methods to real world data sets (see Section 3.2.5).

The SEDAR 46 application of the DLMtool followed the suggested application by the toolkit developer (i.e., to employ management strategy evaluation (MSE) prior to real world application). Management strategy evaluations (MSEs) were conducted for each species-island unit considered, first developing all relevant subclasses of the operating models (OMs) which represent each species' life history dynamics (i.e., stock subclass in the MSE operating model that characterizes the life history dynamics of the stock) and fishery dynamics (fleet subclass in the MSE operating model characterizing the fishery). Sensitivity analyses of the fleet and stock dynamics were conducted to determine the impact of assumptions made regarding representative stocks and fleets on management advice. A summary of MSE in relation to stock assessment in the US Caribbean is presented in SEDAR46-DW-02. Here, we provide a brief overview of the MSE process as it relates to the application of the DLMtool in addition to how the relevant subclasses of the operating models for each species-island unit were configured.

3.2.2 Operating model for management strategy evaluation

The first step in implementing the DLMtool was to explore relative performance among data-limited methods for each species-island unit to be assessed using simulation (Butterworth et al. 2010; Carruthers et al. 2014). Management strategy evaluation (MSE) is a scientifically robust approach used to identify the management option(s) that is (are) most robust to assumptions and uncertainties in data inputs (e.g., depletion estimates required in some models), mis-specified model structure, and to evaluate tradeoffs between alternative management strategies (Punt et al. 2014).

Briefly, MSE consists of capturing system dynamics assumed to represent the "simulated reality" (i.e., truth) and "observed" system dynamics via simulation of (i) biological sampling, (ii) scientific analysis such as conventional fisheries stock assessment, and (iii) harvest control rules or management implementation (Sainsbury et al. 2000; Kell et al. 2007). The simulated reality is then projected forward in time and updated according to the harvest control rule (e.g., TAC) generated by a particular management strategy (Carruthers et al. 2014). A feedback loop between the management strategy and operating model ensures the linkage of observed system dynamics to true system dynamics (Kell et al. 2007), which helps to distinguish MSE from simple risk assessment (Punt et al. 2014). For the purposes of SEDAR 46, results are discussed in terms of the total allowable catch (TAC), assumed equivalent to the overfishing limit (OFL), and no implementation error is currently considered in version 2.1.2 of DLMtool.

The key requirements of the MSE approach are: (1) an operating model (OM) that describes the "true" simulated population (Section 3.2.2.1); (2) a range of candidate data-limited stock assessment methods or management procedures (MP), hereafter referred to collectively as MPs (derived from Table 3.2.1); and (3) criteria for evaluating the performance of MPs (Section 3.2.4). For the SEDAR 46 stock evaluations, a simple MSE was conducted for each species-island unit selected for evaluation by the Panel at the November 2 − 6 2015 San Juan (Puerto Rico) Data/Assessment (DW/AW) Workshop.

Table 3.1. Glossary of DLMtool terms.

Glossary of DLMtool terms	**Description**

Bias	The observed value minus the simulated value all divided by the simulated value
BMSY	Biomass at maximum sustainable yield
BMSY_B0	Biomass at most productive stock size relative to unfished biomass
CV	The standard deviation divided by the mean of a random variable
Data-limited	Insufficient data to conduct a stock assessment
Data-moderate	Dynamic information regarding stock status, trends in abundance or fishing effort
Data-poor	No dynamic data (e.g. relative abundance index, fishing effort) other than annual catch data
Fleet	Subclass for fleet dynamics in operating model within management strategy evaluation
Fgrad	Final historical slope (last five years) in historical fishing mortality rate (% per year)
Fsd	Interannual variability in historical fishing mortality rate (log normal standard deviation)
L5	Length at 5% selectivity by fishery (expressed as a fraction of length at 50% maturity)
LFS	Length at full selectivity by fishery (expressed as a fraction of length at 50% maturity)
Name	Name of the Fleet object
nyears	Number of years of historical exploitation (number of historical simulated years)
qinc	Mean percentage change in fishing efficiency ('catchability', forward projection and input controls)
qcv	Interannual variability in fishing efficiency ('catchability', forward projection and input controls)
Spat_targ	Fishing in relation to vulnerable biomass (proportional to *vulnerable biomass* $^{Spat\_targ}$)
Vmaxlen	The selectivity of the longest length class (controls extent of dome-shaped double normal selectivity)
FMSY	Fishing at maximum sustainable yield (calculated from parameters at the end of the historical simulations)
MP	Management procedure (i.e., data-limited method)
BK	Beddington and Kirkwood life-history MP
CC4	Constant catch MP linked to 70% of average catches
DCAC	Depletion-Corrected Average Catch MP
DCAC40	Depletion-Corrected Average Catch MP assuming a depletion of 40%
DCAC4010	Depletion-Corrected Average Catch MP linked to a 40-10 rule
DD	Delay-Difference stock assessment MP
DD4010	Delay-Difference stock assessment MP linked to a 40-10 rule
EDCAC	Extra Depletion-Corrected Average Catch MP
Fratio	Fixed FMSY to M ratio MP
FMSYref	Perfect overfishing limit MP
Islope1	CPUE slope MP
Islope4	CPUE slope MP (more biologically precautionary)
Itarget1	CPUE target MP
Itarget4	CPUE target MP (more biologically precautionary)

LstepCC1	Mean length MP
LstepCC4	Mean length MP (more biologically precautionary)
Ltarget1	Length target MP
Ltarget4	Length target MP (more biologically precautionary)
MCD	Mean Catch Depletion MP
SPMSY	Catch-trend MSY MP
YPR	Yield Per Recruit MP
MSE	Management strategy evaluation
MSY	Maximum sustainable yield (calculated from parameters at the end of the historical simulations)
Observation model inputs	Subclass for observations in operating model within management strategy evaluation
B0cv	Controls the range of biases sampled for unfished stock size
beta	Bounds on hyperstability / hyper depletion parameter that controls relationship between relative abundance index and biomass (*index(t) = vulnerable biomass(t)*^{beta}) (uniform on log)
BMSY_B0cv	Controls the range of biases sampled for position of most productive stock size relative to unfished
Brefcv	Observation error for target (reference) biomass level (BMSY)
Btbias	Bounds on bias in observations of current absolute stock size (uniform on log)
Btcv	Observation error in current absolute stock size (lognormal standard deviation)
CAA_ESS	Effective sample size of annual catch-at-age observations (independent draws of multinomial observation model)
CAA_nsamp	Total number of catch-at-age observations per year
CAL_cv	The lognormal variability in length at age (lognormal standard deviation)
CAL_ESS	Effective sample size of annual catch-at-length observations (independent draws of multinomial observation model)
CAL_nsamp	Total number of catch-at-length observations per year
Cbiascv	Controls the range of biases for annual catch observations (lognormal standard deviation)
Cobs	Catch observation error (log normal standard deviation)
Crefcv	Observation error for target (reference) catch (MSY)
Dbiascv	Controls the range of biases sampled for stock depletion (biomass relative to unfished)
Dcv	Observation error in stock depletion (lognormal standard deviation)
Fcurbiascv	Controls the range of biases sampled for current fishing mortality rate
Fcurcv	Observation error in current fishing mortality rate (lognormal standard deviation)
FMSYcv	Controls the range of biases sampled for Fishing mortality rate at Maximum Sustainable Yield
FMSY_Mcv	Controls the range of biases sampled for ratio of FMSY to natural mortality rate M
hcv	Controls the range of biases sampled for recruitment compensation (steepness, h)
Icv	Controls the range of biases sampled for relative abundance index
Iobs	Relative abundance index observation error (log normal standard

	deviation)
Irefcv	Observation error for target (reference) relative abundance index (IMSY)
Kcv	Controls the range of biases sampled for growth parameter K
LenMcv	Controls the range of biases for L50 (length at 50% maturity, lognormal standard deviation)
LFCcv	Controls the range of biases sampled for length at first capture (first observed length in fishery)
LFScv	Controls the range of biases sampled for shortest length at full selection by fishery
Linfcv	Controls the range of biases sampled for growth parameter Linf
maxagecv	Controls the range of biases sampled for' for maximum age
Mcv	Controls the range of biases sampled for natural mortality rate (lognormal standard deviation)
Name	Name of the observation object
rcv	Controls the range of biases sampled for intrinsic rate of increase (surplus production parameter r)
Reccv	Observation error for slope in recent recruitment (absolute recruitment over last 10 years, age 1 individuals)
t0cv	Controls the range of biases sampled for growth parameter t0
Observation model output	Sampled parameters of the observation model (a table of nsim rows)
Abias	Bias in observed current absolute stock biomass
Aerr	Imprecision in observations of current absolute stock size (lognormal CV)
BMSY_B0bias	Bias in ratio of most productive stock size relative to unfished
Brefbias	Bias in BMSY stock levels (target or reference biomass levels)
CAA_ESS	Effective sample size of multinomial catch-at-age observation model (number of independent draws)
CAA_nsamp	Number of catch-at-age observations per time step
CAL_ESS	Effective sample size of multinomial catch-at-length observation model (number of independent draws)
CAL_nsamp	Number of catch-at-length observations per time step
Cbias	Bias in observed catches
Crefbias	Bias in MSY prediction (target or reference catch)
Csd	Observation error in observed catches (lognormal CV)
Dbias	Bias in observed stock depletion (also applies to depletion Dt for DCAC)
Derr	Imprecision in observations of current stock depletion (log normal CV)
FMSY_Mbias	Bias in ratio of FMSY to natural mortality rate
hbias	Bias in observed steepness of the stock recruitment relationship
Irefbias	Bias in abundance index corresponding to BMSY stock levels
Isd	Observation error in relative abundance index (lognormal CV)
Kbias	Bias in maximum growth rate (von Bertalanffy K parameter)
LenMcv	Bias in length at 50% maturity
LFCbias	Bias in length at first capture by fishery
LFSbias	Bias in length at full selection by fishery
Linfbias	Bias in maximum length (von Bertalanffy Linf parameter)
Mbias	Bias in observed natural mortality rate
t0bias	Bias in theoretical length at age zero (von Bertalanffy t0 parameter)

Operating model	The simulated true system used to conduct closed loop simulation testing of MPs
Operating model output	Sampled parameters of the operating model (a table of nsim rows)
A	Absolute abundance (biomass) updated in each management update of projection
AC	Autocorrelation in recruitment
BMSY_B0	Most productive stock size relative to unfished
CALcv	Variability in lengths at age around the growth curve (normal standard deviation)
Depletion	Stock depletion (biomass / unfished biomass) in the final historical year (prior to projection)
dFfinal	Gradient in fishing mortality rate over final five years of the historical simulation
Esd	Interannual variability in historical effort (fishing mortality rate)
FMSY	Fishing mortality rate at Maximum Sustainable Yield
FMSY_M	Fishing mortality rate at MSY divided by natural mortality rate
Frac_area_1	Fraction of unfished biomass inhabiting area 1 (can be seen as fraction of habitat in area 1 or relative size of area 1)
hs	Steepness of the stock recruitment relationship (the fraction of unfished recruitment at a fifth of unfished stock levels)
K	Maximum growth rate (von Bertalanffy κ parameter)
Kgrad	Mean gradient in maximum growth rate (percent per time step)
Ksd	Interannual variability in maximum growth rate (log normal standard deviation)
L5	Length at 5% selectivity by fishery (expressed as a fraction of length at 50% maturity)
L50	Length at 50% maturity
LFC	Length at first capture, the smallest length that can be caught by the gear
LFS	Length at full selection (the shortest length class where fishery selectivity is 100 percent)
Linf	Maximum length (von Bertalanffy L_∞ parameter)
Linfgrad	Mean gradient in maximum length (percent per time step)
Linfsd	Inter-annual variability in maximum length (log normal standard deviation)
M	Instantaneous natural mortality rate
Mgrad	Mean percentage gradient in natural mortality rate (percent per time step)
Msd	Interannual variability in natural mortality rate (lognormal standard deviation)
MSY	Maximum Sustainable Yield
OFLreal	True simulated Over Fishing Limit (FMSY x biomass) updated in each management update of the projection
Prob_staying	Probability that individuals in area 1 remain there between time-steps
procsd	Process error - standard deviation in log-normal recruitment deviations
qcv	Interannual variability in future fishing efficiency (catchability) in projected years (input controls only)
qinc	Mean percentage increase in fishing efficiency (catchability) in projected

	years (input controls only)
recgrad	Gradient in recruitment strength (age 1 population numbers) over last 10 years of historical simulations
RefY	Reference yield, the highest long-term yield (mean over last five years of projection) from a fixed F strategy. Used as a reference for framing performance of MPs because it standardizes for starting point and future productivity.
Spat_targ	Spatial targeting parameter, fishing mortality rate is proportional to vulnerable biomass raised to this power
t0	Theoretical length at age zero (von Bertalanffy t_0 parameter)
Vmaxlen	Selectivity of the longest length class (controls dome shape of selectivity curve)
Performance metric	Metric which helps to weigh the tradeoffs between management procedures
LTY	Long-term mean yield over last ten years of the projection
B50	Probability that stock levels are above half of BMSY
PNOF	Fraction of simulation years in which fishing mortality rate does not exceed FMSY
AAVY	Probability that annual average variability in yield is less than 15%
Real world data input	Data inputs needed for real world application of MPs
Abun	Current absolute stock abundance in pounds)
AvC	Average catch over time t (for DCAC only)
BMSY_B0	The depletion level corresponding to the most productive stock size (BMSY)
Bref	Target biomass level (e.g. a proxy of BMSY)
CAA	Catch-at-age data (frequency of catches in each age class)
Cat	Annual catches in weight (landings plus dead discards)
CAL_bins	The definition (break points) of the length classes
CAL	Catch-at-length data (frequency of catches in each length class)
Cref	Target catch level (e.g. a proxy of MSY)
Dep	Current stock depletion (biomass today relative to unfished levels)
Dt	Depletion over time t (for DCAC only)
FMSY_M	The ratio of FMSY to natural mortality rate
Ind	Relative abundance index (e.g. standardized Catch Per Unit Effort (CPUE))
Iref	Target relative abundance level (e.g. a proxy of a CPUE near BMSY)
L50	Length at 50% maturity
L95	Length at 95% maturity
LFC	Length at first capture by fishery (5% selectivity)
LFS	Length at full selection by fishery (95% selectivity)
MaxAge	Maximum age
Mort	Instantaneous natural mortality rate
Name	Species name
Rec	Index of relative recruitment strength
Ref	Reference OFL (e.g. a previous catch recommendation)
Ref_type	Reference OFL type (input control, catch limit)
sigmaL	Imprecision in length composition data
steep	Steepness of the stock-recruitment function (the fraction of unfished

	recruitment at 20% of unfished biomass)
t	Duration of data used for DCAC - relevant only to AvC and Dt
Uncertainty	Coefficient of variation around parameter of interest
CV_Abun	Imprecision in the estimate of current stock abundance
CV_AvC	Imprecision in the average catch over time t (DCAC only)
CV_BMSY_B0	Imprecision in the position of the most productive stock size relative to unfished
CV_Bref	Imprecision in the target biomass level
CV_Cat	Imprecision in historical annual catches
CV_Cref	Imprecision in the target catch level
CV_Dep	Imprecision in the estimate of current stock depletion (biomass relative to unfished)
CV_Dt	Imprecision in value of depletion over time t (DCAC only)
CV_FMSY_M	Imprecision in the ratio of FMSY to natural mortality rate
CV_Ind	Imprecision in historical annual relative abundance
CV_Iref	Imprecision in the target relative abundance index level
CV_L50	Imprecision in the length at 50% maturity
CV_LFC	Imprecision in the length at first capture by the fishery
CV_LFS	Imprecision in the length at full selection by the fishery
CV_Mort	Imprecision in instantaneous natural mortality rate
CV_Rec	Imprecision in historical recruitment strength
CV_steep	Imprecision in the steepness of the stock-recruitment function
CV_vbK	Imprecision in the von Bertalanffy κ parameter
CV_vbLinf	Imprecision in the von Bertalanffy L_∞ parameter
CV_vbt0	Imprecision in the von Bertalanffy t_0 parameter
CV_wla	Imprecision in the length-weight parameter a
CV_wlb	Imprecision in the length-weight parameter b
Units	Units (e.g. pounds)
vbK	Von Bertalanffy κ parameter
vbLinf	Von Bertalanffy L_∞ parameter
vbt0	Von Bertalanffy t_0 parameter
wla	Length-weight parameter a ($W=aL^{b)}$
wlb	Length-weight parameter b ($W=aL^{b}$)
Year	Years corresponding to catch and index of abundance
Reference yield	Highest mean yield over the last five years of the projection that can be obtained from a fixed F strategy
Relative yield	Long-term yield divided by reference yield
Reps	Number of stochastic draws of the TAC (OFL) distribution by a particular MP
Stock input	Subclass for stock dynamics in operating model within management strategy evaluation
AC	Autocorrelation in recruitment deviations
a	a parameter of the length-weight relationship $W=aL^b$
b	b parameter of the length-weight relationship $W=aL^b$
D	Current level of stock depletion (biomass relative to unfished)
Frac_area_1	Fraction of the unfished biomass ('habitat') in area 1
h	Recruitment compensation (steepness)
K	Maximum growth rate of individuals (von Bertalanffy κ)

Ksd	Interannual variability in K parameter (% per year)
Kgrad	Mean slope in K parameter (% per year)
L50	Length at which individuals are 50% mature
L50_95	Length increment from 50% to 95% maturity
Linf	Maximum length of individuals (von Bertalanffy L_∞)
Linfsd	Interannual variability in Linf parameter (% per year)
Linfgrad	Mean slope in Linf parameter (% per year)
maxage	Maximum age of individuals
M	Natural morality rate
Msd	Interannual variability in natural mortality rate (log-normal standard deviation)
Mgrad	Mean slope in natural mortality rate (% per year)
Name	Name of the Stock object
Perr	Process error, the standard deviation of log normal recruitment deviations
Prob_staying	Probability that individuals in area 1 stay in area 1 between years
R0	The magnitude of unfished recruitment (a scalar and usually not important in MSE)
recgrad	Mean slope in recruitment deviations (% per year)
Size_area_1	Relative size of area 1
Source	Primary source of the inputs listed above
SRrel	Type of stock-recruitment relationship: (1) Beverton Holt (2) Ricker
t0	Theoretical length at age zero (von Bertalanffy t_0)
TAC	Total Allowable Catch; assumed equivalent to the overfishing limit (OFL)

Table 3.2.1 Summary of data-limited stock assessment models and management procedures contained within DLMtool, version 2.1.2. Shaded cells denote required data inputs which are defined in Table 3.1.

Method / Management Procedure	Description	Reference	Data Inputs																									
			Mort	L50	vbt0	vbK	vbLinf	wla	wlb	steep	MaxAge	Cat	AvC	LFC	LFS	CAA	CAL	FMSY_M	BMSY_B0	Cref	Bref	Iref	Ind	Rec	Dt	Dep	Abun	Mprec
Catch-based																												
AvC	Average Catch	Carruthers et al. (2014)										▨																
CC1	Constant Catch linked to average catches (TAC = $C_{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨																
CC4	Constant Catch linked to average catches (TAC = 0.7 x $C_{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨																
GB_CC	Constant Catch harvest control rule (use average historical catch as a proxy for MSY)	Geromont and Butterworth (2014a); Carruthers et al. (2015)										▨								▨								
SPMSY	Surplus Production MSY	Martell and Froese (2012)		▨	▨	▨	▨				▨	▨																
Index-based																												
Islope1	CPUE slope (maintain constant CPUE: TAC = 0.8 x $C^{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨											▨					
Islope4	CPUE slope (maintain constant CPUE: TAC = 0.6 x $C^{average}$); more precautionary	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨											▨					
Itarget1	CPUE target (TAC adjusted to achieve a target CPUE: I_{target}=1.5 $I^{average}$, TAC = $C^{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨											▨					
Itarget4	CPUE target (TAC adjusted to achieve a target CPUE: I_{target}=2.5 $I^{average}$, TAC = 0.7 x $C^{average}$); more precautionary	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨											▨					
GB_slope	Slope index harvest control rule (TAC adjusted depending upon trend in recent survey index)	Geromont and Butterworth (2014a); Carruthers et al. (2015)										▨											▨					
SBT1	Simple harvest control rule (uses target catch level)	CCSBT 2011; Carruthers et al. (2015)										▨											▨					
GB_target	Target CPUE and catch harvest control rule (TAC adjusted based on average recent survey index values being above/below the target index value)	Geromont and Butterworth (2014a); Carruthers et al. (2015)										▨								▨		▨	▨					
IT5	Index Target 5, where TAC is modified according to current index levels (mean index over last 5 years) relative to a target level. Maximum annual changes are 5%	Carruthers (2015b)																				▨	▨					▨
IT10	Index Target 10, where TAC is modified according to current index levels (mean index over last 5 years) relative to a target level. Maximum annual changes are 10%	Carruthers (2015b)																				▨	▨					▨

Method / Management Procedure	Description	Reference	Data Inputs																									
			Mort	L50	vbt0	vbK	vbLinf	wla	wlb	steep	MaxAge	Cat	AvC	LFC	LFS	CAA	CAL	FMSY_M	BMSY_B0	Cref	Bref	Iref	Ind	Rec	Dt	Dep	Abun	Mprec
ITM	Index Target with M, wher eTAC is modified according to current index levels (mean index over last yrsmth years) relative to a target level. Maximum fractional annual changes are mc where mc=(5+M*25)/100 yrsmth=4*(1/M)^(0.25)	Carruthers (2015b)	▨																			▨	▨					▨
SBT2	Simple harvest control rule (uses target biomass and catch levels)	CCSBT (2011); Carruthers et al. (2015)										▨								▨				▨				
Depletion-based																												
DCAC	Depletion-Corrected Average Catch (DCAC)	MacCall (2009); Carruthers et al. (2014)	▨										▨					▨	▨						▨			
DCAC_40	DCAC assuming stock depletion is 40% of unfished levels	MacCall (2009); Carruthers et al. (2014)	▨										▨					▨	▨									
DCAC4010	DCAC with a 40:10 harvest control rule	MacCall (2009)	▨										▨					▨	▨						▨			
EDCAC	Extra Depletion-Corrected Average Catch (EDCAC)	Carruthers (2015); Harford and Carruthers (in prep)	▨										▨					▨	▨						▨			
MCD	Mean Catch Depletion	Carruthers (2015b)										▨														▨		
MCD4010	Mean Catch Depletion with 40:10 harvest control rule	Carruthers (2015b)										▨														▨		
DepF	Depletion Corrected Fratio	Carruthers (2015b)	▨															▨								▨	▨	
Fratio4010	FMSY to M ratio with a 40:10 harvest control rule	Gulland (1971); Walters and Martell (2002); Martell and Froese (2012)	▨															▨							▨		▨	
DBSRA	Depletion-Based Stock Reduction Analysis (DBSRA)	Dick and MacCall (2011); Carruthers et al. (2014)	▨	▨	▨	▨	▨					▨						▨	▨							▨		
DBSRA_40	DBSRA assuming stock depletion is 40% of unfished levels	Dick and MacCall (2011); Carruthers et al. (2014)	▨	▨	▨	▨	▨					▨						▨	▨									
DBSRA4010	DBSRA with a 40:10 harvest control rule	Dick and MacCall (2011)	▨	▨								▨						▨	▨							▨		
SPSRA	Surplus Production Stock Reduction Analysis	McAllister et al. (2001)	▨		▨	▨	▨			▨	▨	▨														▨		
Rcontrol	R control (modifies TAC according to trends in apparent surplus production)	Carruthers et al. (2015)	▨		▨	▨	▨			▨	▨	▨											▨			▨	▨	
Rcontrol2	R control with quadratic approximation to surplus production	Carruthers et al. (2015)	▨		▨	▨	▨			▨	▨	▨											▨			▨	▨	
Abundance-based																												
SPmod	Surplus production based catch-limit modifier	Carruthers et al. (2015); Maunder (2014)										▨											▨				▨	
SPslope	Catch trend surplus production MSY	Carruthers et al. (2015); Maunder (2014)										▨											▨				▨	
Gcontrol	G-control (uses trajectory in inferred surplus production to make adjustment to TAC)	C. Walters; Carruthers et al. (2015)										▨											▨				▨	
Fratio	FMSY to M ratio	Gulland (1971); Walters and Martell (2002); Martell and Froese (2012); Carruthers et al. (2014)	▨															▨									▨	
DynF	Dynamic Fratio	Carruthers et al. (2015)	▨									▨						▨					▨				▨	

Method / Management Procedure	Description	Reference	Data Inputs																									
			Mort	L50	vbt0	vbK	vbLinf	wla	wlb	steep	MaxAge	Cat	AvC	LFC	LFS	CAA	CAL	FMSY_M	BMSY_B0	Cref	Bref	Iref	Ind	Rec	Dt	Dep	Abun	Mprec
Fadapt	Adaptive F that uses trajectory in inferred surplus production and F to update TAC	Carruthers et al. (2015)	▨									▨						▨					▨				▨	
BK	Beddington and Kirkwood life history method	Beddington and Kirkwood (2005); Carruthers et al. (2014)				▨	▨							▨													▨	
Fdem	Demographic FMSY method	McAllister et al. (2001)	▨		▨	▨	▨			▨	▨																▨	
YPR	Yield-Per-Recruit analysis	Beverton and Holt (1954)	▨		▨	▨	▨	▨	▨		▨				▨												▨	
Data-moderate																												
DD	Delay-Difference stock assessment model	C. Walters; Carruthers et al. (2014)	▨	▨	▨	▨	▨	▨	▨		▨	▨											▨					
DD4010	Delay-Difference stock assessment model with a 40:10 harvest control rule	C. Walters; Carruthers (2015b)	▨	▨	▨	▨	▨	▨	▨		▨	▨											▨					
Length-based																												
LstepCC1	Mean length (Mean length relative to historical levels used to alter TAC; TAC = $C^{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨					▨											
LstepCC4	Mean length (Mean length relative to lower initial historical catch levels used to alter TAC: TAC = 0.7 x $C^{average}$); more precautionary	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨					▨											
Ltarget1	Length target (TAC adjusted to reach a target mean length: L_{target} = 1.05 $L^{average}$, TAC= $C^{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨					▨											
Ltarget4	Length target (TAC adjusted to reach a target mean length: L_{target} = 1.15 $L^{average}$, TAC= 0.8 x $C^{average}$)	Geromont and Butterworth (2014b); Carruthers et al. (2015)										▨					▨											
BK_ML	Beddington and Kirkwood life history method that uses Mean Length extension to estimate current abundance based on catches and recent F	Beddington and Kirkwood (2005); Gedamke and Hoenig (2006)	▨			▨	▨					▨		▨														
Fratio_ML	FMSY to M ratio that uses a Mean Length estimator of recent Z	Gulland (1971); Walters and Martell (2002); Martell and Froese (2012); Gedamke and Hoenig (2006)	▨			▨	▨					▨						▨										
DCAC_ML	DCAC that uses a Mean Length estimator of current depletion	MacCall (2009); Gedamke and Hoenig (2006)	▨			▨	▨					▨	▨					▨	▨									
DBSRA_ML	DBSRA that uses a Mean Length estimator of current depletion	Dick and MacCall (2011); Gedamke and Hoenig (2006)	▨	▨	▨	▨	▨					▨						▨	▨									
SPSRA_ML	SPSRA that uses a Mean Length estimator of current depletion	McAllister et al. (2001); Gedamke and Hoenig (2006)	▨		▨	▨	▨			▨	▨	▨																
YPR_ML	YPR analysis that uses a Mean Length estimator of current abundance	M. Bryan; Carruthers (2015); Gedamke and Hoenig (2006)			▨	▨	▨	▨	▨		▨	▨			▨													
Fdem_ML	Demographic FMSY method that uses a Mean Length estimator of recent Z	McAllister et al. (2001); Gedamke and Hoenig (2006)	▨		▨	▨	▨			▨	▨	▨																

Method / Management Procedure	Description	Reference	Data Inputs																									
			Mort	L50	vbt0	vbK	vbLinf	wla	wlb	steep	MaxAge	Cat	AvC	LFC	LFS	CAA	CAL	FMSY_M	BMSY_B0	Cref	Bref	Iref	Ind	Rec	Dt	Dep	Abun	Mprec
Age-based																												
Fratio_CC	FMSY to M ratio that uses a Catch Curve to estimate current abundance based on catches and recent F	Gulland (1971); Walters and Martell (2002); Martell and Froese (2012)	▨									▨						▨										
BK_CC	Beddington and Kirkwood life history method that uses a Catch Curve to estimate current abundance based on catches and recent F	Beddington and Kirkwood (2005)	▨			▨	▨					▨		▨														
YPR_CC	Yield Per Recruit analysis that uses a Catch Curve to estimate recent abundance	M. Bryan; Carruthers (2015)	▨		▨	▨	▨	▨	▨		▨	▨			▨													
Fdem_CC	Demographic FMSY method that uses a Catch Curve to estimate recent Z	McAllister et al. (2001)	▨		▨	▨	▨			▨	▨	▨																
CompSRA	Age-composition-based estimate of current stock depletion given constant Z linked to an FMSY estimate	Carruthers (2015b)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨												
CompSRA4010	Age-composition-based estimate of current stock depletion given constant Z linked to an FMSY estimate with a 40:10 harvest control rule	Carruthers (2015b)	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		▨	▨	▨												

Table 3.2.2 Abridged summary of DLMtool methods applied in the SEDAR 46 stock evaluations providing method name, description, source of information and common assumptions. Appendix 4.4 provides a comprehensive description of all methods applied in the SEDAR 46 assessment including TAC derivation equations and a listing of pros and cons for each method.

Method	**Description**	**Reference**	**Assumptions**
Reference FMSY method			
FMSYref	Reference method	Carruthers (2015b)	• Uses perfect information about FMSY from management strategy evaluation • Assume operating models reflect true reality • Fisheries targeting and catchability constant
Catch-based			
CC4	Constant catch linked to average catches	Geromont and Butterworth (2014b); Carruthers et al. (2015)	• Target catch level (e.g., a proxy of MSY) known • Historical catch known exactly • Catch data have reasonable information content and associated observation error is low
SPMSY	Surplus production MSY	Martell and Froese (2012)	• Catch time series known and informative • Schaefer production model • Narrow range of r-k combinations provide proxy for MSY • Productivity not well informed for lightly exploited stocks • Stationary production function over time • Reasonable priors for production function parameters r and k
Index-based			
Islope1	CPUE slope, maintain constant CPUE	Geromont and Butterworth (2014b); Carruthers et al. (2015)	• Catch and relative abundance time series known and informative • Observation error low • CPUE proportional to abundance

			• Constant CPUE is aim
Islope4	CPUE slope, maintain constant CPUE; more precautionary than Islope1	Geromont and Butterworth (2014b); Carruthers et al. (2015)	• Same as Islope1
Itarget1	CPUE target, TAC adjusted to achieve a target CPUE (1.5 historical average CPUE)	Geromont and Butterworth (2014b); Carruthers et al. (2015)	• Same as Islope1
Itarget4	CPUE target, TAC adjusted to achieve a target CPUE (2.5 historical average CPUE); more precautionary than Itarget1	Geromont and Butterworth (2014b); Carruthers et al. (2015)	• Same as Itarget4
IT5	Index Target 5, TAC modified according to current index levels relative to a target level	(Carruthers 2015b)	• Same as Islope1 plus • TAC is maintained at current index level relative to target • Abundance level that is a proxy of CPUE near BMSY
IT10	Index Target 10, TAC modified according to current index levels relative to a target level	(Carruthers 2015b)	• Same as IT5
ITM	Index Target based on M, TAC modified according to current index levels relative to a target level using Mort to set annual changes	(Carruthers 2015b)	• Same as IT5 plus • Assumes Mort is known
Depletion-based			
DCAC	Depletion-Corrected Average Catch (DCAC)	MacCall (2009); Carruthers et al. (2014)	• Current depletion and catch series known • FMSY/M, Mort and BMSY/B0 known • Stochastic stock conditions • One-time "Windfall" harvest that reduces the

			stock by (1 – Dt) • Stock is maintained near the levels of abundance experienced during the historical period from which the catches were derived
DCAC_40	Depletion-Corrected Average Catch (DCAC)	MacCall (2009); Carruthers et al. (2014)	• Same as DCAC • Assumes Depletion is 40% unfished state
DCAC4010	DCAC with a 40:10 harvest control rule	MacCall (2009); Carruthers et al. (2014)	• Same as DCAC plus: • Catches and depletion have occurred since a relatively unfished state (i.e., D = 1−Δ)
EDCAC	Modified DCAC accounting for absolute depletion	MacCall (2009); Harford and Carruthers (in prep)	• Same as DCAC plus: • Mean catches are a suitable proxy of MSY • Stock dynamics follow a Schaefer (1954) production function where BMSY is at half of unfished biomass • Requires reliable estimate of current stock depletion
MCD	Mean Catch Depletion	Carruthers (2015b); Harford and Carruthers (in prep)	• Depletion known • Mean catches are a suitable proxy of MSY • Stock dynamics follow a Schaefer (1954) production function where BMSY is at half of unfished biomass
Abundance-based			
Fratio	FMSY/M ratio MP	Gulland (1971); Walters and Martell (2002); Martell and Froese (2012); Carruthers et al.	• FMSY/M and current abundance known • Mort known and constant over age and time

		(2014)	
BK	Beddington and Kirkwood life history method	Beddington and Kirkwood (2005); Carruthers et al. (2014)	• Current abundance known • Equal vulnerability of fish larger than length at capture
YPR	Yield-Per-Recruit analysis	Beverton and Holt (1957)	• Mort, growth, weight - length relationship, and maximum age known • Growth parameters and Mort do not change over time, stock size, or age • Length-weight relationship has an exponent of value = 3 • Distinct spawning period with all fish recruiting at the same time and age • F constant over all ages • Complete mixing of stock • Assumes no dependence between stock size and recruitment • Static
Data-moderate			
DD	Delay-difference stock assessment biomass dynamics model	C. Walters; Carruthers et al. (2014)	• Growth rate, vbLinf, L50, Mort, weight-length parameters known • Catch time series known and of reliable information content • All fish older than age at first capture equally vulnerable • All fish vulnerable to gear have same annual natural Mort • Harvest takes place in a short time during the start or end of the year • Constant productivity / stationary stock dynamics • Proportionality between index and real abundance • Linear relationship between historical fishing

			effort and F - Selectivity at size constant
DD4010	Delay-difference stock assessment model with a 40:10 HCR	C. Walters; (Carruthers 2015b)	- Same as DD
Length-based			
Ltarget4	Length target MP, TAC adjusted to reach a target mean length; more precautionary than Ltarget1	Geromont and Butterworth (2014b); Carruthers et al. (2015)	- Mean length of catch an indirect and informative indicator of the trend in resource abundance - Catch known
LstepCC1	Mean length MP, mean length relative to historical levels used to alter TAC	Geromont and Butterworth (2014b); Carruthers et al. (2015)	- Mean length informative relative to historic period - Catch known
LstepCC4	Mean length MP, mean length relative to lower initial historical catch levels used to alter TAC; more precautionary than LstepCC1	Geromont and Butterworth (2014b); Carruthers et al. (2015)	- Same as LstepCC1

Graphical summaries of the available data for each species-island unit are provided in Section 3.1 (Figures 3.1.1 – 3.1.6). Appendices 4.3.1 – 4.3.6 provide all data inputs used in DLMtool to calculate total allowable catches (TACs) from real world data. Within the DLMtool, the 'feasibility' function evaluates the sufficiency of data and parameter inputs for each DLMtool MP in terms of presence or abundance; this function was used to identify feasible DLMtool MPs for consideration in the MSE for each of the six species-island units evaluated in SEDAR 46.

Within the MSE process, the operating model (OM) represents the biological components of the system to be managed and the fisher behavior in response to management actions (Carruthers et al. 2014; Punt et al. 2014). For each species-island unit under evaluation, an OM was developed to reflect the life history, stock dynamics, and fleet selectivity. During the SEDAR 46 DW/AW Workshop, multiple working groups were convened to review available data and provide recommendations of appropriate life history, stock dynamics and fleet characterizations to aid in parameterizing the OMs. The multiple working groups included fishery biologists and stock assessment scientists, fishers, and members of the fishing industry from each of the three island units (St. Thomas, St. Croix and Puerto Rico). It is assumed that the OMs specified at the DW/AW Workshop and presented below (Tables 3.2.3, 3.2.5) represent reality and reflect the best available science at this point in time. Sensitivity analyses were carried out on the OM specifications to address assumptions made regarding life history and fleet dynamics. Within DLMtool, the OM is an age-structured, spatial model, with details provided in Carruthers et al. (2014).

3.2.2.1 Stock subclass of OM

Data inputs for each species-island unit OM were obtained from the SEDAR46 DW/AW Workshop. Biological parameters including instantaneous natural mortality rate (M, year^{-1}), Von Bertalanffy asymptotic length (Linf, mm FL for fishes, mm carapace length (CL) for spiny lobster), Von Bertalanffy maximum growth rate (K, year^{-1}), and length at 50% maturity (L50, mm FL) were allowed to vary by ±15% in each OM. Detailed stock dynamics are provided in Tables 3.2.3A − 3.2.3B which identify sources of input parameters. Within the DLMtool, each stock is assumed to have density-dependent recruitment that does not decrease with increasing stock size, with maximum surplus recruitment achieved when spawning output is less than half of unfished (Beverton and Holt 1957; Carruthers et al. 2014). Herein, each base stock OM is referred to as ±15%LH.

Within the stock dynamics, depletion was estimated for each species-island fishery from mean length observations (obtained from the NOAA Fisheries, Southeast Fisheries Science Center [SEFSC] Trip Interview Program database, TIP) and OM parameters including maximum age (maxage), Linf, K, t0, length-weight parameters (a, b), fishing selectivity (L5, LFS, Vmaxage), steepness (h), and natural mortality (M). The ML2D function in DLMtool was applied to estimate current stock depletion (Carruthers 2015b). The function samples from the various parameter distributions (currently input as uniform) and simulates population characteristics. This application provides *highly uncertain* estimates of current stock biomass and equilibrium fishing mortality, and therefore, results using this data input should be interpreted with caution.

To evaluate the assumptions made regarding the range of biological parameter estimates in each OM, a sensitivity analysis on the Stock subclass was carried out for each species-island unit. Under the stock OM sensitivity, the biological parameters including M, Linf, and K were allowed to vary by ±5% for each OM (Tables 3.2.4A − 3.2.4B). Herein, each alternative stock OM is referred to as ±5% LH and is considered in a sensitivity analysis.

3.2.2.2 Fleet subclass of OM

Within the MSE, a fishing fleet subclass was also specified in the OM for each species-island unit and was based on the fleet identified by the DW/AW Panel as the most representative of the stock dynamics (e.g., the gear dominating the landings). The DW/AW Panel discussions pertaining to fleet characterization also included deliberations from commercial and recreational fishers. Based on the Panel recommendations and consensus among fishers and panelists, fleets were parameterized to exhibit either dome-shaped selectivity (STT queen triggerfish, STT spiny lobster, STX spiny lobster) or asymptotic selectivity (PR hogfish, PR yellowtail snapper, STX stoplight parrotfish). Fleet vulnerability parameters were calculated from L50 as provided by the DW/AW Workshop life history working group and estimates of the 5th (L5) and 95th (LFS) percentiles of the selectivity curve for the representative fleet from SEDAR-WP-05. Within DLMtool, fleet vulnerability parameters including L5 and LFS are expressed as multiples of L50 (e.g., 1.25, 125% of L50).

The OMs for species exhibiting dome-shaped selectivity were initially set up to account for moderately dome-shaped selectivity “moderate dome selex”, with the selectivity of the longest length class (Vmaxlen) ranging from 0.2 to 0.6. The Vmaxlen parameter controls the extent of dome-shaped double normal selectivity. Preliminary discussion at the SEDAR 46 DW/AW Workshop suggested that selectivity of the fleets for STT queen triggerfish, STT spiny lobster, and STX spiny lobster could be more dome-shaped than initially parameterized. To assess the assumption of the extent of dome-shaped selectivity in the OMs for these species-island units, a sensitivity analysis was conducted. For these three species-island units, a fleet subclass was developed that assumed high dome selectivity ("High dome selex") (Vmaxlen range: 0 – 0.5).

Herein, each fleet subclass of the base OM is referred to as either 'Asymptotic selex' for PR hogfish, PR yellowtail snapper, and STX stoplight parrotfish or "High dome selex" for STT queen triggerfish, STT spiny lobster, and STX spiny lobster. Alternative fleet sensitivities are identified herein as "Moderate dome selex") and were not chosen as components of the base model due to the concerns raised by the SEDAR 46 DW/AW Panel. Detailed fleet dynamics are provided in Tables 3.2.5 – 3.2.6 which identify sources of input parameters.

3.2.2.3 Observation subclass of OM

For the purposes of the SEDAR 46 stock evaluation, data inputs were assumed precise and unbiased within the observation subclass of the OM for each species-island unit. Input parameters assumed within the observation subclass for all species-island unit OMs are presented in Table 3.2.7. We also tested the sensitivity of the observation subclass model by assuming imprecise biased data inputs, presented in Table 3.2.8.

Table 3.2.3A Stock dynamics characterized in the base operating models assuming ±15% variability in life history parameters for Puerto Rico (PR) hogfish and yellowtail snapper, and St. Thomas (STT) queen triggerfish.

Stock input	**Description/Source**	**Data Input Value or Range**		
Species-island	Island unit where species is assessed	PR hogfish	PR yellowtail snapper	STT queen triggerfish
Name	Name of model run	Base = 15%LH	Base = 15%LH	Base = 15%LH
Life history (LH)				
maxage	Point estimate from LH group	23 yrs.	19 yrs.	14 yrs.
R0	Typical value of 1000 sufficient	1000	1000	1000
M	Point estimate from LH group ± 15% error	c(0.132, 0.179)	c(0.161, 0.217)	c(0.218, 0.295)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25,0.25)	c(−0.25,0.25)	c(−0.25,0.25)
h	Range from literature and panel discussion	c(0.7, 0.9)	c(0.7, 0.9)	c(0.7, 0.9)
SRrel	Type of stock−recruitment relationship	Beverton−Holt	Beverton−Holt	Beverton−Holt
Linf	Point estimate from LH group ± 15% error	c(722, 976)	c(427, 578)	c(514, 696)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
K	Point estimate from LH group ± 15% error	c(0.090, 0.122)	c(0.118, 0.160)	c(0.182, 0.246)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
t0	Point estimate from LH group	c(−1.329, −1.329)	c(−1, −0.9)	c(0, 0)
a	Point estimate from LH group	9.50E-05	3.54E-05	8.64E-05
b	Point estimate from LH group	2.745	2.859	2.784
D	Estimate based on mean length and LH parameters obtained from operating model	c(0.05, 0.24)	c(0.12, 0.35)	c(0.05, 0.28)
L50	Point estimate from LH group ± 15% error	c(150,203)	c(211,285)	c(182,248)
L50_95	Length increment from 50% to 95% maturity	c(91,145)	c(30, 104)	c(28, 92)
recgrad	Assuming no slope in recruitment deviations	c(0, 0)	c(0, 0)	c(0, 0)
Perr	Assuming low to moderate process error in recruitment	c(0.2, 0.4)	c(0.2, 0.4)	c(0.2, 0.4)
AC	Testing wide range of low to high autocorrelation	c(0.2, 0.8)	c(0.2, 0.8)	c(0.2, 0.8)
Size_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Frac_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Prob_staying	Assuming 50%; parameter not currently used	c(0.45, 0.55)	c(0.45, 0.55)	c(0.45, 0.55)

Table 3.2.3B Stock dynamics characterized in the base operating models assuming ±15% variability in life history parameters for St. Thomas (STT) spiny lobster, St. Croix (STX) spiny lobster and stoplight parrotfish.

Stock input	**Description/Source**	**Data Input Value or Range**		
Species-island	Island unit where species is assessed	STT spiny lobster	STX spiny lobster	STX stoplight parrotfish
Name	Name of model run	Base = 15%LH	Base = 15%LH	Base = 15%LH
Life history (LH)				
maxage	Point estimate from LH group	20 yrs.	20 yrs.	12 yrs.
R0	Typical value of 1000 sufficient	1000	1000	1000
M	Point estimate from LH group ± 15% error	c(0.298, 0.403)	c(0.298, 0.403)	c(0.255, 0.345)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25,0.25)	c(−0.25,0.25)	c(−0.25,0.25)
h	Range from literature and panel discussion	c(0.3, 0.7)	c(0.3, 0.7)	c(0.7, 0.9)
SRrel	Type of stock−recruitment relationship	Beverton−Holt	Beverton−Holt	Beverton−Holt
Linf	Point estimate from LH group ± 15% error	c(155, 210)	c(155, 210)	c(537, 726)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
K	Point estimate from LH group ± 15% error	c(0.204, 0.276)	c(0.204, 0.276)	c(0.212, 0.287)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
t0	Point estimate from LH group	c(0.44, 0.44)	c(0.44, 0.44)	c(0, 0)
a	Point estimate from LH group	9.21E-03	9.21E-03	3.70E-05
b	Point estimate from LH group	2.4804	2.4804	2.9051
D	Estimate based on mean length and LH parameters obtained from operating model	c(0.09, 0.54)	c(0.05, 0.42)	c(0.05, 0.10)
L50	Point estimate from LH group ± 15% error	c(56,76)	c(56,76)	c(174, 236)
L50_95	Length increment from 50% to 95% maturity	c(0, 18)	c(0, 18)	c(0, 61)
recgrad	Assuming no slope in recruitment deviations	c(0, 0)	c(0, 0)	c(0, 0)
Perr	Assuming low to moderate process error in recruitment	c(0.2, 0.4)	c(0.2, 0.4)	c(0.2, 0.4)
AC	Testing wide range of low to high autocorrelation	c(0.2, 0.8)	c(0.2, 0.8)	c(0.2, 0.8)
Size_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Frac_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Prob_staying	Assuming 50%; parameter not currently used	c(0.45, 0.55)	c(0.45, 0.55)	c(0.45, 0.55)

Table 3.2.4A Alternative stock dynamics characterized in the sensitivity operating models assuming ±5% variability in life history parameters for Puerto Rico (PR) hogfish and yellowtail snapper, and St. Thomas (STT) queen triggerfish.

Stock input	**Description/Source**	**Data Input Value or Range**		
Species-island	Island unit where species is assessed	PR hogfish	PR yellowtail snapper	STT queen triggerfish
Name	Name of model run	Alt = 5%LH	Alt = 5%LH	Alt = 5%LH
Life history (LH)				
maxage	Point estimate from LH group	23 yrs.	19 yrs.	14 yrs.
R0	Typical value of 1000 sufficient	1000	1000	1000
M	Point estimate from LH group ± 5% error	c(0.148, 0.164)	c(0.179, 0.198)	c(0.244, 0.270)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25,0.25)	c(−0.25,0.25)	c(−0.25,0.25)
h	Range from literature and panel discussion	c(0.7, 0.9)	c(0.7, 0.9)	c(0.7, 0.9)
SRrel	Type of stock−recruitment relationship	Beverton−Holt	Beverton−Holt	Beverton−Holt
Linf	Point estimate from LH group ± 5% error	c(807, 891)	c(477, 527)	c(575, 636)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
K	Point estimate from LH group ± 5% error	c(0.101, 0.111)	c(0.132, 0.146)	c(0.203, 0.225)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
t0	Point estimate from LH group	c(−1.329, −1.329)	c(−1, −0.9)	c(0, 0)
a	Point estimate from LH group	9.50E-05	3.54E-05	8.64E-05
b	Point estimate from LH group	2.745	2.859	2.784
D	Estimate based on mean length and LH parameters obtained from operating model	c(0.05, 0.15)	c(0.12, 0.35)	c(0.06, 0.17)
L50	Point estimate from LH group ± 5% error	c(150,203)	c(211,285)	c(182,248)
L50_95	Length increment from 50% to 95% maturity	c(91,145)	c(30, 104)	c(28, 92)
recgrad	Assuming no slope in recruitment deviations	c(0, 0)	c(0, 0)	c(0, 0)
Perr	Assuming low to moderate process error in recruitment	c(0.2, 0.4)	c(0.2, 0.4)	c(0.2, 0.4)
AC	Testing wide range of low to high autocorrelation	c(0.2, 0.8)	c(0.2, 0.8)	c(0.2, 0.8)
Size_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Frac_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Prob_staying	Assuming 50%; parameter not currently used	c(0.45, 0.55)	c(0.45, 0.55)	c(0.45, 0.55)

Table 3.2.4B Alternative stock dynamics characterized in the sensitivity operating models assuming ±5% variability in life history parameters for St. Thomas (STT) spiny lobster, St. Croix (STX) spiny lobster, and St. Croix (STX) stoplight parrotfish.

Stock input	**Description/Source**	**Data Input Value or Range**		
Species-island	Island unit where species is assessed	STT spiny lobster	STX spiny lobster	STX stoplight parrotfish
Name	Name of model run	Alt = 5%LH	Alt = 5%LH	Alt = 5%LH
Life history (LH)				
maxage	Point estimate from LH group	20 yrs.	20 yrs.	12 yrs.
R0	Typical value of 1000 sufficient	1000	1000	1000
M	Point estimate from LH group ± 5% error	c(0.333, 0.368)	c(0.333, 0.368)	c(0.285, 0.315)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25,0.25)	c(−0.25,0.25)	c(−0.25,0.25)
h	Range from literature and panel discussion	c(0.3, 0.7)	c(0.3, 0.7)	c(0.7, 0.9)
SRrel	Type of stock−recruitment relationship	Beverton−Holt	Beverton−Holt	Beverton−Holt
Linf	Point estimate from LH group ± 5% error	c(174, 192)	c(174, 192)	c(600, 663)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
K	Point estimate from LH group ± 5% error	c(0.228, 0.252)	c(0.228, 0.252)	c(0.237, 0.262)
sd	Assuming range 0 to 0.01 adequate	c(0, 0.01)	c(0, 0.01)	c(0, 0.01)
grad	Assuming range −0.25 to 0.25 adequate	c(−0.25, 0.25)	c(−0.25, 0.25)	c(−0.25, 0.25)
t0	Point estimate from LH group	c(0.44, 0.44)	c(0.44, 0.44)	c(0, 0)
a	Point estimate from LH group	9.21E-03	9.21E-03	3.70E-05
b	Point estimate from LH group	2.4804	2.4804	2.9051
D	Estimate based on mean length and LH parameters obtained from operating model	c(0.05, 0.60)	c(0.07, 0.29)	c(0.05, 0.10)
L50	Point estimate from LH group ± 5% error	c(56,76)	c(56,76)	c(174, 236)
L50_95	Length increment from 50% to 95% maturity	c(0, 18)	c(0, 18)	c(0, 61)
recgrad	Assuming no slope in recruitment deviations	c(0, 0)	c(0, 0)	c(0, 0)
Perr	Assuming low to moderate process error in recruitment	c(0.2, 0.4)	c(0.2, 0.4)	c(0.2, 0.4)
AC	Testing wide range of low to high autocorrelation	c(0.2, 0.8)	c(0.2, 0.8)	c(0.2, 0.8)
Size_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Frac_area_1	Assuming 10%; parameter not currently used	c(0.095, 0.105)	c(0.095, 0.105)	c(0.095, 0.105)
Prob_staying	Assuming 50%; parameter not currently used	c(0.45, 0.55)	c(0.45, 0.55)	c(0.45, 0.55)

Table 3.2.5 Fleet dynamics characterized in the base operating models for Puerto (PR) Rico hogfish and yellowtail snapper, St. Thomas (STT) queen triggerfish and spiny lobster, and St. Croix (STX) spiny lobster and stoplight parrotfish.

Fleet input	**Description/Source**	**Data Input Value or Range**					
Species-island	Island unit where species is assessed	PR hogfish	PR yellowtail snapper	STT queen triggerfish	STT spiny lobster	STX spiny lobster	STX stoplight parrotfish
Name	Name of model run	Base - Asymptotic selex	Base - Asymptotic selex	Base - High dome selex	Base - High dome selex	Base - High dome selex	Base - Asymptotic selex
Fleet							
nyears	Number of years of historical simulation	75	75	75	75	75	75
Spat_targ	Distribution of fishing in relation to vulnerable biomass (= 1, fishers indiscriminate in where they fish with respect to the stock; >1, fishers actively targeting areas of highest biomass)	c(1.2, 1.5)	c(1.2, 1.5)	c(1.2, 1.5)	c(1.2, 1.5)	c(1.2, 1.5)	c(1.2, 1.5)
LFS	Length at full selectivity, expressed as a fraction of L50	c(2.68, 3.62)	c(1.11, 1.25)	c(1.56, 2.11)	c(1.76, 2.38)	c(1.59, 2.15)	c(1.43, 1.94)
L5	Length at 5% selectivity, expressed as a fraction of L50	c(1.14, 1.54)	c(0.72, 0.98)	c(0.86, 1.17)	c(0.96, 1.31)	c(1.07, 1.45)	c(0.93, 1.26)
Fsd	Inter-annual variability in historical fishing mortality rate estimated from effort trends	c(0.1, 0.4)	c(0.1, 0.4)	c(0.1, 0.4)	c(0.1, 0.4)	c(0.1, 0.4)	c(0.1, 0.4)
Fgrad	Final historical slope (last five years) in historical fishing mortality rate	c(−1, 0)	c(−0.5, 0.5)	c(−1, 0)	c(−1, 0)	c(−1, 0)	c(−1, 0)
Trend	Estimated trend in F from effort data	decreasing	constant	decreasing	decreasing	decreasing	decreasing
qinc	Mean percentage change in fishing efficiency	c(−2.0, 2.0)	c(−2.0, 2.0)	c(−2.0, 2.0)	c(−2.0, 2.0)	c(−2.0, 2.0)	c(−2.0, 2.0)
qcv	Inter-annual variability in fishing efficiency	c(0.1, 0.3)	c(0.1, 0.3)	c(0.1, 0.3)	c(0.1, 0.3)	c(0.1, 0.3)	c(0.1, 0.3)
Vmaxlen	Vulnerability of oldest age class (controls extent of dome-shaped selectivity)	c(0.999, 1.0)	c(0.999, 1.0)	c(0.0, 0.5)	c(0, 0.5)	c(0, 0.5)	c(0.999, 1.0)
Type	Classification of selectivity	Asymptotic	Asymptotic	High dome	High dome	High dome	Asymptotic

Table 3.2.6 Alternative fleet dynamics characterized in the sensitivity operating models for St. Thomas (STT) queen triggerfish and spiny lobster, and St. Croix (STX) spiny lobster.

Fleet input	**Description/Source**	**Data Input Value or Range**		
Species-island	Island unit where species is assessed	STT queen triggerfish	STT spiny lobster	STX spiny lobster
Name	Name of model run	Base - High dome selex	Base - High dome selex	Base - High dome selex
Fleet				
nyears	Number of years of historical simulation	75	75	75
Spat_targ	Distribution of fishing in relation to vulnerable biomass (= 1, fishers indiscriminate in where they fish with respect to the stock; >1, fishers are actively targeting areas of highest biomass)	c(1.2, 1.5)	c(1.2, 1.5)	c(1.2, 1.5)
LFS	Length at full selectivity, expressed as a fraction of L50	c(1.56, 2.11)	c(1.76, 2.38)	c(1.59, 2.15)
L5	Length at 5% selectivity, expressed as a fraction of L50	c(0.86, 1.17)	c(0.96, 1.31)	c(1.07, 1.45)
Fsd	Inter-annual variability in historical fishing mortality rate estimated from effort trends	c(0.1, 0.4)	c(0.1, 0.4)	c(0.1, 0.4)
Fgrad	Final historical slope (last five years) in historical fishing mortality rate	c(−1, 0)	c(−1, 0)	c(−1, 0)
Trend	Estimated trend in F from effort data	decreasing	decreasing	decreasing
qinc	Mean percentage change in fishing efficiency	c(−2.0, 2.0)	c(−2.0, 2.0)	c(−2.0, 2.0)
qcv	Inter-annual variability in fishing efficiency	c(0.1, 0.3)	c(0.1, 0.3)	c(0.1, 0.3)
Vmaxlen	Vulnerability of oldest age class (controls extent of dome-shaped selectivity)	c(0.2, 0.5)	c(0.3, 0.6)	c(0.3, 0.6)
Type	Classification of selectivity	Moderate dome	Moderate dome	Moderate dome

Table 3.2.7 Observation subclass model parameters for all species-island units examined based on precise, unbiased inputs in the DLMtool.

Observation input	Name of the observation object	Value
LenMcv	Controls the range of biases for L50 (lognormal SD)	0.05
Cobs	Catch observation error (lognormal SD)	c(0.1, 0.2)
Cbiascv	Controls the range of biases for annual catch observations (lognormal SD)	0.05
CAA_nsamp	Total number of CAA observations per year	c(150, 300)
CAA_ESS	Effective sample size of annual CAA observations (independent draws of multinomial observation model)	c(50, 100)
CAL_nsamp	Total number of CAL observations per year	c(150, 300)
CAL_ESS	Effective sample size of annual CAL observations (independent draws of multinomial observation model)	c(50, 100)
CAL_cv	The lognormal variability in length at age (lognormal SD)	c(0.05, 0.1)
Iobs	Relative abundance index observation error (lognormal SD)	c(0.10, 0.25)
Mcv	Controls the range of biases sampled for M (lognormal SD)	0.05
Kcv	Controls the range of biases sampled for K	0.05
t0cv	Controls the range of biases sampled for t0	0.05
Linfcv	Controls the range of biases sampled for Linf	0.05
LFCcv	Controls the range of biases sampled for LFC	0.05
LFScv	Controls the range of biases sampled for LFS	0.05
B0cv	Controls the range of biases sampled for B0	0.5
FMSYcv	Controls the range of biases sampled for FMSY	0.1
FMSY_Mcv	Controls the range of biases sampled for FMSY_M	0.25
BMSY_B0cv	Controls the range of biases sampled for BMSY_B0	0.1
rcv	Controls the range of biases sampled for intrinsic rate of increase (surplus production parameter r)	0.2
Dbiascv	Controls the range of biases sampled for Dep (biomass relative to unfished)	0.2
Dcv	Observation error in Dep (lognormal SD)	c(0.1, 0.5)
Btbias	Bounds on bias in observations of current absolute stock size (uniform on log)	c(0.333, 3.0)
Btcv	Observation error in current absolute stock size (lognormal SD)	c(0.1, 0.5)
Fcurbiascv	Controls the range of biases sampled for current F	0.2
Fcurcv	Observation error in current F (lognormal SD)	c(0.1, 0.5)
hcv	Observation error in h	0.1
Icv	Observation error in relative abundance index	0.1
maxagecv	Observation error in maxage	0.1
Reccv	Observation error for slope in recent recruitment (absolute recruitment over last 10 years, age 1 individuals)	c(0.05, 0.1)
Irefcv	Observation error for target (reference) relative abundance index (IMSY)	0.1
Crefcv	Observation error for target (reference) catch (MSY)	0.1
Brefcv	Observation error for target (reference) biomass level (BMSY)	0.1
beta	Bounds on hyperstability / hyper depletion parameter that controls relationship between relative abundance index and biomass (*index(t) = vulnerable biomass(t)*^{beta}) (uniform on log)	c(0.666, 1.50)

Table 3.2.8 Observation subclass model parameters for all species-island units examined based on imprecise, biased inputs in the DLMtool.

Observation input	Name of the observation object	Value
LenMcv	Controls the range of biases for L50 (lognormal SD)	0.2
Cobs	Catch observation error (lognormal SD)	c(0.2, 0.6)
Cbiascv	Controls the range of biases for annual catch observations (lognormal SD)	0.3
CAA_nsamp	Total number of CAA observations per year	c(50, 100)
CAA_ESS	Effective sample size of annual CAA observations (independent draws of multinomial observation model)	c(10, 20)
CAL_nsamp	Total number of CAL observations per year	c(50, 100)
CAL_ESS	Effective sample size of annual CAL observations (independent draws of multinomial observation model)	c(10, 20)
CAL_cv	The lognormal variability in length at age (lognormal SD)	c(0.1, 0.15)
Iobs	Relative abundance index observation error (lognormal SD)	c(0.2, 0.6)
Mcv	Controls the range of biases sampled for M (lognormal SD)	0.4
Kcv	Controls the range of biases sampled for K	0.1
t0cv	Controls the range of biases sampled for t0	0.1
Linfcv	Controls the range of biases sampled for Linf	0.1
LFCcv	Controls the range of biases sampled for LFC	0.1
LFScv	Controls the range of biases sampled for LFS	0.1
B0cv	Controls the range of biases sampled for B0	4.0
FMSYcv	Controls the range of biases sampled for FMSY	0.2
FMSY_Mcv	Controls the range of biases sampled for FMSY_M	0.5
BMSY_B0cv	Controls the range of biases sampled for BMSY_B0	0.2
rcv	Controls the range of biases sampled for intrinsic rate of increase (surplus production parameter *r*)	0.5
Dbiascv	Controls the range of biases sampled for Dep (biomass relative to unfished)	0.75
Dcv	Observation error in Dep (lognormal SD)	c(0.5, 1.0)
Btbias	Bounds on bias in observations of current absolute stock size (uniform on log)	c(0.2, 5.0)
Btcv	Observation error in current absolute stock size (lognormal SD)	c(0.5, 1.0)
Fcurbiascv	Controls the range of biases sampled for current F	0.75
Fcurcv	Observation error in current F (lognormal SD)	c(0.5, 1.0)
hcv	Observation error in h	0.3
Icv	Observation error in relative abundance index	0.4
maxagecv	Observation error in maxage	0.2
Reccv	Observation error for slope in recent recruitment (absolute recruitment over last 10 years, age 1 individuals)	c(0.1, 0.3)
Irefcv	Observation error for target (reference) relative abundance index (IMSY)	0.3
Crefcv	Observation error for target (reference) catch (MSY)	0.3
Brefcv	Observation error for target (reference) biomass level (BMSY)	0.5
beta	Bounds on hyperstability / hyper depletion parameter that controls relationship between relative abundance index and biomass ($index(t) = vulnerable\ biomass(t)^{beta}$) (uniform on log)	c(0.333, 3.00)

3.2.3 Application of MSEs using the DLMtool to six stocks evaluated under SEDAR 46

Within the MSE for each species-island unit, populations were simulated for 75 years with random selections made for each parameter of the stock and fleet subclass of the OM. This historical time period was assumed of sufficient length to reasonably characterize the historical exploitation pattern for US Caribbean fisheries. Within the simulated population, bias and imprecision of all parameters (e.g., M) were generated for each variable and parameter from the observation subclass of the OM as defined by each MP applied. For each of the six SEDAR 46 species-island unit simulation exercises, 500 simulations were conducted with 250 replicates. Projections of each simulation were run for 40 years. Within the MSE, every three years the MP was implemented to obtain a new TAC. This TAC was then assumed equivalent to the overfishing limit (OFL) and applied for the next three years. This allowed updating of new information in a frequency similar to a typical assessment schedule. Model stability was assessed by examining convergence criteria (level = 1%) of performance metrics for each MP.

Between-simulations variability in many of the biological parameters (M, Linf, K, etc.) was accounted for by allowing the parameters to change over a specified range. For each simulation, values for each stock subclass and fleet subclass parameter were randomly drawn from a uniform distribution. Autocorrelation in recruitment was considered for all species-island units. Several biological parameters were not allowed to vary among simulations for any species and included t0, L50, a, b, maxage, and the magnitude of unfished recruitment (R0) (i.e., a single point estimate was used). R0 serves as a scalar, with value not usually important in the MSE (Carruthers 2015a).

The trend in effort from the most representative fishery (over the most recent 5 years) was assumed to be representative of the total effort on the stock from all sources of fishing for each species-island unit. Both the mean trend and inter-annual variability in effort were allowed to vary across simulations. The same inter-annual variation in fishing effort was simulated for each species-island unit stock with a coefficient of variation (CV) ranging from 0.2 and 0.4. Some species-specific fishery characteristics were also specified, including vulnerability-at-age (i.e., selectivity) and spatial targeting (e.g., fishing where abundance is highest). While fishing effort, targeting and fishing efficiency could change temporally, all other fishery characteristics (e.g., number of fishing areas =1) were assumed to remain constant over time.

3.2.4 Performance metrics

Management objectives are provided in the Caribbean Fishery Management Council’s (CFMC) Fishery Management Plan for shallow-water reef fish (CFMC 1985; CFMC 1993). At present, no management objectives are listed within the Fishery Management Plan for spiny lobster (CFMC 1981; CFMC 1990). Three performance metrics were selected by the SEDAR 46 DW/AW Panel at the 2 − 6 November Workshop. The three performance criteria considered: the probability of not overfishing, the probability of the biomass remaining above half of BMSY, and the average annual variability in yield.

Probability of not overfishing ≥ 50% (Pr[PNOF] ≥ 50%)

The probability of overfishing is recorded for each simulation by calculating the fraction of projected years in which fishing mortality rate (F) > fishing mortality rate at maximum sustainable yield (FMSY). This was averaged over the multiple simulations to create a probability of overfishing (POF) metric that is the expected probability of overfishing in a projected year for each MP. The probability of ‘*not overfishing*’ (PNOF) was then calculated as 1.0 – probability of overfishing. The SEDAR 46 DW/AW Panel agreed upon *Pr*(PNOF ≥ 50%) ≥ 50% in concordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), National Standard 1 (NS1) Guidelines. Both the CFMC and Scientific and Statistical Committee (SSC) indicated consensus with the SEDAR 46 DW/AW Panel selection of *Pr*(NOFL ≥ 50%) as a performance metric at their respective meetings in December 2015 (CFMC and SSC recordings available from CFMC).

Probability of the biomass remaining above half BMSY (Pr[B50] ≥ 50%)

The probability of the biomass dropping below 50% biomass at maximum sustainable yield (BMSY) over the entire projection is recorded for each simulation by calculating the fraction of projection years in which biomass (B) < BMSY. The future stock biomass relative to BMSY was averaged over projected years and simulations to provide the expectation of stock status for each MP. The probability of being above 50% BMSY (B50) was then calculated as 1.0 – probability of being below 50% BMSY. The SEDAR 46 DW/AW Panel agreed upon *Pr*(B50 ≥ 50%) ≥ 50% to adhere to the MSFMCA, NS1. Both the CFMC and SSC were in agreement at their respective meetings in December 2015 (CFMC and SSC recordings available from CFMC).

Average annual variability in yield to remain within 15% (Pr[AAVY 15%] ≥ 50%)

The average annual variability in yield (AAVY) is the mean difference in the yield of adjacent projected years (starting from the last historical year) divided by the mean yield over the same time period.

$$\mathrm{AAVY} = \frac{\left(\mathrm{n_p} + 1\right)\sum_{\mathrm{y=n_h}}^{\mathrm{n_h+n_p-1}} \left|\mathrm{C_{y+1}} - \mathrm{C_y}\right|}{\mathrm{n_p}\bar{\mathrm{C}}_y}$$

Where:
n_p = number of projected year
n_h = number of historical years,
C_y = true simulated catch in year y, and
$\bar{C}_y$ = mean yield of adjacent projected years.

The SEDAR 46 DW/AW Panel selected a threshold of 15% allowable variation on annual yield, which translated to a *Pr*[AAVY < 15%] ≥ 50%. Both the CFMC and SSC were in agreement on the 15% threshold in variability of annual yield at their respective meetings in December 2015 (CFMC and SSC recordings available from CFMC). This performance metric identifies the MPs that achieve maintaining the year to year variability in yield to <- 15% and achieving this variability threshold at least 50% of the projection period (n=40 years).

3.2.5 Calculation of total allowable catch (TAC) as a real world application for SEDAR 46

Catch recommendations (i.e., TACs) were made for each species-island unit using the management procedures (MPs) that met all the performance criteria specified at the SEDAR 46 DW/AW Workshop. At the SEDAR 46 DW/AW workshop, the Panel selected the top six MPs, which met all performance criteria and also exhibited the six highest relative long-term yields in the MSE, for the calculation of catches (i.e.., TACs). These six MPs were applied in a real world scenario using the data inputs provided in Appendix 4.3.1 − 4.3.6. Within the DLMtool, 200 random draws from parameter distributions defined by the input mean and CV provided a stochastic sample of the plausible TACs for each management procedure. The spread of the distribution can help provide insight into the potential uncertainty within the calculated TAC, with wider TAC distributions suggesting greater uncertainty. TAC distributions have been characterized by either mean (e.g., constant catch) or median TAC values (e.g., DCAC) (Carruthers et al. 2014).

For the purpose of the TAC calculations, estimates of several key parameters were necessary. These included current stock abundance (Abun), depletion (Dep), the ratio of FMSY to Mort (FMSY_M), and steepness (steep). For the SEDAR 46 evaluations these were estimated as follows: Abun was estimated using the simplistic assumption Abundance = Catch / F, where F was derived from FMSY_M x Mort. Further, it was assumed that an FMSY_M of 0.75 was a reasonable approximate for each species-island unit. As discussed in Section 3.2.2.1, depletion was estimated using the ML2D function in DLMtool, with the mode of the distribution used as the point estimate for the real world data input. It is important to note that estimates of both depletion and abundance may be highly uncertain. A meta-analysis was conducted to determine the most appropriate estimates of steepness for each species-island unit (Table 3.2.9).

The coefficients of variation (CV) for catch (Cat) and average catch (AvC) were set using the mean and SD of the catch from the entire landings time series. Relatively large CVs (0.5) were assigned for data inputs including Dep, Dt, Abun, FMSY_M, and BMSY_M0 to highlight the uncertainty within these parameters.

Additonally, examinations of the length frequency observations were necessary to identify aberrant observations. Catch-at-length data were analyzed for outliers and observations were excluded from analysis if: (1) a length measurement was greater than 1 SD above the Linf provided by the LHWG or (2) la ength measurement was lesser than 3 SD from the mean length identified from the TIP data.

Sensitivity in TAC calculations due to uncertainty in real world parameter inputs was examined through two processes for each species-island unit: (1) a sensitivity analysis within the DLMtool application; and (2) sensitivity runs which varied parameter inputs in the DLMtool data input file: Dep, Abun, CV_Cat, Mort, vbLinf, and vbK.

Table 3.2.9 Estimates and background information supporting the parametrization of steepness for the five species assessed.

SEDAR 46 Species	**Species**	**Value**	**Region**	**Source**
Hogfish	Hogfish	0.748 (prior) **0.830** (estimate)	Florida Keys / Eastern Florida	Cooper et al. (2014)
	Hogfish	0.748 (prior) 0.847 (estimate)	West Florida Shelf	
	Hogfish	0.748 (prior) 0.909 (estimate)	South Atlantic	
Hogfish	Hogfish	none	Caribbean	SEDAR (2003)
Yellowtail snapper	Yellowtail snapper	**0.79**	Puerto Rico	SEDAR (2005b)
	Yellowtail snapper	0.75 (initial) 0.697 (estimated)	Southeastern US	O'Hop et al. (2012)
	Yellowtail snapper	0.8 (initial) 0.7 - 0.9 (range)	South Atlantic, Gulf of Mexico	Muller et al. (2003)
Queen triggerfish	Reef fish meta-analysis	**0.84**	Gulf of Mexico	Shertzer and Conn (2012)
	Queen triggerfish	none	Caribbean	SEDAR (2013)
	Gray triggerfish (*Balistes capriscus*)	0.80 (prior) 0.65 (estimated) 0.67-0.95 (range)	Gulf of Mexico	SEDAR (2006)
	Gray triggerfish (*Balistes capriscus*)	0.459 (estimated)	Gulf of Mexico	SEDAR (2015)
Spiny lobster	Australian rock lobster (*Panulirus ornatus*)	**0.5** (initial), 0.27 (estimated)	Australia	Plaganyi et al. (2010)
	Spiny lobster	none	Southeastern US	SEDAR (2005a)
	Spiny lobster	0.97	Southeastern US	SEDAR (2010)
	California spiny lobster (*Panulirus interruptus*)	0.15 - 0.5	Pacific	Neilson (2011)
Stoplight parrotfish	Reef fish meta-analysis	**0.84**	Gulf of Mexico	Shertzer and Conn (2012)
	Redtail parrotfish	none	Caribbean	SEDAR (2011)

3.3 MSE results (by species-island units)

Results of the MSEs for each of the six species-island units were examined for model stability, consistency of MSE results across varying assumptions of stock and fleet characterizations in the OM, sensitivity of MSE results to OM parameterizations, and performance of the candidate management procedures (herein referred to as MPs) based on performance measures identified in Section 3.2.4. The results are presented by species-island unit for each of these individual components below. Of 37 MPs that were considered feasible for each species-island unit, a total of 23 produced results which met the performance criteria for at least one species-island unit.

3.3.1 Puerto Rico hogfish

3.3.1.1 Model stability

Model stability was evaluated graphically and through inspection of the convergence values for each of the three performance metrics across simulations for all MPs. All of the feasible MPs within the MSE converged at the 1% criteria level. Convergence plots for standard performance metrics, as selected by the SEDAR 46 DW/AP, in the MSE are shown in Figure 3.3.1.1 for the base OM (15%LH, Asymptotic selex). The majority of MPs appear to have converged by approximately 200 simulations for each performance metric. For the convergence plots below, convergence can be visualy seen occurring for a given MP when the observed change in the performance metric gradually falls within 1% across simulations.

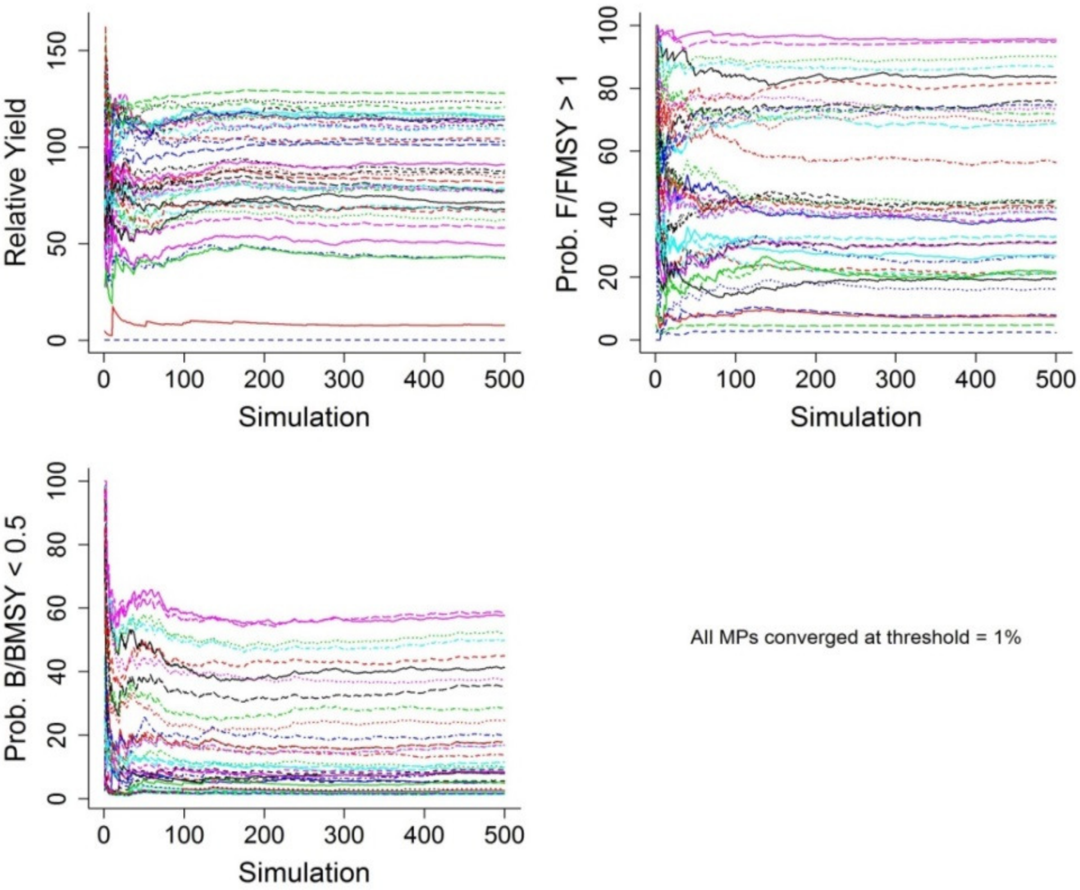


Figure 3.3.1.1 Convergence of performance metrics for each feasible MP within the management strategy evaluation for Puerto Rico hogfish using the base operating model (15%LH, Asymptotic selex). Colored lines each reflect an MP.

3.3.1.2 Operating model evaluation

The consistency of MSE results across varying assumptions on stock dynamics in the OM was examined with respect to life history (stock) characterizations as described in Section 3.2.2.1. For Puerto Rico hogfish, the 15%LH, Asymptotic selex OM was chosen as the base OM. An alternative stock OM was constructed assuming 5% LH and Asymptotic selex. Tables 3.2.3 − 3.2.5 provided specifics on the base stock and fleet dynamics and the alternative characterizations that were considered.

Performance between MPs within the MSEs was further examined by investigating tradeoff plots among OMs. Figures 3.3.1.2 − 3.3.1.3 present the tradeoff plots for the base OM (15%LH, Asymptotic selex) and for the alternative OM (5%LH, Asymptotic selex). Metrics shown in the tradeoff plots are the Panel-selected performance metrics as defined in Section 3.2.4. MPs located within the top-right corner in each panel are preferred according to the AW Panel performance criteria. MPs yielding the highest *Pr*(NOF ≥ 50%), *Pr*(B50 ≥ 50%), and *Pr*([AAVY 15%] ≥ 50%) were similar between the base and sensitivity OMs. Specific details on definitions of performance metrics were previously provided in Section 3.2.4.

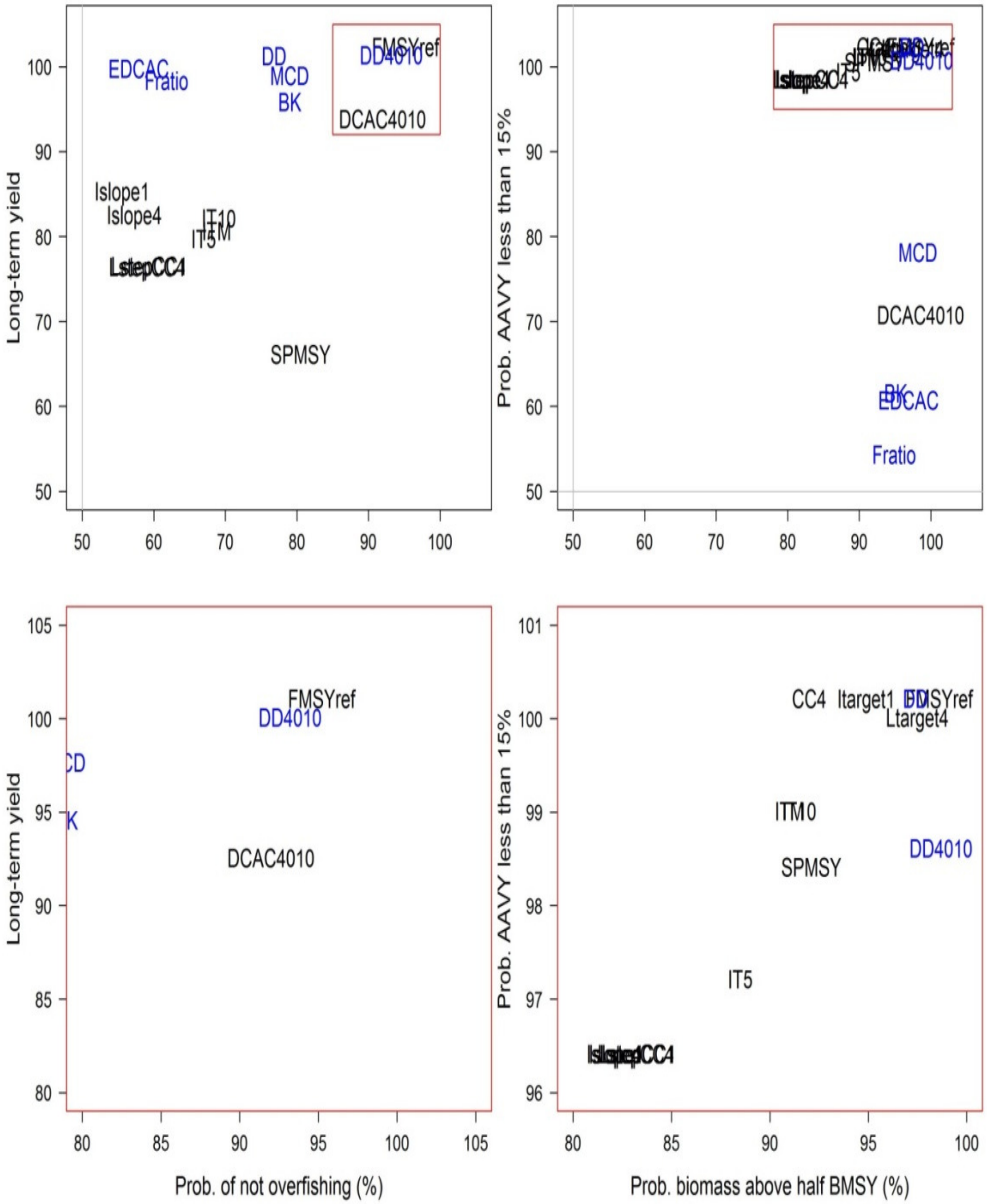


Figure 3.3.1.2 Tradeoffs in performance metrics between management procedures for the Puerto Rico hogfish base operating model (15%LH, Asymptotic Selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot in the upper panel. MPs are as defined in Table 3.1.

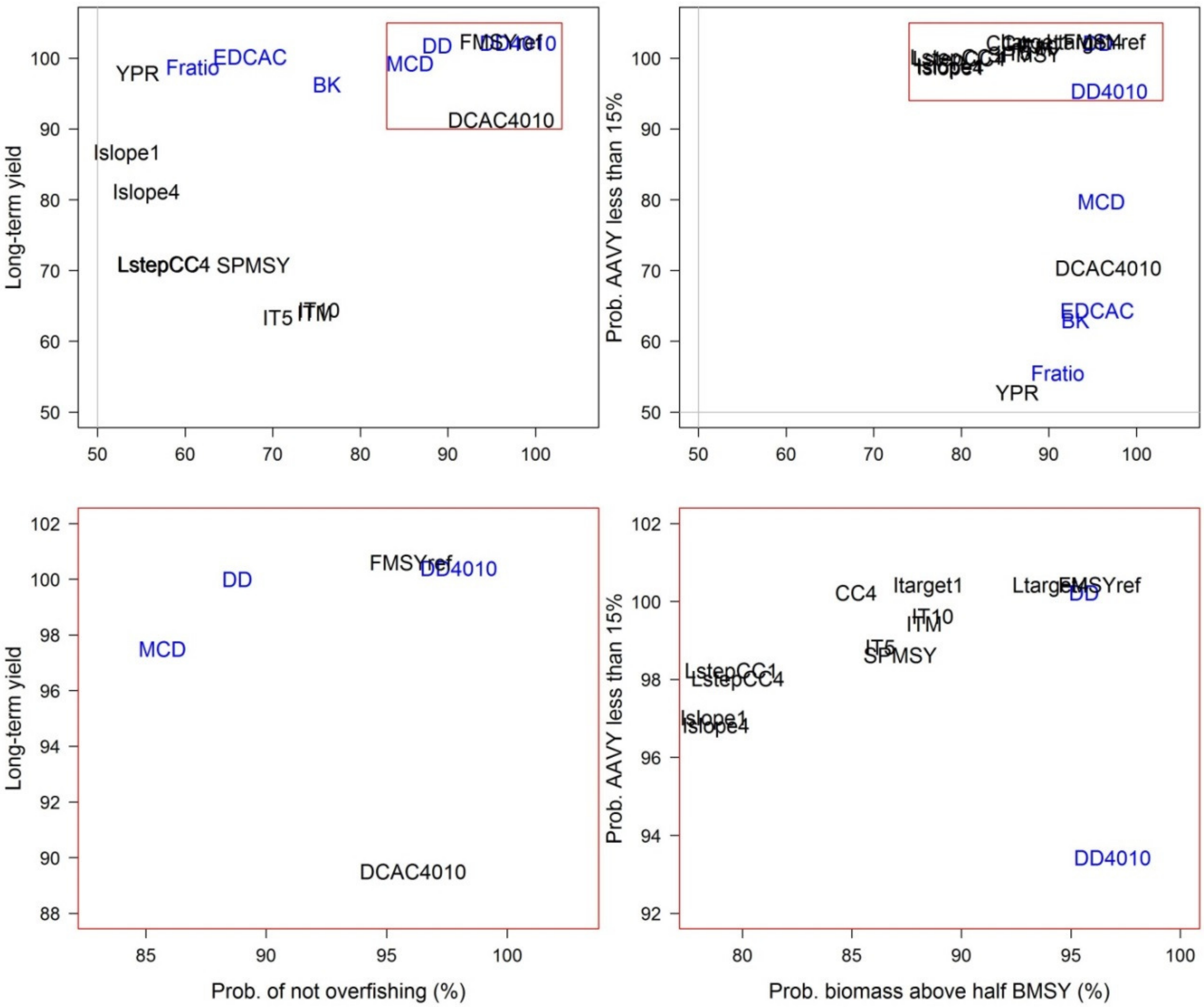


Figure 3.3.1.3 Tradeoffs in performance metrics between management procedures for the Puerto Rico hogfish alternative operating model (5%LH, Asymptotic Selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot in the upper panel. MPs are as defined in Table 3.1.

Additional information to aid in understanding the contribution of information in each OM is provided in Figures 3.3.1.4 − 3.3.1.5 for the base operating model. These figures are a graphical visualization of the 'value of information (VOI)' in the OM, a metric which identifies relevant parameters in the operating and observation models that are most correlated with utility. For the operating model parameters (Figure 3.3.1.4), most MPs indicated FMSY, FMSY_M, or LFS as the highest correlated parameters with long-term yield relative to MSY. For the observation model parameters (Figure 3.3.1.5), parameters displaying the highest correlations with long-term yield relative to MSY were more divergent across MPs. These parameters included Kbias for DD and DD4010, BMSY_B0bias for EDCAC, Dbias for MCD, and Abias for Fratio and BK. These results may be used to inform data collection, by identifying which inputs are more important in assessing OM behavior.

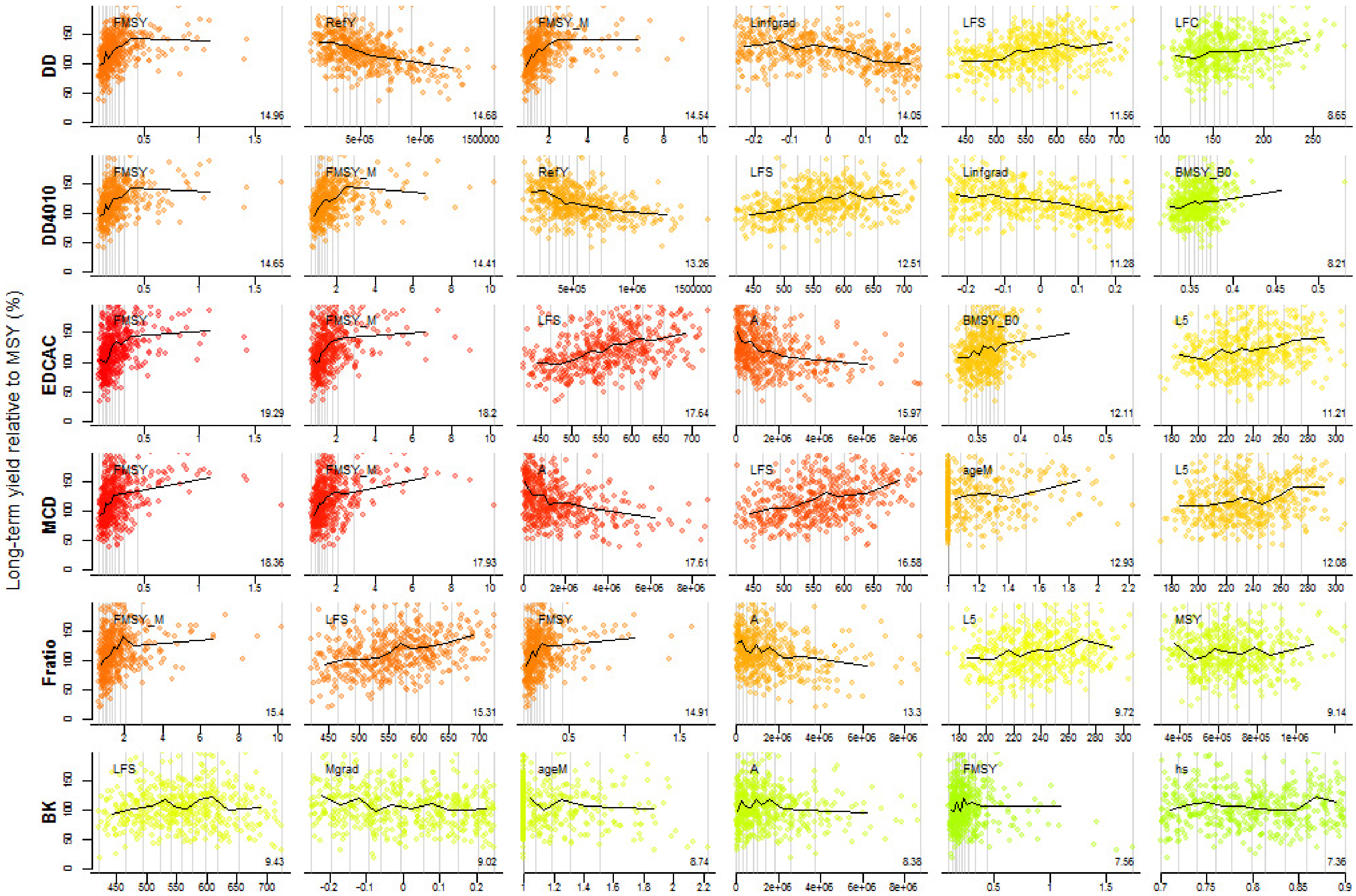


Figure 3.3.1.4 Value of information (VOI) that detects relevant operating model parameters that are most correlated with utility for the Puerto Rico hogfish base operating model (15%LH, Asymptotic selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). Parameters and MPs are as defined in Table 3.1.

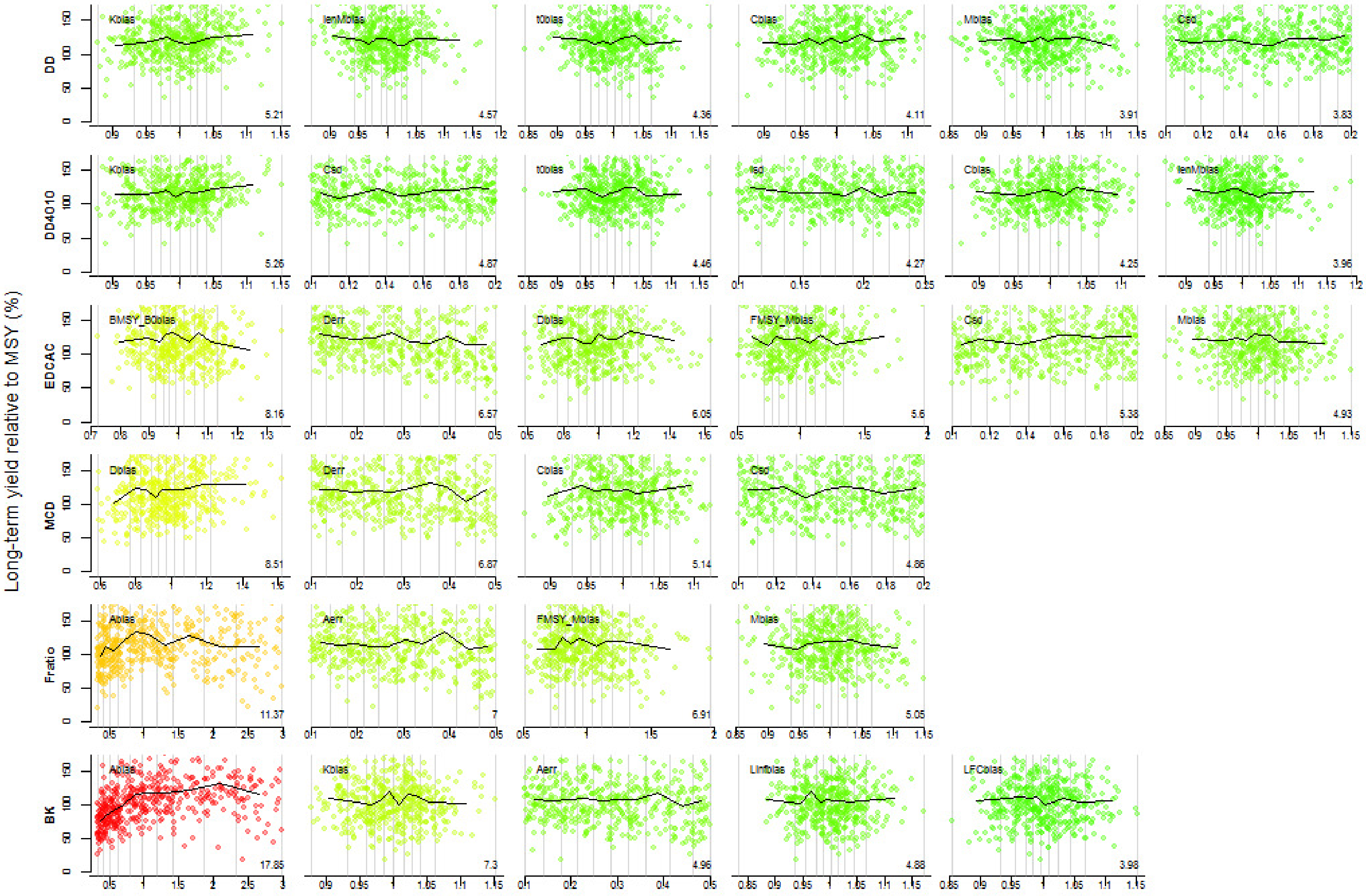


Figure 3.3.1.5 Value of information (VOI) that detects relevant observation model parameters that are most correlated with utility for the Puerto Rico hogfish base operating model (15%LH, Asymptotic selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). Parameters and MPs are as defined in Table 3.1.

3.3.1.3 Performance of management procedures

MP performance results against the three MSE performance criteria (PNOF, B50, AAVY) selected by the SEDAR 46 DW/AW Panel as well as relative long-term yield (LTY) are provided in Table 3.3.1.1 for the Puerto Rico hogfish base (15%LH, Asymptotic selex) and alternative (5%LH, Asymptotic selex) OMs.

Table 3.3.1.1 Performance of management procedures within the MSE for the Puerto Rico hogfish base (15%LH, Asymptotic selex) and alternative operating model (5% LH, Asymptotic selex) as determined using the performance metrics specified by the SEDAR 46 DW/AW Panel. PNOF = probability of not overfishing (%), B50 = probability of the biomass being above half BMSY (%), LTY = relative long-term yield, defined as the fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection, and AAVY = fraction of simulations where average annual variability in yield < 15%. MPs are as defined in Table 3.1.

	Base Stock					Alt Stock			
	15% LH, Asymptotic selex					5% LH, Asymptotic selex			
MP	PNOF	B50	LTY	AAVY	MP	PNOF	B50	LTY	AAVY
Reference MP									
FMSYref	95.2	98.6	100	100	FMSYref	96	96.3	100	100
MPs producing 6 highest long-term yields that meet management criteria									
DD4010	93.2	98.7	99	98.4	DD4010	98	96.9	99.8	93
DD	76.8	97.4	98.9	100	DD	88.8	95.6	99.4	99.8
EDCAC	57.9	96.9	97.4	58.4	EDCAC	67.4	95.5	97.8	62
MCD	79	98.2	96.6	75.8	MCD	85.7	96	96.9	77.4
Fratio	61.8	94.9	96	52	Fratio	60.9	91	96.4	53.2
BK	79	95.1	93.5	59.2	YPR	54.6	86.4	95.5	50.4
Other MPs that meet management criteria									
DCAC4010	92	98.6	91.5	68.4	BK	76.2	93	93.9	60.6
Islope1	55.6	82.2	83	96.2	DCAC4010	96.1	96.8	88.9	68
Islope4	57.3	82.1	80.2	96.2	Islope1	53.4	78.7	84.4	96.6
IT10	69.1	91.5	79.8	98.8	Islope4	55.6	78.8	78.8	96.4
ITM	68.8	91	78.3	98.8	LstepCC4	57.6	79.8	68.6	97.6
IT5	67	88.5	77.4	97	LstepCC1	57.7	79.5	68.5	97.8
LstepCC1	59.4	83.3	74.2	96.2	SPMSY	67.8	87.2	68.4	98.2
LstepCC4	59.1	83.2	74.1	96.2	IT10	75.3	88.7	62.1	99.2
SPMSY	80.5	92.1	63.8	98.2	ITM	74.8	88.3	61.6	99
CC4	73.9	92	30.4	100	IT5	70.6	86.3	61	98.4
Itarget1	78.4	94.9	26.3	100	Itarget1	69	88.5	31.3	100
Ltarget4	92.6	97.5	2.4	99.8	CC4	67.3	85.2	23.8	99.8
					Ltarget4	88.4	94.1	2.5	100

Sensitivity of the data quality in the observation subclass (i.e., imprecise and biased data inputs) resulted in very different trends in model performance in the MSE. The top 6 methods tend to be index-based methods, with substantially lower relative long-term yields compared to when data inputs were assumed precise and unbiased (Table 3.3.1.2). Those MPs identified as optimal when assuming precise and unbiased data inputs no longer fall within the top 6 according to selection criteria.

Table 3.3.1.2 Comparison of the top six management procedures between the Puerto Rico hogfish base operating model assuming precise and unbiased data inputs and an alternative operating model assuming imprecise and biased data inputs. Numbers in parentheses represent the relative long-term yield from the management strategy evaluation.

Imprecise-Biased*	Precise-Unbiased
Islope1 (71.2)	DD4010 (99.0)
Islope4 (65.0)	DD (98.9)
LstepCC4 (61.8)	EDCAC (97.4)
LstepCC1 (59.8)	MCD (96.6)
SPMSY (59.8)	Fratio (96.0)
IT5 (57.2)	BK (93.5)

*Note that DD and DD4010 did not fit

3.3.1.4 Calculation of TACs using real world data

Figure 3.3.1.6 provides resulting total allowable catch (TAC) calculations from the MPs that produced the 6 highest relative yields in the MSE and met the performance criteria as specified by the SEDAR 46 DW/AW Panel. In the SEDAR46 evaluations, the TAC calculations are considered equivalent to the overfishing limit (OFL). However, it should be noted that adoption of one or more of these TACs as a harvest control rule may not necessarily achieve maximum sustainable yield in equilibrium (which is difficult to estimate in data-limited situations). Instead the TAC represents a level of yield consistent with the selected management objectives and performance criteria recommended by the DW/AW Panel and is heavily dependent upon the reliability of data inputs. Summary statistics on calculated TACs from the real world data (provided in Appendix 4.3.1) are provided in Table 3.3.1.3 for all of the feasible MPs meeting the performance criteria specified by the SEDAR 46 DW/AW Panel.

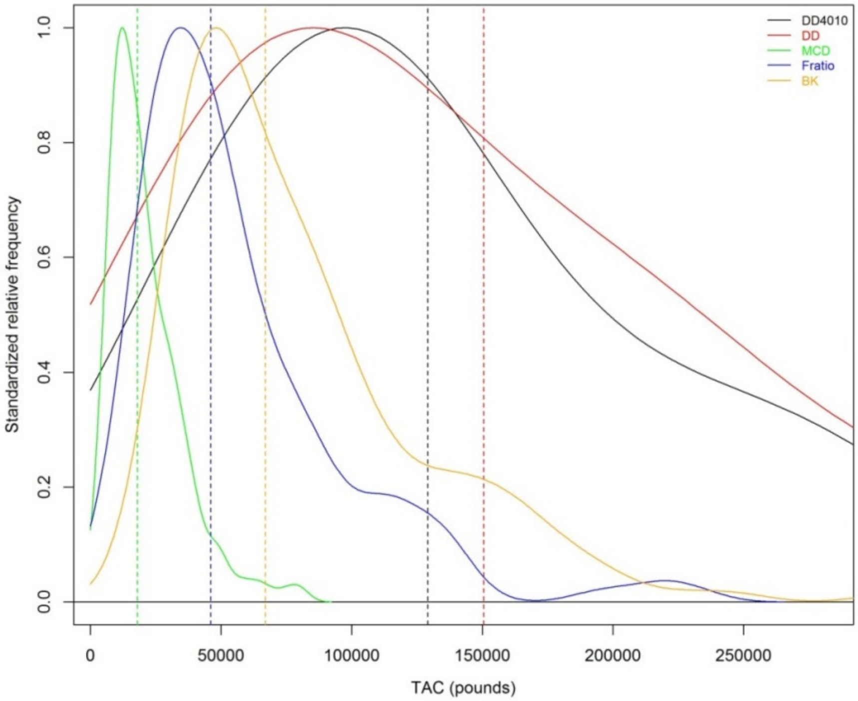


Figure 3.3.1.6 Total allowable catch (TAC) calculations (pounds) for Puerto Rico hogfish obtained from the management procedures that met the SEDAR 46 DW/AW Panel performance criteria and also produced the six highest relative long-term yields in the management strategy evaluation. Note that only 5 of the top six are applicable based on current data availability and/or management procedure configuration. MPs are as defined in Table 3.1.

Table 3.3.1.3 Summary of total allowable catch (TAC) calculations (pounds x 1000s) provided by management procedures that met the SEDAR 46 DW/AW Panel performance criteria for Puerto Rico hogfish. MPs are as defined in Table 3.1.

	Summary statistics				
MP	Minimum	25th Percentile	Median	75th Percentile	Maximum
MPs producing 6 highest long-term yields that meet management criteria					
DD4010	3.637	68.551	123.44	282.43	2948.048
DD	11.387	84.777	173.4	385.546	2333.902
Fratio	6.936	28	44.959	68.063	245.645
MCD	1.652	11.404	17.283	24.213	63.112
BK	17.76	51.302	75.67	105.42	250.913
Other MPs that meet management criteria					
Islope1	33.629	43.635	49.368	54.459	77.728
Islope4	23.369	33.215	37.415	41.354	53.197
SPMSY	1.88	17.922	34.898	48.329	74.192
CC4	27.654	37.053	41.262	45.919	66.965
Itarget1	30.163	37.885	41.765	47.914	59.958

The effect of varying real world parameter inputs on the recommended TACs for each MP was evaluated using a sensitivity analysis available within DLMtool. Figure 3.3.1.7 provides sensitivity results for three of the six MPs which produced the highest relative long-term yields in the MSE. Results are not shown for DD or DD4010 because the sensitivity analysis did not converge. Sensitivities in parameter estimates were evident, with higher TACs obtained for the following MPs: in MCD as Cat and Dep increased; in Fratio as Mort, FMSY_M, and Abun increased; and in BK as Abun, vbK and LFC increased or as vbLinf decreased.

In addition, real world parameter inputs were varied for several key parameters to assess the sensitivity of TAC calculations to data inputs including CV_Cat, Abun, Dep, Mort, vbLinf, and vbK. Figures 3.3.1.8 − 3.3.1.9 provide results for the MPs requiring each data input. Calculated TACs from most MPs were relatively similar when CV_Cat was doubled, with the exception of DD and DD4010. In contrast, changes to both Abun and Dep and life history parameters (Mort, vbLinf, vbK) had a substantial impact on TACs where these inputs were required. Tables 3.3.1.4 − 3.3.1.6 provide the calculated TACs for all sensitivity runs.

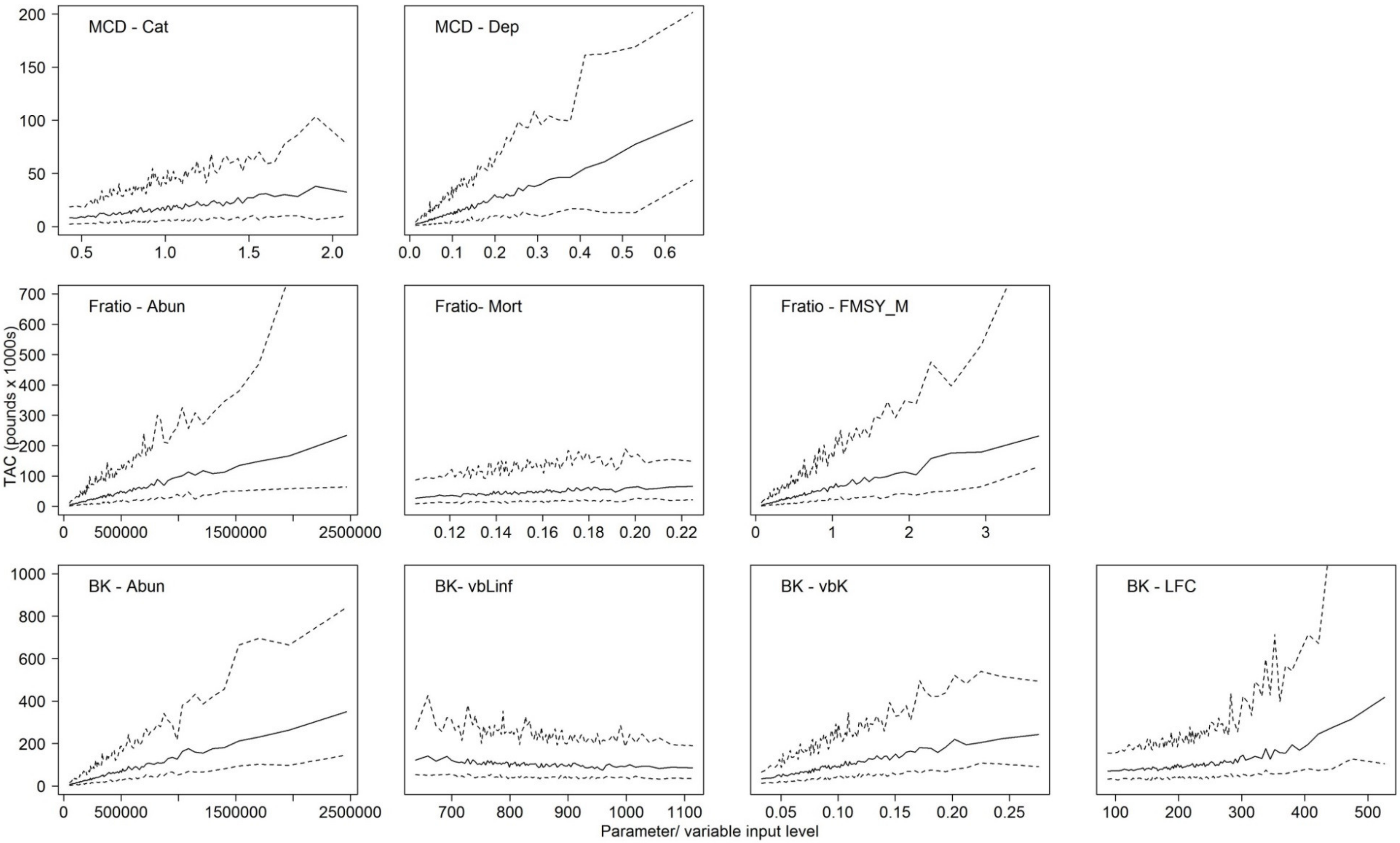


Figure 3.3.1.7 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) for the applicable highest yielding management procedures to varying input parameters for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1. Dashed lines reflect 5% and 95% confidence intervals.

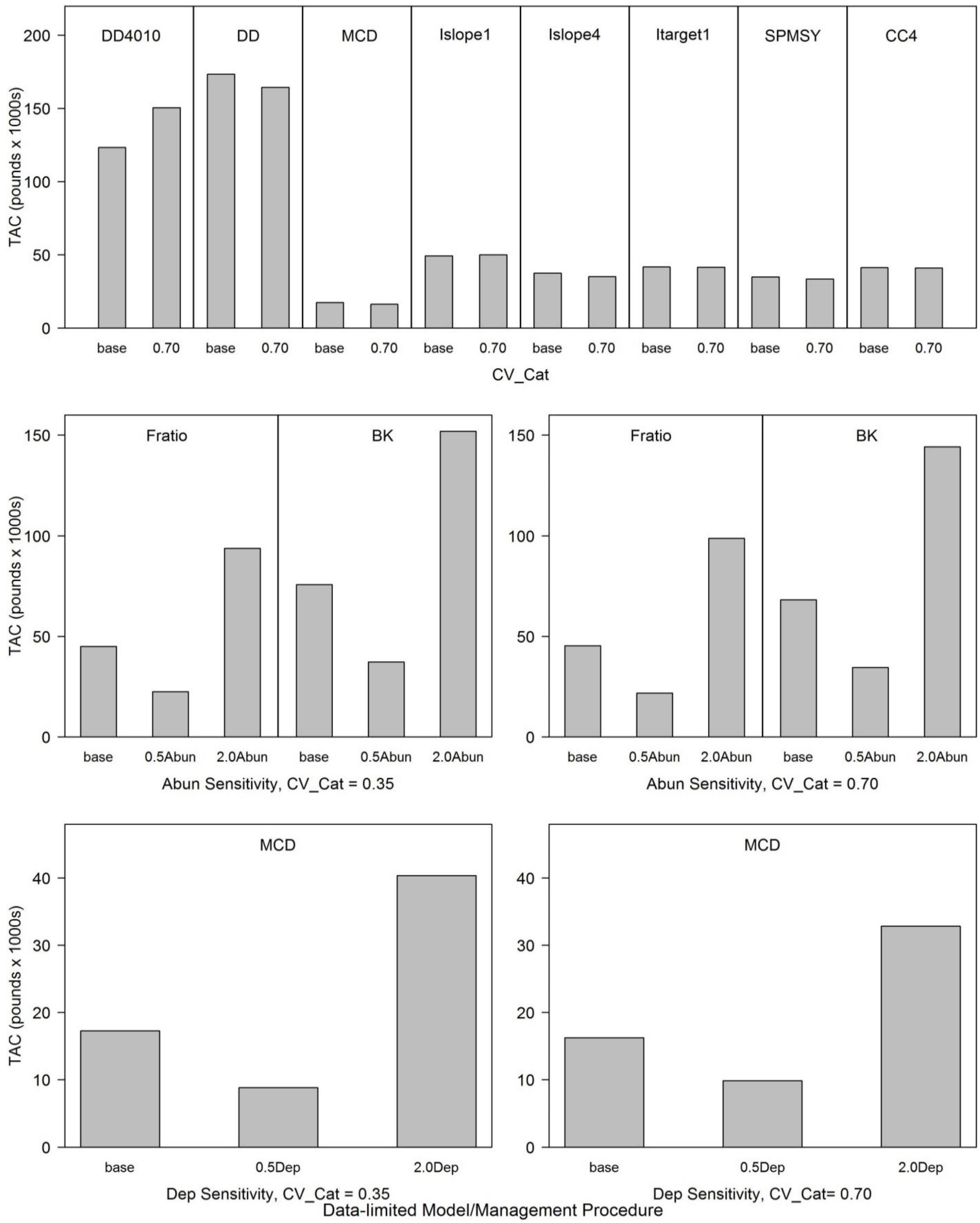


Figure 3.3.1.8 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including CV_Cat, Abun, and Dep for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1.

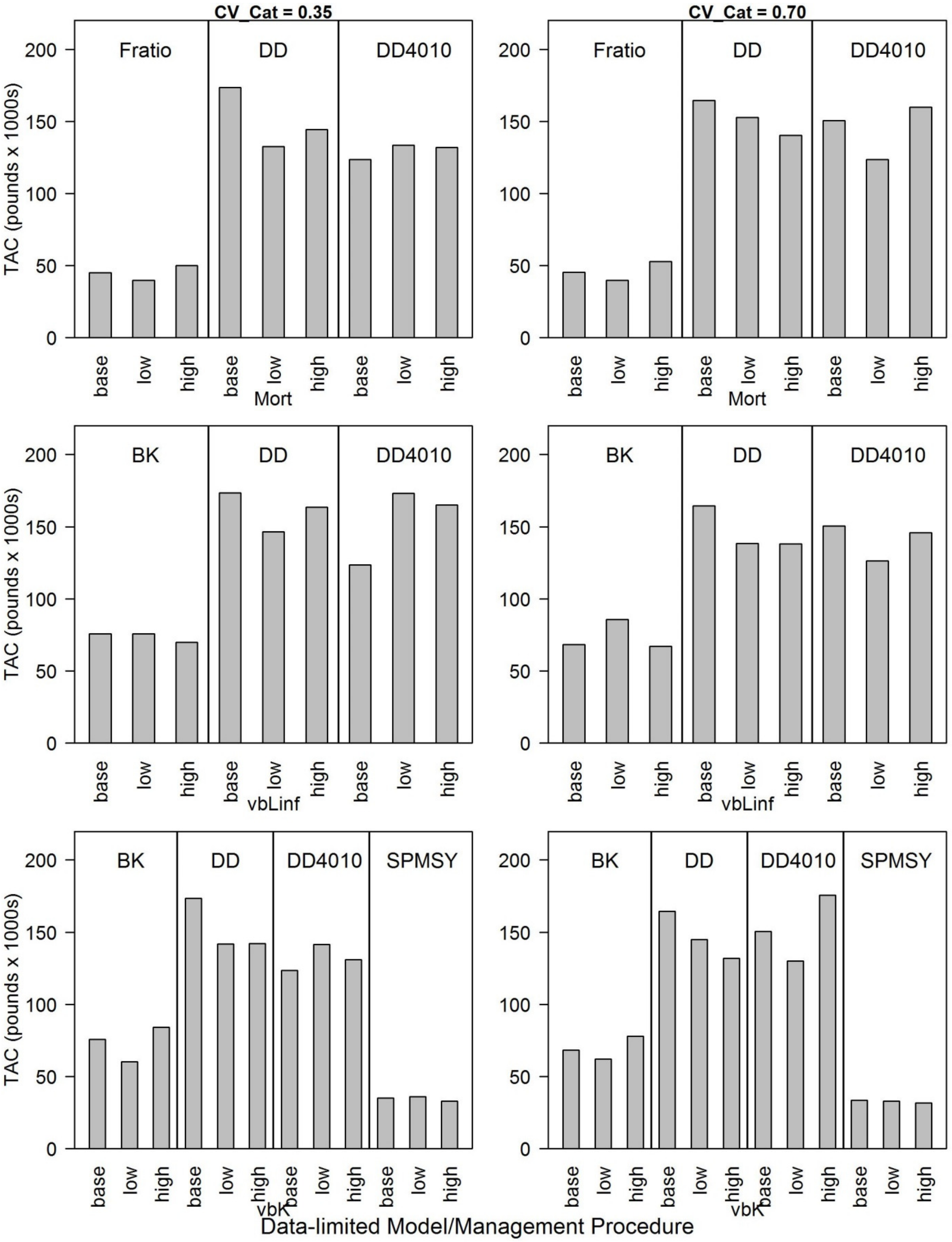


Figure 3.3.1.9 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including Mort, vbLinf, and vbK for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1.

Table 3.3.1.4 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the coefficient of variation for catch (CV_Cat) for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1.

MP	TAC (pounds x 1000s) 0.35 (CV_Cat, base)	 0.70 (2.0 x CV_Cat)
DD4010	123.438	150.623
DD	173.403	164.369
MCD	17.283	16.257
Islope1	49.368	49.896
Islope4	37.415	35.151
Itarget1	41.765	41.513
SPMSY	34.898	33.416
CC4	41.262	41.022

Table 3.3.1.5 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to current abundance and depletion values for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1.

MP	Abundance (Abun)	Depletion (Dep)	TAC (pounds x 1000s) 0.35 (CV_Cat, base)	 0.70 (2.0 x CV_Cat)
Abundance				
Fratio	501235 (Abun, base)	–	44.959	45.356
	250618 (0.5 x Abun)	–	22.534	21.891
	1002470 (2.0 x Abun)	–	93.806	98.812
BK	501235 (Abun, base)	–	75.670	68.237
	250618 (0.5 x Abun)	–	37.297	34.466
	1002470 (2.0 x Abun)	–	151.865	144.204
Depletion				
MCD	–	0.135 (Dep, base)	17.283	16.257
	–	0.0675 (0.5 x Dep)	8.825	9.851
	–	0.27 (2.0 x Dep)	40.356	32.828

Table 3.3.1.6 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to natural mortality (Mort), asymptotic length (vbLinf) and growth rate (vbK) values for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1.

MP	Input	TAC (pounds x 1000s) 0.35 (CV_Cat, base)	 0.70 (2.0 x CV_Cat)
Mort			
Fratio	0.1558 (base)	44.959	45.356
	0.132 (low)	39.685	39.817
	0.179 (high)	49.819	52.687
DD	0.1558 (base)	173.403	164.369
	0.132 (low)	132.498	152.706
	0.179 (high)	144.449	140.403
DD4010	0.1558 (base)	123.438	150.623
	0.132 (low)	133.572	123.501
	0.179 (high)	131.751	159.776
vbLinf			
BK	849 (base)	75.670	68.237
	722 (low)	75.589	85.787
	976 (high)	69.843	66.991
DD	849 (base)	173.403	164.369
	722 (low)	146.324	138.339
	976 (high)	163.521	138.173
DD4010	849 (base)	123.438	150.623
	722 (low)	173.020	126.321
	976 (high)	164.935	145.713
vbK			
BK	0.1058 (base)	75.670	68.237
	0.090 (low)	60.177	62.131
	0.122 (high)	84.029	77.991
DD	0.1058 (base)	173.403	164.369
	0.090 (low)	141.647	144.932
	0.122 (high)	142.234	131.917
DD4010	0.1058 (base)	123.438	150.623
	0.090 (low)	141.509	130.050
	0.122 (high)	131.074	175.585
SPMSY	0.1058 (base)	34.898	33.416
	0.090 (low)	35.841	33.005
	0.122 (high)	32.875	31.665

Table 3.3.1.7 provides a brief summarization of MSE results and inherent assumptions for each applicable method and can help guide which MP to select for TAC calculation. For Puerto Rico hogfish, areas of concern include:

- **Life history input (Mort, L50, vbt0, vbK, vbLinf, wla, wlb, MaxAge):** parameters from South Atlantic assumed representative of US Caribbean trends
- **Catch input (Cat):** underreporting of catch
- **Index input (Ind):** appropriateness of: (1) adjusted effort (Eff1) as an indicator of fishing effort; and (2) of the trend in relative abundance derived from the diving fishery
- **Depletion input (Dep):** method for estimating depletion provides *very uncertain* estimates of current stock biomass and (equilibrium) fishing mortality rate from growth, natural mortality rate, recruitment and fishing selectivity. In addition, the mean length from the diving fishery is considered an appropriate and reliable indicator of trend in resource.
- **Abundance input (Abun):** rough estimate of current abundance based on recent catch and fishing mortality history
- **Fishery input (LFC):** appropriateness of TIP data for the diving fishery in quantifying the length at first capture

In general, MPs cannot realize the full complexity of the biology (e.g., time- and age-varying natural mortality, hermaphroditism) or fishery characteristics (e.g., change in fishing operations, regulations).

Table 3.3.1.7 Guidance table of inherent assumptions within management procedures for calculating the total allowable catch for Puerto Rico hogfish. MPs and data inputs are as defined in Table 3.1. Performance metrics are as defined in Table 3.3.1.1.

Parameter	**Abun-based**		**Dep-based**	**Data-moderate**		**Index-based**			**Catch-based**	
	Fratio	**BK**	**MCD**	**DD**	**DD4010**	**Islope1**	**Islope4**	**Itarget1**	**SPMSY**	**CC4**
PNOF	61.8	79.0	79.0	76.8	93.2	55.6	57.3	78.4	80.5	73.9
B50	94.9	95.1	98.2	97.4	98.7	82.2	82.1	94.9	92.1	92.0
LTY	96.0	93.5	96.6	98.9	99.0	83.0	80.2	26.3	63.8	30.4
AAVY	52.0	59.2	75.8	100.0	98.4	96.2	96.2	100.0	98.2	100.0
Mort	Known, constant across age			Known, constant across age						
L50				Uncertainty from protogyny					Uncertainty from protogyny	
vbt0				Growth characterizations reflective of PR					Life history characterizations reflective of PR	
vbK		Life history characterizations reflective of PR								
vbLinf										
wla										
wlb										
MaxAge				Age characterizations reflective of PR					Age characterizations reflective of PR	
Cat			Known, informative of historical removals							
LFC		TIP sampling representative of selectivity								
FMSY_M	Known									
Ind				Fishery dependent representative of population abundance, dependent upon accurate effort reporting						
Dep			Known, estimated from TIP samples and life history							
Abun	Known, estimated from current catch and F									

3.3.2 Puerto Rico yellowtail snapper

3.3.2.1 Model stability

Model stability was evaluated graphically and through inspection of the convergence values for each performance metric across simulations for all MPs. All of the feasible MPs within the MSE converged at the 1% criteria level. Convergence plots for standard performance metrics in the MSE are shown in Figure 3.3.2.1 for the base OM (15%LH, Asymptotic selex). The majority of MPs appear to have converged by approximately 300 simulations for each performance metric.

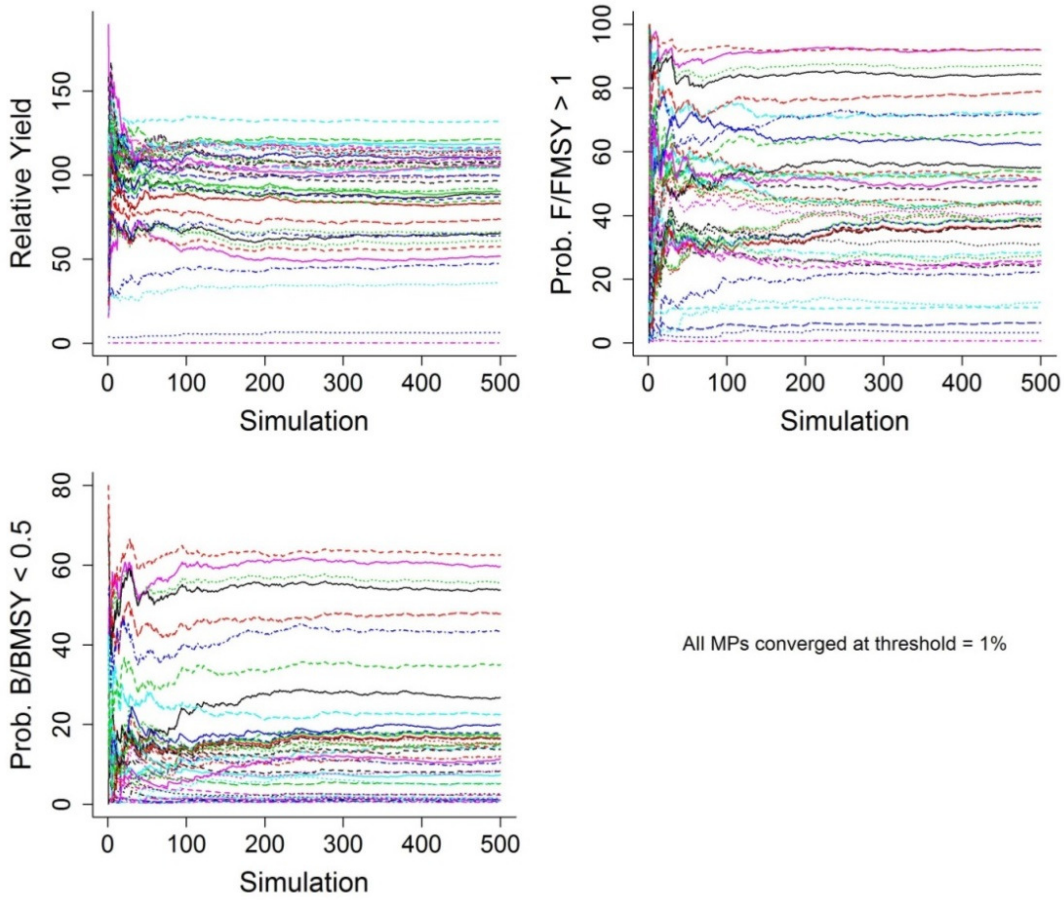


Figure 3.3.2.1 Convergence of performance metrics for each feasible MP within the management strategy evaluation for Puerto Rico yellowtail snapper using the base operating model (15%LH, Asymptotic selex). Colored lines each reflect an MP.

3.3.2.2 Operating model evaluation

The consistency of MSE results across varying assumptions on stock dynamics in the OM was examined with respect to life history (stock) characterizations as described in Section 3.2.2.1. For Puerto Rico yellowtail snapper, the 15%LH, Asymptotic selex OM was chosen as the base OM. An alternative stock OM was constructed assuming 5% LH and Asymptotic selex. Tables 3.2.3 – 3.2.5 provided specifics on stock and fleet dynamics and the alternative characterizations that were considered.

Performance between MPs within the MSEs was further examined by investigating tradeoff plots among OMs. Figures 3.3.2.2 − 3.3.2.3 present the tradeoff plots for the base OM (15%LH, Asymptotic selex) and for the alternative OM (5%LH, Asymptotic selex) respectively. Metrics shown in the tradeoff plots are the Panel-selected performance metrics as defined in Section 3.2.4. MPs located within the top-right corner in each panel are preferred according to the AW Panel performance criteria. MPs yielding the highest *Pr*(NOF ≥ 50%), *Pr*(B50 ≥ 50%), and *Pr*([AAVY 15%] ≥ 50%) were similar between the base and sensitivity OMs. Specific details on definitions of performance metrics were previously provided in Section 3.2.4.

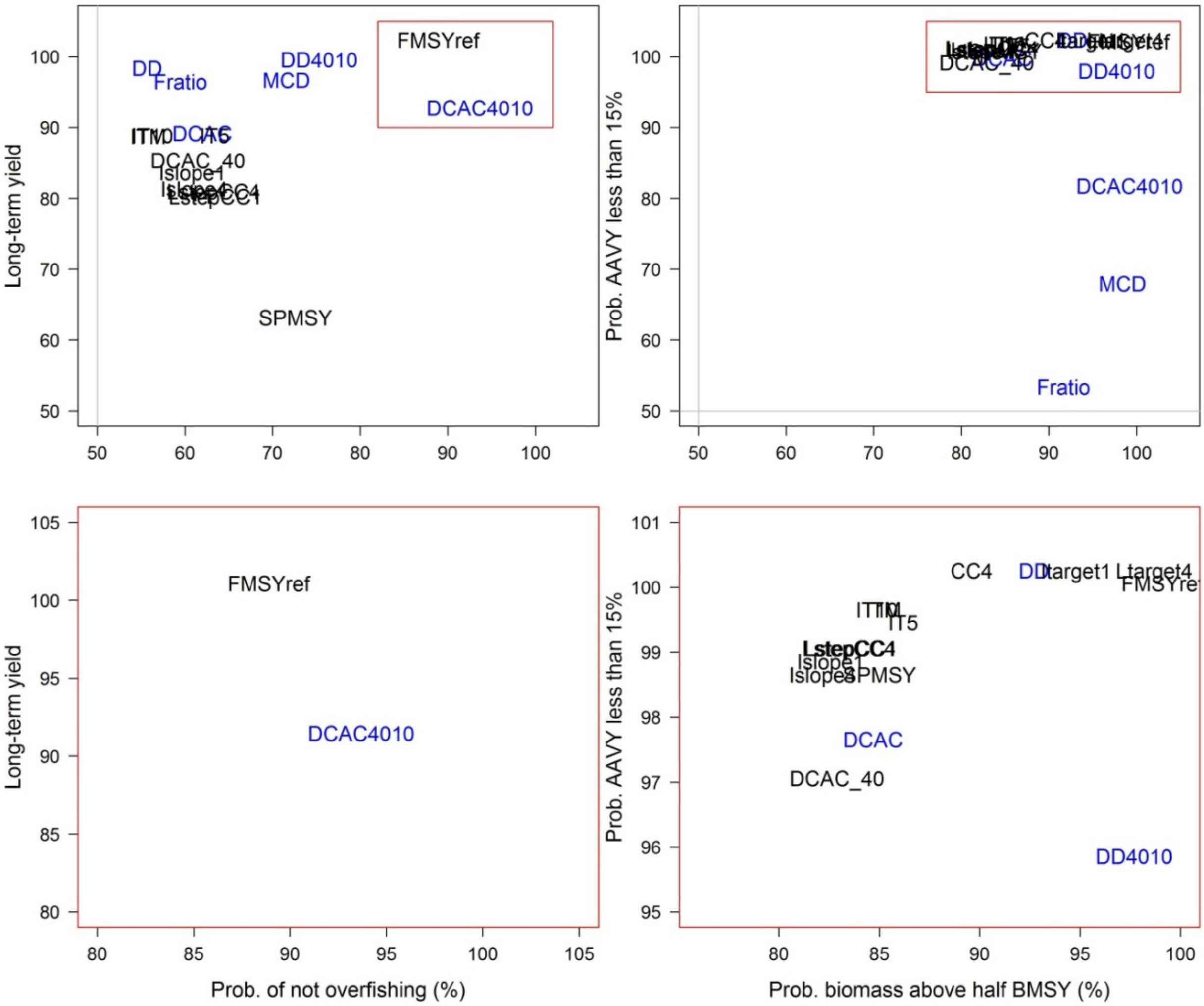


Figure 3.3.2.2 Tradeoffs in performance metrics between management procedures for the Puerto Rico yellowtail snapper base operating model (15%LH, Asymptotic Selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot presented in the top panel. MPs are as defined in Table 3.1.

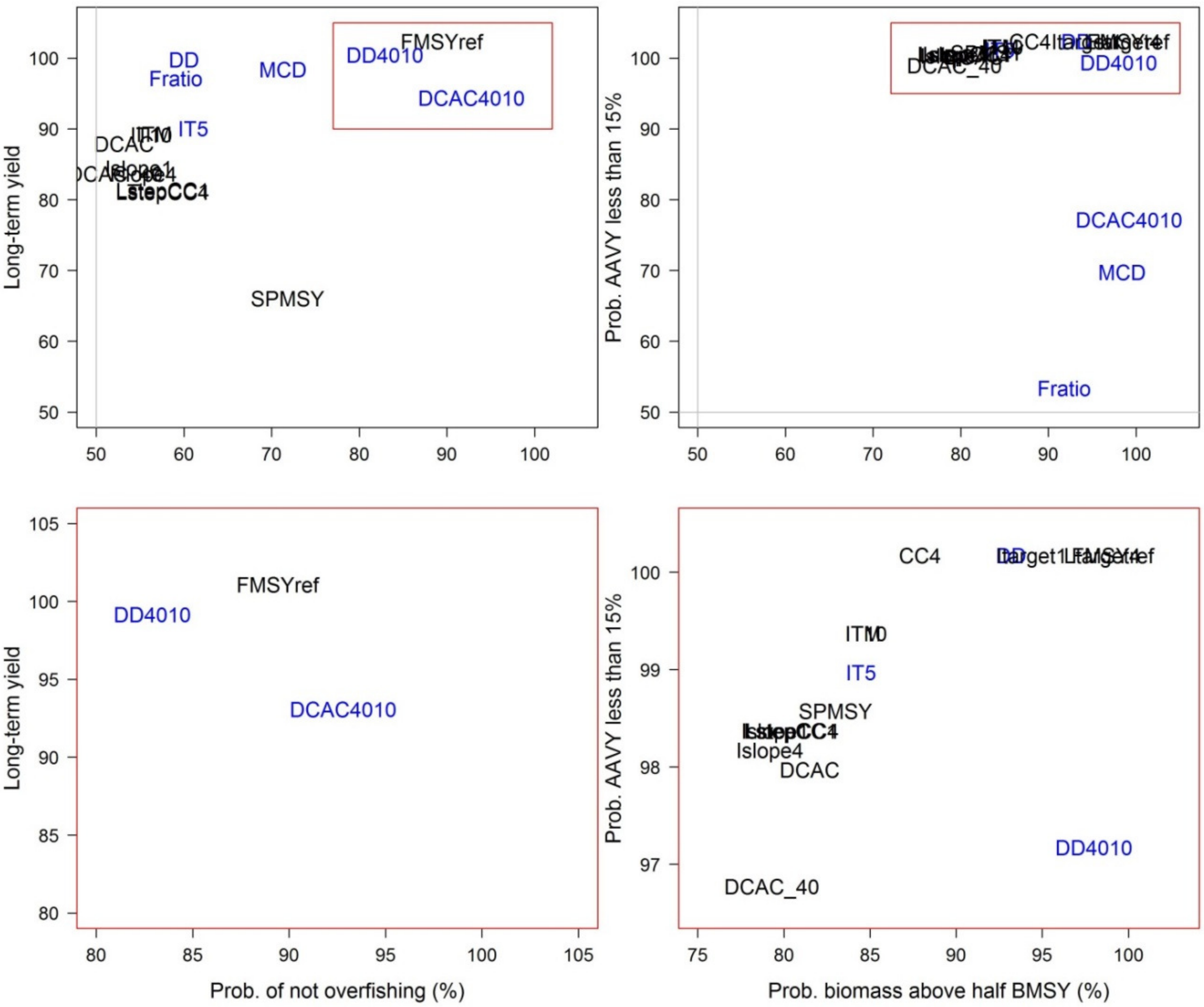


Figure 3.3.2.3 Tradeoffs in performance metrics between management procedures for the Puerto Rico yellowtail snapper alternative operating model (5%LH, Asymptotic Selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot in the top panel. MPs are as defined in Table 3.1.

Additional information to aid in understanding the contribution of information included in each OM is shown in Figures 3.3.2.4 − 3.3.2.5. These figures are a graphical visualization of the value of information in the OM, a metric which identifies relevant parameters in the operating and observation models that are most correlated with utility. For the operating model parameters (Figure 3.3.2.4), the highest correlations occurred between long-term yield relative to MSY and estimates of FMSY, FMSY_M, and ageM for all MPs, with the exception of MCD, which exhibited the highest correlation with absolute abundance (A). For the observation model parameters (Figure 3.3.2.5), parameters displaying the highest correlations with long-term yield relative to MSY were more divergent across MPs. These parameters included Csd for DD and DD4010, Dbias for MCD and DCAC4010, Abias for Fratio, and BMSY_B0bias for DCAC. These results may be used to inform data collection, by identifying which inputs are more important in assessing OM behavior.

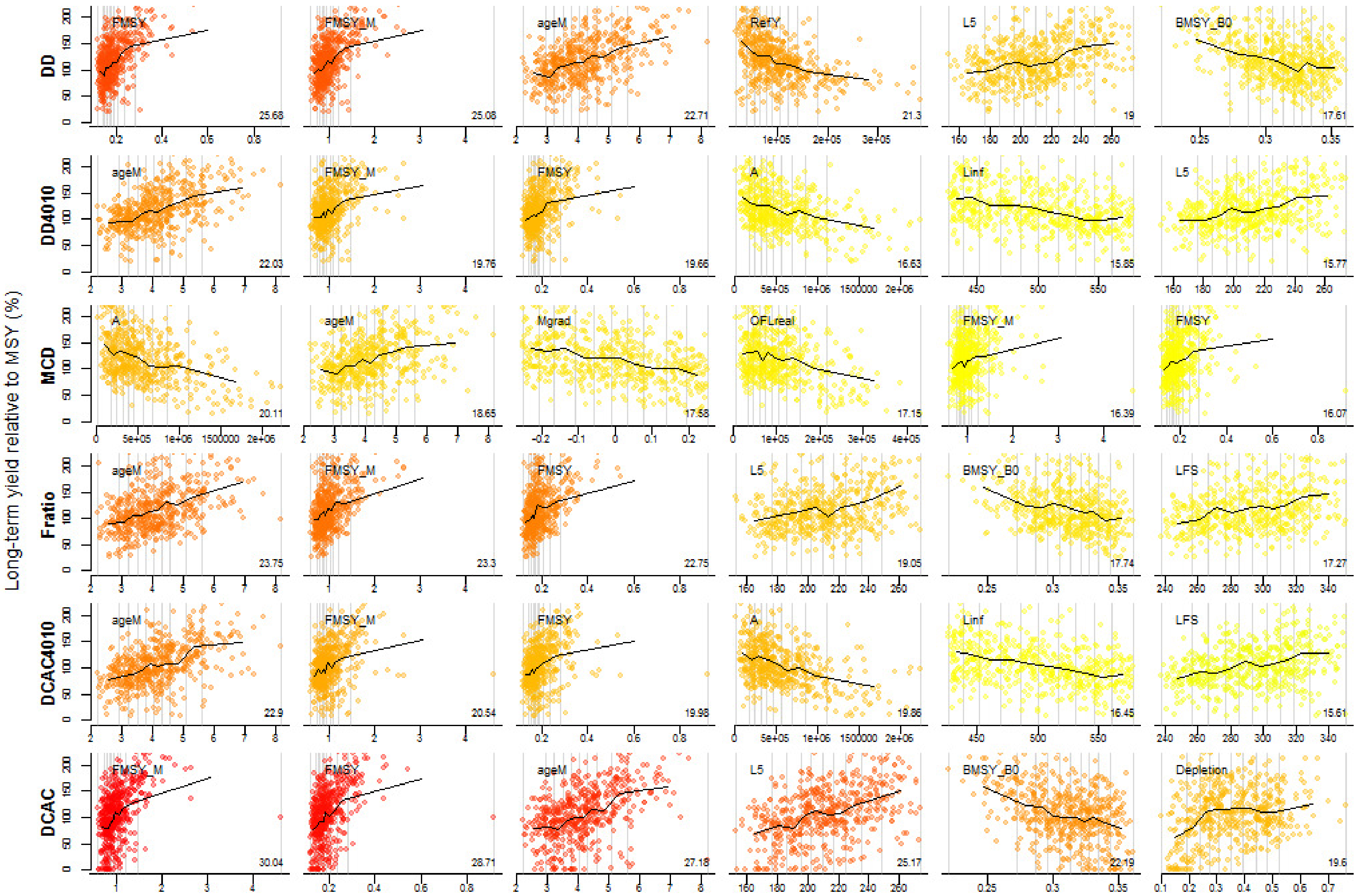


Figure 3.3.2.4 Value of information (VOI) metric that detects relevant operating model parameters that are most correlated with utility for the Puerto Rico yellowtail snapper base operating model (15%LH, Asymptotic selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and operating model parameters are as defined in Table 3.1.

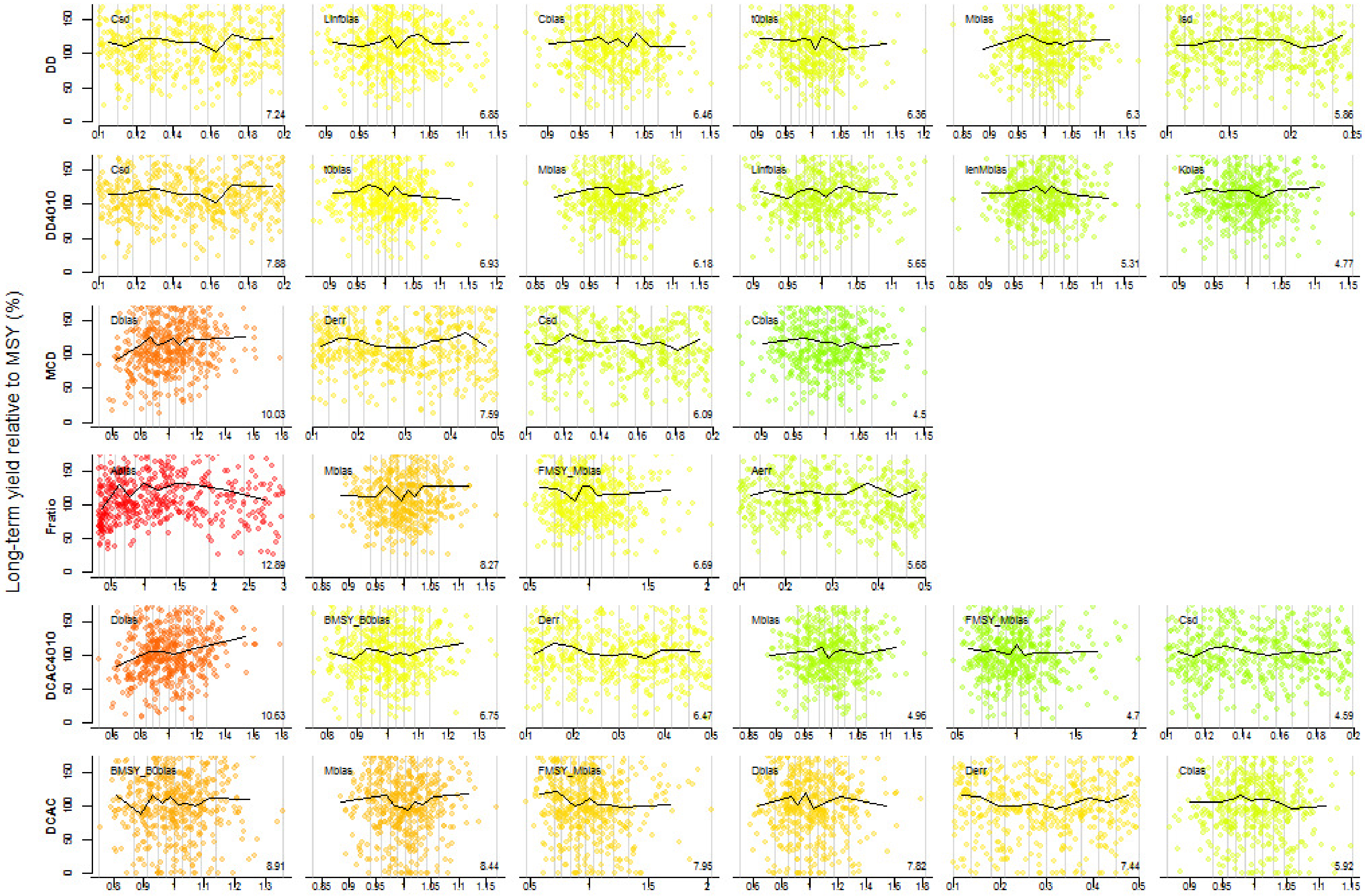


Figure 3.3.2.5 Value of information that detects relevant observation model parameters that are most correlated with utility for the Puerto Rico yellowtail snapper base operating model (15%LH, Asymptotic selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and observation model parameters are as defined in Table 3.1.

3.3.2.3 Performance of management procedures

MP performance results against the three MSE performance criteria (PNOF, B50, AAVY) selected by the SEDAR 46 DW/AW Panel as well as relative long-term yield (LTY) are provided in Table 3.3.2.1 for the Puerto Rico yellowtail snapper base (15%LH, Asymptotic selex) and alternative (5%LH, Asymptotic selex) OMs.

Table 3.3.2.1 Performance of management procedures within the MSE for the Puerto Rico yellowtail snapper base (15%LH, Asymptotic selex) and alternative operating model (5% LH, Asymptotic selex) as determined using the performance metrics specified by the SEDAR 46 DW/AW Panel. PNOF = probability of not overfishing (%), B50 = probability of the biomass being above half BMSY (%), LTY = relative long-term yield, defined as the fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection, and AAVY = fraction of simulations where average annual variability in yield < 15%. MPs are as defined in Table 3.1.

	Base Stock 15%LH, Asymptotic selex					Alt Stock 5%LH, Asymptotic selex			
MP	PNOF	B50	LTY	AAVY	MP	PNOF	B50	LTY	AAVY
Reference MP									
FMSYref	88.9	99.1	100	99.8	FMSYref	89.4	99.1	100	100
MPs producing 6 highest long-term yields that meet performance criteria									
DD4010	75.3	97.7	97.2	95.6	DD4010	82.9	98	98.1	97
DD	55.7	92.7	96	100	DD	60	93.2	97.4	100
MCD	71.6	98.4	94.3	65.6	MCD	71.3	98.4	96	67.4
Fratio	59.5	91.7	94.1	51	Fratio	59.1	91.8	94.8	51
DCAC4010	93.7	99.2	90.4	79.4	DCAC4010	92.8	99.2	92	74.8
DCAC	62	84.7	86.8	97.4	IT5	61.1	84.5	87.7	98.8
Other MPs producing lower long-term yields that met performance criteria									
IT5	63.4	86.2	86.5	99.2	ITM	56.6	84.6	86.9	99.2
IT10	56.3	84.9	86.5	99.4	IT10	56.3	84.8	86.8	99.2
ITM	55.8	85.2	86.4	99.4	DCAC	53.2	81.5	85.5	97.8
DCAC_40	61.5	82.9	83	96.8	Islope1	54.9	79.5	82.1	98.2
Islope1	60.9	82.6	81.3	98.6	DCAC_40	52.2	79.3	81.3	96.6
Islope4	61.1	82.2	79	98.4	Islope4	55.4	79.2	81.3	98
LstepCC4	63.3	83.5	78.6	98.8	LstepCC1	57.6	80.4	79	98.2
LstepCC1	63.5	83.6	77.9	98.8	LstepCC4	57.6	80.5	78.7	98.2
SPMSY	72.6	85	60.8	98.4	SPMSY	71.8	83	63.7	98.4
CC4	77.6	89.6	32.2	100	CC4	74.8	87.9	36.5	100
Itarget1	87.3	94.8	22.2	100	Itarget1	85.3	94.4	24.8	100
Ltarget4	96.7	98.7	1.2	100	Ltarget4	96.2	98.5	0.7	100

Sensitivity of the data quality in the observation subclass (i.e., imprecise and biased data inputs) resulted in very different trends in model performance in the MSE. The top 6 methods tend to be index-based methods, with substantially lower relative long-term yields compared to when data inputs were assumed precise and unbiased (Table 3.3.2.2). Those MPs identified as optimal when assuming precise and unbiased data inputs no longer fall within the top 6 according to selection criteria.

Table 3.3.2.2 Comparison of the top 6 management procedures between the Puerto Rico yellowtail snapper base operating model assuming precise and unbiased data inputs and an alternative operating model assuming imprecise and biased data inputs. Numbers in parentheses represent the relative long-term yield from the management strategy evaluation.

Imprecise-Biased	Precise-Unbiased
DCAC (77.1)	DD4010 (97.2)
Islope1 (72.6)	DD (96.0)
DCAC_40 (72.2)	MCD (94.3)
Islope4 (70.5)	Fratio (94.1)
IT5 (69.3)	DCAC4010 (90.4)
IT10 (69.2)	DCAC (86.8)

3.3.2.4 Calculation of TACS using real world data

Figure 3.3.2.6 provides resulting total allowable catch (TAC) calculations from the MPs that produced the 6 highest relative yields in the MSE and met the performance criteria as specified by the SEDAR 46 DW/AW Panel. In the SEDAR46 evaluations, the TAC calculations are considered equivalent to the overfishing limit (OFL). However, it should be noted that adoption of one or more of these TACs as a harvest control rule may not necessarily achieve maximum sustainable yield in equilibrium (which is difficult to estimate in data-limited situations). Instead the TAC represents a level of yield consistent with the selected management objectives and performance criteria recommended by the DW/AW Panel and is heavily dependent upon the reliability of data inputs. Summary statistics on calculated TACs from the real world data (provided in Appendix 4.3.2) are provided in Table 3.3.2.3 for all of the feasible MPs meeting the performance criteria specified by the SEDAR 46 DW/AW Panel.

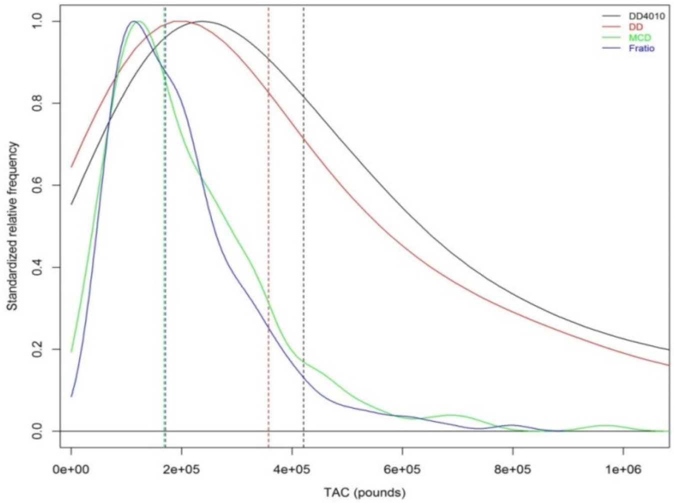


Figure 3.3.2.6 Total allowable catch (TAC) calculations (pounds) for Puerto Rico yellowtail snapper obtained from the management procedures that met the SEDAR 46 AW Panel performance criteria and also produced the 6 highest relative long-term yields in the management strategy evaluation. Note that only 4 of the top 6 are applicable based on current data availability and/or management procedure configuration. MPs are as defined in Table 3.1.

Table 3.3.2.3 Summary of total allowable catch (TAC) calculations (pounds x 1000s) provided by management procedures that met the SEDAR 46 AW Panel performance criteria for Puerto Rico yellowtail snapper. MPs are as defined in Table 3.1.

	Summary statistics				
MP	Minimum	25th Percentile	Median	75th Percentile	Maximum
MPs producing 6 highest long-term yields that meet management criteria					
DD4010	27.628	223.580	450.093	1097.725	5924.792
DD	11.424	155.288	368.194	946.563	7153.145
MCD	8.006	108.531	189.991	287.409	759.445
Fratio	32.926	99.141	156.541	236.985	732.805
Other MPs that meet management criteria					
Islope1	78.516	134.495	157.096	177.837	247.785
Itarget1	68.293	115.929	132.242	151.066	229.522
CC4	72.870	115.029	129.130	153.585	265.171
SPMSY	4.232	77.414	125.071	169.584	255.162
Islope4	69.387	99.364	112.336	129.604	185.335

The effect of varying real world parameter inputs on the recommended TACs for each MP was evaluated using a sensitivity analysis available within DLMtool. Figure 3.3.2.7 provides sensitivity results for all applicable MPs that produced the highest relative long-term yields in the MSE. Sensitivities in parameter estimates were evident, with higher TACs obtained for the following MPs: in MCD as Cat and Dep increased and in Fratio as Mort, FMSY_M, and Abun increased. Trends in sensitivities for both DD and DD4010 were more variable, with less distinctive trends identified.

In addition, real world parameter inputs were varied for several key parameters to assess the sensitivity of TAC calculations to data inputs including CV_Cat, Abun, Dep, Mort, vbLinf, and vbK. Figures 3.3.2.8 − 3.3.2.9 provide results for the MPs requiring each data input. Calculated TACs from most MPs were relatively similar when CV_Cat was doubled, with the exception of DD and DD4010. In contrast, changes to both Abun and Dep and life history parameters (Mort, vbLinf, vbK) had a substantial impact on TACs where these inputs were required. Tables 3.3.2.4 − 3.3.2.6 provide the calculated TACs for all sensitivity runs.

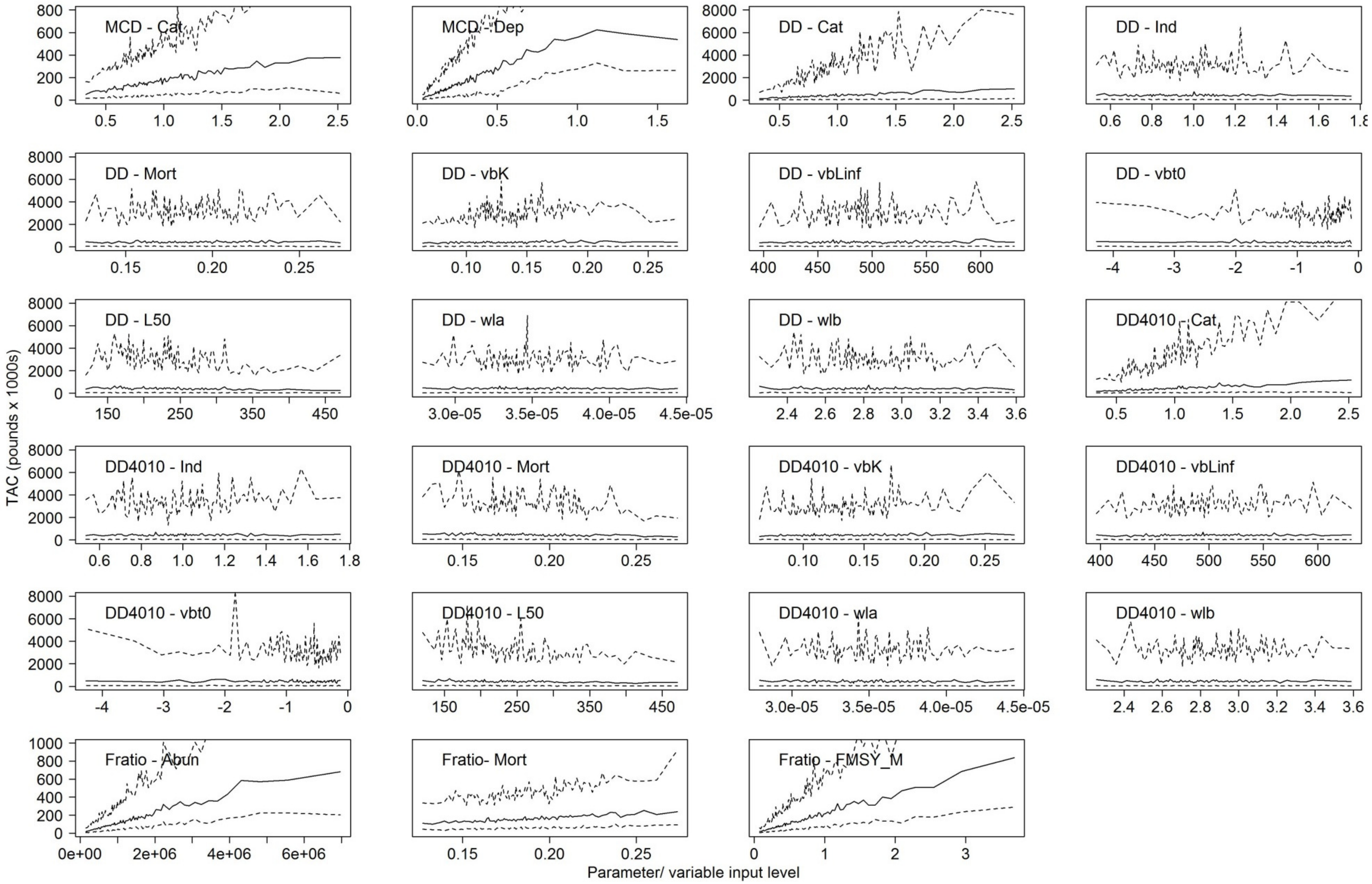


Figure 3.3.2.7 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) for the applicable highest yielding management procedures to varying input parameters for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1. Dashed lines reflect 5% and 95% confidence intervals.

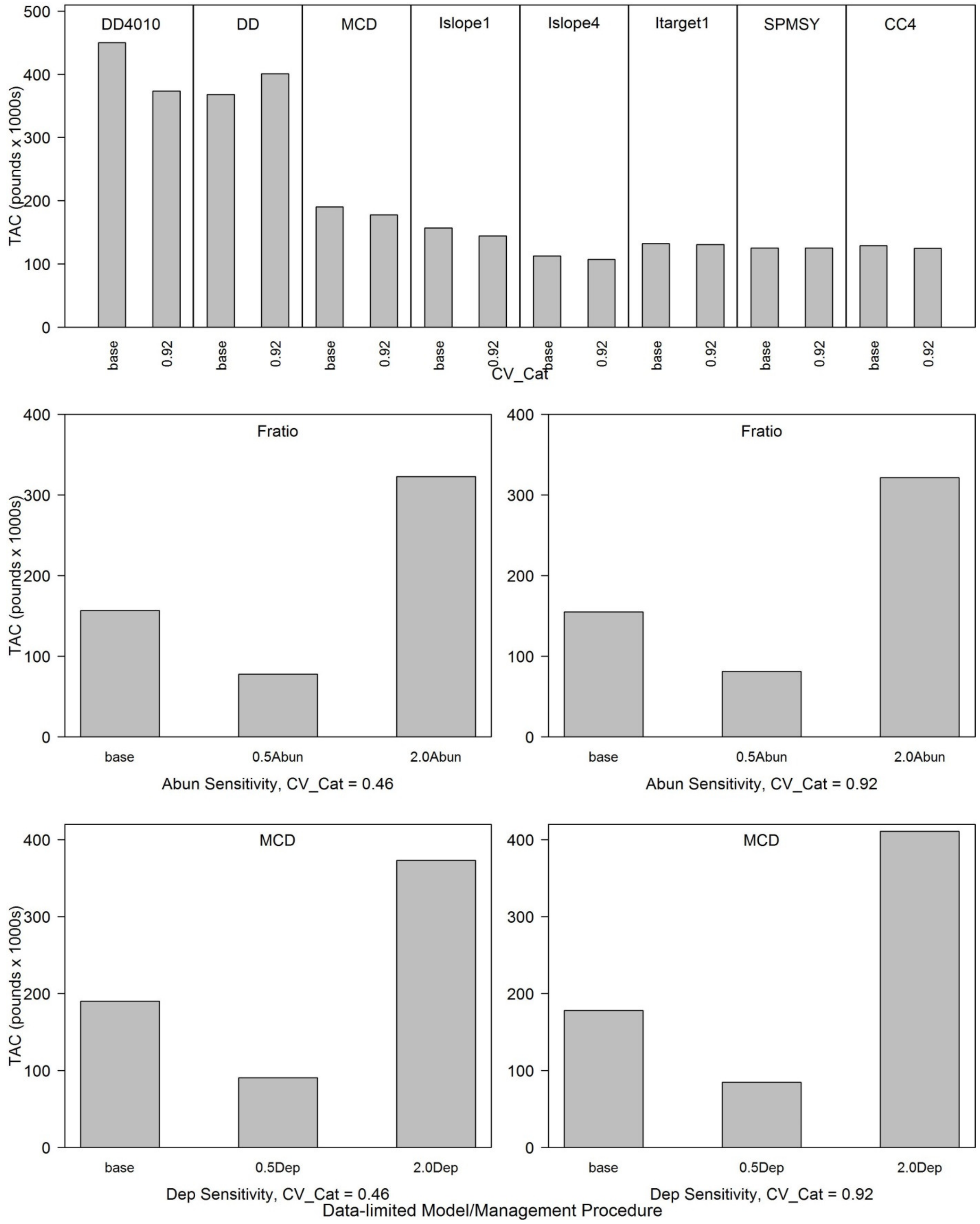


Figure 3.3.2.8 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including CV_Cat, Abun, and Dep for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1.

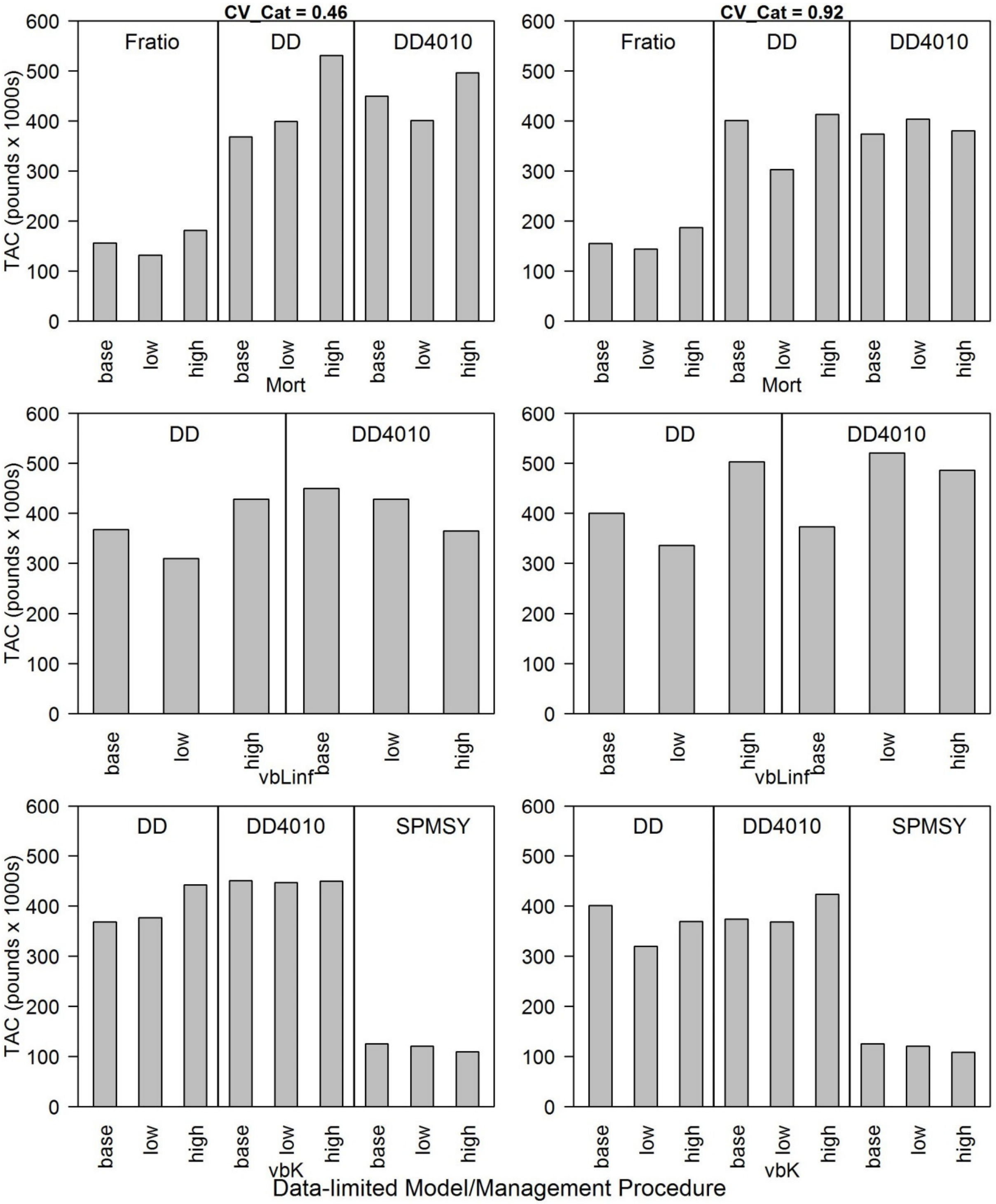


Figure 3.3.2.9 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including Mort, vbLinf, and vbK for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1.

Table 3.3.2.4 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the coefficient of variation for catch (CV_Cat) for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1.

MP	TAC (pounds x 1000s) 0.46 (CV_Cat, base)	 0.92 (2.0 x CV_Cat)
DD4010	450.093	373.682
DD	368.194	400.734
MCD	189.991	177.708
Islope1	157.096	144.150
Islope4	112.336	106.964
Itarget1	132.242	130.849
SPMSY	125.071	125.175
CC4	129.130	124.520

Table 3.3.2.5 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to current abundance and depletion values for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1.

MP	Abundance (Abun)	Depletion (Dep)	TAC (pounds x 1000s) 0.46 (CV_Cat, base)	 0.92 (2.0 x CV_Cat)
Abundance				
Fratio	1416390 (Abun, base)	–	156.541	155.016
	708195 (0.5 x Abun)	–	77.785	81.329
	2832780 (2.0 x Abun)	–	322.823	321.615
Depletion				
MCD	–	0.33 (Dep, base)	189.991	177.708
	–	0.165 (0.5 x Dep)	90.327	84.647
	–	0.66 (2.0 x Dep)	372.922	410.957

Table 3.3.2.6 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to natural mortality (Mort), asymptotic length (vbLinf), and growth rate (vbK) values for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1.

MP	Input	TAC (pounds x 1000s) 0.46 (CV_Cat, base)	 0.92 (2.0 x CV_Cat)
Mort			
Fratio	0.1889 (base)	156.541	155.016
	0.161 (low)	132.353	144.266
	0.217 (high)	181.670	186.956
DD	0.1889 (base)	368.194	400.734
	0.161 (low)	399.593	303.059
	0.217 (high)	530.542	413.213
DD4010	0.1889 (base)	450.093	373.682
	0.161 (low)	400.874	403.490
	0.217 (high)	496.438	380.363
vbLinf			
DD	502 (base)	368.194	400.734
	427 (low)	309.576	336.194
	578 (high)	428.149	502.893
DD4010	502 (base)	450.093	373.682
	427 (low)	428.611	521.224
	578 (high)	364.982	486.739
vbK			
DD	0.139 (base)	368.194	400.734
	0.118 (low)	376.554	319.427
	0.160 (high)	442.215	368.481
DD4010	0.139 (base)	450.093	373.682
	0.118 (low)	446.112	367.700
	0.160 (high)	449.506	423.034
SPMSY	0.139 (base)	125.071	125.175
	0.118 (low)	120.672	120.663
	0.160 (high)	109.097	108.261

Table 3.3.2.7 provides a brief summarization of MSE results and inherent assumptions for each applicable method and can help guide which MP to select for TAC calculation. For Puerto Rico yellowtail snapper, areas of concern include:

- **Life history input (Mort, L50, vbt0, vbK, vbLinf, wla, wlb, MaxAge):** MaxAge and Mort estimate from Central Brazil assumed representative of US Caribbean trends
- **Catch input (Cat):** underreporting of catch, highly uncertain catches due to inconsistencies between data sheets prior to 2011, and species misidentification or lack of identification (snapper versus yellowtail snapper)
- **Index input (Ind):** appropriateness of: adjusted effort (Eff1) as an indicator of fishing effort; and 2) of the trend in relative abundance derived from the handline fishery
- **Depletion input (Dep):** method for estimating depletion provides very uncertain estimates of current stock biomass and (equilibrium) fishing mortality rate from growth, natural mortality rate, recruitment and fishing selectivity. In addition, the mean length from the handline fishery is considered an appropriate and reliable indicator of trend in resource.
- **Abundance input (Abun):** rough estimate of current abundance based on recent catch and fishing mortality history
- **Fishery input (LFC):** appropriateness of TIP data for the handline fishery in quantifying the length at first capture

In general, MPs cannot realize the full complexity of the biology (e.g., time- and age-varying natural mortality) or fishery characteristics (e.g., change in fishing operations, regulations).

Table 3.3.2.7 Guidance table of inherent assumptions within management procedures for calculating the total allowable catch for Puerto Rico yellowtail snapper. MPs and data inputs are as defined in Table 3.1. Performance metrics are as defined in Table 3.3.2.1.

Parameter	**Abun-based**	**Dep-based**	**Data-moderate**		**Index-based**			**Catch-based**	
	Fratio	**MCD**	**DD**	**DD4010**	**Islope1**	**Islope4**	**Itarget1**	**SPMSY**	**CC4**
PNOF	59.5	71.6	55.7	75.3	60.9	61.1	87.3	72.6	77.6
B50	91.7	98.4	92.7	97.7	82.6	82.2	94.8	85.0	89.6
LTY	94.1	94.3	96.0	97.2	81.3	79.0	22.2	60.8	32.2
AAVY	51.0	65.6	100.0	95.6	98.6	98.4	100.0	98.4	100.0
Mort	Known, Constant across age		Known, constant across age						
L50			Life history characterizations reflective of PR					Life history characterizations reflective of PR	
vbt0									
vbK									
vbLinf									
wla									
wlb									
MaxAge			Age characterizations reflective of PR					Age characterizations reflective of PR	
Cat		Known, informative of historical removals							
FMSY_M	Known								
Ind			Fishery dependent representative of population abundance, dependent upon accurate effort reporting						
Dep		Known, estimated from TIP samples and life history							
Abun	Known, estimated from current catch and F								

3.3.3 St. Thomas queen triggerfish

3.3.3.1 Model stability

Model stability was evaluated graphically and through inspection of the convergence values for each performance metric across simulations for all MPs. All of the feasible MPs within the MSE converged at the 1% criteria level. Convergence plots for standard performance metrics in the MSE are shown in Figure 3.3.3.1 for the base OM (15%LH, High dome selex). The majority of MPs appear to have converged by approximately 300 simulations for each performance metric.

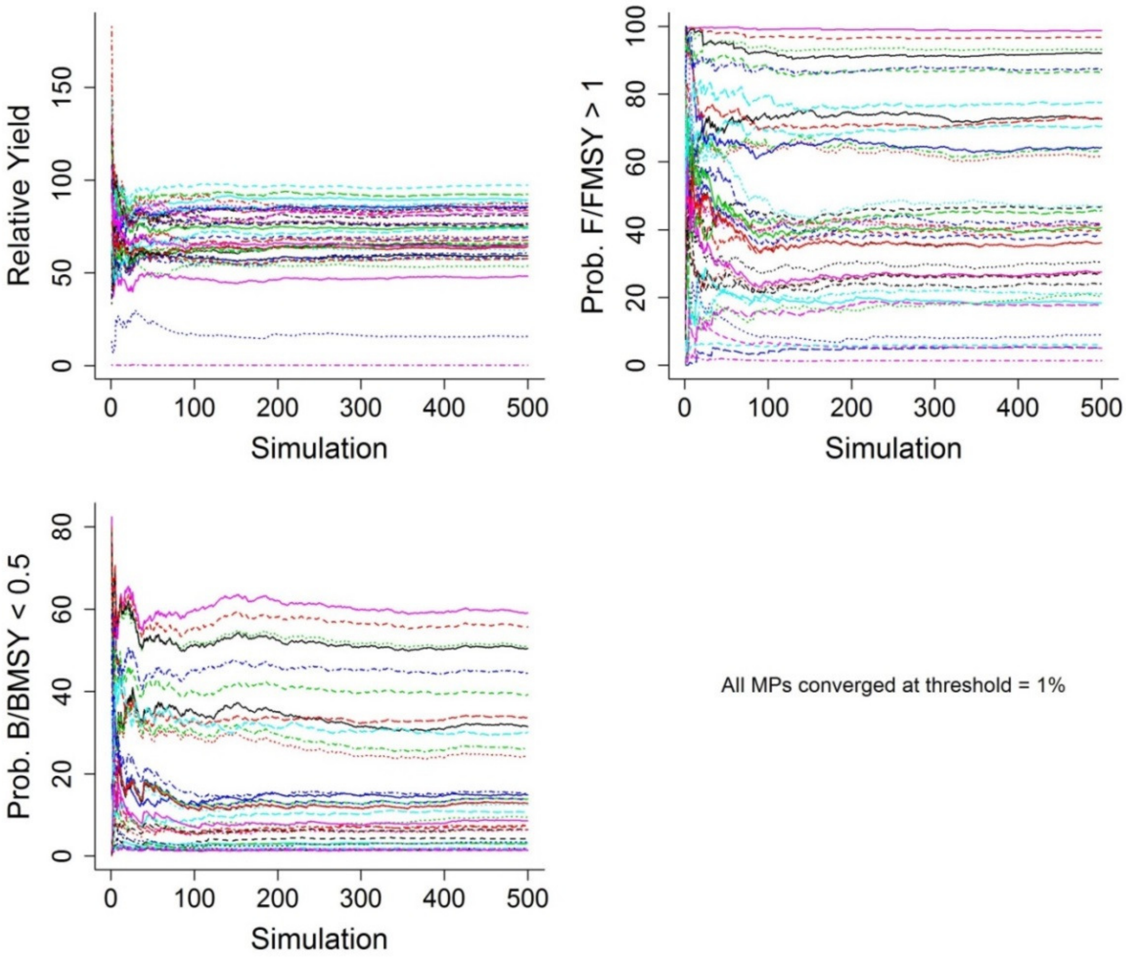


Figure 3.3.3.1 Convergence of performance metrics for each feasible MP within the management strategy evaluation for St. Thomas queen triggerfish using the base operating model (15%LH, High dome selex). Colored lines each reflect an MP.

3.3.3.2 Operating model evaluation

The consistency of MSE results across varying assumptions on stock and fleet dynamics in the OM was examined with respect to life history (stock) and fishery (fleet) characterizations as described in Section 3.2.2.1. Tables 3.2.3 – 3.2.6 provided specifics on stock and fleet dynamics and alternative characterizations considered including the base operating model (15%LH, high dome selex) and two alternative operating models specified: (1) 15%LH, Moderate dome selex and (2) 5%LH, Moderate dome selex.

Performance between MPs within the MSEs was further examined by investigating tradeoff plots among OMs. Figures 3.3.3.2 − 3.3.3.4 present the tradeoff plots for the base (15%LH, High dome selex) and two alternative OMs (5%LH, Moderate dome selex; 15%LH, Moderate dome selex). Metrics shown in the tradeoff plots are the Panel-selected performance metrics as defined in Section 3.2.4. MPs located within the top-right corner in each panel are preferred according to the AW Panel performance criteria. MPs yielding the highest Pr(NOF ≥ 50%), Pr(B50 ≥ 50%), and Pr([AAVY 15%] ≥ 50%) were similar between the base and sensitivity OMs. Specific details on definitions of performance metrics were previously provided in Section 3.2.4.

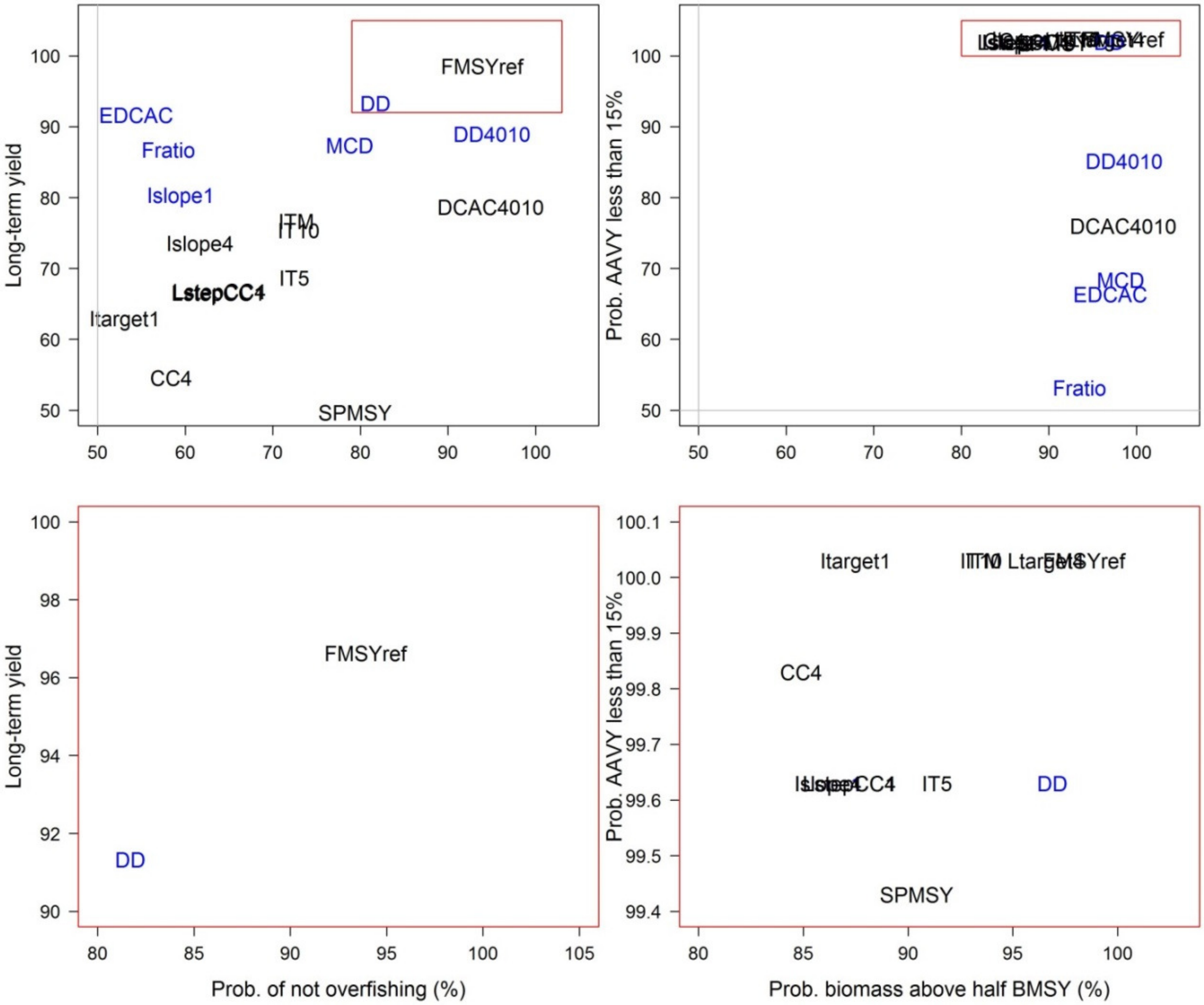


Figure 3.3.3.2 Tradeoffs in performance metrics between management procedures for the St. Thomas queen triggerfish base operating model (15%LH, High dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot. MPs are as defined in Table 3.1.

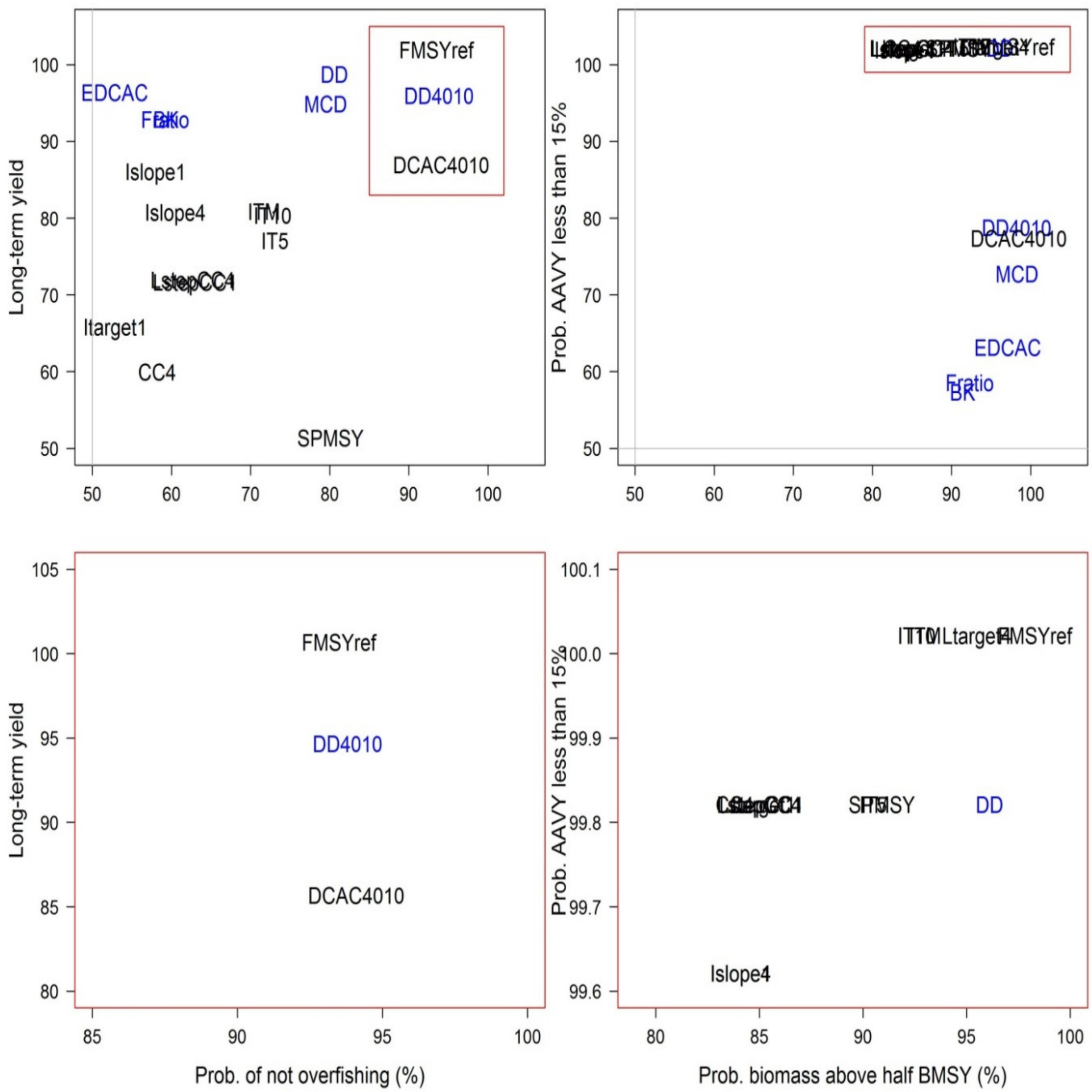


Figure 3.3.3.3 Tradeoffs in performance metrics between management procedures for the St. Thomas queen triggerfish alternative operating model (15%LH, Moderate dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panel. MPs are as defined in Table 3.1.

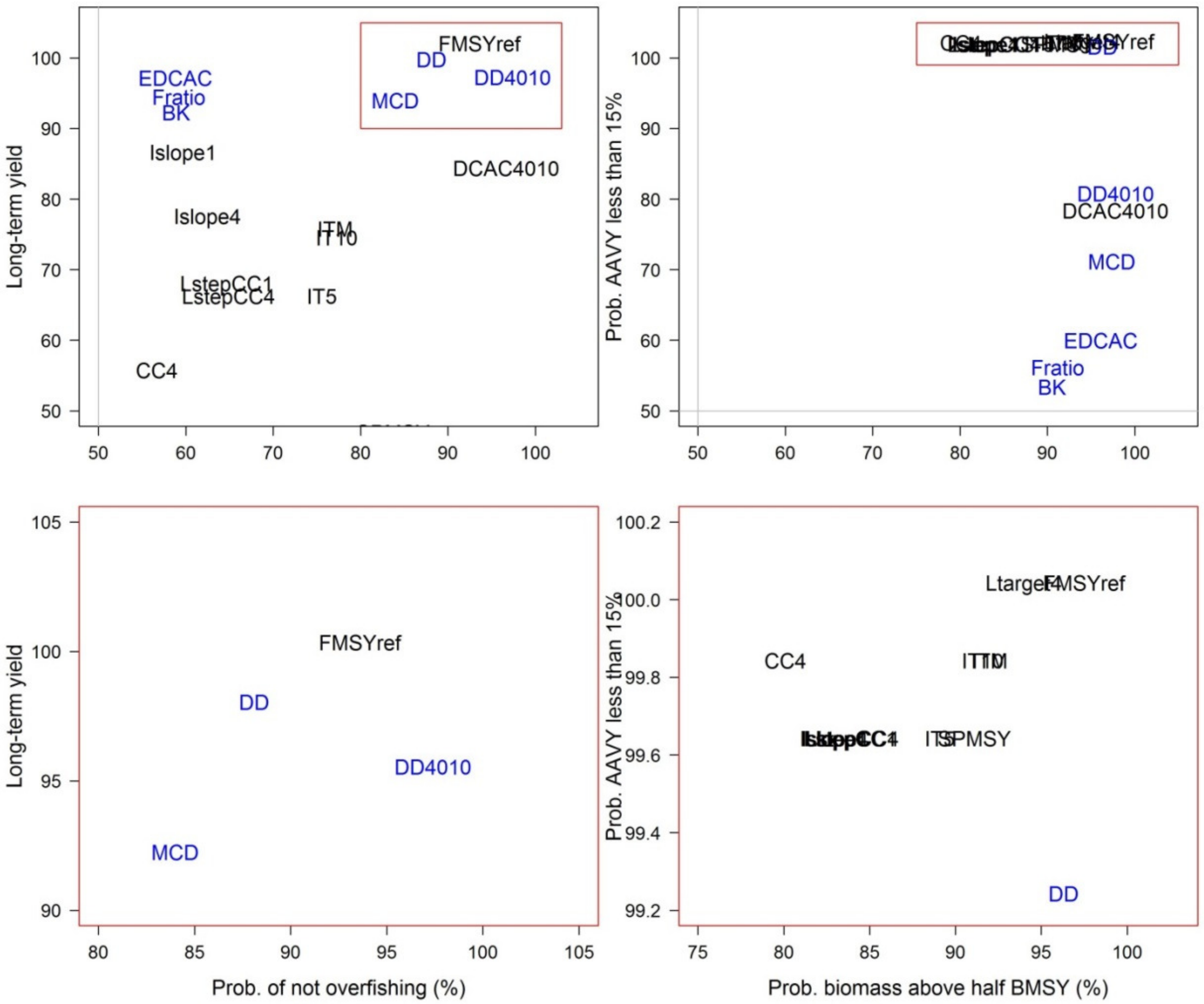


Figure 3.3.3.4 Tradeoffs in performance metrics between management procedures for the St. Thomas queen triggerfish alternative operating model (5%LH, Moderate dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the 6 MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot. MPs are as defined in Table 3.1.

Additional information to aid in understanding the contribution of information included in each OM is shown in Figures 3.3.3.5 − 3.3.3.6. These figures are a graphical visualization of the value of information in the OM, a metric which identifies relevant parameters in the operating and observation models that are most correlated with utility. For the operating model parameters (Figure 3.3.3.5), the highest correlations occurred between long-term yield relative to MSY and estimates of ageM, RefY, LFS, or FMSY for all MPs. For the observation model parameters (Figure 3.3.3.6), parameters displaying the highest correlations with long-term yield relative to MSY were also divergent across MPs. These parameters included Csd for DD and Islope1, Derr for EDCAC, t0bias for DD4010, Dbias for MCD, and Abias for Fratio. These results may be used to inform data collection, by identifying which inputs are more important in assessing OM behavior.

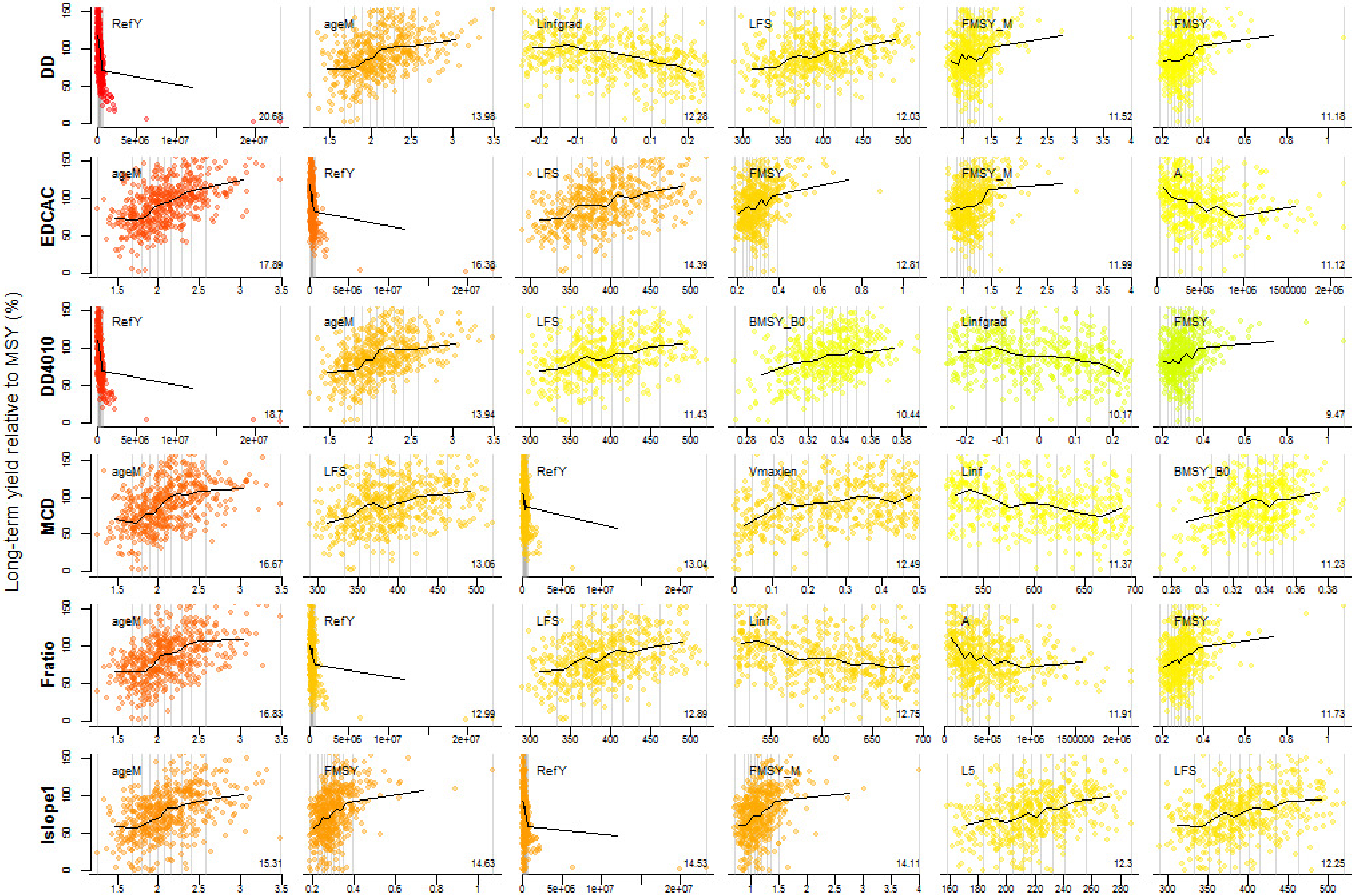


Figure 3.3.3.5 Value of information that detects relevant operating model parameters that are most correlated with utility for the St. Thomas queen triggerfish base operating model (15%LH, High dome selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and operating model parameters are as defined in Table 3.1.

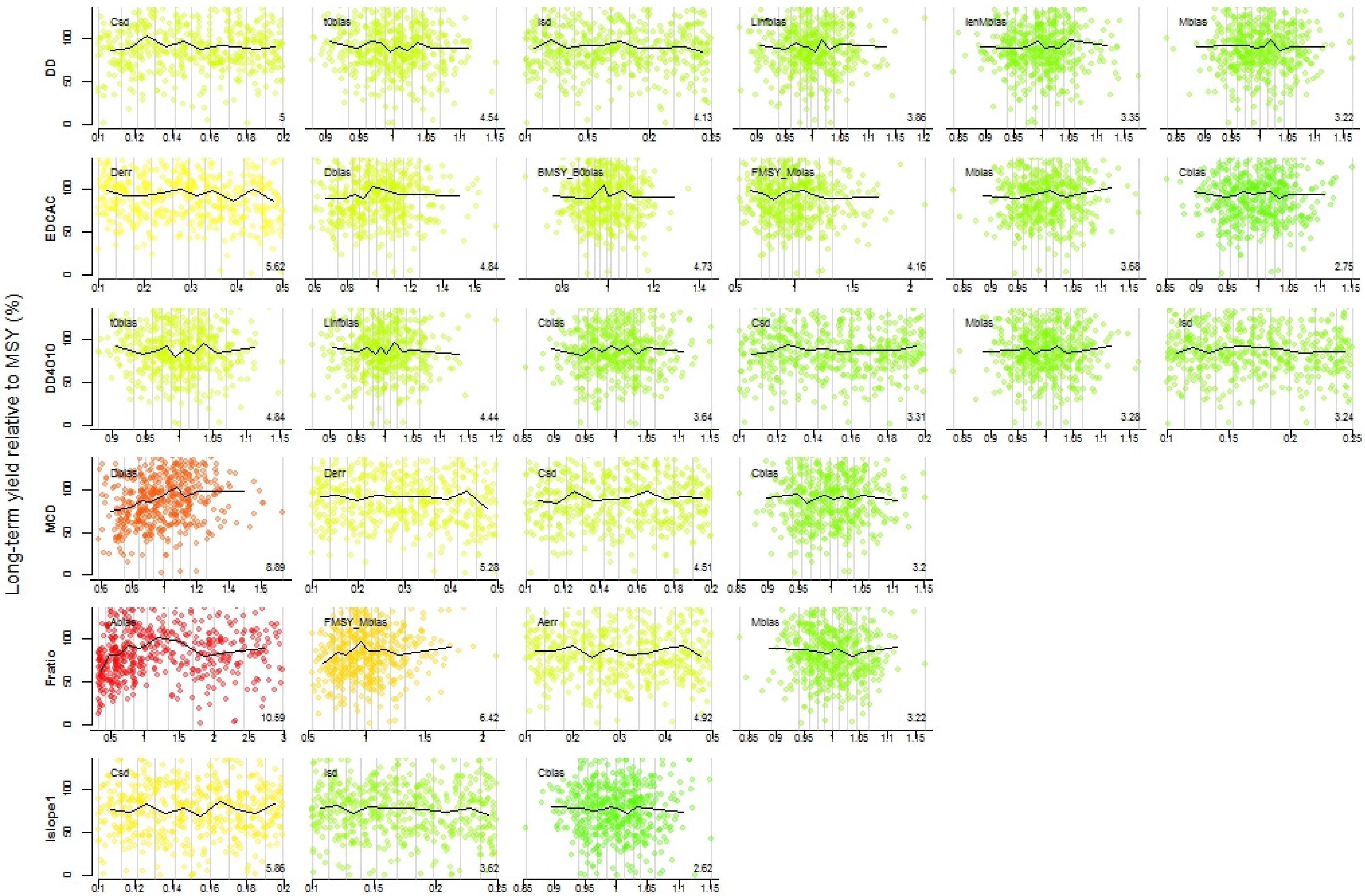


Figure 3.3.3.6 Value of information that detects relevant observation model parameters that are most correlated with utility for the St. Thomas queen triggerfish base operating model (15%LH, High dome selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and observation model parameters are as defined in Table 3.1.

3.3.3.3 Performance of management procedures

MP performance results against the three MSE performance criteria (PNOF, B50, AAVY) selected by the SEDAR 46 DW/AW Panel as well as relative long-term yield (LTY) are provided in Table 3.3.3.1 for the St. Thomas queen triggerfish base (15%LH, High dome selex) and two alternative OMs: (1) 15%LH, Moderate dome selex; and (2) 5%LH, Moderate dome selex.

Sensitivity of the data quality in the observation subclass (i.e., imprecise and biased data inputs) resulted in very different trends in model performance in the MSE. The top 6 methods tend to be index-based methods, with substantially lower relative long-term yields compared to when data inputs were assumed precise and unbiased (Table 3.3.3.2). Those MPs identified as optimal when assuming precise and unbiased data inputs no longer fall within the top 6 according to selection criteria.

Table 3.3.3.1 Performance of management procedures within the MSE for the St. Thomas queen triggerfish base (15%LH, High dome selex) and alternative stock/fleet (5% LH, Moderate dome selex) and alternative fleet (15%LH, Moderate dome selex) operating models as determined using the performance metrics specified by the SEDAR 46 DW/AW Panel. PNOF = probability of not overfishing (%), B50 = probability of the biomass being above half BMSY (%), LTY = relative long-term yield, defined as the fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection, and AAVY = fraction of simulations where average annual variability in yield < 15%. MPs are as defined in Table 3.1.

Base Stock/Fleet					Alt Fleet					Alt Stock/Fleet				
15% LH, high dome selex					15% LH, Moderate dome selex					5% LH, Moderate dome selex				
MP	PNOF	B50	LTY	AAVY	MP	PNOF	B50	LTY	AAVY	MP	PNOF	B50	LTY	AAVY
<u>Reference MP</u>														
FMSYref	93.9	98.4	96.2	100	FMSYref	93.5	98.3	99.6	100	FMSYref	93.6	97.5	99.7	100
<u>MPs producing 6 highest long-term yields that meet criteria</u>														
DD	81.7	96.9	90.9	99.6	DD	80.6	96.1	96.4	99.8	DD	88.1	96.3	97.4	99.2
EDCAC	54.4	97	89.3	64	EDCAC	52.8	97.1	94	60.8	DD4010	97.4	97.8	94.9	78.4
DD4010	95	98.6	86.6	82.8	DD4010	93.8	98.2	93.6	76.4	EDCAC	58.8	96.1	94.8	57.6
MCD	78.8	98.2	85	66	MCD	79.5	98.3	92.5	70.4	Fratio	59.2	91.2	92.1	53.8
Fratio	58.1	93.5	84.4	50.8	BK	59.3	91.4	90.5	55	MCD	84	97.4	91.6	68.8
Islope1	59.5	86.2	78	99.6	Fratio	59.2	92.3	90.5	56.2	BK	58.9	90.5	89.9	51
<u>Other MPs producing lower long-term yields that meet criteria</u>														
DCAC4010	94.9	98.5	76.3	73.6	DCAC4010	94.1	98.5	84.6	75	Islope1	59.7	82.9	84.3	99.6
ITM	72.7	93.6	74.3	100	Islope1	58	84.1	83.7	99.6	DCAC4010	96.7	97.8	82	76
IT10	73	93.5	73	100	ITM	71.7	93	78.5	100	Islope4	62.5	83	75.2	99.6
Islope4	61.7	86.2	71.2	99.6	Islope4	60.5	84.1	78.4	99.6	ITM	77.1	92	73.4	99.8
IT5	72.5	91.4	66.3	99.6	IT10	72.8	92.6	78	100	IT10	77.3	91.6	72.2	99.8
LstepCC4	63.9	87.2	64.4	99.6	IT5	73.1	90.5	74.7	99.8	LstepCC1	64.7	83.9	65.7	99.6
LstepCC1	63.8	87.2	64.2	99.6	LstepCC4	62.7	85	69.6	99.8	LstepCC4	64.9	84	63.9	99.6
Itarget1	53.1	87.5	60.6	100	LstepCC1	63	85.1	69.3	99.8	IT5	75.6	89.1	63.9	99.6
CC4	58.4	84.9	52.2	99.8	Itarget1	52.9	85.2	63.5	99.8	CC4	56.7	80.1	53.4	99.8
SPMSY	79.4	90.4	47.3	99.4	CC4	58.2	83.8	57.6	99.8	SPMSY	83.7	91.1	44.6	99.6
Ltarget4	91	96.6	9.1	100	SPMSY	80.1	90.9	49	99.8	Ltarget4	88.1	94	9	100
					Ltarget4	89.1	95.5	9.4	100					

3.3.3.4 Calculation of TACs using real world data

Figure 3.3.3.7 provides resulting total allowable catch (TAC) calculations from the MPs that produced the 6 highest relative yields in the MSE and met the performance criteria as specified by the SEDAR 46 DW/AW Panel. In the SEDAR46 evaluations, the TAC calculations are considered equivalent to the overfishing limit (OFL). However, it should be noted that adoption of one or more of these TACs as a harvest control rule may not necessarily achieve maximum sustainable yield in equilibrium (which is difficult to estimate in data-limited situations). Instead the TAC represents a level of yield consistent with the selected management objectives and performance criteria recommended by the DW/AW Panel and are heavily dependent upon the reliability of data inputs. Summary statistics on calculated TACs from the real world data (provided in Appendix 4.3.3) are provided in Table 3.3.3.3 for all of the feasible MPs meeting the performance criteria specified by the SEDAR 46 DW/AW Panel.

Table 3.3.3.3 Summary of total allowable catch (TAC) calculations (pounds x 1000s) provided by management procedures that met the SEDAR 46 DW/AW Panel performance criteria for St. Thomas queen triggerfish. MPs are as defined in Table 3.1.

	Summary statistics				
MP	Minimum	25 Percentile	Median	75th Percentile	Maximum
MPs producing 6 highest long-term yields that meet management criteria					
DD	22.311	222.507	580.772	1185.747	9990.730
DD4010	15.025	189.053	444.872	982.765	6774.825
Islope1	28.381	35.944	40.033	43.179	53.618
Fratio	7.648	23.170	33.454	56.018	167.219
MCD	3.403	10.893	16.844	25.157	64.207
Other MPs that meet management criteria					
CC4	26.371	33.963	36.986	39.559	50.565
Itarget1	23.978	31.256	33.912	36.315	46.302
Islope4	20.571	28.092	30.520	32.957	39.667
SPMSY	1.196	13.344	23.927	33.598	56.094

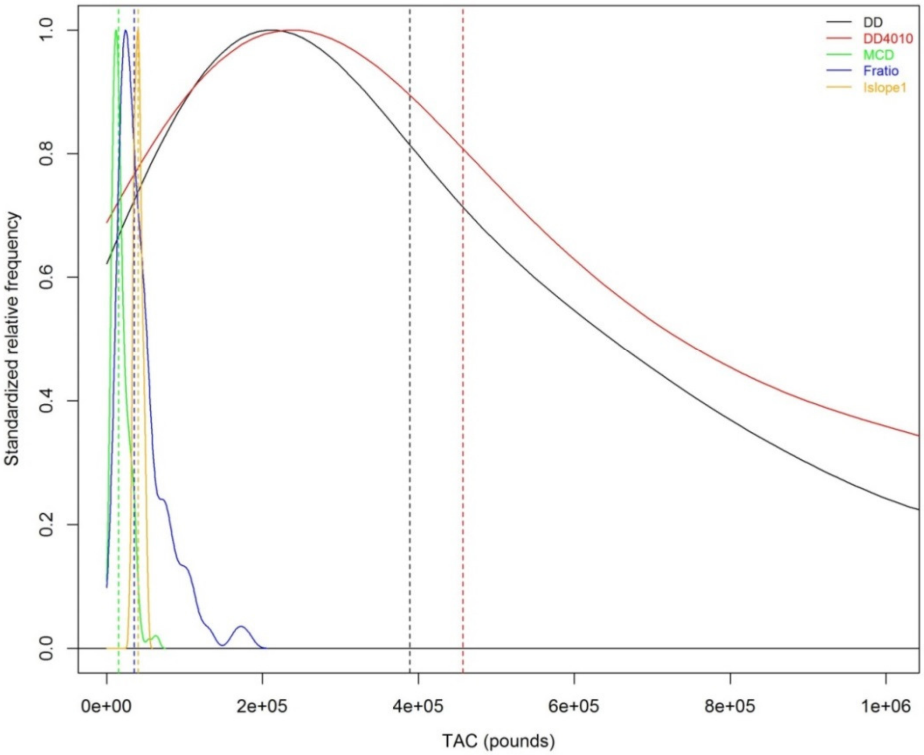


Figure 3.3.3.7 Total allowable catch (TAC) calculations (pounds) for St. Thomas queen triggerfish obtained from the management procedures that met the SEDAR 46 AW Panel performance criteria and also produced the 6 highest relative long-term yields in the management strategy evaluation. Note that only 5 of the top 6 are applicable based on current data availability and/or management procedure configuration. MPs are as defined in Table 3.1.

The effect of varying real world parameter inputs on the recommended TACs for each MP was evaluated using a sensitivity analysis available within DLMtool. Figure 3.3.3.8 provides results for three of the five MPs which produced the highest relative long-term yields in the MSE. Results are not shown for DD or DD4010 because the sensitivity analysis did not converge. Sensitivities in parameter estimates were evident, with higher TACs obtained for the following MPs: in MCD as Cat and Dep increased; in Fratio as Mort, FMSY_M, and Abun increased; and in Islope1 as Cat increased or Ind decreased.

In addition, real world parameter inputs were varied for several key parameters to assess the sensitivity of TAC calculations to data inputs including CV_Cat, Abun, Dep, Mort, vbLinf, and vbK. Figures 3.3.3.9 − 3.3.3.10 provide results for the MPs requiring each data input. Calculated TACs from most MPs were relatively similar when CV_Cat was doubled, with the exception of DD and DD4010. In contrast, changes to both Abun and Dep and life history parameters (Mort, vbLinf, vbK) had a substantial impact on TACs where these inputs were required. Tables 3.3.3.4 − 3.3.3.6 provide the calculated TACs for all sensitivity runs.

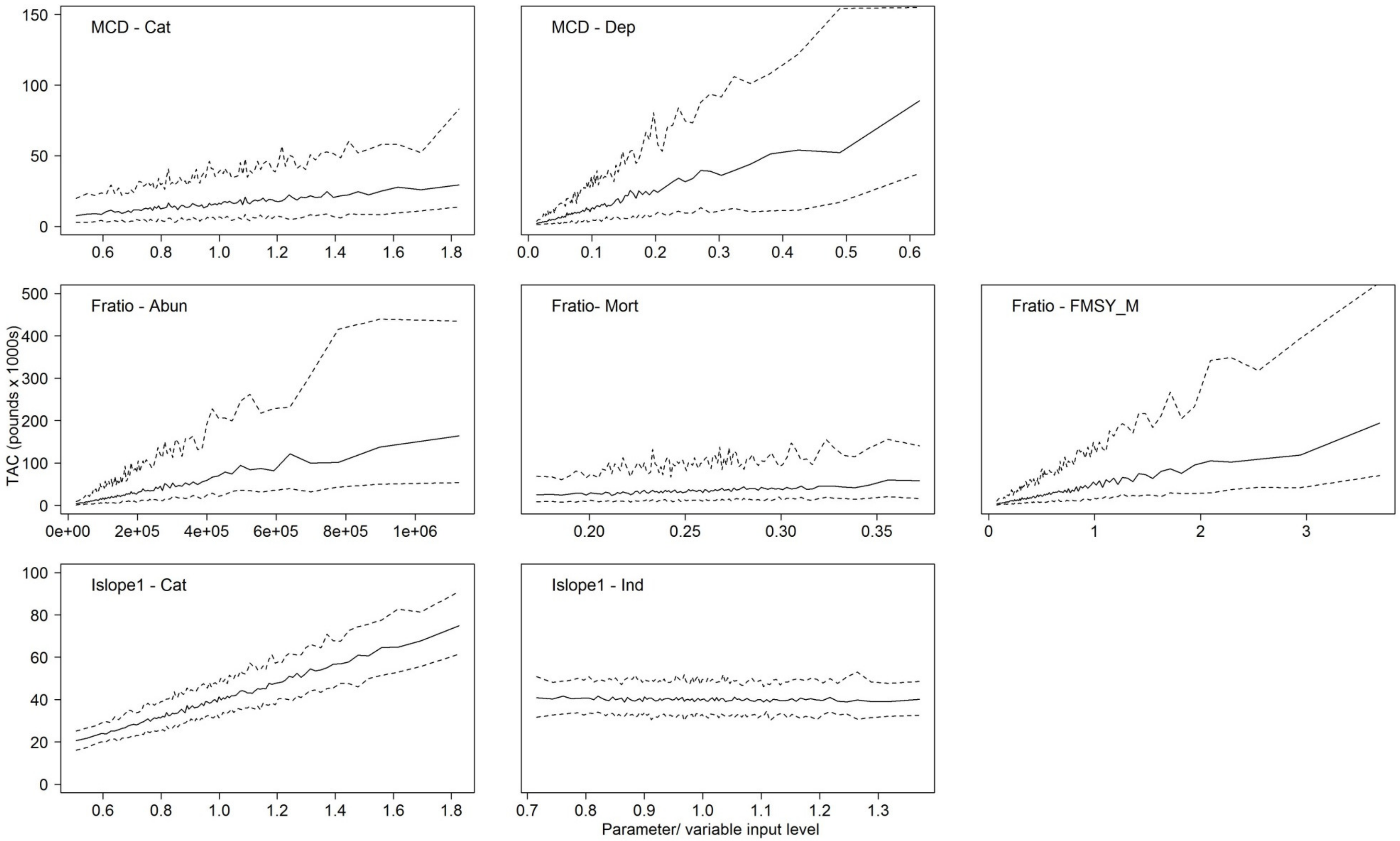


Figure 3.3.3.8 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) for the applicable highest yielding management procedures to varying input parameters for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1. Dashed lines reflect 5% and 95% confidence intervals.

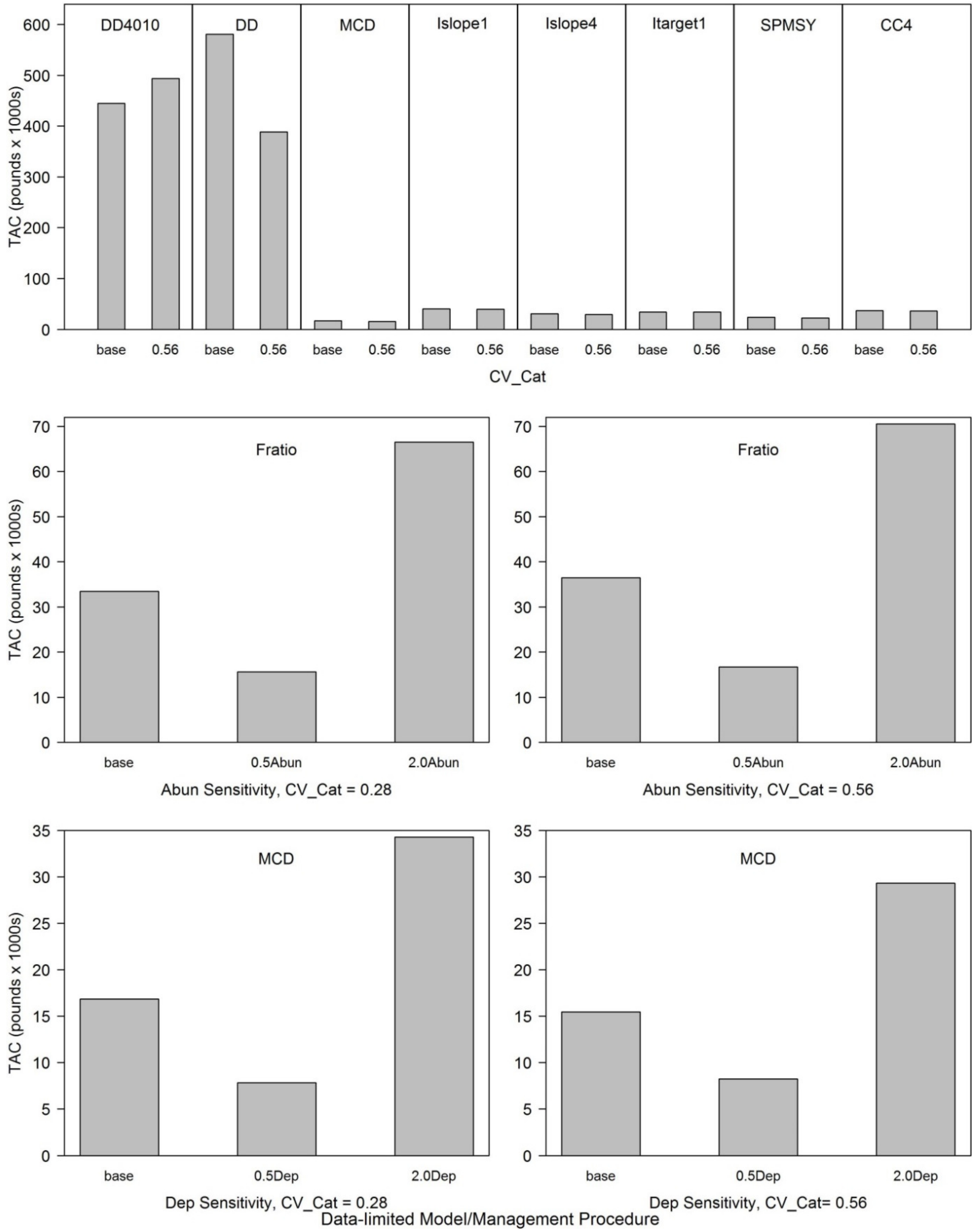


Figure 3.3.3.9 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including CV_Cat, Abun, and Dep for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1.

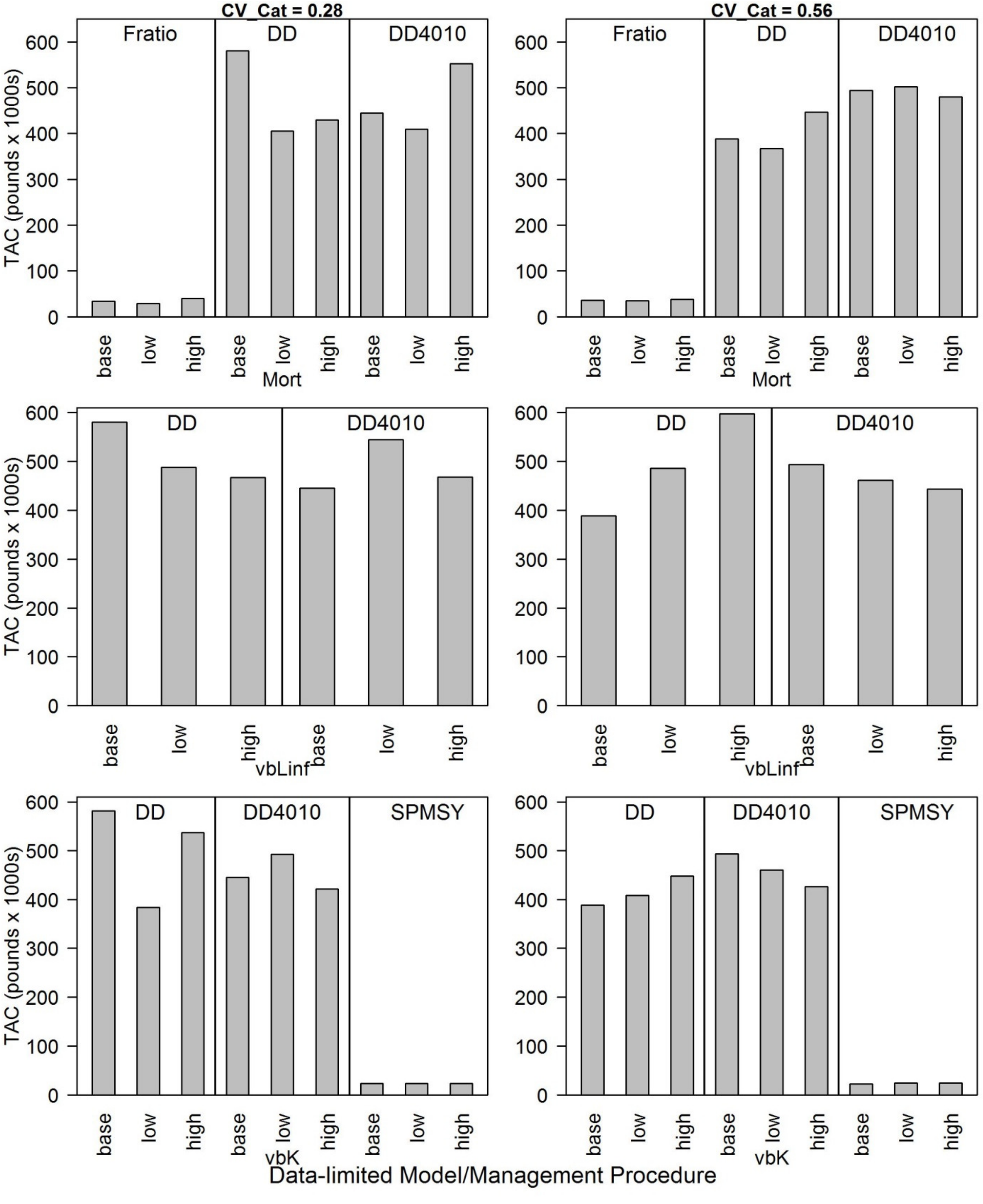


Figure 3.3.3.10 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including Mort, vbLinf, and vbK for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1.

Table 3.3.3.4 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the coefficient of variation for catch (CV_Cat) for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1.

MP	TAC (pounds x 1000s) 0.28 (CV_Cat, base)	 0.56 (2.0 x CV_Cat)
DD4010	444.872	493.559
DD	580.772	388.474
MCD	16.844	15.449
Islope1	40.033	39.503
Islope4	30.520	29.562
Itarget1	33.912	33.991
SPMSY	23.927	22.476
CC4	36.986	35.988

Table 3.3.3.5 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to current abundance and depletion values for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1.

MP	Abundance (Abun)	Depletion (Dep)	TAC (pounds x 1000s) 0.28 (CV_Cat, base)	 0.56 (2.0 x CV_Cat)
Abundance				
Fratio	229008 (Abun, base)	–	33.454	36.436
	114504 (0.5 x Abun)	–	15.590	16.682
	458016 (2.0 x Abun)	–	66.505	70.563
Depletion				
MCD	–	0.125 (Dep, base)	16.844	15.449
	–	0.0625 (0.5 x Dep)	7.845	8.250
	–	0.25 (2.0 x Dep)	34.278	29.324

Table 3.3.3.6 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to natural mortality (Mort), asymptotic length (vbLinf), and growth rate (vbK) values for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1.

MP	Input	TAC (pounds x 1000s) 0.28 (CV_Cat, base)	 0.56 (2.0 x CV_Cat)
Mort			
Fratio	0.2568 (base)	33.454	36.436
	0.218 (low)	29.132	34.486
	0.295 (high)	40.422	37.678
DD	0.2568 (base)	580.772	388.474
	0.218 (low)	405.793	367.281
	0.295 (high)	429.999	446.535
DD4010	0.2568 (base)	444.872	493.559
	0.218 (low)	409.592	501.666
	0.295 (high)	552.102	479.878
vbLinf			
DD	605 (base)	580.772	388.474
	514 (low)	487.511	485.917
	696 (high)	467.510	597.187
DD4010	605 (base)	444.872	493.559
	514 (low)	544.441	461.607
	696 (high)	467.947	443.372
vbK			
DD	0.214 (base)	580.772	388.474
	0.182 (low)	383.189	407.657
	0.246 (high)	536.187	447.501
DD4010	0.214 (base)	444.872	493.559
	0.182 (low)	491.983	459.625
	0.246 (high)	421.619	425.659
SPMSY	0.214 (base)	23.927	22.476
	0.182 (low)	23.974	24.719
	0.246 (high)	23.194	24.268

Table 3.3.3.7 provides a brief summarization of MSE results and inherent assumptions for each applicable method and can help guide which MP to select for TAC calculation. For St. Thomas queen triggerfish, areas of concern include:

- **Life history input (Mort, L50, vbt0, vbK, vbLinf, wla, wlb, MaxAge):** many are estimated from regions outside the US Caribbean including Brazil, Gulf of Mexico, Japan, and Jamaica). In addition, the LHWG identified substantial uncertainty in the MaxAge.
- **Catch input (Cat):** underreporting of catch, highly uncertain catches due to inconsistencies between data sheets prior to 2011 (e.g., potfish, triggerfish), and species misidentification or lack of identification (triggerfish versus queen triggerfish).
- **Index input (Ind):** appropriateness of: adjusted effort (Eff1) as an indicator of fishing effort; and 2) of the trend in relative abundance derived from the pots and traps fishery.
- **Depletion input (Dep):** method for estimating depletion provides very uncertain estimates of current stock biomass and (equilibrium) fishing mortality rate from growth, natural mortality rate, recruitment and fishing selectivity. In addition, the mean length from the pots and traps fishery is considered an appropriate and reliable indicator of trend in resource.
- **Abundance input (Abun):** rough estimate of current abundance based on recent catch and fishing mortality history.
- **Fishery input (LFC):** appropriateness of TIP data for the pots and traps fishery in quantifying the length at first capture.

In general, MPs cannot realize the full complexity of the biology (e.g., time- and age-varying natural mortality) or fishery characteristics (e.g., change in fishing operations, regulations, dome-shaped selectivity).

Table 3.3.3.7 Guidance table of inherent assumptions within management procedures for calculating the total allowable catch for St. Thomas queen triggerfish. MPs and data inputs are as defined in Table 3.1. Performance metrics are as defined in Table 3.3.3.1.

Parameter	**Abun-based**	**Dep-based**	**Data-moderate**		**Index-based**			**Catch-based**	
	Fratio	**MCD**	**DD**	**DD4010**	**Islope1**	**Islope4**	**Itarget1**	**SPMSY**	**CC4**
PNOF	58.1	78.8	81.7	95.0	59.5	61.7	53.1	79.4	58.4
B50	93.5	98.2	96.9	98.6	86.2	86.2	87.5	90.4	84.9
LTY	84.4	85.0	90.9	86.6	78.0	71.2	60.6	47.3	52.2
AAVY	50.8	66.0	99.6	82.8	99.6	99.6	100.0	99.4	99.8
Mort	Known, Constant across age		Known, constant across age						
AM			Life history characterizations reflective of STT					Life history characterizations reflective of STT	
vbt0									
vbK									
vbLinf									
wla									
wlb									
MaxAge			Age characterizations reflective of STT					Age characterizations reflective of STT	
Cat		Known, informative of historical removals							
FMSY_M	Known								
Ind			Fishery dependent representative of population abundance, dependent upon accurate effort reporting						
Dep		Known, estimated from TIP samples and life history							
Abun	Known, estimated from current catch and F								

3.3.4 St. Thomas spiny lobster

3.3.4.1 Model stability

Model stability was evaluated graphically and through inspection of the convergence values for each performance metric across simulations for all MPs. All of the feasible MPs within the MSE converged at the 1% criteria level. Convergence plots for standard performance metrics in the MSE are shown in Figure 3.3.4.1 for the base OM (15%LH, High dome selex). The majority of MPs appear to have converged by approximately 400 simulations for each performance metric.

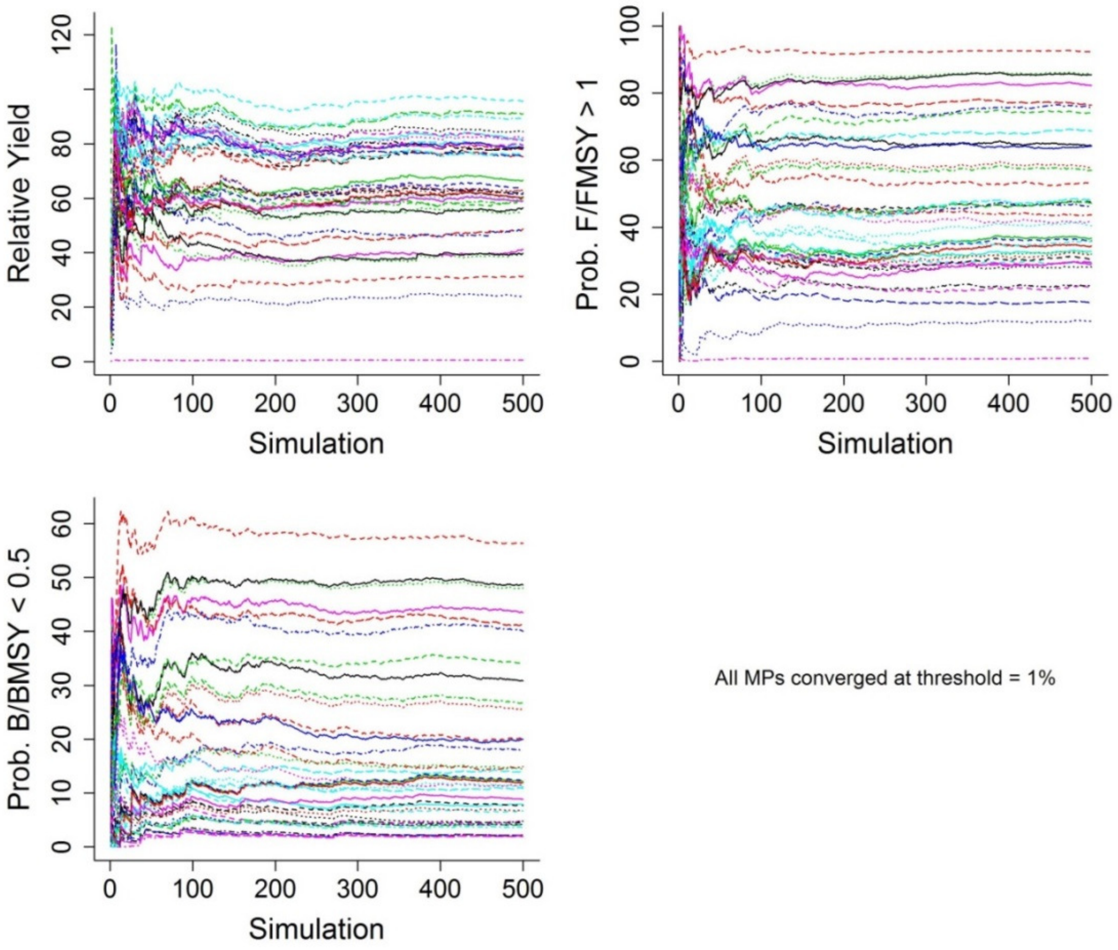


Figure 3.3.4.1 Convergence of performance metrics for each feasible MP within the management strategy evaluation for St. Thomas spiny lobster using the base operating model (15%LH, High dome selex). Colored lines each reflect an MP.

3.3.4.2 Operating model evaluation

The consistency of MSE results across varying assumptions on stock and fleet dynamics in the OM was examined with respect to life history (stock) and fishery (fleet) characterizations as described in Section 3.2.2.1. Tables 3.2.3 – 3.2.6 provided specifics on stock and fleet dynamics and the alternative characterizations considered in the the base operating model (15%LH, high dome selex) and two alternative operating models: (1) 15%LH, Moderate dome selex; and (2) 5%LH, Moderate dome selex.

Performance between MPs within the MSEs was further examined by investigating tradeoff plots among OMs. Figures 3.3.4.2 − 3.3.4.4 present the tradeoff plots for the base (15%LH, High dome selex) and two alternative OMs (5%LH, Moderate dome Selex; 15%LH, Moderate dome Selex). Metrics shown in the tradeoff plots are the Panel-selected performance metrics as defined in Section 3.2.4. MPs located within the top-right corner in each panel are preferred according to the AW Panel performance criteria. MPs yielding the highest *Pr*(NOF ≥ 50%), *Pr*(B50 ≥ 50%), and *Pr*([AAVY 15%] ≥ 50%) were similar between the base and sensitivity OMs. Specific details on definitions of performance metrics were previously provided in Section 3.2.4.

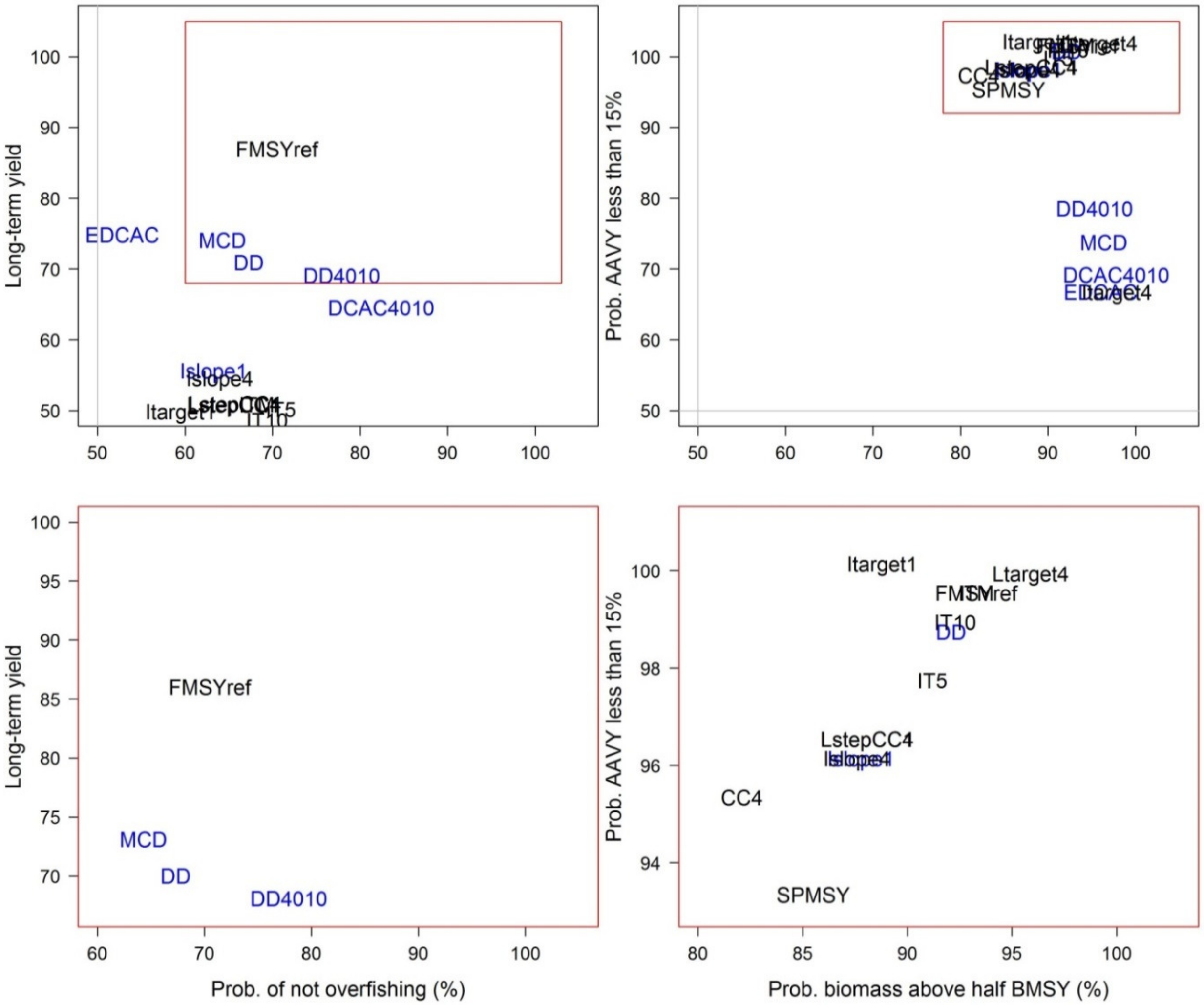


Figure 3.3.4.2 Tradeoffs in performance metrics between management procedures for the St. Thomas spiny lobster base operating model (15%LH, High dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panels. MPs are as defined in Table 3.1.

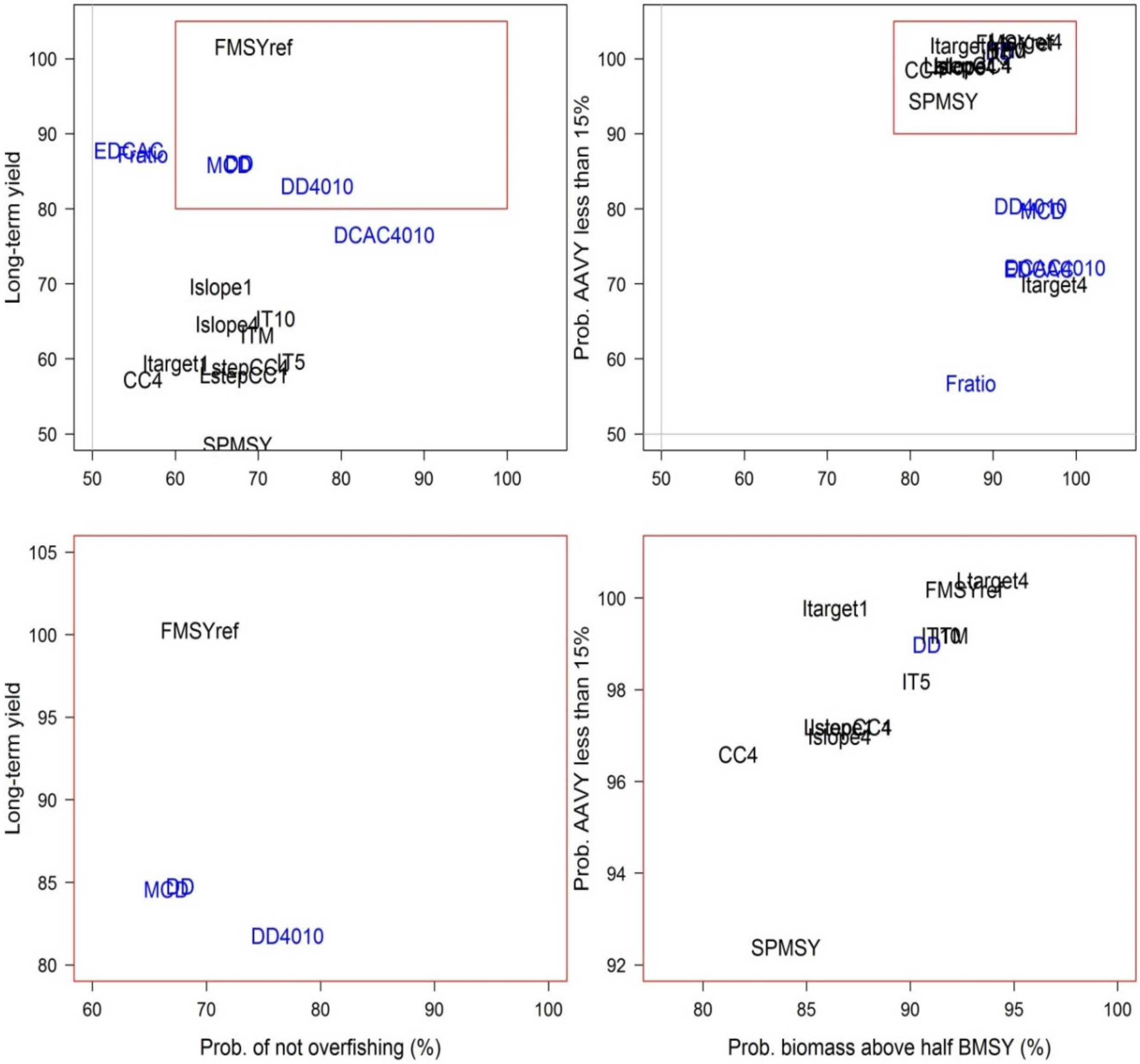


Figure 3.3.4.3 Tradeoffs in performance metrics between management procedures for the St. Thomas spiny lobster alternative operating model (15%LH, Moderate dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the SEDAR 46 DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panels. MPs are as defined in Table 3.1.

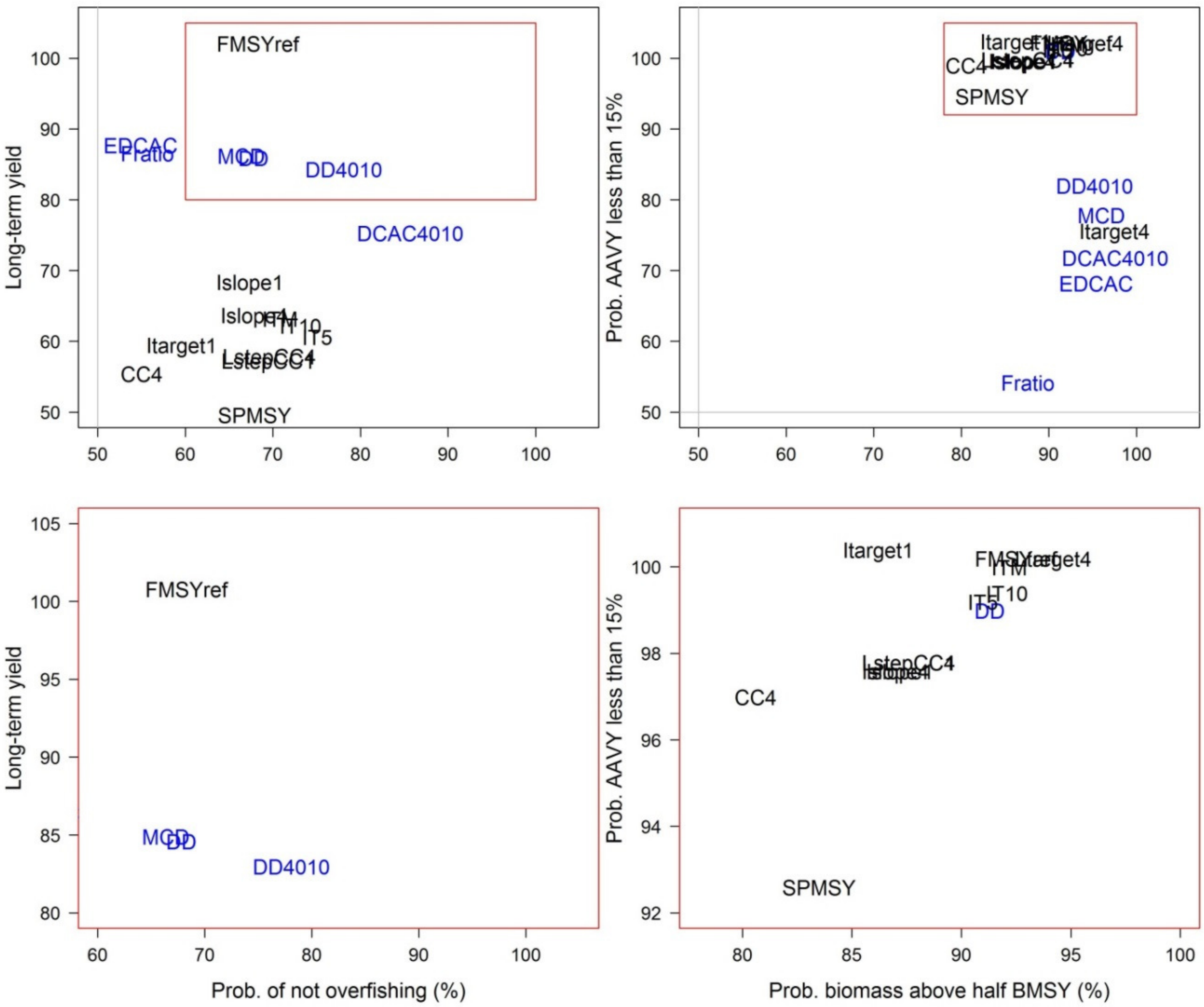


Figure 3.3.4.4 Tradeoffs in performance metrics between management procedures for the St. Thomas spiny lobster alternative operating model (5%LH, Moderate dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panels. MPs are as defined in Table 3.1.

Additional information to aid in understanding the contribution of information included in the operating model is shown in Figures 3.3.4.5 − 3.3.4.6. These figures are a graphical visualization of the value of information in the OM, a metric which identifies relevant parameters in the operating and observation models that are most correlated with utility. For the operating model parameters (Figure 3.3.4.5), the highest correlations occurred between long-term yield relative to MSY and estimates of FMSY_M, FMSY, or ageM. For the observation model parameters (Figure 3.3.4.6), parameters displaying the highest correlations with long-term yield relative to MSY were more divergent across MPs. These parameters included Isd for DD, Mbias for DD4010, Derr for EDCAC, Dbias for MCD and DCAC4010, and Cbias for Islope1. These results may be used to inform data collection, by identifying which inputs are more important in assessing OM behavior.

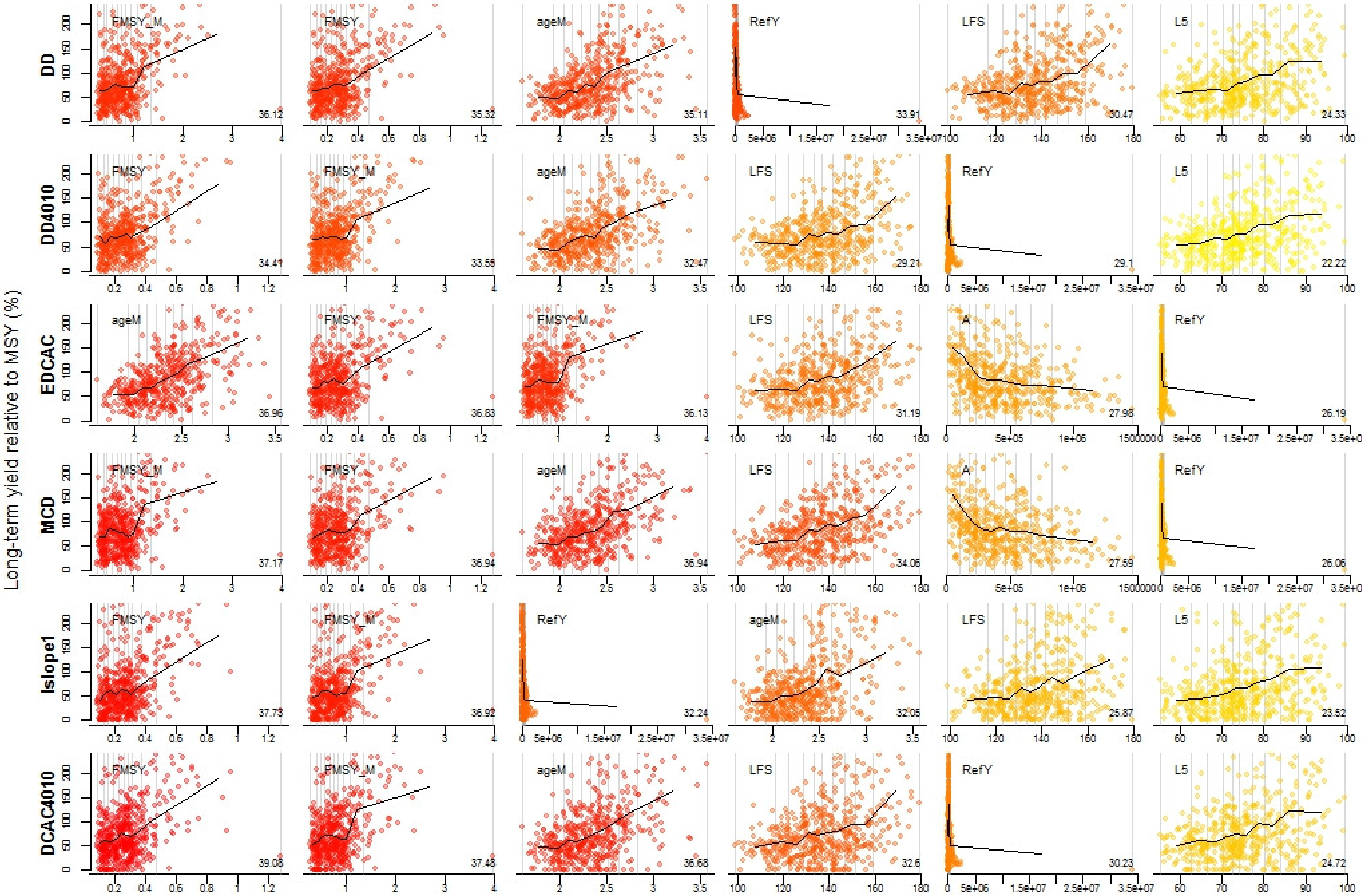


Figure 3.3.4.5 Value of information that detects relevant operating model parameters that are most correlated with utility for the St. Thomas spiny lobster base operating model (15%LH, High dome selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and operating model parameters are as defined in Table 3.1.

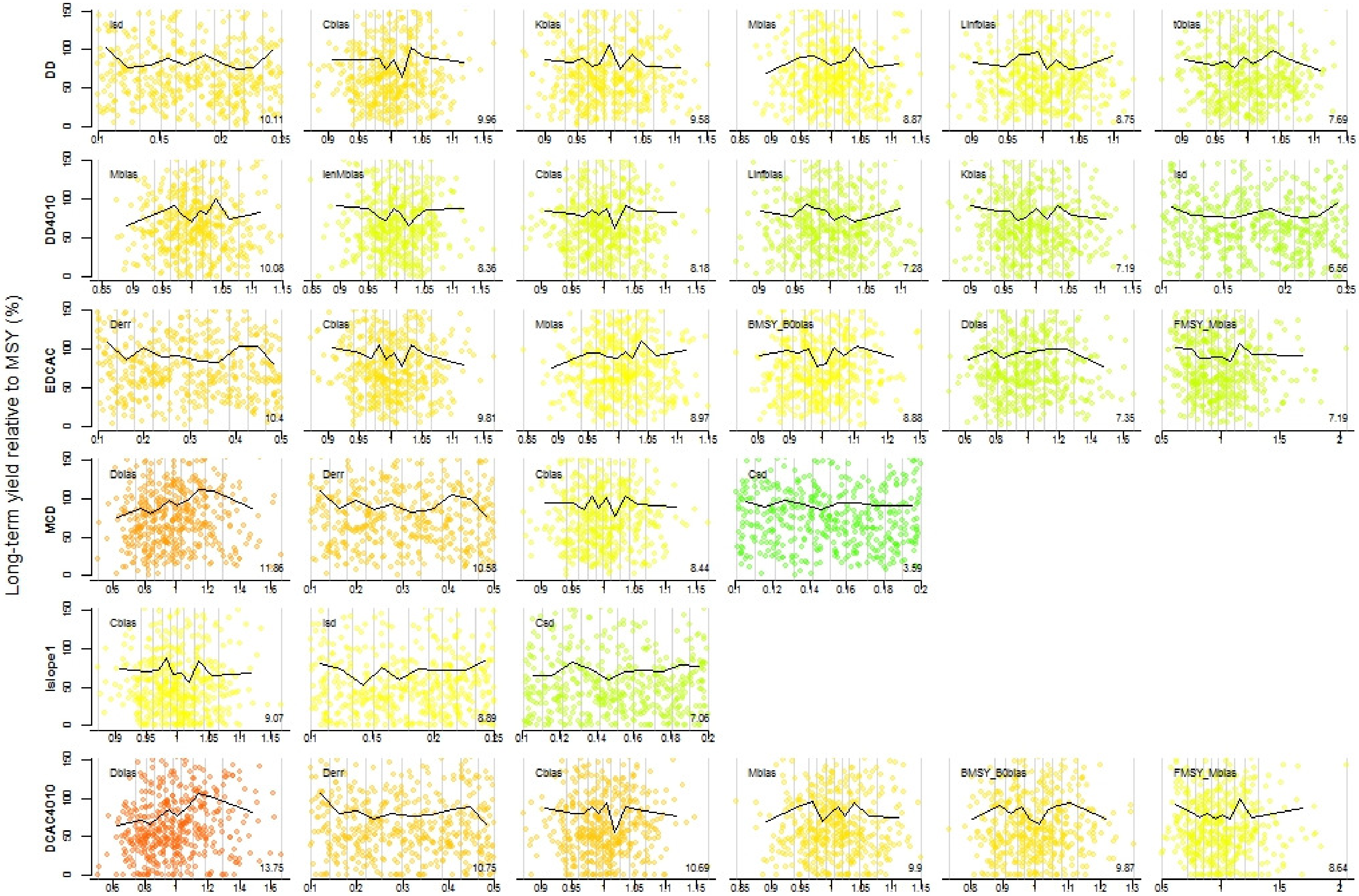


Figure 3.3.4.6 Value of information that detects relevant observation model parameters that are most correlated with utility for the St. Thomas spiny lobster base operating model (15%LH, High dome selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and observation model parameters are as defined in Table 3.1.

3.3.4.3 Performance of management procedures

MP performance results against the three MSE performance criteria (PNOF, B50, AAVY) selected by the SEDAR 46 DW/AW Panel as well as relative long-term yield (LTY) are provided in Table 3.3.4.1 for the St. Thomas spiny lobster base (15%LH, High dome selex) and two alternative (15%LH, Moderate dome selex; 5%LH, Moderate dome selex) OMs.

Sensitivity of the data quality in the observation subclass (i.e., imprecise and biased data inputs) resulted in very different trends in model performance in the MSE. The top 6 methods tend to be index-based methods, with substantially lower relative long-term yields compared to when data inputs were assumed precise and unbiased (Table 3.3.4.2). Those MPs identified as optimal when assuming precise and unbiased data inputs no longer fall within the top 6 according to selection criteria.

Table 3.3.4.1 Performance of management procedures within the MSE for the St. Thomas spiny lobster base (15%LH, High dome selex) and alternative fleet (15% LH, Moderate dome selex) and stock/fleet (5%LH, Moderate dome selex) operating models as determined using the performance metrics specified by the SEDAR 46 DW/AW Panel.. PNOF = probability of not overfishing (%), B50 = probability of the biomass being above half BMSY (%), LTY = relative long-term yield, defined as the fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection, and AAVY = fraction of simulations where average annual variability in yield < 15%. MPs are as defined in Table 3.1.

	Base Stock					Alt Stock/Fleet					Alt Stock/Fleet			
	15% LH, highly-dome					5% LH, moderate-dome					15% LH, moderate-dome			
MP	PNOF	B50	LTY	AAVY	MP	PNOF	B50	LTY	AAVY	MP	PNOF	B50	LTY	AAVY
Reference MP														
FMSYref	70.5	93.3	84.6	99.2	FMSYref	68.3	92.5	99.7	99.8	FMSYref	69.4	92.6	99.2	99.8
MPs producing 6 highest long-term yields that meet criteria														
EDCAC	52.8	96	72.5	64.4	EDCAC	54.9	95.4	85.3	65.8	EDCAC	54.4	95.5	85.4	69.6
MCD	64.3	96.4	71.7	71.4	Fratio	55.7	87.6	84.2	51.8	Fratio	56.1	87.3	84.9	54.4
DD	67.3	92.1	68.6	98.4	MCD	66.4	96	83.8	75.4	DD	67.7	90.8	83.7	98.6
DD4010	77.9	95.3	66.7	76.2	DD	67.8	91.3	83.5	98.6	MCD	66.5	96	83.5	77.4
DCAC4010	82.4	97.8	62.2	66.8	DD4010	78.1	95.2	81.9	79.6	DD4010	77.1	94.5	80.7	78
Islope1	63.3	87.8	53.3	95.8	DCAC4010	85.7	97.6	72.9	69.4	DCAC4010	85.2	97.5	74.2	69.8
Other MPs producing lower long-term yields that meet criteria														
Islope4	64	87.6	52.2	95.8	Islope1	67.4	87.2	66	97.2	Islope1	65.6	86.7	67.3	96.8
LstepCC4	65.7	88.1	48.6	96.2	Islope4	67.9	87	61.3	97.2	IT10	72.1	91.5	63	98.8
LstepCC1	65.6	88.1	48.5	96.2	ITM	70.8	92.2	60.8	99.6	Islope4	66.3	86.6	62.3	96.6
ITM	68.2	93.3	48.5	99.2	IT10	73.2	92.1	59.8	99	ITM	69.9	92	60.8	98.8
IT5	71	91.2	47.8	97.4	IT5	75.1	91	58.2	98.8	IT5	74	90.3	57.3	97.8
Itarget1	59.5	88.8	47.5	99.8	Itarget1	59.6	86.2	57.1	100	Itarget1	60.1	86.4	57.1	99.4
IT10	69.4	92.3	46.3	98.6	LstepCC4	69.6	87.6	55.5	97.4	LstepCC4	68.4	87	56.6	96.8
CC4	53.9	82.1	43.6	95	LstepCC1	69.5	87.6	54.9	97.4	LstepCC1	68.3	87	55.5	96.8
SPMSY	68.1	85.5	39.1	93	CC4	55	80.6	53	96.6	CC4	56.1	81.7	54.9	96.2
Ltarget4	88	95.9	12.2	99.6	SPMSY	67.9	83.5	47.2	92.2	SPMSY	67.5	84	46.2	92
Itarget4	99.1	97.9	0	64.4	Ltarget4	88	94.2	14.8	99.8	Ltarget4	88.2	94	14.2	100
					Itarget4	98.9	97.5	0	73.2	Itarget4	98.8	97.4	0.2	67.6

Table 3.3.4.2 Comparison of the top 6 management procedures between the St. Thomas spiny lobster base operating model assuming precise and unbiased data inputs and an alternative operating model assuming imprecise and biased data inputs. Numbers in parentheses represent the relative long-term yield from the management strategy evaluation.

Imprecise-Biased	Precise-Unbiased
DD (61.5)	EDCAC (72.5)
Islope1 (44.7)	MCD (71.7)
Islope4 (43.5)	DD (68.6)
IT10 (40.2)	DD4010 (66.7)
ITM (40.2)	DCAC4010 (62.2)
IT5 (39.4)	Islope1 (53.3)

3.3.4.4 Calculation of TACs using real world data

Figure 3.3.4.7 provides resulting total allowable catch (TAC) calculations from the MPs that produced the 6 highest relative yields in the MSE and met the performance criteria as specified by the SEDAR 46 DW/AW Panel. In the SEDAR46 evaluations, the TAC calculations are considered equivalent to the overfishing limit (OFL). However, it should be noted that adoption of one or more of these TACs as a harvest control rule may not necessarily achieve maximum sustainable yield in equilibrium (which is difficult to estimate in data-limited situations). Instead the TAC represents a level of yield consistent with the selected management objectives and performance criteria recommended by the DW/AW Panel and is heavily dependent upon the reliability of data inputs. Summary statistics on calculated TACs from the real world data (provided in Appendix 4.3.4) are provided in Table 3.3.4.3 for all of the feasible MPs meeting the performance criteria specified by the SEDAR 46 DW/AW Panel.

Table 3.3.4.3 Summary of total allowable catch (TACs) calculations (pounds x 1000s) provided by management procedures that met the SEDAR 46 DW/AW Panel performance criteria for St. Thomas spiny lobster. MPs are as defined in Table 3.1.

	Summary statistics				
MP	Minimum	25th Percentile	Median	75th Percentile	Maximum
MPs producing 6 highest long-term yields that meet management criteria					
DD4010	57.788	399.78	975.309	2093.507	14037.83
DD	42.888	420.632	869.317	1959.024	18334
Islope1	34.146	64.716	74.327	84.898	137.648
MCD	4.271	22.374	37.994	58.522	163.253
Other MPs that meet management criteria					
SPMSY	34.351	71.492	96.269	119.107	150.547
CC4	24.725	52.999	60.922	71.612	115.889
Itarget1	34.357	50.268	59.332	70.475	104.463
Islope4	30.786	45.473	52.064	60.951	89.433
Itarget4	17.124	31.27	35.017	41.316	63.534

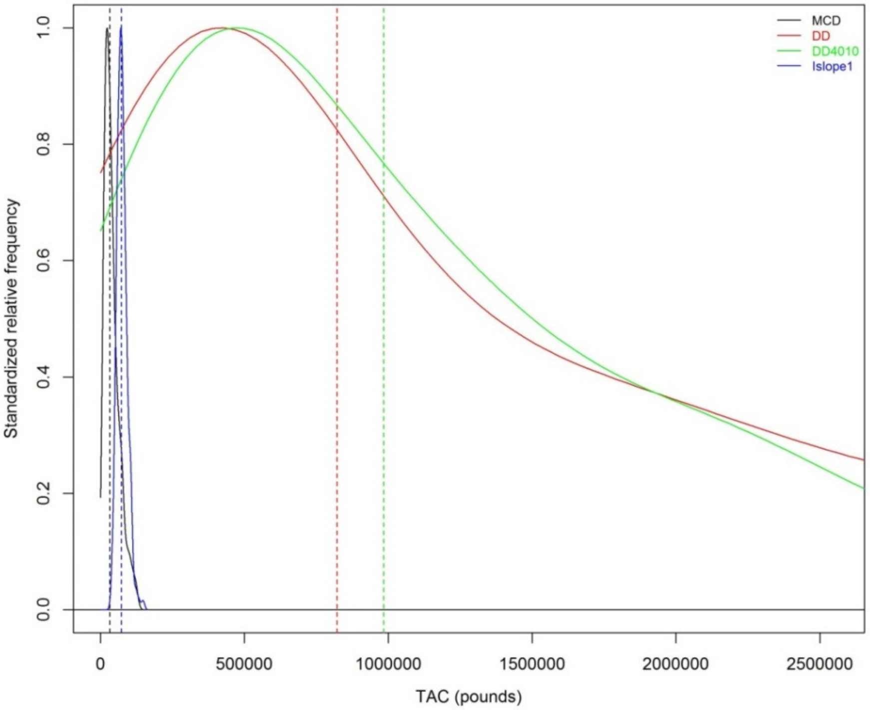


Figure 3.3.4.7 Total allowable catch (TAC) calculations (pounds) for St. Thomas spiny lobster obtained from the management procedures that met the SEDAR 46 DW/AW Panel performance criteria and also produced the 6 highest relative long-term yields in the management strategy evaluation. Note that only 4 of the top 6 are applicable based on current data availability and/or management procedure configuration. MPs are as defined in Table 3.1.

The effect of varying real world parameter inputs on the recommended TACs for each MP was evaluated using a sensitivity analysis available within DLMtool. Figure 3.3.4.8 provides sensitivity results for all applicable MPs which produced the highest relative long-term yields in the MSE. Sensitivities in parameter estimates were evident, with higher TACs obtained for the following MPs: in MCD as Cat and Dep increased; and in Islope1 as Cat increased.

In addition, real world parameter inputs were varied for several key parameters to assess the sensitivity of TAC calculations to data inputs including CV_Cat, Abun, Dep, Mort, vbLinf, and vbK. Figures 3.3.4.9 − 3.3.4.10 provide results for the MPs requiring each data input. Calculated TACs from most MPs were relatively similar when CV_Cat was doubled, with the exception of DD and DD4010. In contrast, changes to both Abun and Dep and life history parameters (Mort, vbLinf, vbK) had a substantial impact on TACs where these inputs were required. Tables 3.3.4.4 − 3.3.4.6 provide the calculated TACs for all sensitivity runs.

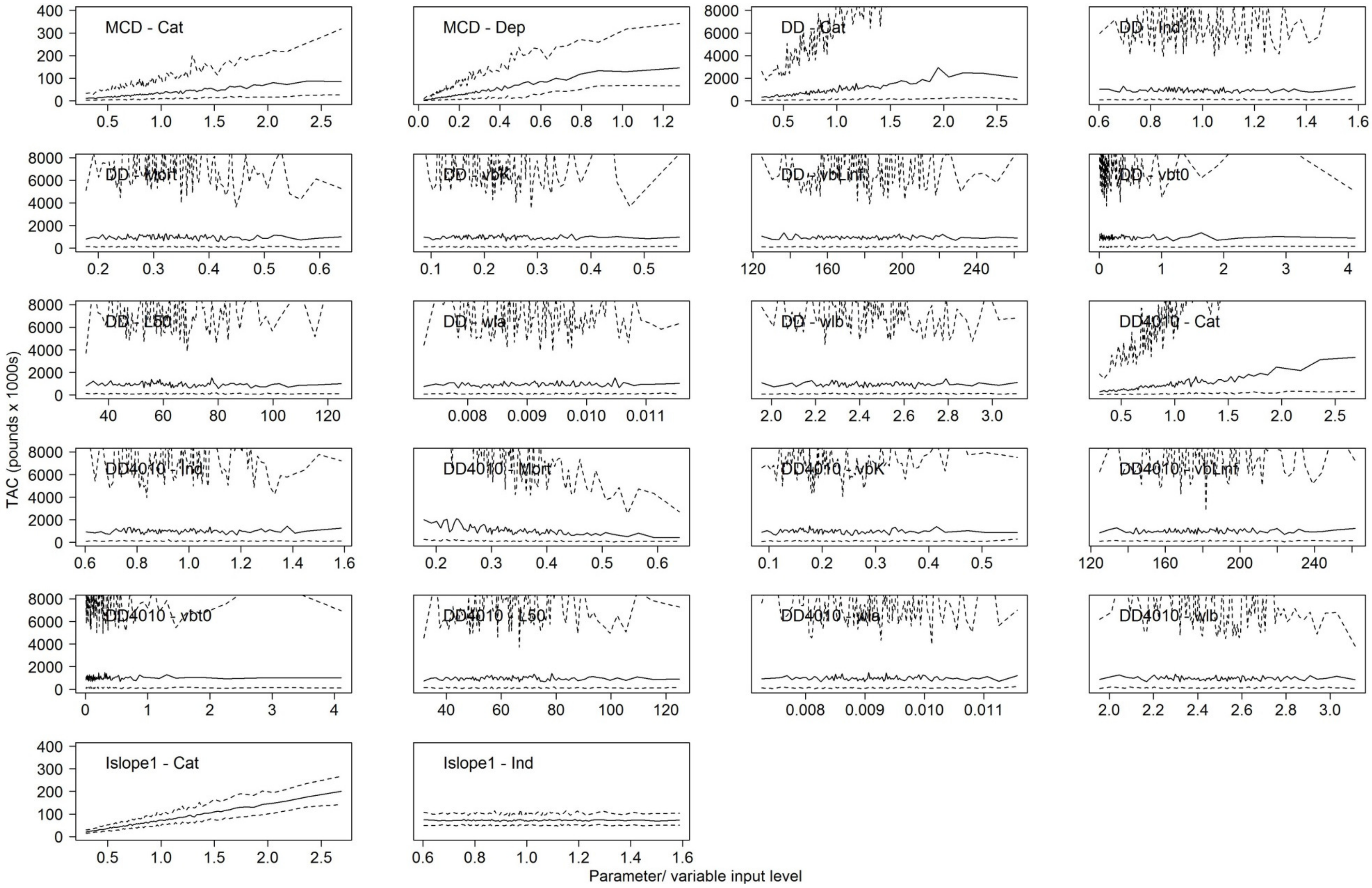


Figure 3.3.4.8 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) for the applicable highest yielding management procedures to varying input parameters for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1.. Dashed lines reflect 5% and 95% confidence intervals.

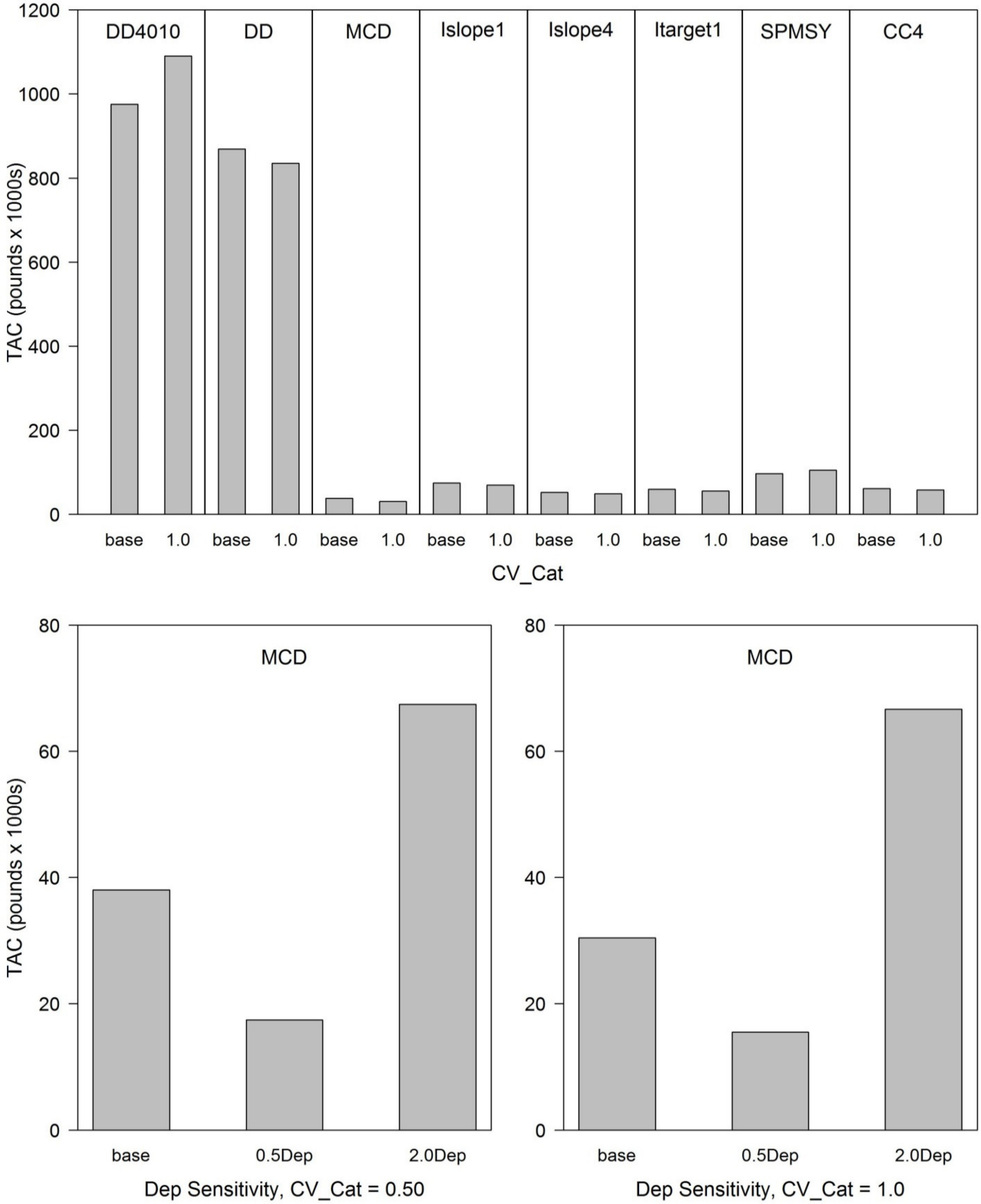


Figure 3.3.4.9 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including CV_Cat, and Dep for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1.

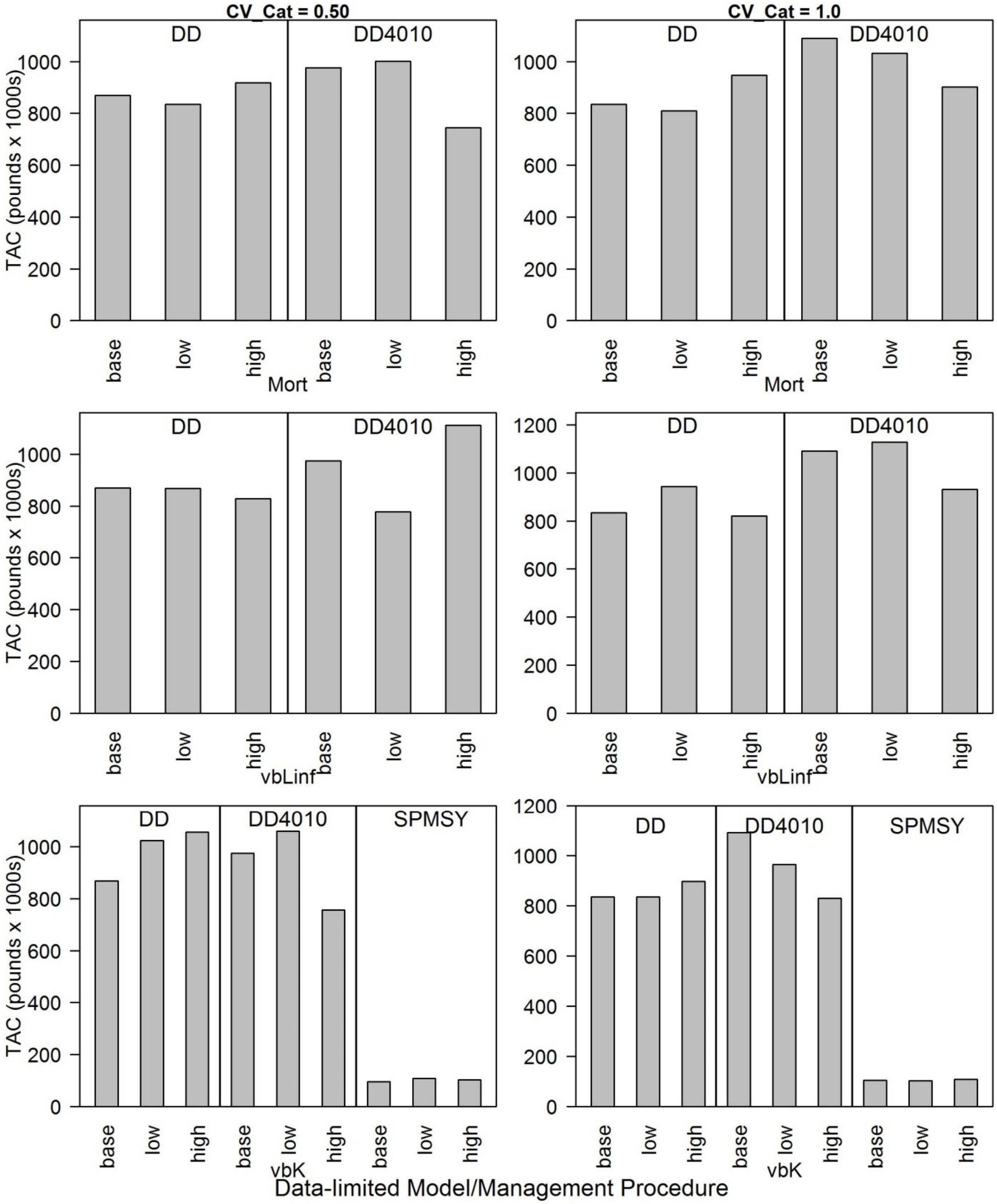


Figure 3.3.4.10 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including Mort, vbLinf, and vbK for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1.

Table 3.3.4.4 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the coefficient of variation for catch (CV_Cat) for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1.

MP	TAC (pounds x 1000s) 0.50 (CV_Cat, base)	 1.0 (2.0 x CV_Cat)
DD4010	975.309	1090.472
DD	869.317	835.180
MCD	37.994	30.392
Islope1	74.327	69.026
Islope4	52.064	48.403
Itarget1	59.332	55.293
Itarget4	35.017	33.200
SPMSY	96.269	104.859
CC4	60.922	57.945

Table 3.3.4.5 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the current depletion value for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1.

MP	Abundance (Abun)	Depletion (Dep)	TAC (pounds x 1000s) 0.50 (CV_Cat, base)	 1.0 (2.0 x CV_Cat)
Depletion				
MCD	–	0.26 (Dep base)	17.283	16.257
	–	0.13 (0.5 x Dep)	8.825	9.851
	–	0.52 (2.0 x Dep)	40.356	32.828

Table 3.3.4.6 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to natural mortality (Mort), asymptotic length (vbLinf), and growth rate (vbK) values for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1.

MP	Input	TAC (pounds x 1000s) 0.50 (CV_Cat, base)	1.0 (2.0 x CV_Cat)
Mort			
DD	0.350 (base)	869.317	835.180
	0.298 (low)	835.596	810.060
	0.403 (high)	918.566	947.948
DD4010	0.350 (base)	975.309	1090.472
	0.298 (low)	1001.204	1032.226
	0.403 (high)	744.144	902.754
vbLinf			
DD	183 (base)	869.317	835.180
	155 (low)	868.771	942.750
	210 (high)	828.569	819.925
DD4010	183 (base)	975.309	1090.472
	155 (low)	777.284	1128.593
	210 (high)	1112.256	931.472
vbK			
DD	0.240 (base)	869.317	835.180
	0.204 (low)	1022.988	835.463
	0.276 (high)	1056.827	897.136
DD4010	0.240 (base)	975.309	1090.472
	0.204 (low)	1060.007	964.145
	0.276 (high)	756.983	828.795
SPMSY	0.240 (base)	96.269	104.859
	0.204 (low)	107.880	102.638
	0.276 (high)	102.902	108.559

Table 3.3.4.7 provides a brief summarization of MSE results and inherent assumptions for each applicable method and can help guide which MP to select for TAC calculation. For St. Thomas spiny lobster, areas of concern include:

- **Life history input (Mort, L50, vbt0, vbK, vbLinf, wla, wlb, MaxAge):** the LHWG identified substantial uncertainty in the MaxAge and Mort.
- **Catch input (Cat):** underreporting of catch.
- **Index input (Ind):** appropriateness of: adjusted effort (Eff1) as an indicator of fishing effort; and 2) of the trend in relative abundance derived from the pots and traps fishery.
- **Depletion input (Dep):** method for estimating depletion provides very uncertain estimates of current stock biomass and (equilibrium) fishing mortality rate from growth, natural mortality rate, recruitment and fishing selectivity. In addition, the mean length from the pots and traps fishery is considered an appropriate and reliable indicator of trend in resource.
- **Fishery input (LFC):** appropriateness of TIP data for the pots and traps fishery in quantifying the length at first capture.

In general, MPs cannot realize the full complexity of the biology (e.g., time- and age-varying natural mortality, molting) or fishery characteristics (e.g., change in fishing operations, regulations, dome-shaped selectivity).

Table 3.3.4.7 Guidance table of inherent assumptions within management procedures for calculating the total allowable catch for St. Thomas spiny lobster. MPs and data inputs are as defined in Table 3.1. Performance metrics are as defined in Table 3.3.4.1.

Parameter	**Dep-based**	**Data-moderate**		**Index-based**				**Catch-based**	
	MCD	**DD**	**DD4010**	**Islope1**	**Islope4**	**Itarget1**	**Itarget4**	**SPMSY**	**CC4**
PNOF	64.3	67.3	77.9	63.3	64.0	59.5	99.1	68.1	53.9
B50	96.4	92.1	95.3	87.8	87.6	88.8	97.9	85.5	82.1
LTY	71.7	68.6	66.7	53.3	52.2	47.5	0.0	39.1	43.6
AAVY	71.4	98.4	76.2	95.8	95.8	99.8	64.4	93.0	95.0
Mort		Known, constant across age							
L50		Life history characterizations reflective of STT						Life history characterizations reflective of STT	
vbt0									
vbK									
vbLinf									
wla									
wlb									
MaxAge		Age characterizations reflective of STT						Age characterizations reflective of STT	
Cat	Known, informative of historical removals								
Ind		Fishery dependent representative of population abundance, dependent upon accurate effort reporting							
Dep	Known, estimated from TIP samples and life history								

3.3.5 St. Croix spiny lobster

3.3.5.1 Model stability

Model stability was evaluated graphically and through inspection of the convergence values for each performance metric across simulations for all MPs. All of the feasible MPs within the MSE converged at the 1% criteria level. Convergence plots for standard performance metrics in the MSE are shown in Figure 3.3.5.1 for the base OM (15%LH, High dome selex). The majority of MPs appear to have converged by approximately 300 simulations for each performance metric.

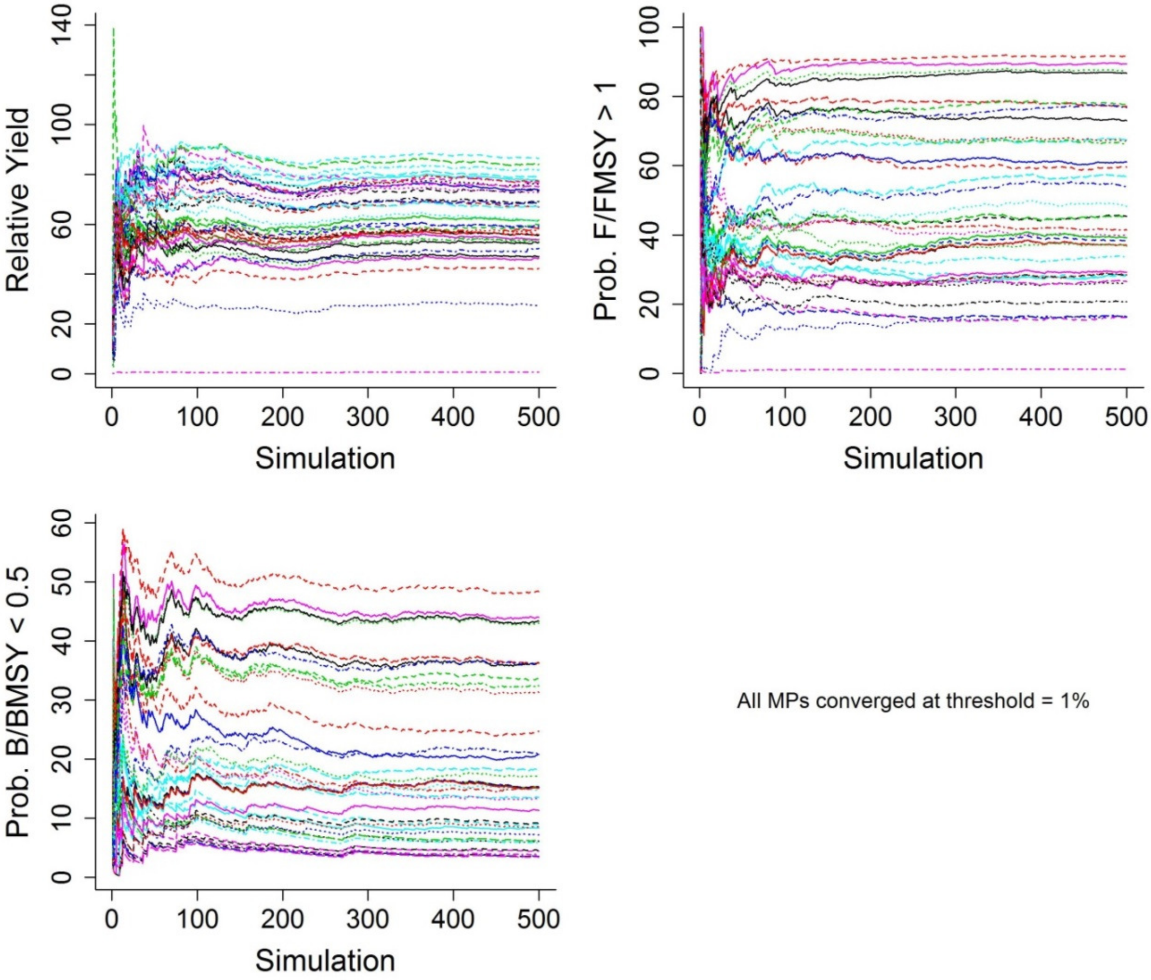


Figure 3.3.5.1 Convergence of performance metrics for each MP within the management strategy evaluation for St.Croix spiny lobster using the base operating model (15%LH, High dome selex). Colored lines each reflect an MP.

3.3.5.2 Operating model evaluation

The consistency of MSE results across varying assumptions on stock and fleet dynamics in the OM was examined with respect to life history (stock) and fishery (fleet) characterizations as described in Section 3.2.2.1. Tables 3.2.3 – 3.2.6 provided specifics on stock and fleet dynamics and alternative characterizations considered in the the base operating model (15%LH, high dome selex) and two alternative operating models: (1) 15%LH, Moderate dome selex and (2) 5%LH, Moderate dome selex.

Performance between MPs within the MSEs was further examined by investigating tradeoff plots among OMs. Figures 3.3.5.2 − 3.3.5.4 present the tradeoff plots for the base (15%LH, High dome selex) and two alternative OMs (5%LH, Moderate dome selex; 15%LH, Moderate dome selex). Metrics shown in the tradeoff plots are the Panel-selected performance metrics as defined in Section 3.2.4. MPs located within the top-right corner in each panel are preferred according to the AW Panel performance criteria. MPs yielding the highest *Pr*(NOF ≥ 50%), *Pr*(B50 ≥ 50%), and *Pr*([AAVY 15%] ≥ 50%) were similar between the base and sensitivity OMs. Specific details on definitions of performance metrics were previously provided in Section 3.2.4.

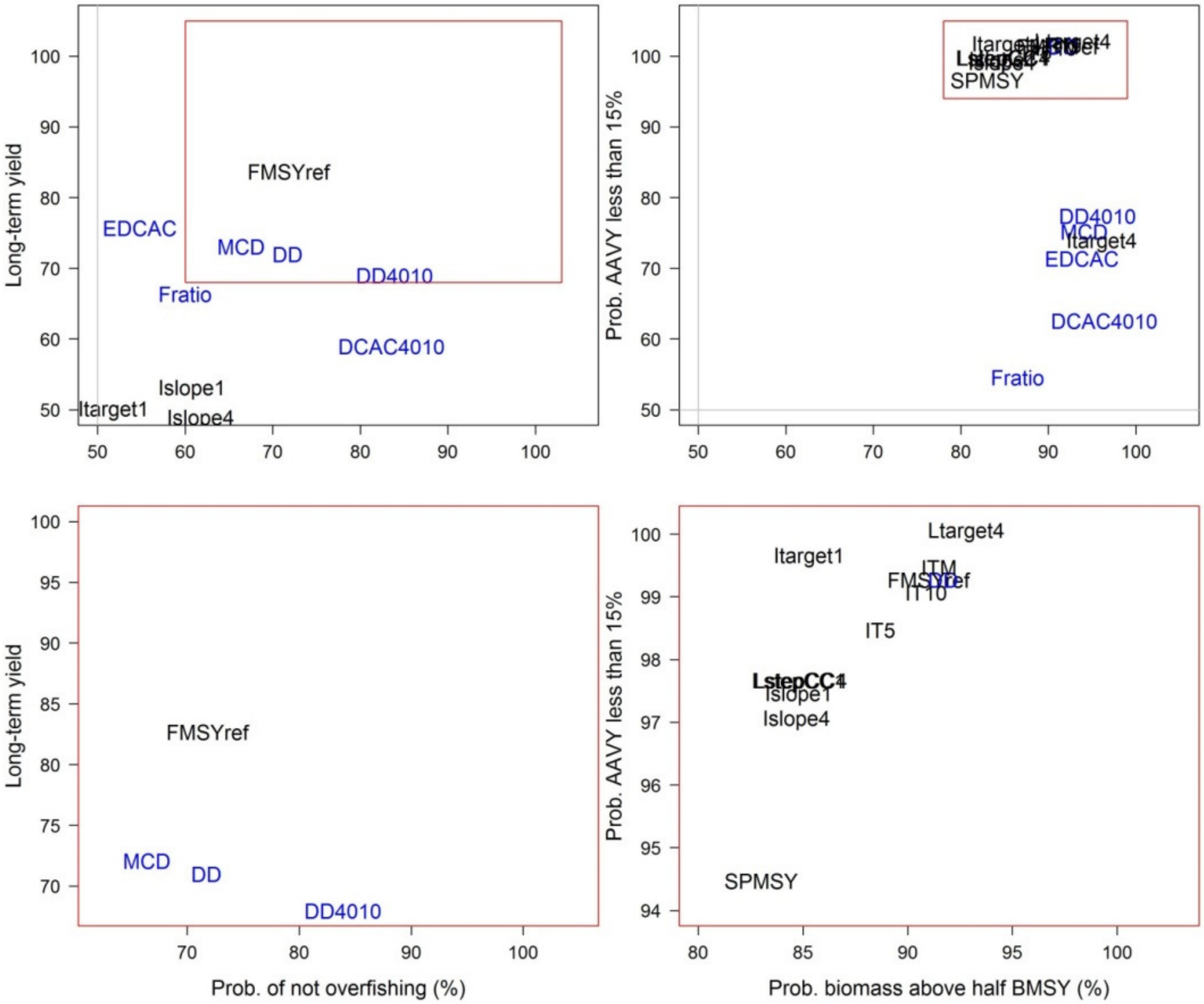


Figure 3.3.5.2 Tradeoffs in performance metrics between management procedures for the St. Croix spiny lobster base operating model (15%LH, High dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panels. MPs are as defined in Table 3.1.

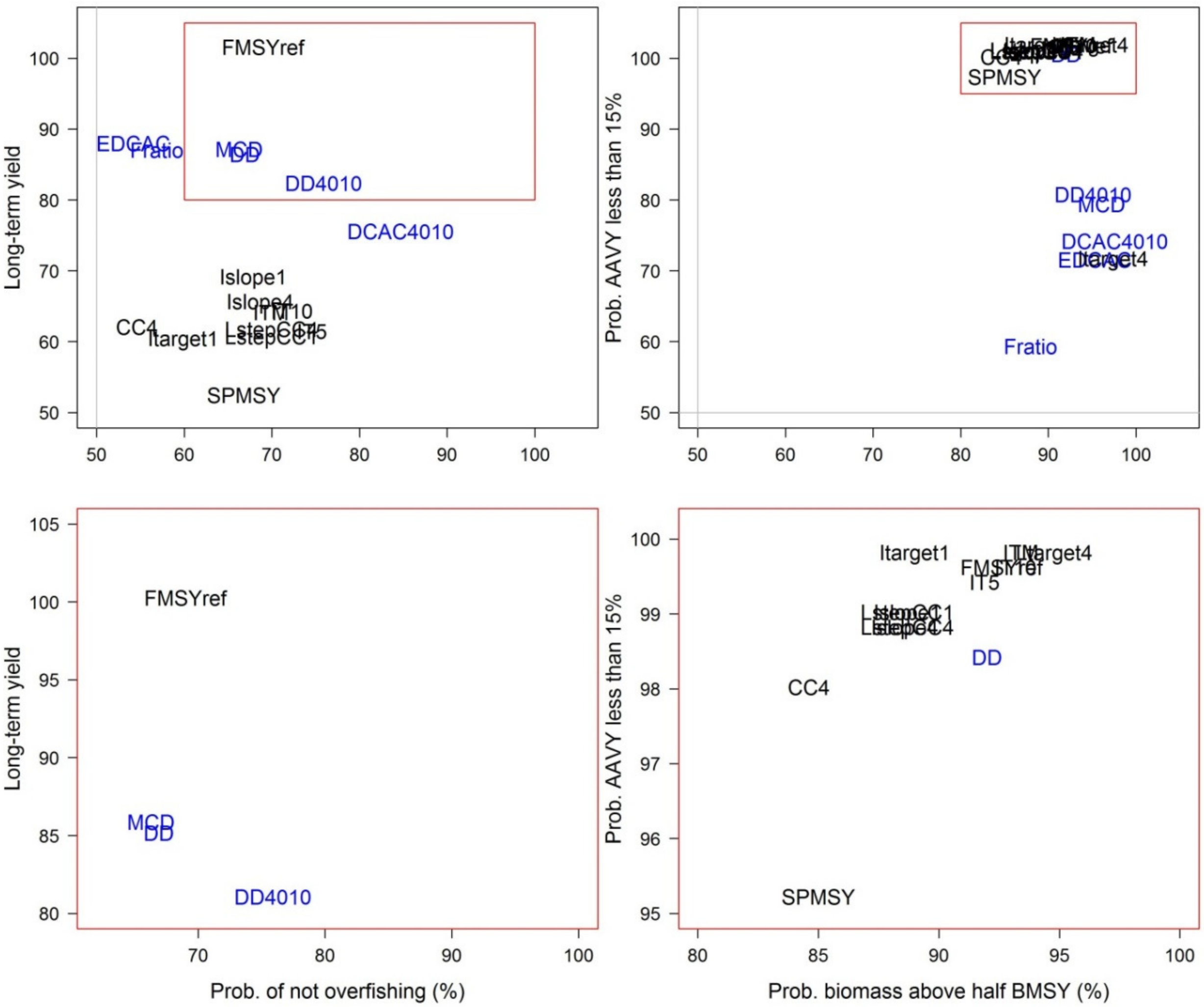


Figure 3.3.5.3 Tradeoffs in performance metrics between management procedures for the St. Croix spiny lobster alternative operating model (15%LH, Moderate dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the SEDAR 46 DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot. MPs are as defined in Table 3.1.

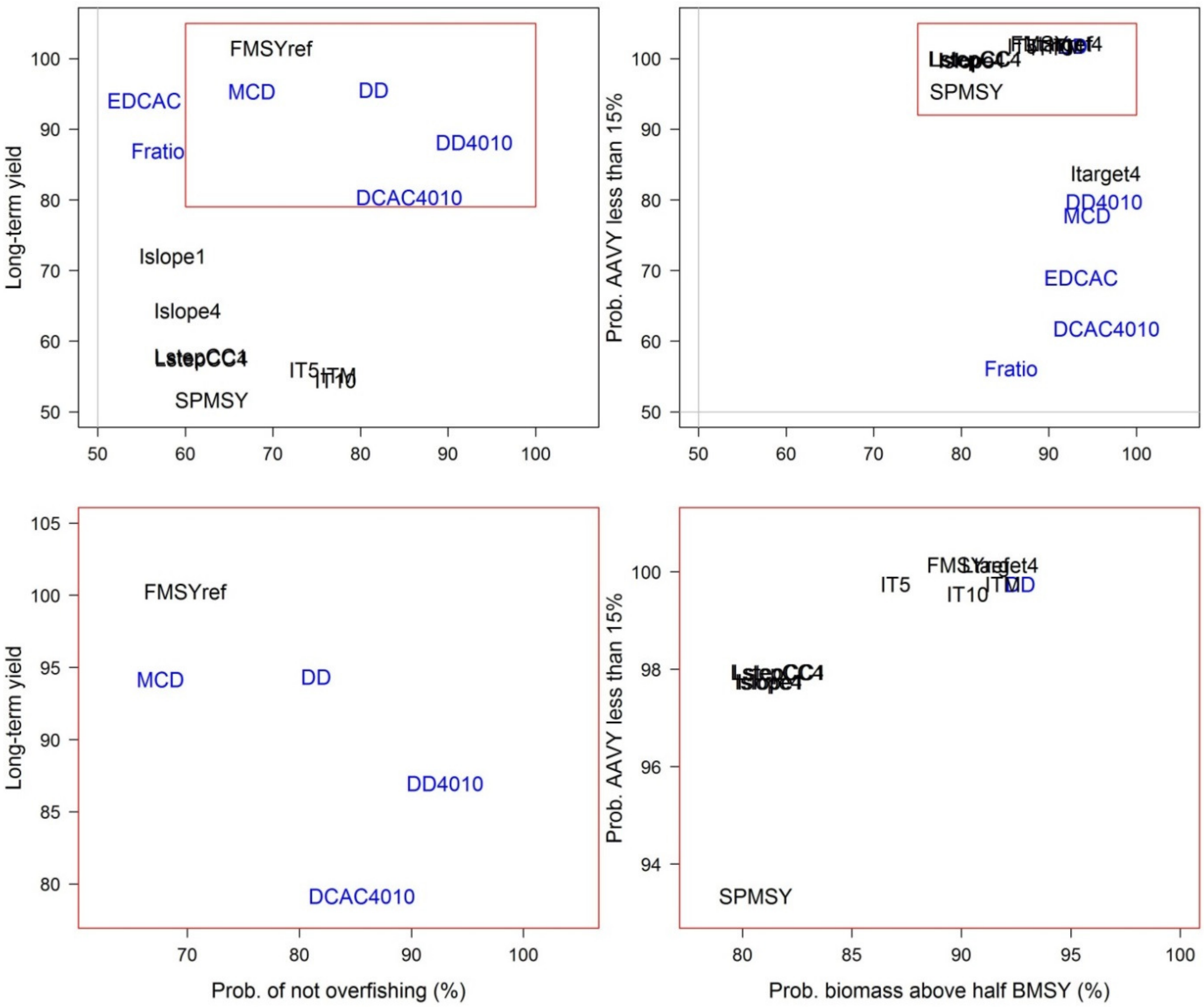


Figure 3.3.5.4 Tradeoffs in performance metrics between management procedures for the St. Croix spiny lobster alternative operating model (5%LH, Moderate dome selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the SEDAR 46 DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot. MPs are as defined in Table 3.1.

Additional information to aid in understanding the contribution of information included in the operating model is shown in Figures 3.3.5.5 − 3.3.5.6. These figures are a graphical visualization of the value of information in the OM, a metric which identifies relevant parameters in the operating and observation models that are most correlated with utility. For the operating model parameters (Figure 3.3.5.5), the highest correlations occurred between long-term yield relative to MSY and estimates of ageM for all MPs with the exception of DD. For DD, FMSY_M was most correlated with the long-term yield relative to MSY. For the observation model parameters (Figure 3.3.5.6), parameters displaying the highest correlations with long-term yield relative to MSY were more divergent across MPs. These parameters included Cbias for DD, Mbias for DD4010, Dbias for EDCAC, MCD, and DCAC4010, and Abias for Fratio. These results may be used to inform data collection, by identifying which inputs are more important in assessing OM behavior.

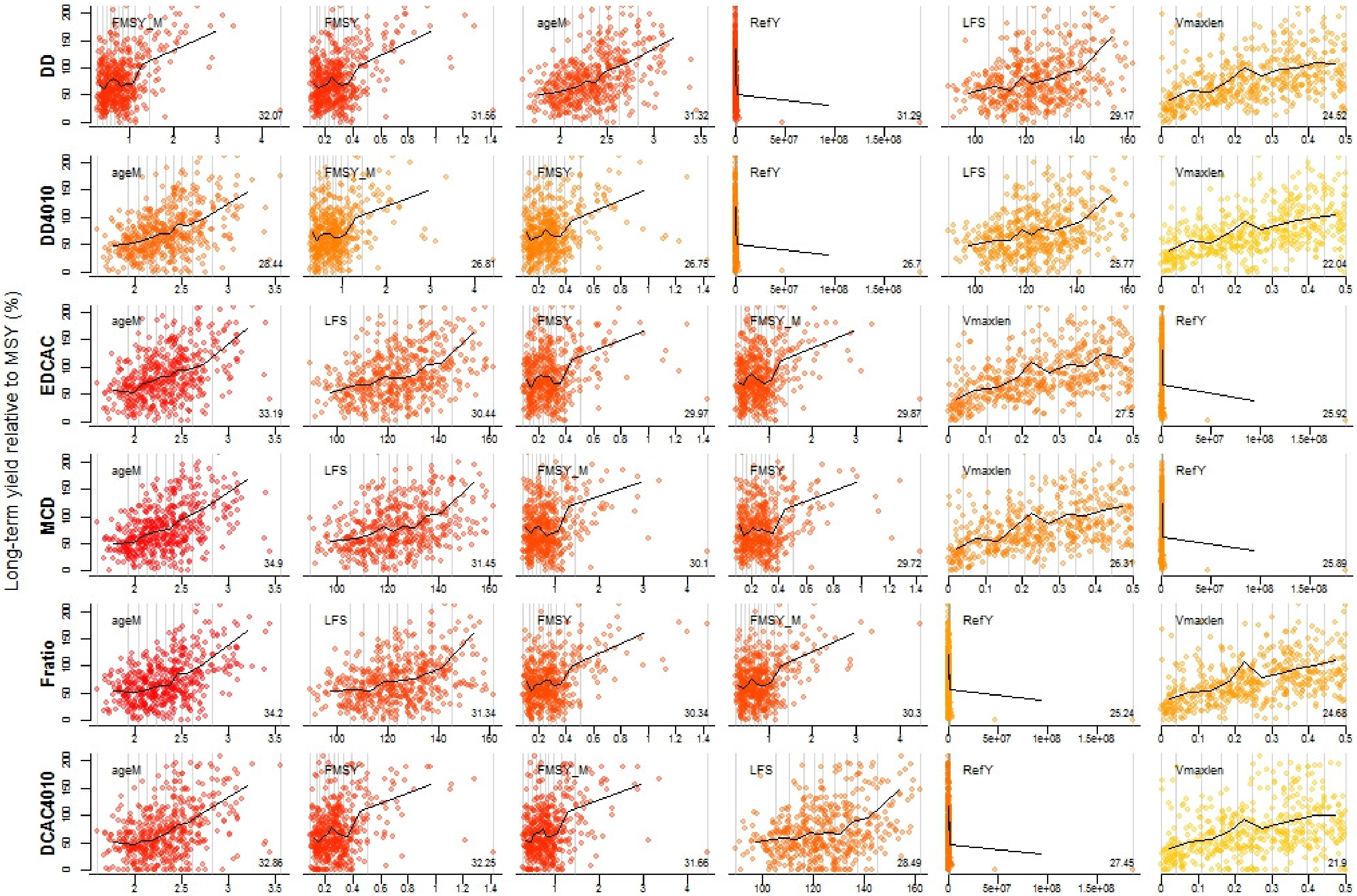


Figure 3.3.5.5 Value of information that detects relevant operating model parameters that are most correlated with utility for the St. Croix spiny lobster base operating model (15%LH, High dome selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and operating model parameters are as defined in Table 3.1.

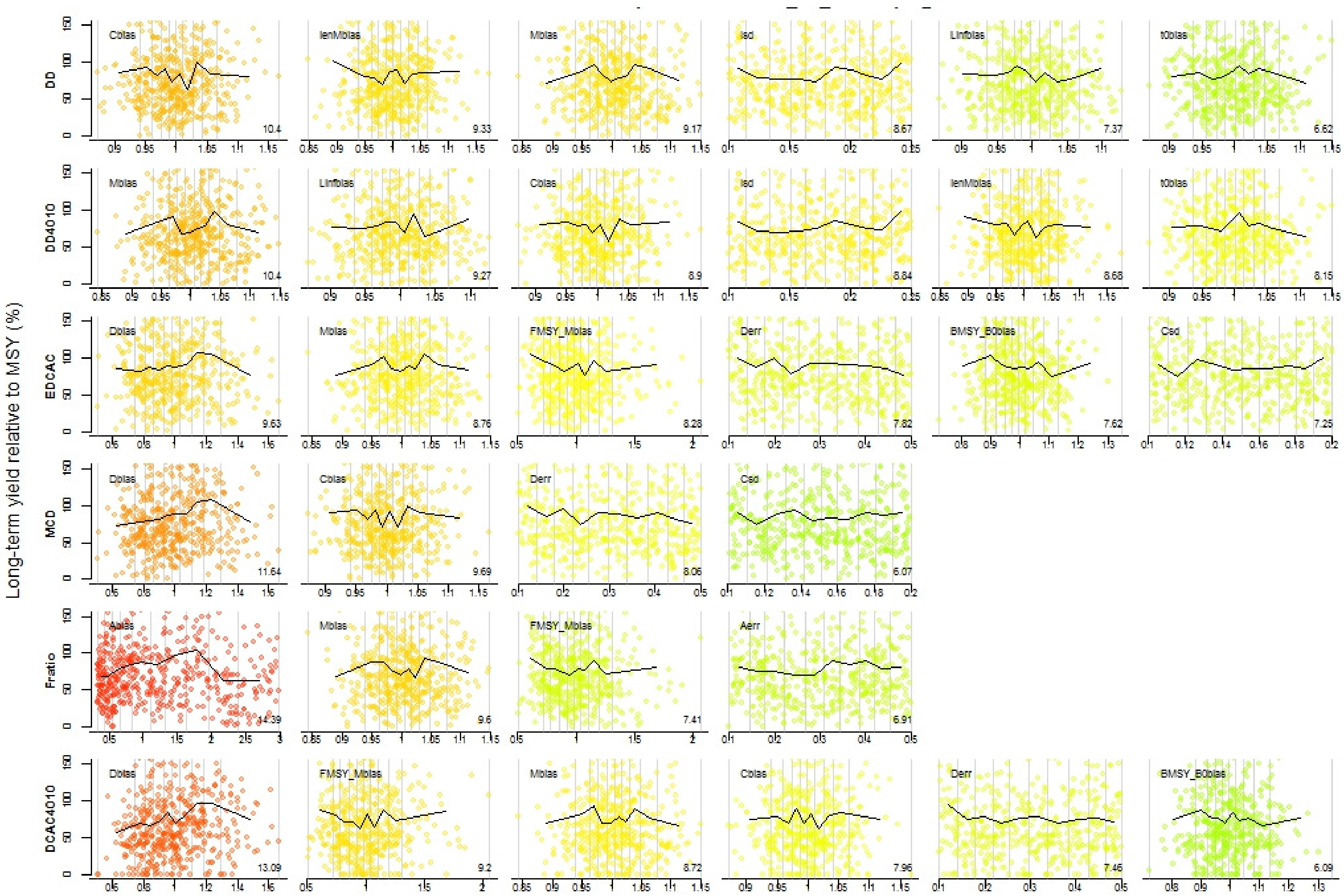


Figure 3.3.5.6 Value of information that detects relevant observation model parameters that are most correlated with utility for the St. Croix spiny lobster base operating model (15%LH, High dome selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and observation model parameters are as defined in Table 3.1.

3.3.5.3 Performance of management procedures

MP performance results against the three MSE performance criteria (PNOF, B50, AAVY) selected by the SEDAR 46 DW/AW Panel as well as relative long-term yield (LTY) are provided in Table 3.3.5.1 for the St. Croix spiny lobster base (15%LH, High dome selex) and two alternative (15%LH, Moderate dome selex; 5%LH, Moderate dome selex) OMs.

Sensitivity of the data quality in the observation subclass (i.e., imprecise and biased data inputs) resulted in very different trends in model performance in the MSE. The top 6 methods tend to be index-based methods, with substantially lower relative long-term yields compared to when data inputs were assumed precise and unbiased (Table 3.3.5.2). Those MPs identified as optimal when assuming precise and unbiased data inputs no longer fall within the top 6 according to selection criteria.

Table 3.3.5.1 Performance of management procedures within the MSE for the St. Croix spiny lobster base (15%LH, High dome selex) and alternative fleet (15% LH, Moderate dome selex) and stock/fleet (5%LH, Moderate dome selex) operating models. PNOF = probability of not overfishing (%), B50 = probability of the biomass being above half BMSY (%), LTY = relative long-term yield, defined as the fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection, and AAVY = fraction of simulations where average annual variability in yield < 15%. MPs are as defined in Table 3.1.

	Base Stock					Alt Stock/Fleet					Alt Fleet			
	15% LH, highly-dome					5% LH, moderate-dome					15% LH, moderate-dome			
	PNOF	B50	LTY	AAVY		PNOF	B50	LTY	AAVY		PNOF	B50	LTY	AAVY
Reference MP														
FMSYref	71.8	91	81.3	99	FMSYref	69.8	90.3	99.1	99.8	FMSYref	69	92.6	99.2	99.4
MPs producing 6 highest long-term yields that meet criteria														
EDCAC	54.8	93.8	73.3	69	DD	81.5	92.7	93.2	99.4	EDCAC	54.2	95.3	85.6	69.2
MCD	66.4	94.1	70.7	72.8	MCD	67.6	94.4	93	75.4	MCD	66.3	96.1	84.8	77
DD	71.7	91.7	69.6	99	EDCAC	55.3	93.7	91.7	66.6	Fratio	56.9	88	84.7	57
DD4010	83.9	95.6	66.6	75	DD4010	93	96.3	85.8	77.4	DD	66.9	92	84.1	98.2
Fratio	60	86.5	64	52.2	Fratio	56.9	85.7	84.6	53.8	DD4010	75.9	95.1	80	78.4
DCAC4010	83.6	96.4	56.6	60.2	DCAC4010	85.6	96.6	78	59.4	DCAC4010	84.7	97.6	73.2	71.8
Other MPs producing lower long-term yields that meet criteria														
Islope1	60.8	84.8	50.8	97.2	Islope1	58.6	81.3	69.7	97.4	Islope1	67.9	88.7	66.8	98.8
Itarget1	51.8	85.3	47.8	99.4	Islope4	60.3	81.2	62	97.4	Islope4	68.7	88.6	63.3	98.6
Islope4	61.8	84.7	46.6	96.8	LstepCC1	61.8	81.7	55.5	97.6	IT10	72.3	93.2	62	99.4
LstepCC1	63	84.8	44	97.4	LstepCC4	61.9	81.6	55.2	97.6	ITM	69.9	93.4	61.8	99.6
LstepCC4	63	84.9	44	97.4	IT5	73.6	87	53.6	99.4	CC4	54.6	84.6	59.7	97.8
IT10	71.6	90.9	43.4	98.8	ITM	77.5	91.9	52.8	99.4	LstepCC4	70	88.7	59.4	98.6
ITM	71.5	91.5	43.4	99.2	IT10	77.2	90.3	52.1	99.2	IT5	74.6	91.9	59.1	99.2
SPMSY	63.3	83	40.7	94.2	SPMSY	63	80.6	49.3	93	LstepCC1	70	88.7	58.4	98.8
IT5	70.8	88.7	40.2	98.2	Ltarget4	80.6	91.8	24.2	99.8	Itarget1	59.9	89	58.1	99.6
Ltarget4	83.7	92.8	16.6	99.8	Itarget4	98.2	96.5	0	81.4	SPMSY	66.8	85	50.1	95
Itarget4	98.7	96.1	0	71.6						Ltarget4	87	94.8	18.4	99.6
										Itarget4	98.8	97.4	0	69.4

Table 3.3.5.2 Comparison of the top 6 management procedures between the St. Croix spiny lobster base operating model assuming precise and unbiased data inputs and an alternative operating model assuming imprecise and biased data inputs. Numbers in parentheses represent the relative long-term yield from the management strategy evaluation.

Imprecise-Biased	Precise-Unbiased
DD (62.6)	EDCAC (73.3)
Islope1 (44.3)	MCD (70.7)
Islope4 (41.2)	DD (69.6)
LstepCC4 (38.2)	DD4010 (66.6)
ITM (38.2)	Fratio (64.0)
LstepCC1 (37.5)	DCAC4010 (56.6)

3.3.5.4 Calculation of TACs using real world data

Figure 3.3.5.7 provides resulting total allowable catch (TAC) calculations from the MPs that produced the 6 highest relative yields in the MSE and met the performance criteria as specified by the SEDAR 46 DW/AW Panel. In the SEDAR46 evaluations, the TAC calculations are considered equivalent to the overfishing limit (OFL). However, it should be noted that adoption of one or more of these TACs as a harvest control rule may not necessarily achieve maximum sustainable yield in equilibrium (which is difficult to estimate in data-limited situations). Instead the TAC represents a level of yield consistent with the selected management objectives and performance criteria recommended by the DW/AW Panel and is heavily dependent upon the reliability of data inputs. Summary statistics on calculated TACs from the real world data (provided in Appendix 4.3.5) are provided in Table 3.3.5.3 for all of the feasible MPs meeting the performance criteria specified by the SEDAR 46 DW/AW Panel.

Table 3.3.5.3 Summary of total allowable catch (TAC) calculations (pounds x 1000s) provided by management procedures that met the SEDAR 46 DW/AW Panel performance criteria for St. Croix spiny lobster. MPs are as defined in Table 3.1.

	Summary statistics				
MP	Minimum	25th Percentile	Median	75th Percentile	Maximum
MPs producing 6 highest long-term yields that meet management criteria					
DD	38.692	439.183	1047.478	3168.908	17270.4
DD4010	24.497	360.933	894.563	2187.226	23764.31
Fratio	4.637	19.68	29.015	51.439	144.193
MCD	1.242	11.324	21.247	45.899	247.998
Other MPs that meet management criteria					
Islope1	15.102	39.873	55.563	75.385	178.913
Itarget1	13.8	39.022	50.164	68.139	162.328
Islope4	11.589	35.526	47.936	61.063	146.667
SPMSY	1.356	20.811	39.761	53.744	80.001
Itarget4	10.098	23.521	30.551	40.036	107.502

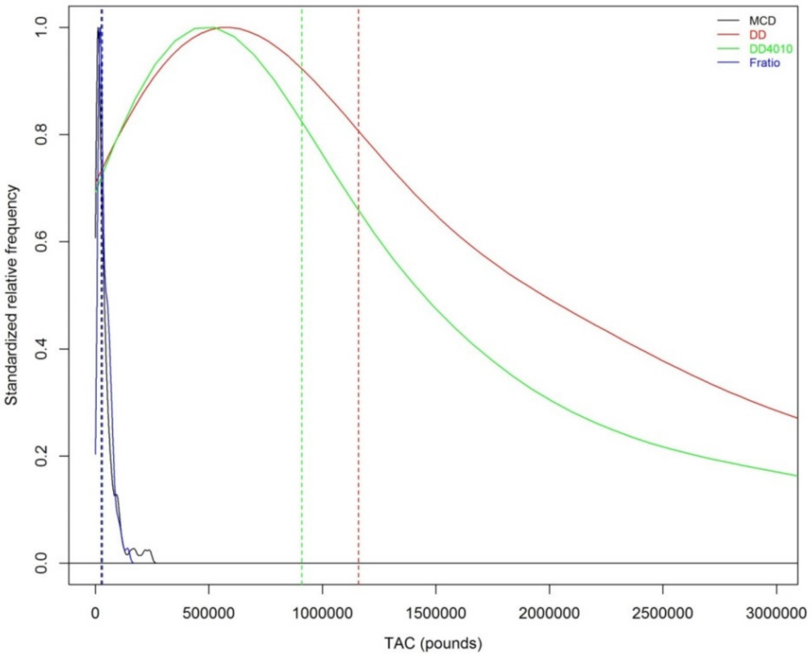


Figure 3.3.5.7 Total allowable catch (TAC) calculations (pounds) for St. Croix spiny lobster obtained from the management procedures that met the SEDAR 46 AW Panel performance criteria and also produced the 6 highest relative long-term yields in the management strategy evaluation. Note that only 4 of the top 6 are applicable based on current data availability and/or management procedure configuration. MPs are as defined in Table 3.1.

The effect of varying real world parameter inputs on the recommended TACs for each MP was evaluated using a sensitivity analysis available within DLMtool. Figure 3.3.5.8 provides sensitivity results for all applicable MPs which produced the highest relative long-term yields in the MSE. Sensitivities in parameter estimates were evident, with higher TACs obtained for the following MPs: in MCD as Cat and Dep increased; and in Fratio as Mort, FMSY_M, and Abun increased.

In addition, real world parameter inputs were varied for several key parameters to assess the sensitivity of TAC calculations to data inputs including CV_Cat, Abun, Dep, Mort, vbLinf, and vbK. Figures 3.3.5.9 – 3.3.5.10 provide results for the MPs requiring each data input. Calculated TACs from most MPs were relatively similar when CV_Cat was doubled, with the exception of DD and DD4010. In contrast, changes to both Abun and Dep and life history parameters (Mort, vbLinf, vbK) had a substantial impact on TACs where these inputs were required. Tables 3.3.5.4 – 3.3.5.6 provide the calculated TACs for all sensitivity runs.

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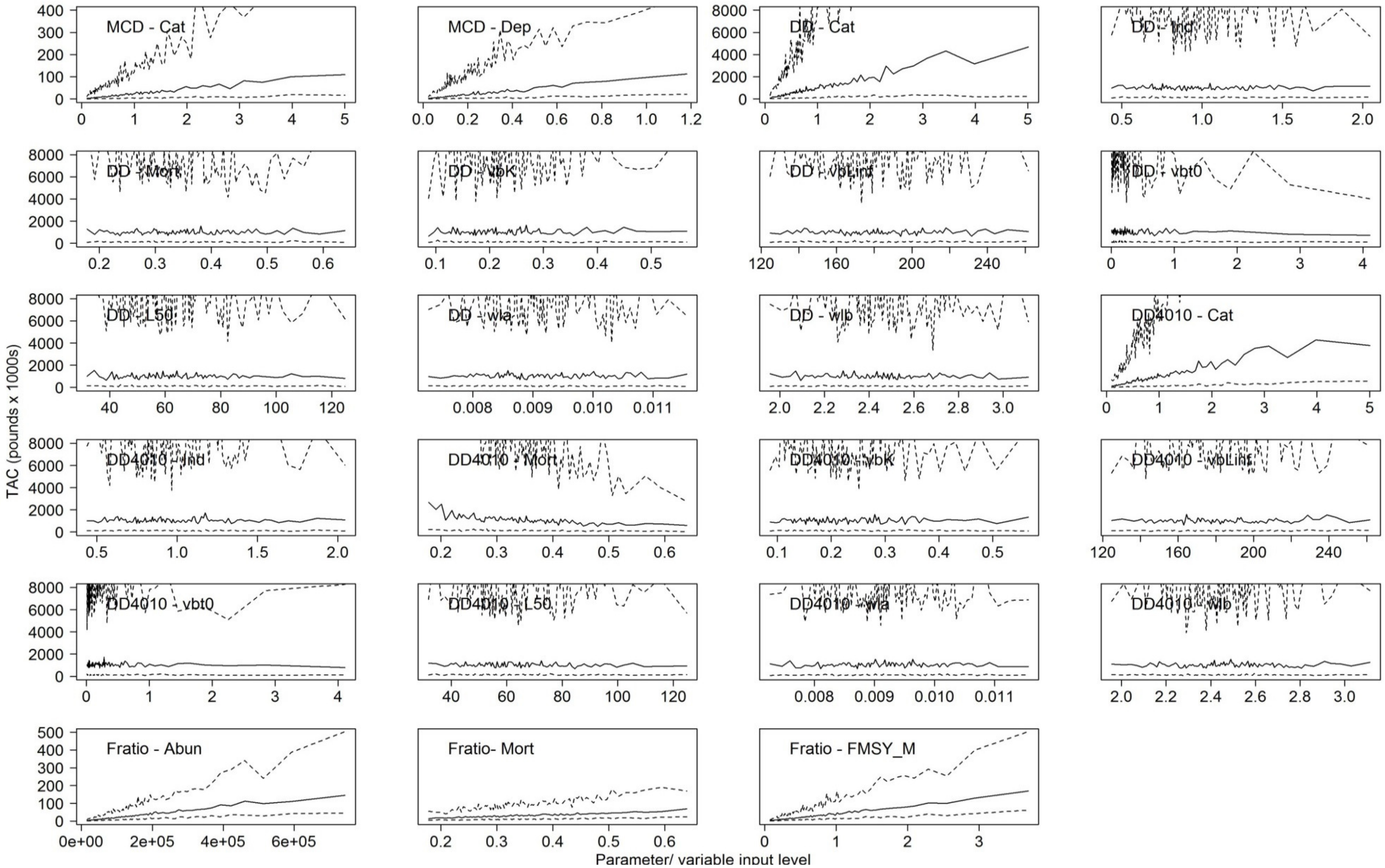

Figure 3.3.5.8 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) for the applicable highest yielding management procedures to varying input parameters for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1.. Dashed lines reflect 5% and 95% confidence intervals.

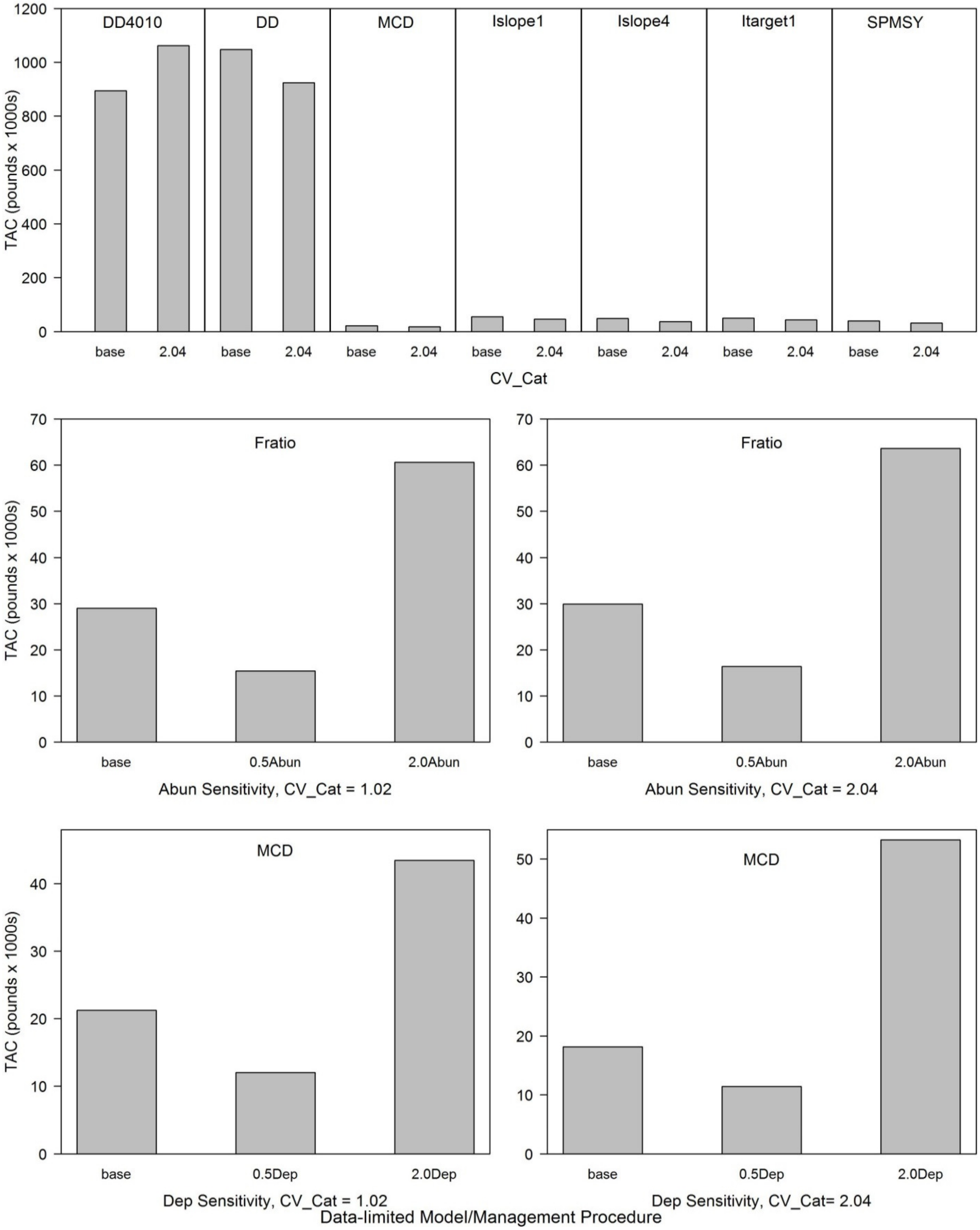

Figure 3.3.5.9 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including CV_Cat, Abun, and Dep for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1.

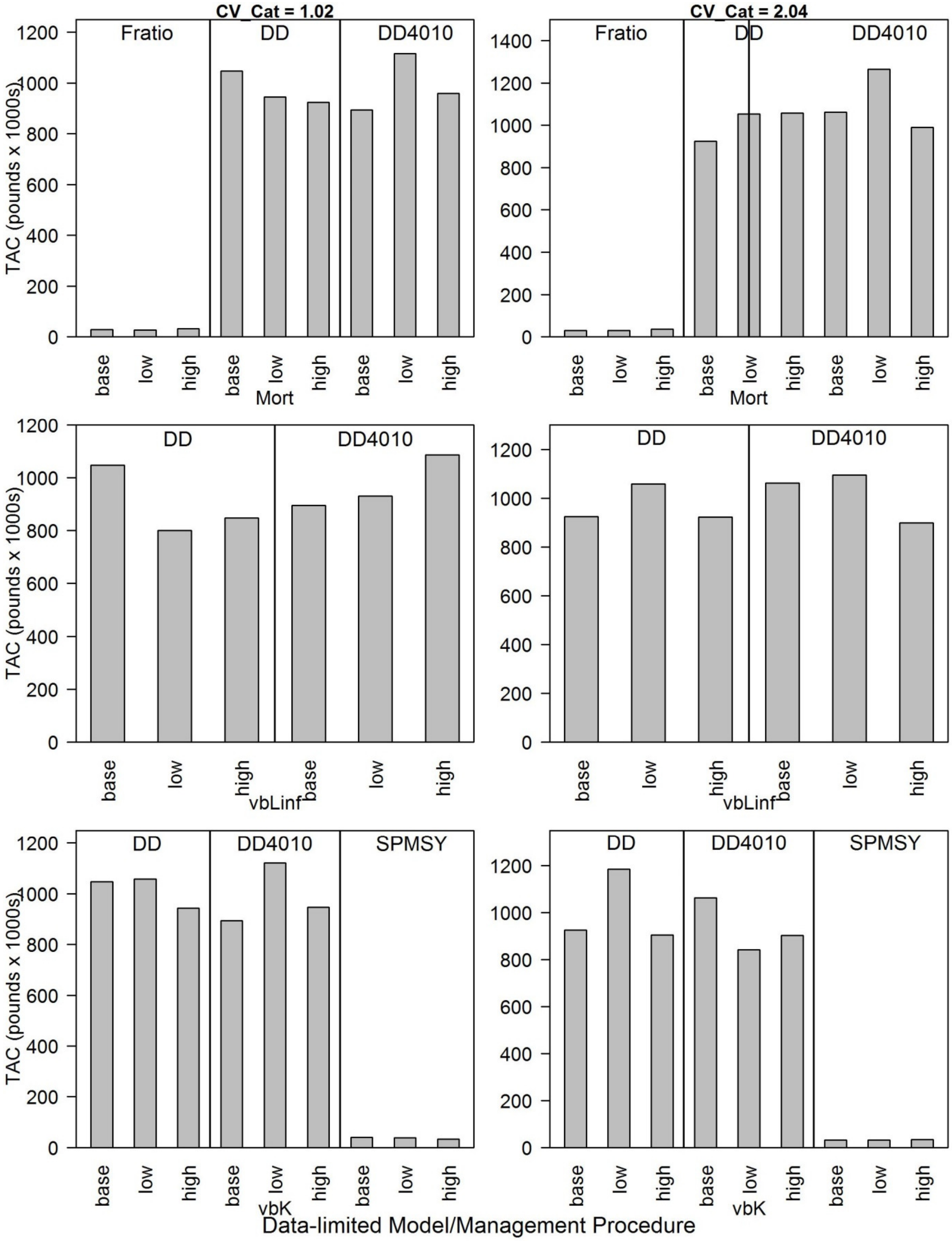

Figure 3.3.5.10 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including Mort, vbLinf, and vbK for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1.

Table 3.3.5.4 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the coefficient of variation for catch (CV_Cat) for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1.

MP	TAC (pounds x 1000s)	
	1.02 (CV_Cat, base)	2.04 (2.0 x CV_Cat)
DD4010	894.563	1062.216
DD	1047.478	924.525
MCD	21.247	18.160
Islope1	55.563	46.321
Islope4	47.936	36.849
Itarget1	50.164	42.997
Itarget4	30.551	23.558
SPMSY	39.761	32.204

Table 3.3.5.5 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to current abundance and depletion values for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1.

MP	Abundance (Abun)	Depletion (Dep)	TAC (pounds x 1000s)	
			1.02 (CV_Cat, base)	2.04 (2.0 x CV_Cat)
Abundance				
Fratio	151166 (Abun, base)	–	29.015	29.939
	75583 (0.5 x Abun)	–	15.372	16.369
	302332 (2.0 x Abun)	–	60.585	63.642
Depletion				
MCD	–	0.24 (Dep, base)	21.247	18.160
	–	0.12 (0.5 x Dep)	12.029	11.439
	–	0.48 (2.0 x Dep)	43.426	53.278

Table 3.3.5.6 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to natural mortality (Mort), asymptotic length (vbLinf), and growth rate (vbK) values for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1.

MP	Input	TAC (pounds x 1000s) 1.02 (CV_Cat, base)	 2.04 (2.0 x CV_Cat)
Mort			
Fratio	0.350 (base)	29.015	29.939
	0.298 (low)	26.724	29.909
	0.403 (high)	31.233	35.113
DD	0.350 (base)	1047.478	924.525
	0.298 (low)	944.482	1052.765
	0.403 (high)	924.360	1058.894
DD4010	0.350 (base)	894.563	1062.216
	0.298 (low)	1115.592	1264.770
	0.403 (high)	960.042	989.321
vbLinf			
DD	183 (base)	1047.478	924.525
	155 (low)	800.027	1057.377
	210 (high)	847.134	922.160
DD4010	183 (base)	894.563	1062.216
	155 (low)	931.475	1094.608
	210 (high)	1087.366	898.073
vbK			
DD	0.240 (base)	1047.478	924.525
	0.204 (low)	1057.431	1185.050
	0.276 (high)	943.513	903.778
DD4010	0.240 (base)	894.563	1062.216
	0.204 (low)	1121.501	841.378
	0.276 (high)	945.960	902.866
SPMSY	0.240 (base)	39.761	32.204
	0.204 (low)	37.967	33.104
	0.276 (high)	33.545	33.535

Table 3.3.5.7 provides a brief summarization of MSE results and inherent assumptions for each applicable method and can help guide which MP to select for TAC calculation. For St. Croix spiny lobster, areas of concern include:

- **Life history input (Mort, L50, vbt0, vbK, vbLinf, wla, wlb, MaxAge):** the LHWG identified substantial uncertainty in the MaxAge and Mort
- **Catch input (Cat):** underreporting of catch
- **Index input (Ind):** appropriateness of: adjusted effort (Eff1) as an indicator of fishing effort; and 2) of the trend in relative abundance derived from the diving fishery
- **Depletion input (Dep):** method for estimating depletion provides very uncertain estimates of current stock biomass and (equilibrium) fishing mortality rate from growth, natural mortality rate, recruitment and fishing selectivity. In addition, the mean length from the diving fishery is considered an appropriate and reliable indicator of trend in resource.
- **Abundance input (Abun):** rough estimate of current abundance based on recent catch and fishing mortality history
- **Fishery input (LFC):** appropriateness of TIP data for the diving fishery in quantifying the length at first capture

In general, MPs cannot realize the full complexity of the biology (e.g., time- and age-varying natural mortality) or fishery characteristics (e.g., change in fishing operations, regulations, dome-shaped selectivity).

Table 3.3.5.7 Guidance table of inherent assumptions within management procedures for calculating the total allowable catch for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1. Performance metrics are as defined in Table 3.3.5.1.

Parameter	**Abun-based**	**Dep-based**	**Data-moderate**		**Index-based**				**Catch-based**
	Fratio	**MCD**	**DD**	**DD4010**	**Islope1**	**Islope4**	**Itarget1**	**Itarget4**	**SPMSY**
PNOF	60.0	66.4	71.7	83.9	60.8	61.8	51.8	98.7	63.3
B50	86.5	94.1	91.7	95.6	84.8	84.7	85.3	96.1	83.0
LTY	64.0	70.7	69.6	66.6	50.8	46.6	47.8	0.0	40.7
AAVY	52.2	72.8	99.0	75.0	97.2	96.8	99.4	71.6	94.2
Mort	Known, constant across age		Known, constant across age						
AM			Life history characterizations reflective of STX						Life history characterizations reflective of STX
vbt0									
vbK									
vbLinf									
wla									
wlb									
MaxAge			Age characterizations reflective of STX						Age characterizations reflective of STX
Cat		Known, informative of historical removals							
FMSY_M	Known								
Ind			Fishery dependent representative of population abundance, dependent upon accurate effort reporting						
Dep		Known, estimated from TIP samples and life history							
Abun	Known, estimated from current catch and F								

3.3.6 St. Croix stoplight parrotfish

3.3.6.1 Model stability

Model stability was evaluated graphically and through inspection of the convergence values for each performance metric across simulations for all MPs. All of the feasible MPs within the MSE converged at the 1% criteria level. Convergence plots for standard performance metrics in the MSE are shown in Figure 3.3.6.1 for the base OM (15%LH, Asymptotic selex). The majority of MPs appear to have converged by approximately 200 simulations for relative yield and 300 simulations for the other metrics.

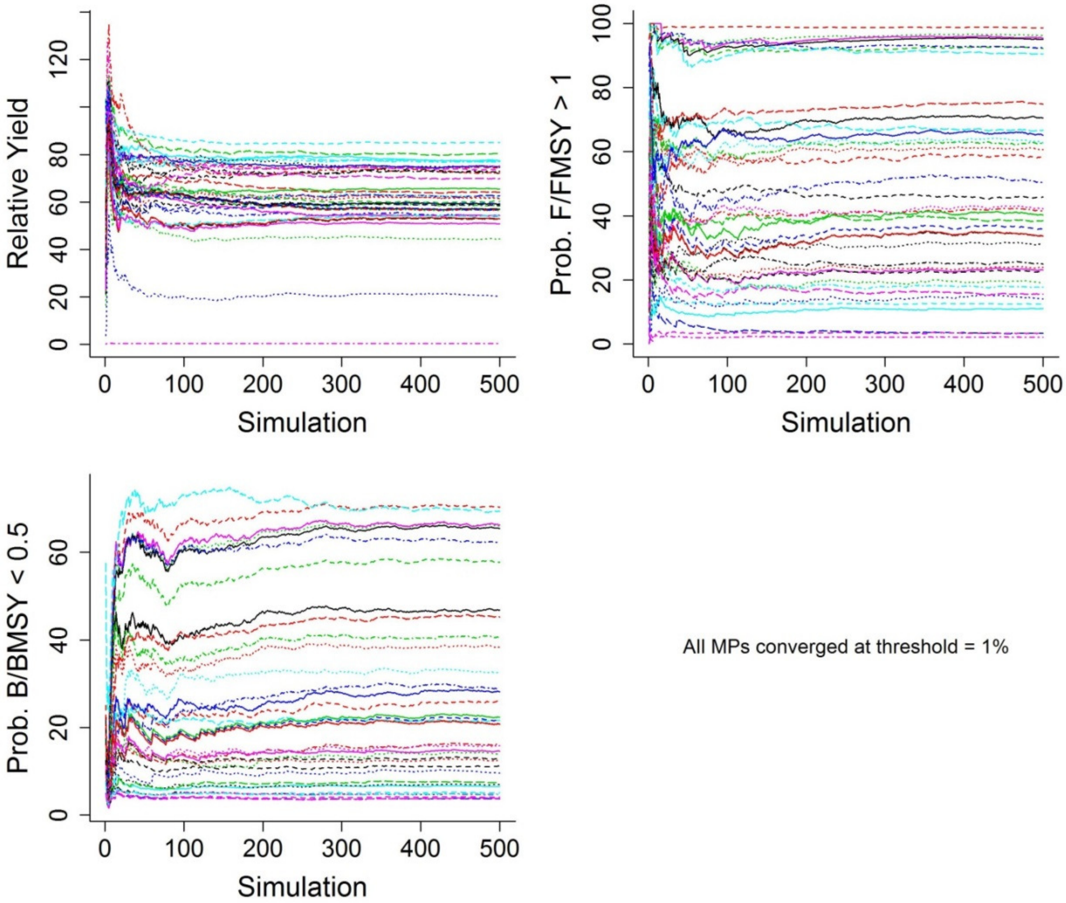

Figure 3.3.6.1 Convergence of performance metrics for each MP within the management strategy evaluation for St. Croix stoplight parrotfish using the base operating model (15%LH, Asymptotic selex). Colored lines each reflect an MP.

3.3.6.2 Operating model evaluation

The consistency of MSE results across varying assumptions on stock and fleet dynamics in the OM was examined with respect to life history (stock) and fishery (fleet) characterizations as described in Section 3.2.2.1. For St. Croix stoplight parrotfish, the 15%LH, Asymptotic selex OM was chosen as the base OM. An alternative stock OM was constructed assuming 5% LH and Asymptotic selex. Tables 3.2.3 – 3.2.5 provided specifics on stock and fleet dynamics and alternative characterizations considered.

Performance between MPs within the MSEs was further examined by investigating tradeoff plots among OMs. Figures 3.3.6.2 − 3.3.6.3 present the tradeoff plots for the base OM (15%LH, Asymptotic selex) and for the alternative OM (5%LH, Asymptotic selex). Metrics shown in the tradeoff plots are the Panel-selected performance metrics as defined in Section 3.2.4. Management procedures located within the top-right corner in each panel are preferred according to the AW Panel performance criteria. MPs yielding the highest Pr(NOF ≥ 50%), Pr(B50 ≥ 50%), and Pr([AAVY 15%] ≥ 50%) were similar between the base and sensitivity OMs. Specific details on definitions of performance metrics were previously provided in Section 3.2.4.

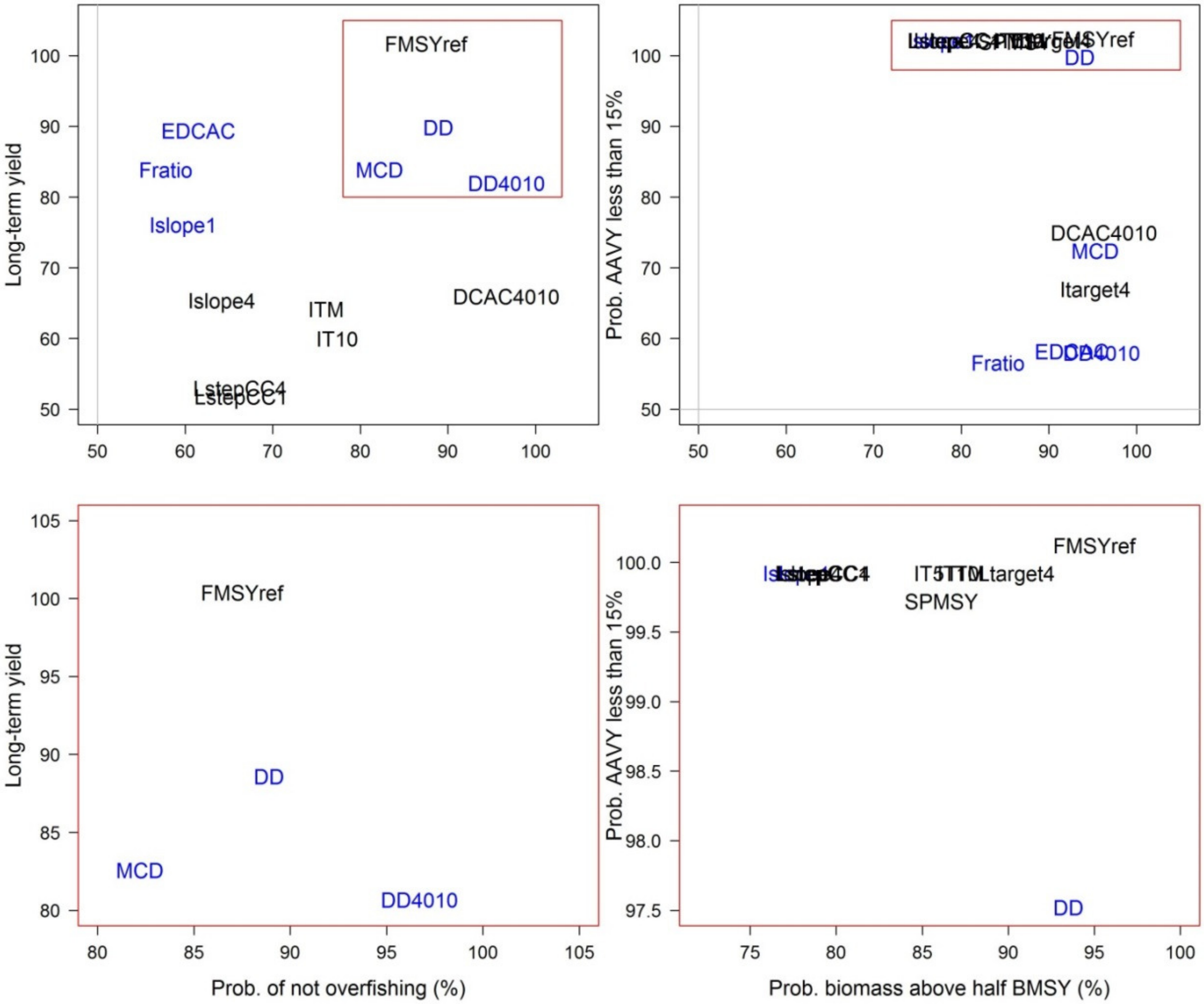

Figure 3.3.6.2 Tradeoffs in performance metrics between management procedures for the St. Croix stoplight parrotfish base operating model (15%LH, Asymptotic Selex). Gray lines at 50% in the top panels represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panels. MPs are as defined in Table 3.1.

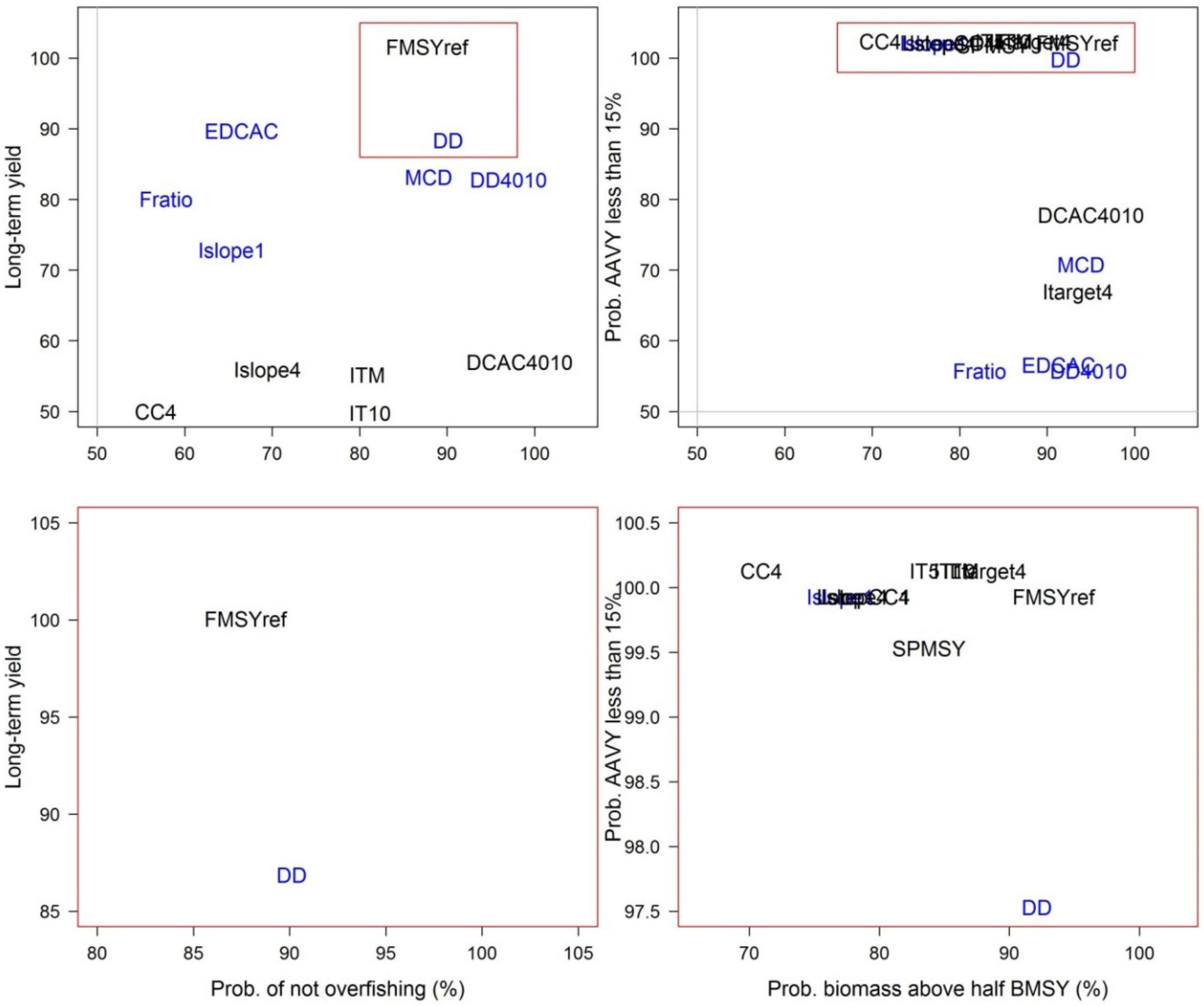

Figure 3.3.6.3 Tradeoffs in performance metrics between management procedures for the St. Croix stoplight parrotfish alternative operating model (5%LH, Asymptotic Selex). Gray lines at 50% in the top panel represent the thresholds decided upon at the DW/AW Workshop. The blue font identifies the six MPs producing the highest relative long-term yields. The bottom panels reflect the upper right-hand corner (red box) of each tradeoff plot from the top panels. MPs are as defined in Table 3.1.

Additional information to aid in understanding the contribution of information included in each OM is shown in Figures 3.3.6.4 − 3.3.6.5. These figures are a graphical visualization of the value of information in the OM, a metric which identifies relevant parameters in the operating and observation models that are most correlated with utility. For the operating model parameters (Figure 3.3.6.4), the parameters displaying the highest correlations with long-term yield relative to MSY were divergent across MPs. These parameters included FMSY_M for Islope1, FMSY for Fratio, ageM for MCD and EDCAC, and RefY for DD4010 and DD. For the observation model parameters (Figure 3.3.6.5), parameters displaying the highest correlations with long-term yield relative to MSY were also divergent across MPs. These parameters included Mbias for DD, Csd for DD4010, Cbias for Islope1, Dbias for EDCAC and Dbias, and Abias for Fratio. These results may be used to inform data collection, by identifying which inputs are more important in assessing OM behavior.

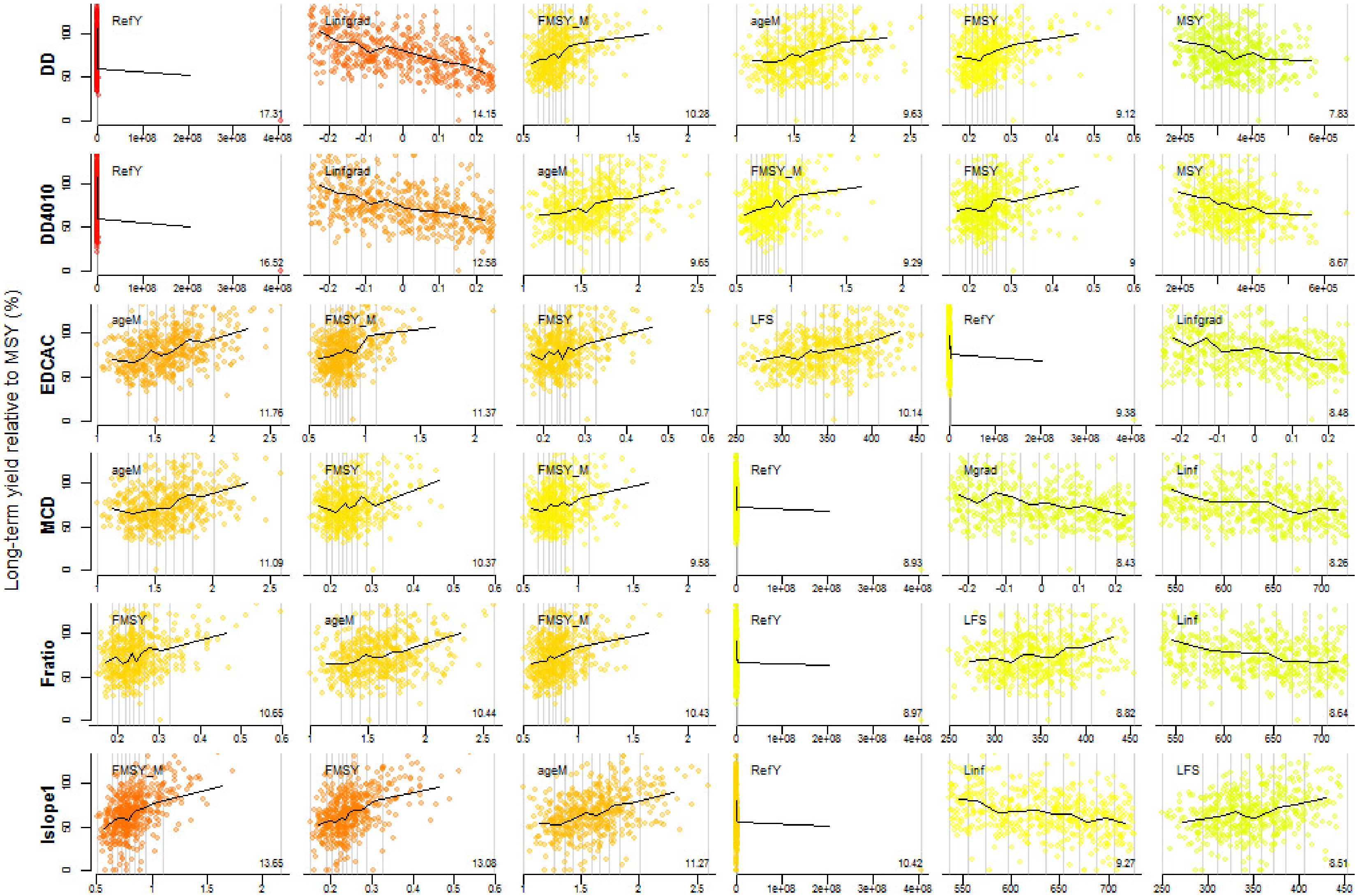

Figure 3.3.6.4 Value of information that detects relevant operating model parameters that are most correlated with utility for the St. Croix stoplight parrotfish base operating model (15%LH, Asymptotic selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and operating model parameters are as defined in Table 3.1.

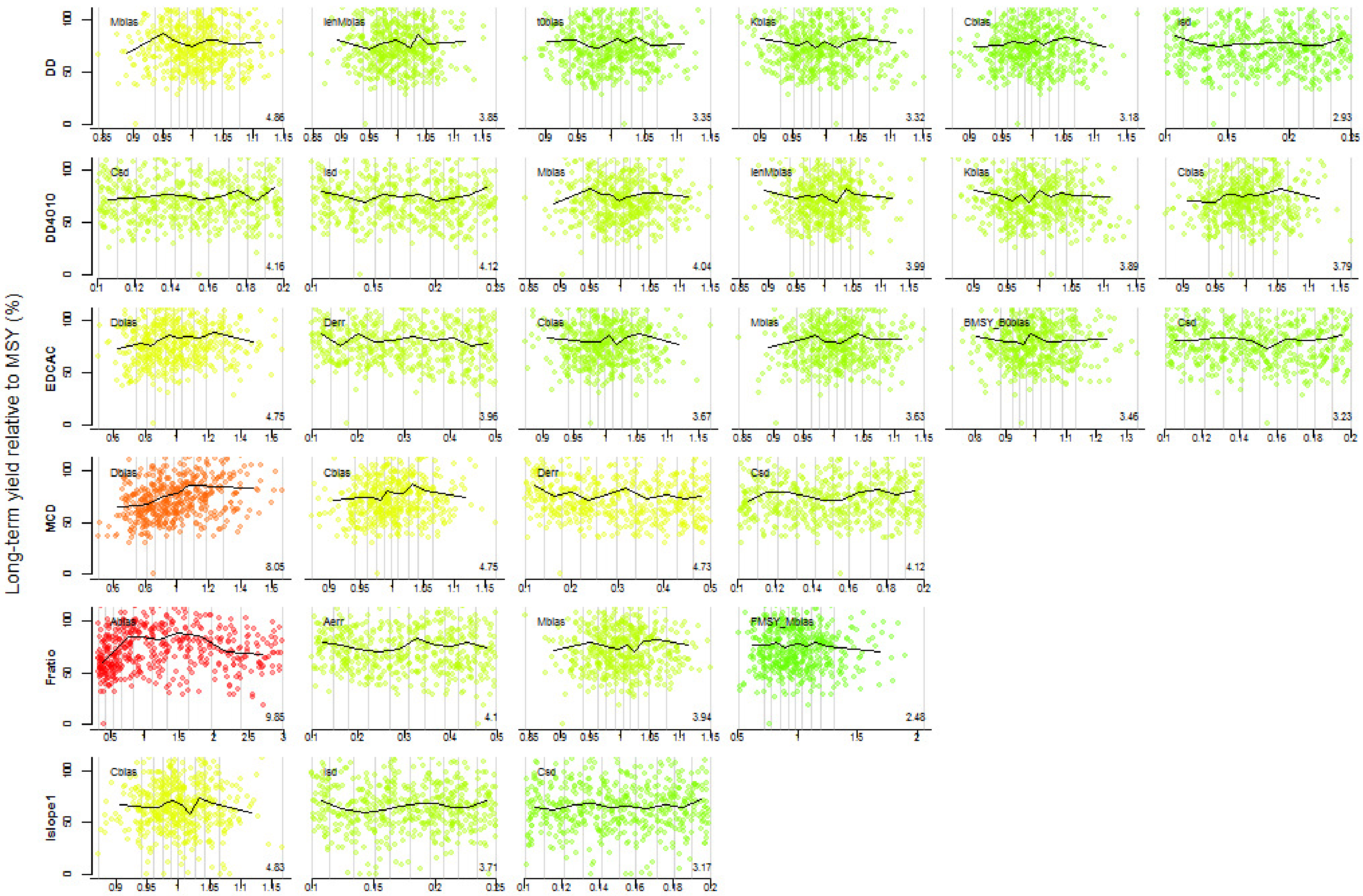

Figure 3.3.6.5 Value of information that detects relevant observation model parameters that are most correlated with utility for the St. Croix stoplight parrotfish base operating model (15%LH, Asymptotic selex). The top 6 parameters are plotted in descending order of importance in determining utility (left to right; red = high, green = low). MPs and observation model parameters are as defined in Table 3.1.

3.3.6.3 Performance of management procedures

MP performance results against the three MSE performance criteria (PNOF, B50, AAVY) selected by the SEDAR 46 DW/AW Panel as well as relative long-term yield (LTY) are provided in Table 3.3.6.1 for the St. Croix stoplight parrotfish base (15%LH, Asymptotic selex) and alternative (5%LH, Asymptotic selex) OMs.

Table 3.3.6.1 Performance of management procedures within the MSE for the St. Croix stoplight parrotfish base (15%LH, Asymptotic selex) and alternative operating model (5% LH, Asymptotic selex) as determined using the performance metrics specified by the SEDAR 46 DW/AW Panel. PNOF = probability of not overfishing (%), B50 = probability of the biomass being above half BMSY (%), LTY = relative long-term yield, defined as the fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection, and AAVY = fraction of simulations where average annual variability in yield < 15%. MPs are as defined in Table 3.1.

	Base Stock					Alt Stock			
	15%LH, Asymptotic selex					5%LH, Asymptotic selex			
	PNOF	B50	LTY	AAVY		PNOF	B50	LTY	AAVY
Reference MP									
FMSYref	87.5	95	99.3	100	FMSYref	87.7	93.4	99.2	99.8
MPs producing 6 highest long-term yields that meet criteria									
DD	88.9	93.5	87.5	97.4	EDCAC	66.5	91.3	87.3	54.2
EDCAC	61.5	92.6	87	55.8	DD	90.1	92.1	86	97.4
Fratio	57.8	84.2	81.5	54.2	MCD	87.9	93.9	80.8	68.4
MCD	82.2	95.3	81.5	70	DD4010	97	94.7	80.4	53.4
DD4010	96.7	96	79.6	55.6	Fratio	57.9	82.3	77.7	53.4
Islope1	59.8	77.7	73.7	99.8	Islope1	65.4	77	70.5	99.8
Other MPs producing lower long-term yields that meet criteria									
DCAC4010	96.7	96.3	63.6	72.6	DCAC4010	98.3	95	54.6	75.4
Islope4	64.2	78.4	63	99.8	Islope4	69.5	78.1	53.6	99.8
ITM	76.1	87.6	61.8	99.8	ITM	80.9	86.3	52.8	100
IT10	77.4	87.1	57.6	99.8	CC4	56.7	70.9	47.6	100
LstepCC4	66.3	79.3	50.6	99.8	IT10	81.2	85.8	47.4	100
LstepCC1	66.4	79.2	49.4	99.8	LstepCC1	71.8	78.8	39.4	99.8
IT5	76.9	85.4	44.2	99.8	LstepCC4	71.9	78.8	38.7	99.8
SPMSY	81	86.1	34.5	99.6	IT5	80	83.5	32.8	100
Ltarget4	85.9	90.5	13.3	99.8	SPMSY	80.9	83.8	28.6	99.4
Itarget4	97.9	95.3	0	64.6	Ltarget4	87.4	88.4	8.6	100
					Itarget4	97.7	93.5	0	64.6

Sensitivity of the data quality in the observation subclass (i.e., imprecise and biased data inputs) resulted in very different trends in model performance in the MSE. The top 6 methods tend to be index-based methods, with substantially lower relative long-term yields compared to when data inputs were assumed precise and unbiased (Table 3.3.6.2). Those MPs identified as optimal when assuming precise and unbiased data inputs no longer fall within the top 6 according to selection criteria.

Table 3.3.6.2 Comparison of the top 6 management procedures between the St. Croix stoplight parrotfish base operating model assuming precise and unbiased data inputs and an alternative operating model assuming imprecise and biased data inputs. Numbers in parentheses represent the relative long-term yield from the management strategy evaluation.

Imprecise-Biased	Precise-Unbiased
Islope1 (55.0)	DD (87.5)
Islope4 (47.6)	EDCAC (87.0)
ITM (45.9)	Fratio (81.5)
IT10 (41.2)	MCD (81.5)
LstepCC4 (40.0)	DD4010 79.6)
Itarget1 (39.6)	Islope1 (73.7)

3.3.6.4 Calculation of TACs using real world data

Figure 3.3.6.6 provides resulting total allowable catch (TAC) calculations from the MPs that produced the 6 highest relative yields in the MSE and met the performance criteria as specified by the SEDAR 46 DW/AW Panel. In the SEDAR46 evaluations, the TAC calculations are considered equivalent to the overfishing limit (OFL). However, it should be noted that adoption of one or more of these TACs as a harvest control rule may not necessarily achieve maximum sustainable yield in equilibrium (which is difficult to estimate in data-limited situations). Instead the TAC represents a level of yield consistent with the selected management objectives and performance criteria recommended by the DW/AW Panel and is heavily dependent upon the reliability of data inputs. Summary statistics on calculated TACs from the real world data (provided in Appendix 4.3.6) are provided in Table 3.3.6.3 for all of the feasible MPs meeting the performance criteria specified by the SEDAR 46 DW/AW Panel.

Table 3.3.6.3 Summary of total allowable catch (TAC) calculations (pounds x 1000s) provided by management procedures that met the SEDAR 46 DW/AW Panel performance criteria for St. Croix stoplight parrotfish. MPs are as defined in Table 3.1.

	Summary statistics				
MP	Minimum	25th Percentile	Median	75th Percentile	Maximum
MPs producing 6 highest long-term yields that meet management criteria					
Islope1	11.089	21.597	25.62	30.713	47.084
MCD	2.355	15.468	23.067	37.042	156.974
Fratio	1.391	10.335	15.415	26.771	107.133
DD4010	0.489	6.652	10.253	17.812	78.481
DD	0.757	5.652	9.749	17.309	90.988
Other MPs that meet management criteria					
SPMSY	0.973	16.646	31.043	43.272	76.106
Islope4	11.312	16.826	19.912	23.81	34.876

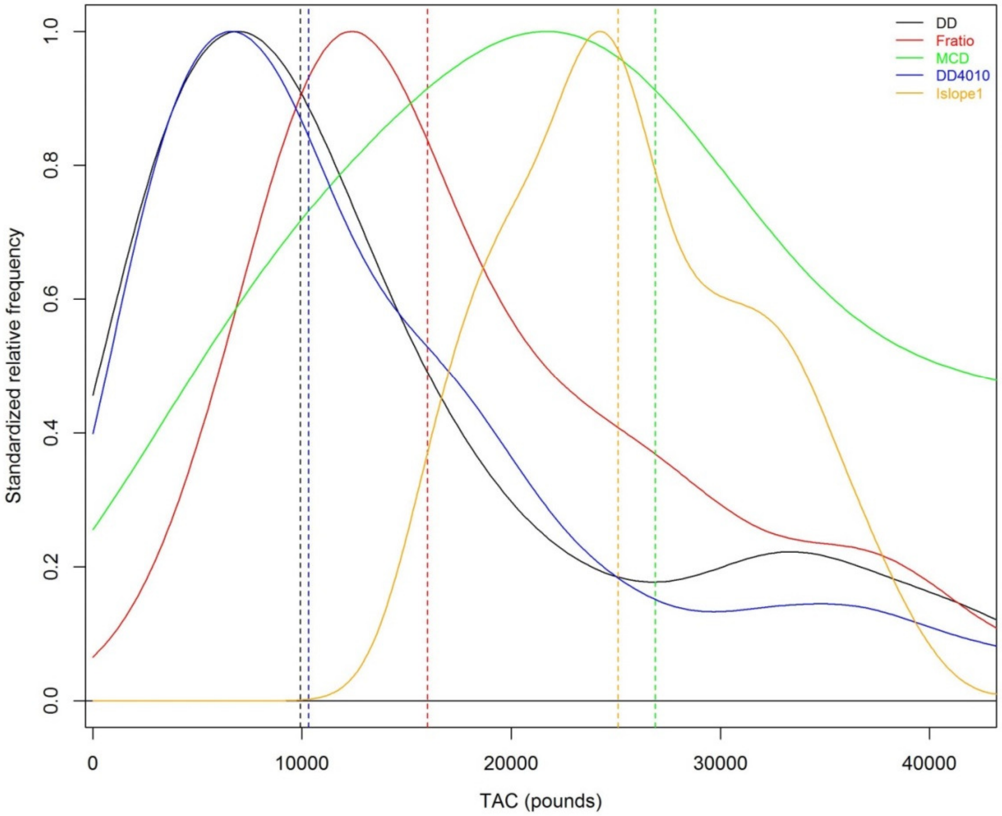

Figure 3.3.6.6 Total allowable catch (TAC) calculations (pounds) for St. Croix stoplight parrotfish obtained from the management procedures that met the SEDAR 46 AW Panel performance criteria and also produced the 6 highest relative long-term yields in the management strategy evaluation. Note that only 5 of the top 6 are applicable based on current data availability and/or management procedure configuration. MPs are as defined in Table 3.1.

The effect of varying real world parameter inputs on the recommended TACs for each MP was evaluated using a sensitivity analysis available within DLMtool. Figure 3.3.6.7 provides results for three of the six MPs which produced the highest relative yields. Results are not shown for DD or DD4010 because the sensitivity analysis did not converge. Sensitivities in parameter estimates were evident, with higher TACs obtained for the following MPs: in Fratio as Mort, FMSY_M, and Abun increased; in MCD as Cat and Dep increased; and in Islope1 as Cat increased or Ind decreased.

In addition, real world parameter inputs were varied for several key parameters to assess the sensitivity of TAC calculations to data inputs including CV_Cat, Abun, Dep, Mort, vbLinf, and vbK. Figures 3.3.6.8 − 3.3.6.9 provide results for the MPs requiring each data input. Calculated TACs from most MPs were relatively similar when CV_Cat was doubled, with the exception of DD and DD4010. In contrast, changes to both Abun and Dep and life history parameters (Mort, vbLinf, vbK) had a substantial impact on TACs where these inputs were required. Tables 3.3.6.4 − 3.3.6.6 provide the calculated TACs for all sensitivity runs.

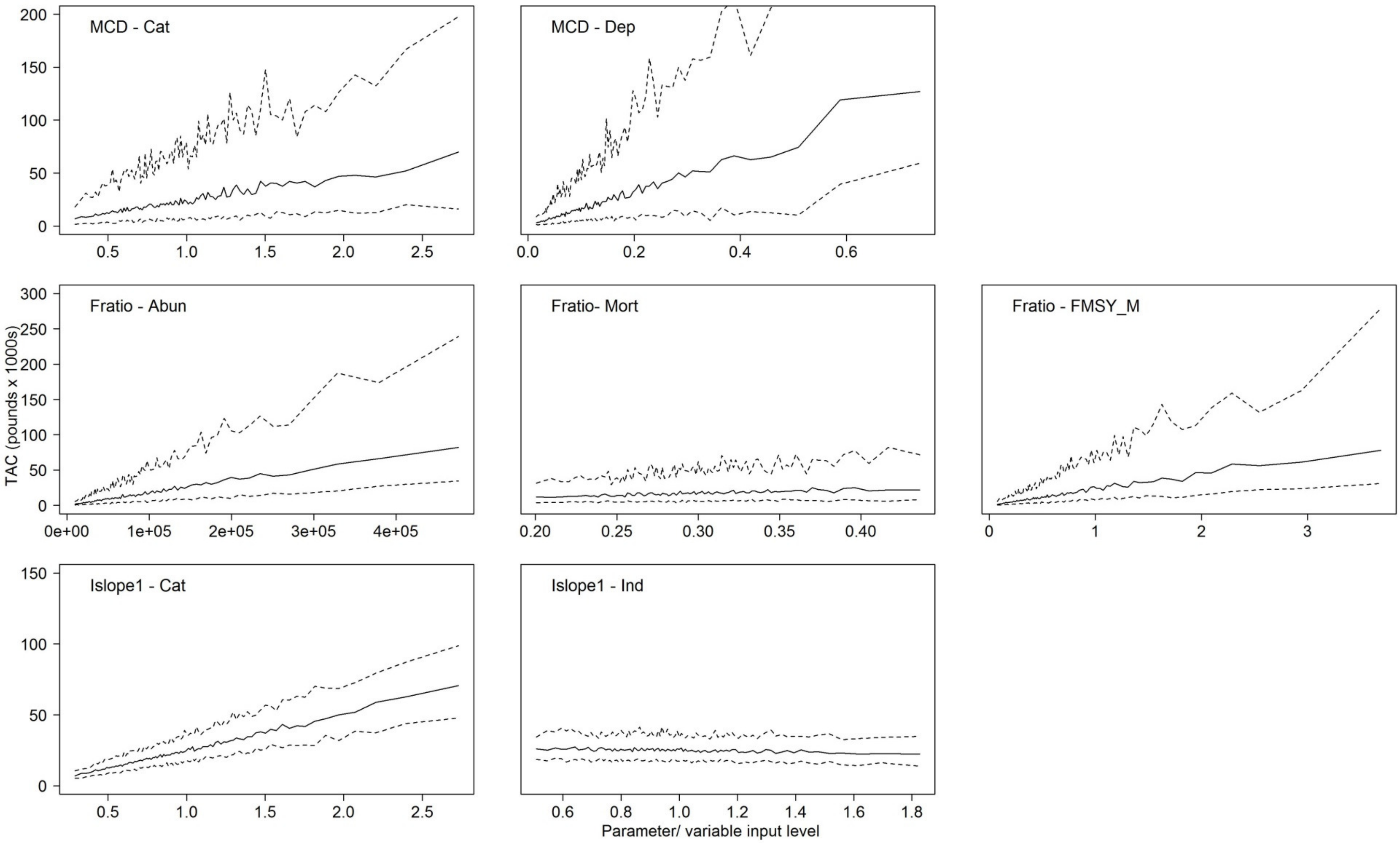

Figure 3.3.6.7 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) for the applicable highest yielding management procedures to varying input parameters for St. Croix stoplight parrotfish. MPs and data inputs are as defined in Table 3.1. Dashed lines reflect 5% and 95% confidence intervals.

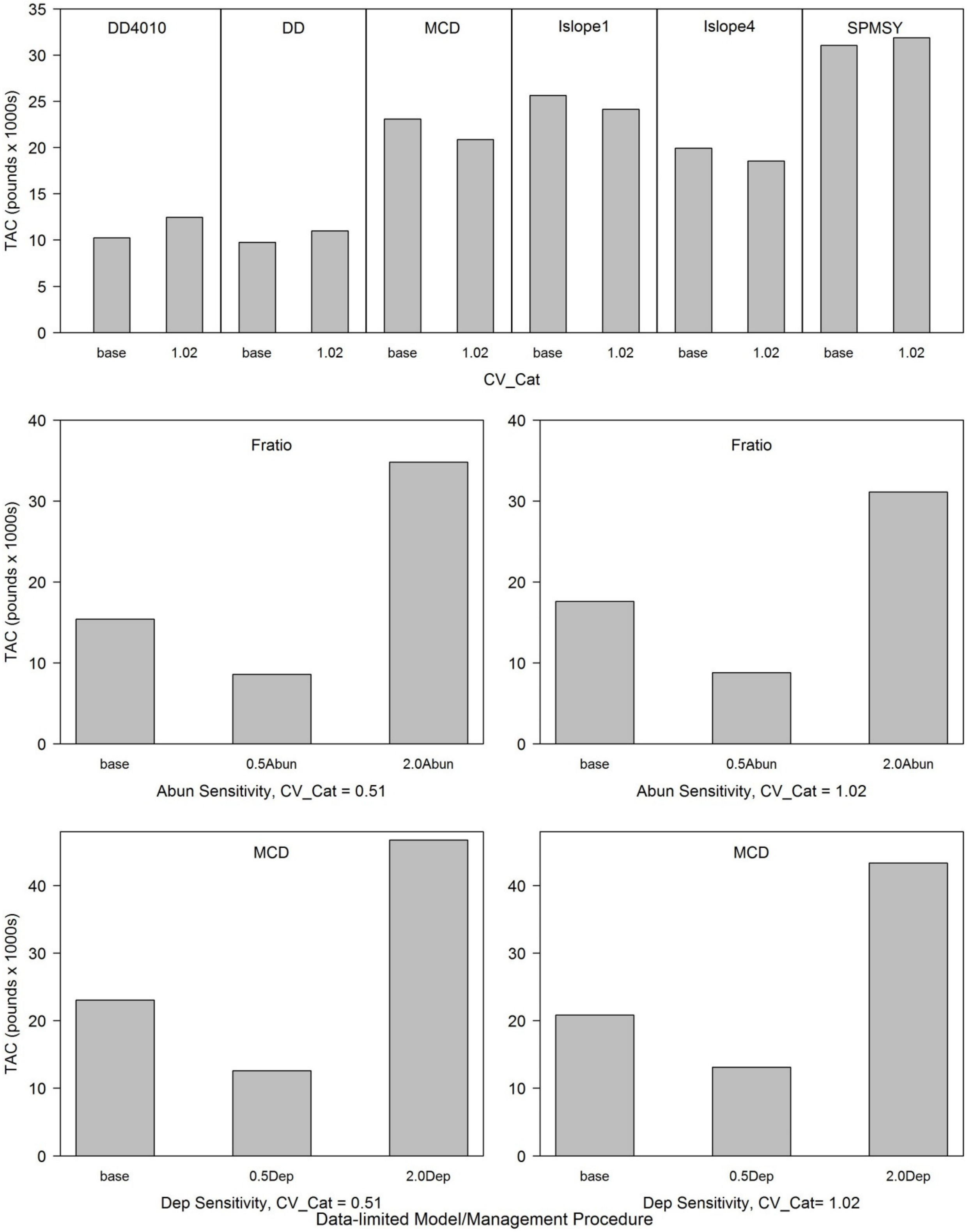

Figure 3.3.6.8 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including CV_Cat, Abun, and Dep for St. Croix stoplight parrotfish. MPs and data inputs are as defined in Table 3.1.

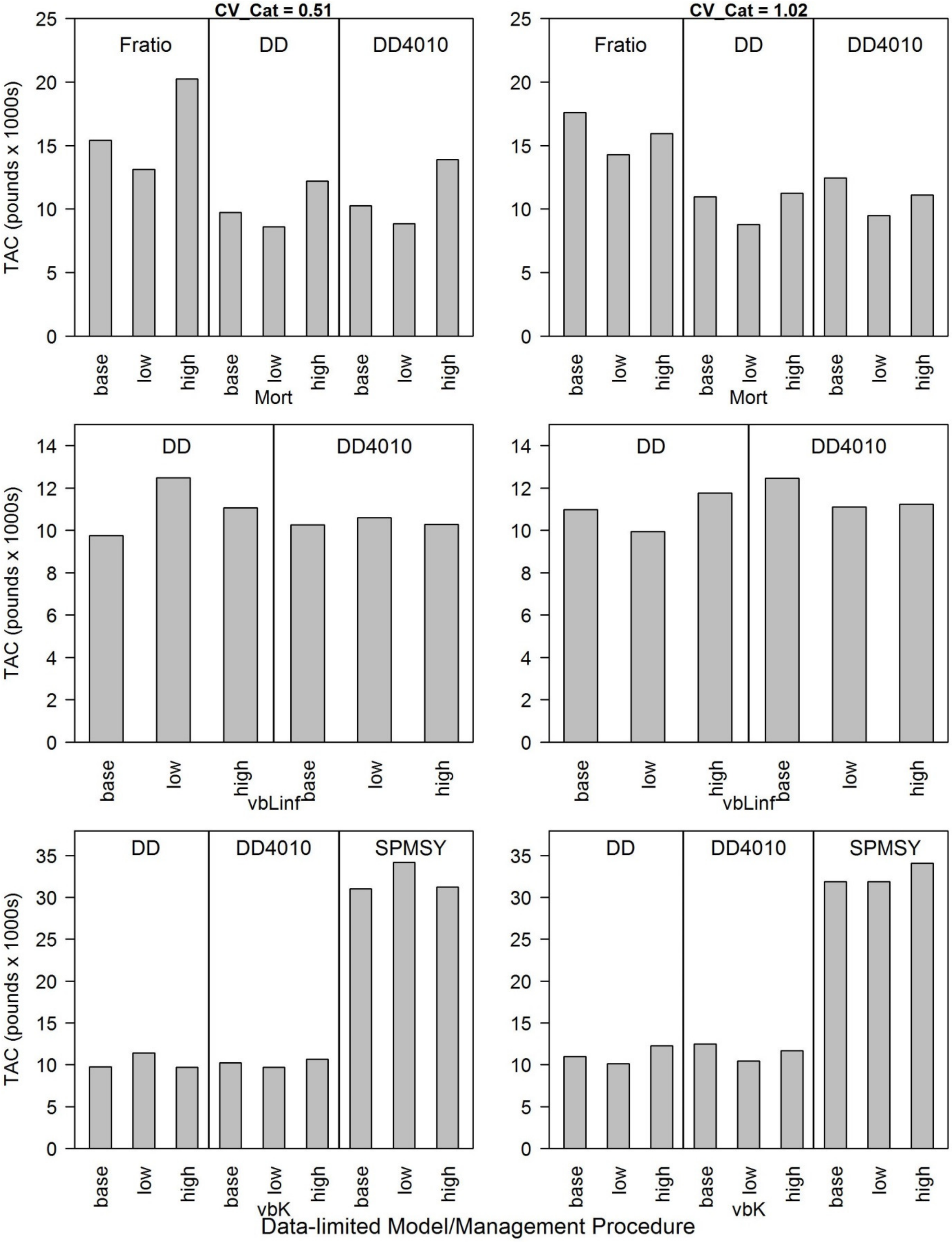

Figure 3.3.6.9 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to data inputs including Mort, vbLinf, and vbK for St. Croix stoplight parrotfish. MPs and data inputs are as defined in Table 3.1.

Table 3.3.6.4 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to the coefficient of variation for catch (CV_Cat) for St. Croix stoplight parrotfish. MPs and data inputs are as defined in Table 3.1.

MP	TAC (pounds x 1000s) 0.51 (CV_Cat, base)	 1.02 (2.0 x CV_Cat)
DD4010	10.253	12.460
DD	9.749	10.975
MCD	23.067	20.852
Islope1	25.620	24.121
Islope4	19.912	18.534
SPMSY	31.043	31.865

Table 3.3.6.5 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to current abundance and depletion values for St. Croix stoplight parrotfish. MPs and data inputs are as defined in Table 3.1.

MP	Abundance (Abun)	Depletion (Dep)	TAC (pounds x 1000s) 0.51 (CV_Cat, base)	 1.02 (2.0 x CV_Cat)
Abundance				
Fratio	96,731 (Abun)	–	15.415	17.599
	48,366 (0.5 x Abun)	–	8.596	8.820
	193,462 (2.0 x Abun)	–	34.808	31.106
Depletion				
MCD	–	0.15 (Dep, base)	23.067	20.852
	–	0.075 (0.5 x Dep)	12.583	13.096
	–	0.30 (2.0 x Dep)	46.719	43.329

Table 3.3.6.6 Sensitivity of total allowable catch (TAC) calculations (pounds x 1000s) to natural mortality (Mort), asymptotic length (vbLinf), and growth rate (vbK) values for St. Croix stoplight parrotfish. MPs and data inputs are as defined in Table 3.1.

MP	Input	TAC (pounds x 1000s) 0.51 (CV_Cat, base)	 1.02 (2.0 x CV_Cat)
Mort			
Fratio	0.2998 (base)	15.415	17.599
	0.255 (low)	13.112	14.269
	0.345 (high)	20.252	15.952
DD	0.2998 (base)	9.749	10.975
	0.255 (low)	8.597	8.796
	0.345 (high)	12.201	11.239
DD4010	0.2998 (base)	10.253	12.460
	0.255 (low)	8.857	9.500
	0.345 (high)	13.907	11.100
vbLinf			
DD	632 (base)	9.749	10.975
	537 (low)	12.476	9.953
	726 (high)	11.059	11.762
DD4010	632 (base)	10.253	12.460
	537 (low)	10.610	11.109
	726 (high)	10.293	11.232
vbK			
DD	0.2496 (base)	9.749	10.975
	0.212 (low)	11.424	10.119
	0.287 (high)	9.718	12.252
DD4010	0.2496 (base)	10.253	12.460
	0.212 (low)	9.710	10.460
	0.287 (high)	10.670	11.689
SPMSY	0.2496 (base)	31.043	31.865
	0.212 (low)	34.211	31.884
	0.287 (high)	31.221	34.112

Table 3.3.6.7 provides a brief summarization of MSE results and inherent assumptions for each applicable method and can help guide which MP to select for TAC calculation. For St. Croix stoplight parrotfish, areas of concern include:

- **Life history input (Mort, L50, vbt0, vbK, vbLinf, wla, wlb, MaxAge):** the LHWG recognized substantial uncertainty in the growth parameters, with maximum lengths in the literature often considerably longer than L_∞ estimates.
- **Catch input (Cat):** underreporting of catch, highly uncertain catches due to inconsistencies between data sheets prior to 2011, and species misidentification or lack of identification (e.g., parrotfish versus stoplight parrotfish).
- **Index input (Ind):** appropriateness of: adjusted effort (Eff1) as an indicator of fishing effort; and 2) of the trend in relative abundance derived from the diving fishery.
- **Depletion input (Dep):** method for estimating depletion provides very uncertain estimates of current stock biomass and (equilibrium) fishing mortality rate from growth, natural mortality rate, recruitment and fishing selectivity. In addition, the mean length from the diving fishery is considered an appropriate and reliable indicator of trend in resource.
- **Abundance input (Abun):** rough estimate of current abundance based on recent catch and fishing mortality history.
- **Fishery input (LFC):** appropriateness of TIP data for the diving fishery in quantifying the length at first capture.

In general, MPs cannot realize the full complexity of the biology (e.g., time- and age-varying natural mortality) or fishery characteristics (e.g., change in fishing operations, regulations).

Table 3.3.6.7 Guidance table of inherent assumptions within management procedures for calculating the total allowable catch for St. Croix spiny lobster. MPs and data inputs are as defined in Table 3.1. Performance metrics are as defined in Table 3.3.6.1.

Parameter	**Abun-based**	**Dep-based**	**Data-moderate**	**Data-moderate**	**Index-based**	**Index-based**	**Catch-based**
	Fratio	**MCD**	**DD**	**DD4010**	**Islope1**	**Islope4**	**SPMSY**
PNOF	57.8	82.2	88.9	96.7	59.8	64.2	81.0
B50	84.2	95.3	93.5	96.0	77.7	78.4	86.1
LTY	81.5	81.5	87.5	79.6	73.7	63.0	34.5
AAVY	54.2	70.0	97.4	55.6	99.8	99.8	99.6
Mort	Known, constant across age		Known, constant across age				
L50			Life history characterizations reflective of STX				Life history characterizations reflective of STX
vbt0							
vbK							
vbLinf							
wla							
wlb							
MaxAge			Age characterizations reflective of STX				Age characterizations reflective of STX
Cat		Known, informative of historical removals					
FMSY_M	Known						
Ind			Fishery dependent representative of population abundance, dependent upon accurate effort reporting				
Dep		Known, estimated from TIP samples and life history					
Abun	Known, estimated from current catch and F						

3.4 Analytical tool - Mean length estimator

Huynh (2016 unpublished) applied the Gedamke-Hoenig mean length estimator to the TIP length frequency data to derive estimates of total mortality and overfishing levels. Huynh (2016) provides details of the data inputs, method, approach, assumptions, and results. A brief summary of the approach and results of the application to the six species-island units considered in the SEDAR 46 follows. Instantaneous total mortality rates were estimated for the six U.S. Caribbean species-island units using the non-equilibrium mean length mortality estimator of Gedamke and Hoenig (2006). Length observations from the appropriate gear were obtained from the Trip Interview Program (TIP) database to obtain an estimate of the critical length L_c for the estimator. For each stock, the length corresponding to the mode of the length frequency histogram of all observations in the time series was used as the L_c (base case), with alternative values of L_c also used to examine the sensitivity of mortality estimates to the chosen L_c. Mean lengths above L_c were calculated for each case and total mortality estimated. For Puerto Rico yellowtail snapper and hogfish, the most recent mortality rates were estimated to be 0.48 and 0.34, respectively. The estimates did not considerably vary with alternative values of L_c. For St. Thomas queen triggerfish and spiny lobster, the most recent mortality rates were estimated to be 1.34 and 0.98, respectively. For St. Croix spiny lobster and stoplight parrotfish, the most recent mortality rates were estimated to be 1.02 and 2.31, respectively. For the St. Thomas and St. Croix stocks, there was generally an increasing trend of estimated total mortality coincident with increasing values of L_c. The recent (benchmark) fishing mortality rates were derived as the difference between the estimated total mortality rates and the assumed natural mortality rates.

Yield-per-recruit (YPR) and spawning potential ratio (SPR) analyses were then used to calculate $F_{0.1}$ and $F_{30\%}$, respectively, as proxies for F_{MSY} for the 6 stocks. Overfishing limits (OFLs) were calculated using the corresponding F_{MSY} proxies and abundance was estimated as the ratio of recent catch and recent fishing mortality rate from the mean length estimator. Recent catch was defined as the mean catch corresponding to the time period of the most recent fishing mortality rate in the mean length estimator. Using $F_{0.1}$ as the F_{MSY} proxy, a reduction from the mean catch was indicated for the OFLs of all 6 stocks. Using $F_{30\%}$ as the F_{MSY} proxy, a reduction from the mean catch was still indicated for the OFLs for Puerto Rico hogfish, St. Thomas queen triggerfish, St. Croix spiny lobster, and St. Croix stoplight parrotfish, while an increase from the mean catch was indicated for the OFL for Puerto Rico yellowtail snapper. For St. Thomas spiny lobster, a spawning potential ratio of 40% (i.e. $F_{40\%}$) was used because $F_{30\%}$ could not be calculated from the high value of L_c of the stock. An increase from mean catch was indicated for the OFL using $F_{40\%}$ as the F_{MSY} proxy. The OFLs using SPR proxies resulted in smaller changes from mean catches than those from YPR proxies. Uncertainty in life history parameters and catch was considered by using the DLMtool R package to calculate distributions of OFLs for the 6 stocks. The medians of the distributions were generally very similar to the point estimates calculated except for St. Croix stoplight parrotfish.

3.5 Discussion and Research Recommendations

A number of research recommendations are identified throughout the SEDAR 46 stock evaluation. These arise from the perspective of information content (i.e., data availability, quantity, and quality and information content) and also the modeling approach. Within this context the following discussion and recommendations are made.

Regarding data availability, continued explorations are warranted on the following topics to address uncertainty within key data inputs for data-limited stock assessment models:

1. A statistical review of existing fishery independent surveys to identify an optimum sampling design for development of fishery independent abundance indices. Fishery independent surveys can contribute critical information regarding trends in stock abundance, which can be applied in relatively simple management procedures.

2. Develop indices of abundance for spiny lobster using all available data since 1970s with focus on a fishery independent survey.

3. Investigate more justifiable estimates of stock depletion (Dep) and depletion over time (Dt), such as through Productivity-Susceptibility Analysis (e.g., Cope et al. 2015) or using methods such as mean length estimators.

4. Investigate more justifiable estimates of current stock abundance.

5. Enhanced catch at length by gear sampling is needed to better inform selectivity at age.

6. Investigate fleet dynamics to more accurately capture fishery characteristics.

7. Identify target catch or index levels which could be used in conjunction with catch and index time series.

8. Identify target length levels which could be used in conjunction with catch and a length frequency series.

9. Develop a weighting scheme for length composition and multiple gear fisheries reflective of the stock.

10. Consider organizing species into species complexes for assessment based on similar life history, market characteristics, and vulnerability. This could help streamline the stock assessment process in a data-limited context.

Within the modeling framework used in SEDAR 46, many limitations are acknowledged within an MSE approach. Pragmatically, results are a product of the specific conditions of the simulation, which are assumed to be as simplistic as possible but contain sufficient complexity to reflect the system in a representative way. Methods tend to perform poorly when fundamental assumptions are invalid or inputs are strongly miss-specified. Detecting model misspecification for data-limited scenarios offers additional challenges including evaluating incongruency between data sources. As well, within the implementation model, assumed management target recommendations (i.e., TACs) were taken as catch with no implementation error simulated. Further, no uncertainty was considered in determining TACs via buffers to account for multiple sources of uncertainty (catch reporting, assessment procedure violations, etc). Thus, additional considerations towards confirmation of the stock and fleet subclass components of the operating models explored in SEDAR 46 are warranted. In particular, assumptions regarding the selectivity pattern of fleets should be further examined.

Recommendations for enhancing the practical use of the DLMtool from the analytical team.

1. Revisions of the DLMtool software to enhance the model functionality to allow multiple indices of abundance.

2. Revision of the DLMtool software to allow age varying M.

3. Allow for implementation error of the harvest control rule (e.g., TAC overages) within the implementation model in the MSE.

Recommendations for enhancing the practical use of the DLMtool from the developer (Carruthers (2015a) that the SEDAR 46 analytical team considers of practical relevance to US Caribbean fisheries application of the toolkit:

1. Idealized observation models for catch composition data
2. "Currently, DLMtool simulates catch-composition data from the true simulated catch composition data via a multinomial distribution and some effective sample size. This observation model may be unrealistically well-behaved and favor those approaches that use these data. Harvest control rules must be integrated into data-limited MPs".

3. Harvest control rules
4. "In the version of DLMtool applied in SEDAR 46 (version 2.1.2), harvest control rules (e.g., the 40-10 rule) must be written into a data-limited MP. There is currently no ability to do a factorial comparison of say 4 harvest controls rules against 3 MPs (the user must describe all 12 combinations). The reason for this is that it would require further subclasses. For example the 40-10 rule may be appropriate for the output of DBSRA but it would not be appropriate for some of the simple management procedures such as DynF that already incorporate throttling of TAC recommendations according to stock depletion."

5. Implementation error
6. "In this edition of DLMtool there is no implementation error. The only imperfection between a management recommendation and the simulated TAC comes in the form of the MaxF argument that limits the maximum fishing mortality rate on any given age-class in the operating model. The default is 0.8 which is high for all but the shortest living fish species."

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4. Appendices

Appendix 4.1.1 Puerto Rico commercial expanded landings summary. Species ordered from highest total landings to lowest landings for the years 1983−2014. The expansion factors calculated for 2013 were used to calculate 2014 landings. Boxes denote landings of species that account for approximately 50%, 75%, and 90% of total landings over the period 1983−2014. Landings units are pounds, whole weight.

Species	**Total expanded landings 1983−2014**	**Average landings per year**	**Number of full years with reported landings**	**Average per year with landings reported**	**Percent of total landings**	**Cumulative percent**
LOBSTERS,SPINY	11,518,070	359,940	32	359,940	9.07	9.07
FISHES,BONY,UNSPECIFIED	11,153,220	348,538	32	348,538	8.78	17.85
SNAPPER,SILK	10,920,028	341,251	32	341,251	8.60	26.45
CONCH,QUEEN	10,509,039	328,407	32	328,407	8.28	34.73
SNAPPER,YELLOWTAIL	9,189,263	287,164	32	287,164	7.24	41.97
SNAPPER,LANE	6,790,847	212,214	32	212,214	5.35	47.31
GRUNT,WHITE	6,330,069	197,815	32	197,815	4.99	52.30
MACKEREL,KING	4,651,239	145,351	32	145,351	3.66	55.96
DOLPHINFISH	4,478,752	139,961	32	139,961	3.53	59.49
PARROTFISHES,UNSPECIFIED	4,170,228	130,320	32	130,320	3.28	62.77
GROUPER,UNSPECIFIED	3,975,519	124,235	32	124,235	3.13	65.90
SNAPPER,QUEEN	3,414,192	106,693	28	121,935	2.69	68.59
SNAPPER,MUTTON	2,431,160	75,974	32	75,974	1.91	70.51
BOXFISH,UNSPECIFIED	2,356,329	73,635	32	73,635	1.86	72.36
TRIGGERFISH,QUEEN	2,285,692	71,428	32	71,428	1.80	74.16
HOGFISH	2,180,226	68,132	32	68,132	1.72	75.88
TUNA AND MACKERELS,UNSPECIFIED	2,156,775	67,399	32	67,399	1.70	77.58
SNAPPER,UNSPECIFIED	2,019,672	63,115	32	63,115	1.59	79.17
GROUPER,RED HIND	1,814,970	56,718	29	62,585	1.43	80.60
MULLET,WHITE	1,682,527	52,579	32	52,579	1.33	81.92
BALLYHOO	1,560,785	48,775	32	48,775	1.23	83.15
SHARKS,REQUIEM, UNSPECIFIED	1,434,077	44,815	28	51,217	1.13	84.28
MACKEREL,CERO	1,425,568	44,549	28	50,913	1.12	85.40
JACKS	1,304,156	40,755	32	40,755	1.03	86.43
OCTOPUS,UNSPECIFIED	1,219,264	38,102	32	38,102	0.96	87.39
PORGY,UNSPECIFIED	1,138,011	35,563	32	35,563	0.90	88.29
SNOOK,UNSPECIFIED	1,128,464	35,264	28	40,302	0.89	89.18
HERRING,SARDINELLA	1,089,910	34,060	32	34,060	0.86	90.03
JACK,BAR	1,014,480	31,702	28	36,231	0.80	90.83

Species	Total expanded landings 1983–2014	Average landings per year	Number of full years with reported landings	Average per year with landings reported	Percent of total landings	Cumulative percent
TUNA,YELLOWFIN	914,517	28,579	28	32,661	0.72	91.55
TUNA,SKIPJACK	858,213	26,819	28	30,650	0.68	92.23
MOJARRAS,UNSPECIFIED	759,899	23,747	32	23,747	0.60	92.83
TUNA,BLACKFIN	703,764	21,993	28	25,134	0.55	93.38
BARRACUDA	647,442	20,233	32	20,233	0.51	93.89
GOATFISH,UNSPECIFIED	624,646	19,520	10	62,465	0.49	94.38
TUNNY,LITTLE	554,088	17,315	28	19,789	0.44	94.82
SQUIRRELFISH	531,868	16,621	32	16,621	0.42	95.24
SNAPPER,VERMILION	479,013	14,969	28	17,108	0.38	95.62
GOATFISH,SPOTTED	403,965	12,624	28	14,427	0.32	95.93
WRASSE,SPANISH HOGFISH	377,546	11,798	14	26,968	0.30	96.23
SNOOK,COMMON	328,310	10,260	18	18,239	0.26	96.49
GROUPER,CONEY	325,861	10,183	28	11,638	0.26	96.75
GROUPER,NASSAU	263,949	8,248	25	10,558	0.21	96.96
MANGROVE OYSTER	257,701	8,053	29	8,886	0.20	97.16
TRUNKFISH,UNSPECIFIED	249,692	7,803	14	17,835	0.20	97.35
SHELLFISH,UNSPECIFIED	230,112	7,191	32	7,191	0.18	97.54
CRAB,BLUE LAND	219,063	6,846	32	6,846	0.17	97.71
GROUPER,MISTY	206,371	6,449	25	8,255	0.16	97.87
SNAPPER,CARDINAL	204,610	6,394	20	10,230	0.16	98.03
WAHOO	176,079	5,502	28	6,289	0.14	98.17
TUNA,ALBACORE	168,212	5,257	23	7,314	0.13	98.30
SNAPPER,BLACKFIN	156,278	4,884	22	7,104	0.12	98.43
HALFBEAK,SILVERSTRIPE	153,175	4,787	9	17,019	0.12	98.55
SCAD,BIGEYE	120,700	3,772	19	6,353	0.10	98.64
TARPON	117,892	3,684	18	6,550	0.09	98.73
JACK,HORSE-EYE	110,081	3,440	24	4,587	0.09	98.82
GOATFISH,YELLOW	97,924	3,060	27	3,627	0.08	98.90
GRUNT,UNSPECIFIED	91,021	2,844	20	4,551	0.07	98.97
DRUM,REEF CROAKER	86,839	2,714	23	3,776	0.07	99.04
MOONFISH,ATLANTIC	80,365	2,511	25	3,215	0.06	99.10
MARLIN,UNSPECIFIED	78,630	2,457	7	11,233	0.06	99.16
MARLIN,BLUE	78,353	2,449	10	7,835	0.06	99.23
GROUPER,YELLOWFIN	77,231	2,413	27	2,860	0.06	99.29
CRAB,UNSPECIFIED	66,631	2,082	23	2,897	0.05	99.34
JACK,YELLOW	51,162	1,599	24	2,132	0.04	99.38
RAY,SPOTTED EAGLE	46,387	1,450	15	3,092	0.04	99.42

Species	**Total expanded landings 1983–2014**	**Average landings per year**	**Number of full years with reported landings**	**Average per year with landings reported**	**Percent of total landings**	**Cumulative percent**
BLUE RUNNER	41,779	1,306	13	3,214	0.03	99.45
GRUNT,MARGATE	36,535	1,142	16	2,283	0.03	99.48
BUMPER,ATLANTIC	32,994	1,031	20	1,650	0.03	99.50
SWORDFISH	31,655	989	10	3,166	0.02	99.53
GROUPER,GOLIATH	31,626	988	10	3,163	0.02	99.55
SNAPPER,BLACK	30,736	960	15	2,049	0.02	99.58
HERRING,ATLANTIC THREAD	30,139	942	12	2,512	0.02	99.60
DRUMMER,WHITEMOUTH	28,202	881	22	1,282	0.02	99.62
PERMIT	23,645	739	25	946	0.02	99.64
JACK,ALMACO	23,488	734	9	2,610	0.02	99.66
AMBERJACK,GREATER	22,411	700	17	1,318	0.02	99.68
RAYS,MANTA	21,074	659	27	781	0.02	99.69
BARRACUDA,SOUTHERN SENNNET	20,800	650	14	1,486	0.02	99.71
SCAD,MACKEREL	20,395	637	3	6,798	0.02	99.73
BONEFISH	18,588	581	22	845	0.01	99.74
SHRIMP,PENAEUS, UNSPECIFIED	17,684	553	19	931	0.01	99.76
BARRACUDA,GUAGUANCHE	14,989	468	15	999	0.01	99.77
TOPSNAIL,WEST INDIAN	14,321	448	19	754	0.01	99.78
SCAD,ROUND	14,081	440	5	2,816	0.01	99.79
SHARK,TIGER	12,573	393	5	2,515	0.01	99.80
STINGRAY,SOUTHERN	11,510	360	13	885	0.01	99.81
CRAB,SPECKLED SWIMMING	10,691	334	16	668	0.01	99.82
LOBSTER,SPANISH SLIPPER	10,272	321	11	934	0.01	99.83
STINGRAYS,UNSPECIFIED	10,046	314	9	1,116	0.01	99.83
LIONFISH	9,404	294	4	2,351	0.01	99.84
RAINBOW RUNNER	9,403	294	17	553	0.01	99.85
GOBY,SIRAJO	8,365	261	6	1,394	0.01	99.85
SHARK,LEMON	8,120	254	5	1,624	0.01	99.86
LADYFISH	7,560	236	9	840	0.01	99.87
CUTLASSFISH,ATLANTIC	7,544	236	10	754	0.01	99.87
HOUNDFISH	6,684	209	10	668	0.01	99.88
SNAPPER,GRAY	6,234	195	9	693	0.00	99.88
REMORA,SHARKSUCKER	6,229	195	4	1,557	0.00	99.89
POMPANO,AFRICAN	5,754	180	9	639	0.00	99.89
CHUB,RUDDERFISH	5,678	177	13	437	0.00	99.90
GRUNT,BLACK MARGATE	5,625	176	10	563	0.00	99.90

Species	Total expanded landings 1983–2014	Average landings per year	Number of full years with reported landings	Average per year with landings reported	Percent of total landings	Cumulative percent
MULLET,LIZA	5,335	167	8	667	0.00	99.91
SHARK,REEF	5,165	161	5	1,033	0.00	99.91
PARROTFISH,RAINBOW	5,040	158	6	840	0.00	99.91
BARRACUDA,GREAT	4,783	149	7	683	0.00	99.92
MOJARRA,YELLOWFIN	4,601	144	5	920	0.00	99.92
FILEFISH,ORANGESPOTTED	4,392	137	8	549	0.00	99.92
SNAPPER,MAHOGANY	4,337	136	6	723	0.00	99.93
PORGY,JOLTHEAD	3,989	125	7	570	0.00	99.93
GROUPER,TIGER	3,866	121	1	3,866	0.00	99.93
BIGEYE	3,858	121	9	429	0.00	99.94
CLAM,UNSPECIFIED	3,345	105	6	558	0.00	99.94
SCOMBROPS,ATLANTIC	2,931	92	5	586	0.00	99.94
TILEFISH,BLACKLINE	2,882	90	7	412	0.00	99.94
SNAPPER,CUBERA	2,833	89	6	472	0.00	99.95
FLYING GUNARD	2,809	88	4	702	0.00	99.95
CUTLASSFISH	2,735	85	5	547	0.00	99.95
CHUB,YELLOW	2,713	85	2	1,356	0.00	99.95
DRUM,UNSPECIFIED	2,637	82	4	659	0.00	99.96
GROUPER,YELLOWEDGE	2,548	80	4	637	0.00	99.96
SNAPPER,DOG	2,522	79	11	229	0.00	99.96
FLYINGFISH,UNSPECIFIED	2,405	75	2	1,202	0.00	99.96
GROUPER,ROCK HIND	2,157	67	1	2,157	0.00	99.96
BARBU	2,153	67	9	239	0.00	99.96
LOBSTER,SPOTTED SPINY	2,089	65	4	522	0.00	99.97
CARDINALFISH	2,031	63	2	1,015	0.00	99.97
SHARK,HAMMERHEAD,GREAT	1,918	60	2	959	0.00	99.97
GRUNT,BLUESTRIPED	1,902	59	8	238	0.00	99.97
TRIPLETAIL	1,901	59	6	317	0.00	99.97
CRAB,CORAL	1,807	56	1	1,807	0.00	99.97
SARDINE,SCALED	1,631	51	2	815	0.00	99.97
DURGON,BLACK	1,602	50	2	801	0.00	99.98
SNAPPER,SCHOOLMASTER	1,554	49	9	173	0.00	99.98
SARDINE,REDEAR	1,497	47	3	499	0.00	99.98
MULLET,UNSPECIFIED	1,484	46	6	247	0.00	99.98
LOBSTER,RIDGED SLIPPER	1,472	46	2	736	0.00	99.98
GROUPER,RED	1,467	46	2	733	0.00	99.98
TILEFISH,SAND	1,228	38	9	136	0.00	99.98
BUTTERFLYFISH,FOUREYE	1,056	33	1	1,056	0.00	99.98

Species	**Total expanded landings 1983–2014**	**Average landings per year**	**Number of full years with reported landings**	**Average per year with landings reported**	**Percent of total landings**	**Cumulative percent**
PALOMETA	965	30	4	241	0.00	99.98
CHUB,BERMUDA	877	27	4	219	0.00	99.99
SPADEFISH,ATLANTIC	809	25	7	116	0.00	99.99
SHARK,SHARPNOSE SEVENGILL	782	24	4	196	0.00	99.99
SARGASSUMFISH	762	24	1	762	0.00	99.99
SAILFISH	760	24	3	253	0.00	99.99
PORGY,SEA BREAM	745	23	2	373	0.00	99.99
DRUMMER,MONGOLAR	727	23	2	364	0.00	99.99
PARROTFISH,STOPLIGHT	721	23	5	144	0.00	99.99
SQUIDS,UNSPECIFIED	705	22	2	352	0.00	99.99
TRIGGERFISH,UNSPECIFIED	698	22	9	78	0.00	99.99
TOBACCOFISH	603	19	1	603	0.00	99.99
ANGELFISH,GRAY	602	19	1	602	0.00	99.99
WRASSES,UNSPECIFIED	596	19	3	199	0.00	99.99
SURGEONFISH,OCEAN	562	18	2	281	0.00	99.99
MULLET,MOUNTAIN	504	16	1	504	0.00	99.99
SHARK,NURSE	493	15	1	493	0.00	99.99
MOJARRA,STRIPED	488	15	2	244	0.00	99.99
TRIGGERFISH,OCEAN	481	15	2	240	0.00	99.99
FLAMEFISH	476	15	1	476	0.00	99.99
THREADFIN	411	13	4	103	0.00	99.99
MOJARRA,SILVER JENNY	399	12	3	133	0.00	100.00
SLEEPERS	359	11	1	359	0.00	100.00
EEL,CONGER,MANYTOOTH	345	11	1	345	0.00	100.00
EEL,AMERICAN	342	11	1	342	0.00	100.00
TUNA,BIGEYE	322	10	2	161	0.00	100.00
DAMSELFISH,SERGEANT MAJOR	317	10	2	158	0.00	100.00
SHARK,MAKO,SHORTFIN	308	10	1	308	0.00	100.00
COBIA	283	9	1	283	0.00	100.00
SNOOK,SWORDSPINE	276	9	2	138	0.00	100.00
PORGY,PLUMA	273	9	4	68	0.00	100.00
FLASHERS	265	8	1	265	0.00	100.00
JACK,BLACK	231	7	2	115	0.00	100.00
MACKEREL,BULLET	218	7	1	218	0.00	100.00
EEL,MORAY	214	7	1	214	0.00	100.00
GRUNT,SMALLMOUTH	197	6	3	66	0.00	100.00
BURRFISHES,UNSPECIFIED	193	6	2	97	0.00	100.00

Species	Total expanded landings 1983–2014	Average landings per year	Number of full years with reported landings	Average per year with landings reported	Percent of total landings	Cumulative percent
SLEEPER,BIGMOUTH	179	6	1	179	0.00	100.00
BUTTERFLYFISH, UNSPECIFIED	155	5	1	155	0.00	100.00
PARROTFISH,REDTAIL	149	5	1	149	0.00	100.00
SURGEONFISH,UNSPECIFIED	148	5	3	49	0.00	100.00
SHARK,COW	145	5	1	145	0.00	100.00
GRUNT,BURRO	141	4	1	141	0.00	100.00
SHARK,HAMMERHEAD, SCALLOPED	140	4	1	140	0.00	100.00
GRUNT,TOMTATE	139	4	1	139	0.00	100.00
PUFFER,BANDTAIL	118	4	1	118	0.00	100.00
SOAPFISH	114	4	1	114	0.00	100.00
TRIGGERFISH,SARGASSUM	102	3	1	102	0.00	100.00
GRUNT,SPANISH	90	3	1	90	0.00	100.00
NEEDLEFISH,UNSPECIFIED	84	3	1	84	0.00	100.00
CREOLE-FISH	75	2	1	75	0.00	100.00
BEARDFISH	73	2	1	73	0.00	100.00
SPANISH FLAG	63	2	1	63	0.00	100.00
RAYS,EAGLE	56	2	1	56	0.00	100.00
DOLPHINFISH,POMPANO	48	2	1	48	0.00	100.00
MOJARRA,RHOMBOID	43	1	1	43	0.00	100.00
SURGEONFISH,DOCTORFISH	36	1	1	36	0.00	100.00
DRUM,JACKKNIFE-FISH	31	1	1	31	0.00	100.00
FLYINGFISH, ATLANTIC	25	1	1	25	0.00	100.00
PORCUPINEFISH	21	1	1	21	0.00	100.00

Appendix 4.1.2 St. Thomas/St. John reported landings summary. Species ordered from highest total landings to lowest landings summed over the years 2000–2014. Landings were by species-groups (except for a spiny lobster, queen conch, dolphin, and wahoo) during the period 2000 – July, 2011. Boxes denote landings of species that account for approximately 50%, 75%, and 90% of total landings over the period 2000–2014. Landings units are pounds, whole weight.

Species	**Total reported landings 2000–2014**	**Average landings per year**	**Number of full years with reported landings**	**Average per year with landings reported**	**Percent of total landings**	**Cumulative percent**
SNAPPER,UNSPECIFIED	1,733,146	115,543	12	144,429	17.92	17.92
LOBSTERS,SPINY	1,613,006	107,534	15	107,534	16.68	34.60
TRIGGERFISH,UNSPECIFIED	938,377	62,558	15	62,558	9.70	44.31
GROUPER,UNSPECIFIED	693,110	46,207	13	53,316	7.17	51.48
JACKS	655,982	43,732	12	54,665	6.78	58.26
PARROTFISHES,UNSPECIFIED	496,117	33,074	14	35,437	5.13	63.39
GRUNT,UNSPECIFIED	466,245	31,083	15	31,083	4.82	68.21
SURGEONFISH,UNSPECIFIED	425,827	28,388	12	35,486	4.40	72.62
BOXFISH,UNSPECIFIED	343,713	22,914	12	28,643	3.55	76.17
FISHES,BONY,UNSPECIFIED	294,072	19,605	12	24,506	3.04	79.21
PORGY,UNSPECIFIED	268,970	17,931	15	17,931	2.78	81.99
TUNA,UNSPECIFIED	174,562	11,637	12	14,547	1.81	83.80
TRIGGERFISH,QUEEN	159,068	10,605	4	44,235	1.65	85.44
GROUPER,RED HIND	122,271	8,151	4	33,494	1.26	86.71
ANGELFISH,UNSPECIFIED	120,627	8,042	12	10,052	1.25	87.96
SNAPPER,YELLOWTAIL	106,054	7,070	4	29,263	1.10	89.05
BLUE RUNNER	104,540	6,969	4	29,899	1.08	90.13
DOLPHINFISH	95,752	6,383	15	6,383	0.99	91.13
MACKEREL,KING AND CERO,UNSPECIFIED	92,585	6,172	12	7,715	0.96	92.08
WAHOO	62,931	4,195	15	4,195	0.65	92.73
WHELK,UNSPECIFIED	59,417	3,961	12	4,951	0.61	93.35
ANGELFISH,GRAY	56,939	3,796	4	15,312	0.59	93.94
SQUIRRELFISH	48,797	3,253	13	3,754	0.50	94.44
SURGEONFISH,DOCTORFISH	45,425	3,028	4	12,631	0.47	94.91
GRUNT,WHITE	42,706	2,847	4	11,152	0.44	95.35
COWFISH,SCRAWLED	38,388	2,559	4	10,683	0.40	95.75
PORGY,SAUCEREYE	35,202	2,347	4	9,676	0.36	96.11
SQUIRRELFISH,LONGSPINE	33,426	2,228	4	9,289	0.35	96.46
PARROTFISH,REDTAIL	33,313	2,221	4	9,056	0.34	96.80
SNAPPER,MUTTON	31,542	2,103	4	8,194	0.33	97.13
JACK,BAR	29,637	1,976	4	8,334	0.31	97.44
PARROTFISH,STOPLIGHT	27,842	1,856	4	7,554	0.29	97.72

Species	Total reported landings 2000–2014	Average landings per year	Number of full years with reported landings	Average per year with landings reported	Percent of total landings	Cumulative percent
BARRACUDA	25,532	1,702	15	1,702	0.26	97.99
CONCH,QUEEN	21,749	1,450	14	1,554	0.22	98.21
SNAPPER,BLACKFIN	20,336	1,356	4	6,123	0.21	98.42
HOGFISH	17,998	1,200	13	1,384	0.19	98.61
TUNNY,LITTLE	17,684	1,179	4	5,037	0.18	98.79
LIONFISH	12,258	817	4	3,724	0.13	98.92
GROUPER,CONEY	12,091	806	4	3,304	0.13	99.04
NEEDLEFISH,UNSPECIFIED	11,792	786	12	983	0.12	99.17
SHARK,UNSPECIFIED	9,778	652	8	1,222	0.10	99.27
SNAPPER,SILK	8,046	536	4	2,095	0.08	99.35
TOPSNAIL,WEST INDIAN	7,502	500	3	2,501	0.08	99.43
GROUPER,YELLOWFIN	5,420	361	4	1,417	0.06	99.48
MACKEREL,KING	5,168	345	4	1,607	0.05	99.54
ANGELFISH,QUEEN	4,205	280	4	1,206	0.04	99.58
TUNA,YELLOWFIN	3,881	259	3	1,294	0.04	99.62
HERRING,SARDINELLA	3,589	239	4	976	0.04	99.66
GRUNT,BLUESTRIPED	3,508	234	4	832	0.04	99.70
GOATFISH,UNSPECIFIED	3,343	223	11	304	0.03	99.73
TUNA,BLACKFIN	3,342	223	4	1,046	0.03	99.76
ANGELFISH,FRENCH	3,169	211	4	833	0.03	99.80
RAINBOW RUNNER	3,093	206	4	817	0.03	99.83
SURGEONFISH,BLUE TANG	2,894	193	3	965	0.03	99.86
GRUNT,MARGATE	1,911	127	4	513	0.02	99.88
JACK,CREVALLE	1,808	121	2	904	0.02	99.90
SNAPPER,LANE	1,796	120	4	436	0.02	99.92
BALLYHOO	1,141	76	1	1,141	0.01	99.93
GROUPER,RED	788	53	4	235	0.01	99.94
COWFISH,HONEYCOMBED	727	48	1	727	0.01	99.94
GROUPER,GRAYSBY	695	46	4	167	0.01	99.95
GRUNT,FRENCH	691	46	2	346	0.01	99.96
GROUPER,YELLOWMOUTH	650	43	4	169	0.01	99.96
SCHOOLMASTER	570	38	1	570	0.01	99.97
TUNA,SKIPJACK	476	32	2	238	0.00	99.98
MARLIN,UNSPECIFIED	465	31	1	465	0.00	99.98
TUNA,BIGEYE	323	22	3	108	0.00	99.98
SNAPPER,VERMILION	292	19	3	97	0.00	99.99
SCAD,MACKEREL	279	19	1	279	0.00	99.99

Species	**Total reported landings 2000–2014**	**Average landings per year**	**Number of full years with reported landings**	**Average per year with landings reported**	**Percent of total landings**	**Cumulative percent**
SNAPPER,QUEEN	203	14	2	102	0.00	99.99
GRUNT,COTTONWICK	174	12	1	174	0.00	99.99
GROUPER,MISTY	159	11	1	159	0.00	99.99
SHARK,TIGER	159	11	1	159	0.00	100.00
MACKEREL,CERO	153	10	3	51	0.00	100.00
SHARK,LEMON	73	5	1	73	0.00	100.00
GROUPER,YELLOWEDGE	67	4	1	67	0.00	100.00
SNAPPER,BLACK	50	3	1	50	0.00	100.00

Appendix 4.1.3 St. Thomas/St. John reported landings summary. Species ordered from highest total landings to lowest landings summed over the years 1974–1999. Landings were primarily by species-groups. Landings reported by gear are not shown. Boxes denote landings of species that account for approximately 75% and 90% of total landings over the period 1974–1999. Multiple reporting forms with different reporting requirements, often more than one form type per year, were in use during the period July, 1974–December, 1999; therefore, landings totals shown may not include all landings of a species-group (i.e., some landings were reported by gear type and had no species-group information). Landings reports from 1974 begin in July. Landings units are pounds, whole weight.

Species	Total reported landings 1974–1999	Average landings per year	Number of full years with reported landings	Average per full year with landings reported	Percent of total landings	Cumulative percent
FISH NOT SNAPPER GROUPER	5,351,249	205,817	18	297,292	38.25	38.25
FISH UNCLASSIFIED	5,161,165	198,506	13	397,013	36.89	75.14
LOBSTER	1,279,028	49,193	26	49,193	9.14	84.28
SNAPPER GROUPER	1,145,247	44,048	18	63,625	8.19	92.47
SNAPPER	206,773	7,953	3	68,924	1.48	93.95
TRIGGERFISH	124,976	4,807	3	41,659	0.89	94.84
BAITFISH	124,437	4,786	8	15,555	0.89	95.73
GROUPER	72,962	2,806	3	24,321	0.52	96.25
GRUNT	66,711	2,566	3	22,237	0.48	96.73
PARROTFISH	62,456	2,402	3	20,819	0.45	97.18
OTHER SPECIES	55,561	2,137	7	7,937	0.40	97.57
JACK	53,525	2,059	3	17,842	0.38	97.96
SURGEONFISH	49,110	1,889	3	16,370	0.35	98.31
SHELLFISH UNCLASSIFIED	45,724	1,759	13	3,517	0.33	98.63
SHELLFISH	38,106	1,466	3	12,702	0.27	98.91
ANGELFISH	31,250	1,202	3	10,417	0.22	99.13
CONCH	23,724	912	12	1,977	0.17	99.30
TUNA	23,098	888	5	4,620	0.17	99.46
WHELK	23,080	888	14	1,649	0.16	99.63
PORGY	16,083	619	3	5,361	0.11	99.74
MACKEREL	14,144	544	3	4,715	0.10	99.84
DOLPHIN	6,043	232	5	1,209	0.04	99.89
WAHOO	5,163	199	5	1,033	0.04	99.93
BARRACUDA	3,241	125	3	1,080	0.02	99.95
GOATFISH	2,962	114	3	987	0.02	99.97
SHARK	1,792	69	3	597	0.01	99.98
SQUIRRELFISH	1,691	65	1	1,691	0.01	99.99
HOGFISH	772	30	3	257	0.01	100.00

Appendix 4.1.4 St. Croix reported landings summary. Species ordered from highest total landings to lowest landings summed over the years 1998–2014. Landings were by species-groups (except for a spiny lobster, queen conch, dolphin, and wahoo) during the period 1998–July, 2011. Boxes denote landings of species that account for approximately 50%, 75%, and 90% of total landings over the period 1998–2014. Landings units are pounds, whole weight.

Species	Total reported landings 1998–2014	Average landings per year	Number of full years with reported landings	Average per full year with landings reported	Percent of total landings	Cumulative percent
PARROTFISHES,UNSPECIFIED	4,046,140	238,008	14	289,010	27.50	27.50
LOBSTERS,SPINY	1,818,432	106,967	17	106,967	12.36	39.86
CONCH,QUEEN	1,607,978	94,587	17	94,587	10.93	50.79
SNAPPER,UNSPECIFIED	1,560,880	91,816	14	111,491	10.61	61.39
DOLPHINFISH	930,207	54,718	17	54,718	6.32	67.72
SURGEONFISH,UNSPECIFIED	572,095	33,653	14	40,864	3.89	71.60
GRUNT,UNSPECIFIED	538,644	31,685	16	33,665	3.66	75.27
GROUPER,UNSPECIFIED	444,471	26,145	14	31,748	3.02	78.29
TUNA,UNSPECIFIED	398,494	23,441	14	28,464	2.71	80.99
TRIGGERFISH,UNSPECIFIED	389,391	22,905	17	22,905	2.65	83.64
FISHES,BONY,UNSPECIFIED	300,365	17,669	14	21,455	2.04	85.68
WAHOO	269,334	15,843	17	15,843	1.83	87.51
JACKS	214,762	12,633	14	15,340	1.46	88.97
BARRACUDA	166,062	9,768	17	9,768	1.13	90.10
PARROTFISH,STOPLIGHT	117,544	6,914	4	29,386	0.80	90.90
BOXFISH,UNSPECIFIED	113,569	6,681	14	8,112	0.77	91.67
MACKEREL,KING AND CERO,UNSPECIFIED	113,050	6,650	14	8,075	0.77	92.44
PORGY,UNSPECIFIED	63,270	3,722	13	4,867	0.43	92.87
TRIGGERFISH,QUEEN	53,785	3,164	3	17,928	0.37	93.24
PARROTFISH,QUEEN	53,092	3,123	3	17,697	0.36	93.60
PARROTFISH,PRINCESS	52,465	3,086	3	17,488	0.36	93.95
GOATFISH,UNSPECIFIED	49,374	2,904	14	3,527	0.34	94.29
PARROTFISH,REDFIN	48,324	2,843	3	16,108	0.33	94.62
TUNNY,LITTLE	47,396	2,788	3	15,799	0.32	94.94
GROUPER,RED HIND	47,306	2,783	3	15,769	0.32	95.26
PARROTFISH,REDTAIL	45,700	2,688	3	15,233	0.31	95.57
BALLYHOO	44,945	2,644	3	14,982	0.31	95.88
PARROTFISH,REDBAND	40,544	2,385	3	13,515	0.28	96.15
SNAPPER,BLACKFIN	39,559	2,327	3	13,186	0.27	96.42
MACKEREL,KING	36,257	2,133	3	12,086	0.25	96.67
SURGEONFISH,BLUE TANG	33,960	1,998	3	11,320	0.23	96.90
SNAPPER,SILK	33,345	1,961	3	11,115	0.23	97.12

Species	Total reported landings 1998–2014	Average landings per year	Number of full years with reported landings	Average per full year with landings reported	Percent of total landings	Cumulative percent
SCHOOLMASTER	33,129	1,949	3	11,043	0.23	97.35
GROUPER,CONEY	31,922	1,878	3	10,641	0.22	97.57
GRUNT,BLUESTRIPED	31,107	1,830	3	10,369	0.21	97.78
GRUNT,WHITE	29,188	1,717	3	9,729	0.20	97.98
JACK,BAR	28,372	1,669	3	9,457	0.19	98.17
SNAPPER,YELLOWTAIL	26,832	1,578	3	8,944	0.18	98.35
SNAPPER,GRAY	22,822	1,342	3	7,607	0.16	98.51
SNAPPER,MUTTON	20,721	1,219	3	6,907	0.14	98.65
ANGELFISH,FRENCH	16,682	981	3	5,561	0.11	98.76
MARLIN,UNSPECIFIED	14,803	871	6	2,467	0.10	98.86
TUNA,YELLOWFIN	12,837	755	3	4,279	0.09	98.95
ANGELFISH,GRAY	12,829	755	3	4,276	0.09	99.04
SNAPPER,QUEEN	12,281	722	3	4,094	0.08	99.12
SURGEONFISH,OCEAN	12,199	718	3	4,066	0.08	99.20
SURGEONFISH,DOCTORFISH	12,145	714	3	4,048	0.08	99.28
ANGELFISH,UNSPECIFIED	11,932	702	8	1,492	0.08	99.37
WHELK,UNSPECIFIED	11,091	652	8	1,386	0.08	99.44
SQUIRRELFISHES	9,302	547	3	3,101	0.06	99.50
GRUNT,FRENCH	7,571	445	3	2,524	0.05	99.56
ANGELFISH,QUEEN	7,132	420	3	2,377	0.05	99.60
SCAD,ROUND	6,836	402	3	2,279	0.05	99.65
TUNA,BLACKFIN	5,084	299	3	1,695	0.03	99.69
COWFISH,HONEYCOMBED	4,733	278	3	1,578	0.03	99.72
BLUE RUNNER	4,225	249	3	1,408	0.03	99.75
SNAPPER,MAHOGANY	3,144	185	3	1,048	0.02	99.77
TUNA,SKIPJACK	2,986	176	3	995	0.02	99.79
SNAPPER,VERMILION	2,814	166	3	938	0.02	99.81
NEEDLEFISH,UNSPECIFIED	2,811	165	5	562	0.02	99.83
LIONFISH	2,708	159	3	903	0.02	99.84
TRUNKFISH,SPOTTED	2,681	158	3	894	0.02	99.86
GROUPER,YELLOWFIN	2,271	134	3	757	0.02	99.88
SQUIRRELFISH,LONGSPINE	2,099	123	3	700	0.01	99.89
SNAPPER,LANE	1,864	110	3	621	0.01	99.91
GRUNT,TOMTATE	1,817	107	3	606	0.01	99.92
SHARK,NURSE	1,715	101	3	572	0.01	99.93
SHARK,UNSPECIFIED	1,477	87	5	295	0.01	99.94
MACKEREL,CERO	1,243	73	3	414	0.01	99.95

Species	Total reported landings 1998–2014	Average landings per year	Number of full years with reported landings	Average per full year with landings reported	Percent of total landings	Cumulative percent
SQUIRRELFISH	1,123	66	5	225	0.01	99.96
JACK,HORSE-EYE	1,078	63	3	359	0.01	99.96
HERRING,SARDINELLA	951	56	1	951	0.01	99.97
GOATFISH,YELLOW	939	55	3	313	0.01	99.98
GOATFISH,SPOTTED	463	27	3	154	0.00	99.98
SCAD,BIGEYE	385	23	1	385	0.00	99.98
TOPSNAIL,WEST INDIAN	378	22	3	126	0.00	99.98
GRUNT,CAESAR	370	22	3	123	0.00	99.99
SWORDFISH	356	21	1	356	0.00	99.99
PORGY,SHEEPSHEAD (CALAMUS)	338	20	3	113	0.00	99.99
SNAPPER,CARDINAL	270	16	2	135	0.00	99.99
EEL,MORAY,GREEN	210	12	2	105	0.00	99.99
GRUNT,MARGATE	182	11	2	91	0.00	100.00
COWFISH,SCRAWLED	178	10	3	59	0.00	100.00
PORGY,JOLTHEAD	127	7	3	42	0.00	100.00
GROUPER,TIGER	100	6	1	100	0.00	100.00
TRUNKFISH	73	4	1	73	0.00	100.00
BARRACUDA,GREAT	65	4	1	65	0.00	100.00
HOGFISH	49	3	1	49	0.00	100.00
PORGY,SAUCEREYE	34	2	1	34	0.00	100.00

Appendix 4.1.5 St. Croix reported landings summary. Species ordered from highest total landings to lowest landings summed over the years 1975–1997. Landings were primarily by species-groups. Boxes denote landings of species that account for approximately 70% and 90% of total landings over the period 1975–1997. Multiple reporting forms with different reporting requirements, often more than one form type per year, were in use during the period July, 1975–December, 1999; therefore, landings totals shown may not include all landings of a species-group (i.e., some landings were reported by gear type and had no species-group information). Reports from 1975 begin in July. Landings units are pounds, whole weight.

Species	Total reported landings 1975–1997	Average landings per year	Number of full years with reported landings	Average per full year with landings reported	Percent of total landings	Cumulative percent
FISH UNCLASSIFIED	2,947,257	128,142	11	267,932	43.68	43.68
FISH NOT SNAPPER GROUPER	1,757,947	76,432	16	109,872	26.05	69.73
SNAPPER GROUPER	464,354	20,189	16	29,022	6.88	76.61
LOBSTER	307,019	13,349	23	13,349	4.55	81.16
CONCH	298,029	12,958	12	24,836	4.42	85.58
PARROTFISH	252,065	10,959	3	84,022	3.74	89.32
SHELLFISH UNCLASSIFIED	135,119	5,875	12	11,260	2.00	91.32
TUNA	109,733	4,771	4	27,433	1.63	92.95
SNAPPER	93,729	4,075	3	31,243	1.39	94.33
DOLPHIN	54,721	2,379	4	13,680	0.81	95.15
GRUNT	51,838	2,254	3	17,279	0.77	95.91
JACK	42,219	1,836	3	14,073	0.63	96.54
SURGEONFISH	39,223	1,705	3	13,074	0.58	97.12
WAHOO	34,773	1,512	5	6,955	0.52	97.64
PELAGIC	27,623	1,201	3	9,208	0.41	98.05
TRIGGERFISH	25,695	1,117	3	8,565	0.38	98.43
GROUPER	23,794	1,035	3	7,931	0.35	98.78
BAITFISH	20,967	912	6	3,495	0.31	99.09
OTHER SPECIES	15,086	656	9	1,676	0.22	99.31
BARRACUDA	12,547	546	3	4,182	0.19	99.50
GOATFISH	9,221	401	3	3,074	0.14	99.64
ANGELFISH	8,732	380	3	2,911	0.13	99.77
SHELLFISH	8,713	379	2	4,356	0.13	99.89
MACKEREL	4,672	203	3	1,557	0.07	99.96
GAR	759	33	1	759	0.01	99.97
TRUNKFISH	686	30	2	343	0.01	99.98
WHELK	472	21	5	94	0.01	99.99
SHARK	343	15	3	114	0.01	100.00
FLYING FISH	199	9	1	199	0.00	100.00
SQUIRRELFISH	7	0	1	7	0.00	100.00

Appendix 4.2 Summary of indices of abundance for SEDAR 46, Derived from SEAMAP-C Data

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The following sections summarizing the development of delta-lognormal (D-L) indices are arranged based on survey area and gear. Within each section is a list of the years of data included, the numbers of survey stations, the parameters tested and retained in the D-L model based on a backward selection procedure, a table of indices, and the results of power analyses.

I. Puerto Rico West Trap (PRW Trap)

- Years of data used: 1991–1995
- Number of Stations: 4423
- Parameters used in D-L model: year, bottom type, depth
- Caveats: Low catch rates, short time series

Hogfish PRW Trap
No catch in PRW Traps.

Yellowtail snapper PRW Trap

- Parameters retained in D-L model:
  - Binomial submodel: year
  - Lognormal submodel: year, depth

Index Summary:

Year	Nominal Frequency	N	Index	Scaled Index	CV	LCL	UCL
1991	0.014019	428	.008754819	2.22080	1.16100	0.34998	14.0919
1992	0.008089	989	.005956015	1.51084	1.08765	0.25808	8.8446
1993	0.003834	1826	.001863179	0.47262	2.11608	0.03482	6.4158
1994	0.002193	912	.001271172	0.32245	4.48560	0.00981	10.6036
1995	0.003731	268	.001865797	0.47329	5.36610	0.01188	18.8535

Power Analyses Results:

Power analyses indicated that more than 150 stations are needed annually to detect a 25% annual change in abundance over a ten-year time series. Detailed information on the power analyses is provided at the end of Appendix 4.2.

II. Puerto Rico West Reef Fish Handline (PRW RFHL)

- Years of data used: 1991–1995, 1997–2001, 2004–2006, 2009–2010
- Number of Stations: 1949
- Parameters used in D-L model: year, bottom type, depth, closed area (i.e., are the stations located in a marine closed area or not)

- Caveats: Numerous data holidays

Hogfish PRW RFHL
No catch in PRW RFHLs.

Yellowtail snapper PRW RFHL

- Parameters retained in D-L model:
    - Binomial submodel: year
    - Lognormal submodel: year

Index Summary:

Year	Nominal Frequency	N	Index	Scaled Index	CV	LCL	UCL
1991	0.00000	94	.	.	.	.	.
1992	0.00962	312	0.001905	0.23512	0.59162	0.07860	0.7033
1993	0.01972	355	0.004319	0.53301	0.38551	0.25317	1.1222
1994	0.01311	305	0.003086	0.38076	0.51153	0.14518	0.9986
1995	0.00000	18	.	.	.	.	.
1997	0.00535	187	0.001070	0.13198	1.02643	0.02419	0.7200
1998	0.00000	82	.	.	.	.	.
1999	0.01235	162	0.002598	0.32066	0.72355	0.08759	1.1739
2000	0.03333	90	0.008689	1.07217	0.58485	0.36236	3.1724
2001	0.02439	82	0.005682	0.70111	0.71935	0.19269	2.5510
2004	0.00000	45	.	.	.	.	.
2005	0.02632	152	0.006713	0.82836	0.50827	0.31758	2.1607
2006	0.04444	45	0.011261	1.38966	0.71230	0.38591	5.0041
2009	0.07692	13	.	.	.	.	.
2010	0.14286	7	0.035714	4.40718	0.95664	0.87900	22.0969

Power Analyses Results:

Power analyses indicated that much more than 150 stations are needed annually to detect a 25% annual change in abundance over a ten-year time series. Detailed information on the power analyses is provided at the end of Appendix 4.2.

III. Puerto Rico East Reef Fish Handline (PRE RFHL)

- Years of data used: 2009–2011
- Number of Stations: 88
- Parameters used in D-L model: year, depth
- Caveats: Short time series

Hogfish PRE RFHL
No catch in PRW RFHLs.

Yellowtail snapper PRE RFHL

- Parameters retained in D-L model:

  - Binomial submodel: year
  - Lognormal submodel: year, depth

Index Summary:

Year	*Nominal Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
2009	0.15385	26	0.042409	1.12646	0.47101	0.46016	2.75751
2010	0.12245	49	0.032887	0.87354	0.39220	0.40996	1.86137
2011	0.00000	13	.	.	.	.	.

Power Analyses Results:

Power analyses indicated that at least 83 stations are needed annually to detect a 10% annual change in abundance over a five-year time series.

IV. St. Thomas Trap (STT Trap)

- Years of data used: 1992–1994, 1999–2000
- Number of Stations: 357
- Parameters used in D-L model: year, depth
- Caveats: Low catch rates, data holidays, different mesh sizes in traps, low sampling effort

Queen triggerfish STT Trap

- Parameters retained in D-L model:
  - Binomial submodel: year
  - Lognormal submodel: year

Index Summary:

Year	*Nominal Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
1992	0.10000	60	0.13094	0.58710	0.45492	0.24660	1.39772
1993	0.00000	36	.	.	.	.	.
1994	0.04167	72	0.18982	0.85114	0.65555	0.25743	2.81408
1999	0.13699	73	0.22957	1.02935	0.34830	0.52318	2.02522
2000	0.17241	116	0.34176	1.53242	0.24437	0.94665	2.48064

Power Analyses Results:

Power analyses indicated that at least 81 stations are needed annually to detect a 20% annual change in abundance over a five-year time series. Detailed information on the power analyses is provided at the end of Appendix 4.2.

V. St. Thomas Reef Fish Handline (STT RFHL)

- Years of data used: 1992–1994, 1999–2000, 2009–2012
- Number of Stations: 88

- Parameters used in D-L model: year
- Caveats: Low catch rates, data holidays, low sampling effort, changes in sampling effort

Queen triggerfish STT RFHL

- Parameters retained in D-L model:
  - Binomial submodel: year
  - Lognormal submodel: year

Index Summary:

Year	*Nominal Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
1992	0.15789	19	0.049040	1.29607	0.67990	0.37775	4.44684
1993	0.11111	9	0.027778	0.73413	1.17735	0.11370	4.74014
1994	0.05882	17	0.033613	0.88836	1.20136	0.13416	5.88228
1999	0.25000	12	0.017888	0.47275	0.65478	0.14316	1.56119
2000	0.30000	10	0.040507	1.07054	0.64073	0.33127	3.45954
2009	0.00000	4	.	.	.	.	.
2010	0.37500	8	0.047961	1.26754	0.61906	0.40572	3.95997
2011	0.50000	8	0.048077	1.27062	0.50655	0.48854	3.30465
2012	1.00000	1	.	.	.	.	.

Power Analyses Results:

Power analyses indicated that at least 72 stations are needed annually to detect a 20% annual change in abundance over a five-year time series, or 49 stations are needed annually to detect a 10% annual change in abundance over a ten-year time series. Detailed information on the power analyses is provided at the end of Appendix 4.2.

VI. St. Croix Trap (STX Trap)

- Years of data used: 1993–1994, 2002
- Number of Stations: 164
- Parameters used in D-L model: year, depth
- Caveats: Low catch rates, data holidays, different mesh sizes in traps, changes in sampling effort, short time series

Queen triggerfish STX Trap

- Parameters retained in D-L model:
  - Binomial submodel: year, depth
  - Lognormal submodel: year

Index Summary:

Year	*Nominal Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
1993	0.22222	18	1.15484	2.60290	0.45163	1.09960	6.16142
1994	0.07407	27	0.12848	0.28957	0.70201	0.08165	1.02698
2002	0.05882	119	0.04771	0.10753	0.44136	0.04625	0.25002

Power Analyses Results:

Power analyses indicated that at least 83 stations are needed annually to detect a 15% annual change in abundance over a ten-year time series.

VII. ST. Croix Reef Fish Handline (STX RFHL)

- Years of data used: 1993–1994, 2002
- Number of Stations: 73
- Parameters used in D-L model: year
- Caveats: Low catch rates, data holidays, low sampling effort, changes in sampling effort

Queen triggerfish STX RFHL

- Parameters retained in D-L model:
    - Binomial submodel: year
    - Lognormal submodel: year

Index Summary:

Year	*Nominal Frequency*	*N*
1993	0.00000	6
1994	0.14286	7
2002	0.00000	60

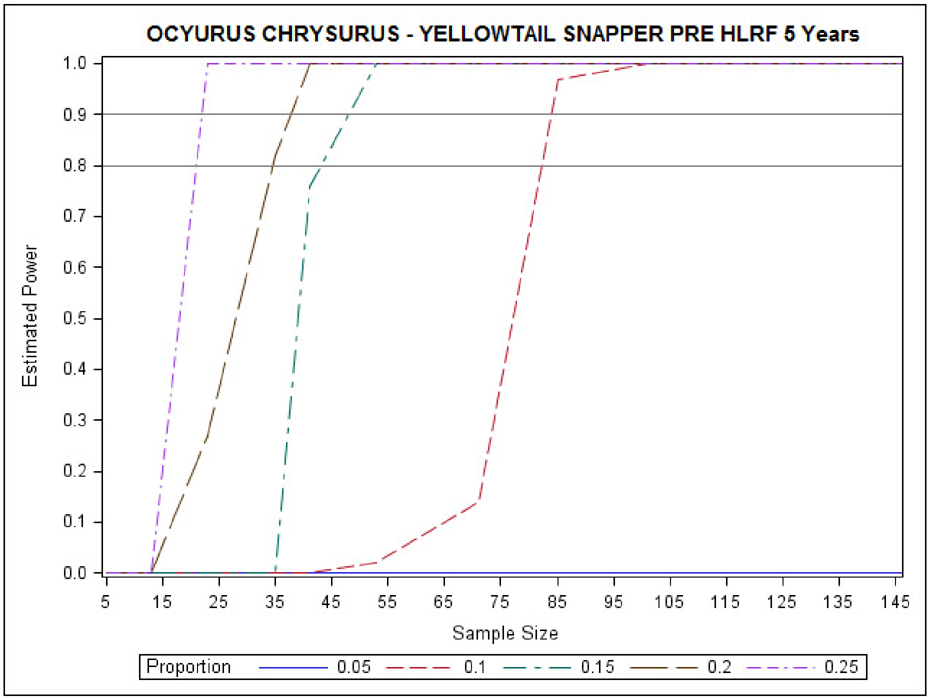
Power Analyses Results:

Power analyses indicated that more than 150 stations are needed annually to detect a 25% annual change in abundance over a ten-year time series.. Detailed information on the power analyses is provided at the end of Appendix 4.2.

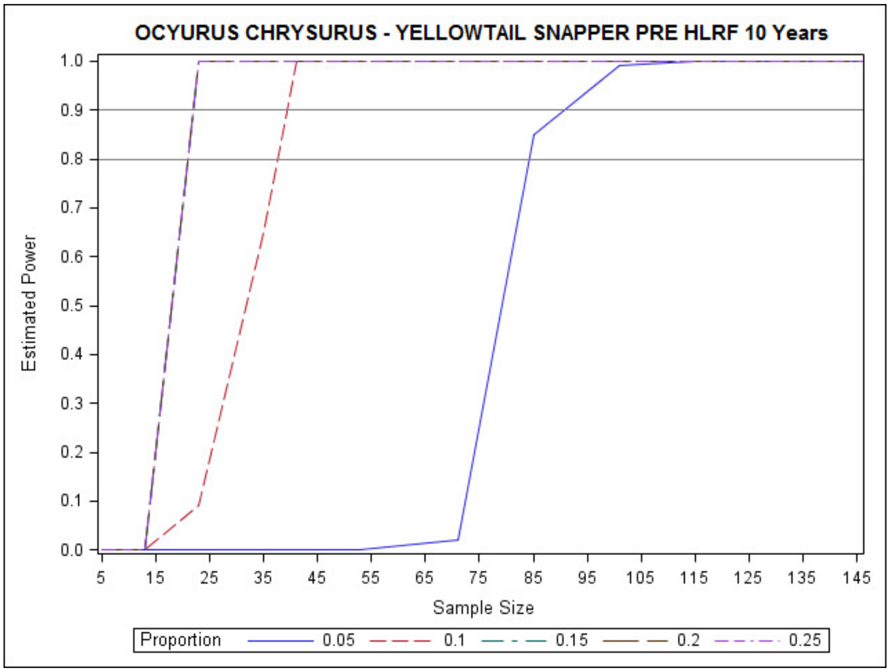
Power Analyses Detailed Information

Simulations of populations derived from the parameters of the delta-lognormal model developed for each species for each area (i.e. PRW, PRE, STT, STX) and gear type (i.e. RFHL, Trap) were ran. The statistical power to discern a significant year effect (α=0.05, β=0.2) was calculated for increasing sample sizes and increasing proportions of theoretical annual population growth. This was done for both five and ten year time series.

Below are graphical representations of a run conducted for yellowtail snapper collected from the PRE RFHL. The first graph is for a five year time series and the second for a ten year time series with estimated power on the vertical axis and theoretical sample size on the horizontal axis. Estimates of statistical power by sample size at different proportions of theoretical annual population growth are depicted by the multicolored lines.



Power analyses indicated that at least 83 stations are needed annually to detect a 10% annual change in abundance over a five-year time series (i.e. a 50% increase or decrease over the five-year time series).



Power analyses indicated that at least 84 stations are needed annually to detect a 5% annual change in abundance over a ten-year time series (i.e. a 50% increase or decrease over the ten-year time series).

Appendix 4.3.1 Puerto Rico hogfish data and parameter inputs available for use in calculating total allowable catch with DLMtool (Source: SEDAR 46 DW/AW Workshop). NA = not available.

Name	Hogfish_PR_Dive								
Year	1983	1984	1985	1986	1987	1988	1989	1990	1991
	1992	1993	1994	1995	1996	1997	1998	1999	2000
	2001	2002	2003	2004	2005	2006	2007	2008	2009
	2010	2011	2012	2013	2014				
Catch	119075	120254	74668	49999	48647	53827	50096	42514	60712
	35297	35308	50341	69687	84051	87610	62968	58854	107364
	108000	79591	71163	87343	131073	52455	57814	79819	77217
	68540	56177	71732	49537	58569				
Abundance index	NA	NA	NA	NA	NA	NA	NA	1.10	1.48
	1.48	0.33	1.12	1.06	1.12	1.10	1.39	1.37	1.69
	1.22	1.25	0.76	0.68	0.65	0.73	0.74	0.76	0.70
	0.69	0.72	0.90	0.96	0.99				
Duration t	32								
Average catch over time t	70634								
Depletion over time t	0.135								
M	0.1558								
FMSY/M	0.75								
BMSY/B0	0.35								
Cref	NA								
Bref	NA								
Length at 50% maturity	176.8								
Length at 95% maturity	295								
Length at first capture	231								
Length at full selection	544								
CAA	NA								
Current stock depletion	0.135								
Current stock abundance	501235								
Von Bertalanffy t0 parameter	-1.329								
Von Bertalanffy K parameter	0.1058								
Von Bertalanffy Linf parameter	848.9889								
Length-weight parameter a	9.50E-05								
Length-weight parameter b	2.7452								
Steepness	0.83								
Maximum age	23								
CV Catch	0.35								
CV Depletion over time t	0.5								
CV Average catch over time t	0.35								
CV Abundance index	0.33								
CV M	0.082								
CV FMSY/M	0.5								
CV BMSY/B0	0.5								
CV_MSY	NA								
CV_BMSY	NA								
CV current stock depletion	0.5								
CV current stock abundance	0.5								
CV von B. K parameter	0.24								
CV von B. Linf parameter	0.06								
CV von B. t0 parameter	0.38								
CV Length at 50% maturity	0.11								
CV Length at 95% maturity	0.17								
CV Length at first capture	0.2								

CV Length at full selection	0.2								
CV Length-weight parameter a	0.05								
CV Length-weight parameter b	0.05								
CV Steepness	0.2								
Sigma length composition	0.2								
Units	pounds								
Reference TAC	NA								
Reference TAC type	NA								
CAL_bins	50	60	70	80	90	100	110	120	130
CAL 1983	0	0	0	0	0	0	0	0	0
CAL 1984	0	0	0	0	0	0	0	0	0
CAL 1985	0	0	0	0	0	0	0	0	0
CAL 1986	0	0	0	0	0	0	0	0	0
CAL 1987	0	0	0	0	0	0	0	0	0
CAL 1988	1	0	0	0	0	0	0	0	0
CAL 1989	0	0	0	0	0	0	0	0	0
CAL 1990	0	0	0	0	0	0	0	0	0
CAL 1991	0	0	0	0	0	0	0	0	0
CAL 1992	0	0	1	0	2	0	1	0	0
CAL 1993	0	0	0	0	2	1	0	0	0
CAL 1994	0	0	0	0	0	0	0	0	0
CAL 1995	0	0	0	0	0	0	4	4	0
CAL 1996	0	0	1	0	0	0	0	0	0
CAL 1997	0	0	0	1	0	1	1	0	0
CAL 1998	0	0	0	0	0	0	0	0	0
CAL 1999	0	0	1	0	0	1	0	0	0
CAL 2000	0	0	0	0	1	0	1	0	0
CAL 2001	0	0	0	0	0	2	0	0	0
CAL 2002	0	0	0	0	0	0	0	0	0
CAL 2003	1	0	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0
CAL 2005	0	0	0	0	0	0	0	3	0
CAL 2006	0	0	0	0	0	0	0	0	0
CAL 2007	0	0	0	0	0	0	0	0	0
CAL 2008	0	0	1	1	8	5	7	5	0
CAL 2009	0	0	0	0	0	0	0	0	0
CAL 2010	0	0	0	0	0	0	0	0	0
CAL 2011	0	0	0	0	0	0	0	0	0
CAL 2012	0	0	0	0	0	0	0	0	0
CAL 2013	0	0	0	0	0	0	0	0	0
CAL_bins	140	150	160	170	180	190	200	210	220
CAL 1983	0	0	0	0	0	0	0	0	0
CAL 1984	0	0	0	0	0	0	0	0	0
CAL 1985	0	0	0	0	0	0	0	0	0
CAL 1986	0	0	0	0	0	0	0	0	0
CAL 1987	0	0	0	0	0	0	0	0	0
CAL 1988	0	0	0	0	0	1	1	0	2
CAL 1989	0	0	0	0	1	0	0	1	1
CAL 1990	0	0	0	0	0	0	0	1	1
CAL 1991	0	0	0	0	0	0	0	1	1
CAL 1992	0	0	0	0	1	0	0	0	0
CAL 1993	0	0	0	0	0	0	0	0	0
CAL 1994	0	0	0	0	0	0	0	0	1
CAL 1995	0	0	0	0	0	0	0	0	0
CAL 1996	0	0	0	0	0	1	0	0	1
CAL 1997	0	0	0	0	0	0	0	0	0

CAL 1998	0	0	1	0	0	0	0	2	4
CAL 1999	0	0	0	0	0	0	1	4	4
CAL 2000	0	0	0	0	0	0	1	1	2
CAL 2001	0	0	0	0	1	0	2	1	1
CAL 2002	0	0	0	0	0	0	0	1	4
CAL 2003	0	0	0	0	0	0	0	1	2
CAL 2004	0	0	0	0	0	0	0	2	0
CAL 2005	0	0	0	0	0	0	0	0	1
CAL 2006	0	0	0	0	0	0	0	0	0
CAL 2007	0	0	0	0	0	0	0	0	1
CAL 2008	2	0	0	0	0	0	0	0	0
CAL 2009	0	0	0	0	0	0	0	1	1
CAL 2010	0	0	0	0	0	0	1	0	1
CAL 2011	0	0	0	0	0	0	0	0	3
CAL 2012	0	0	0	0	0	1	0	3	4
CAL 2013	0	0	0	0	0	0	0	1	4
CAL_bins	230	240	250	260	270	280	290	300	310
CAL 1983	0	0	0	0	1	1	2	0	1
CAL 1984	2	2	4	1	2	1	1	3	0
CAL 1985	1	0	6	0	2	3	4	2	0
CAL 1986	2	1	0	0	3	0	2	1	2
CAL 1987	0	5	8	5	9	10	4	3	2
CAL 1988	0	3	5	6	6	10	3	12	6
CAL 1989	1	1	2	2	2	5	8	9	4
CAL 1990	0	3	1	3	2	8	6	3	3
CAL 1991	2	1	4	4	9	11	11	15	4
CAL 1992	2	0	0	2	2	4	7	3	6
CAL 1993	0	0	1	4	5	3	3	5	3
CAL 1994	1	0	0	1	1	1	0	0	0
CAL 1995	1	4	0	4	2	7	2	3	6
CAL 1996	2	4	2	5	5	5	4	2	3
CAL 1997	0	1	1	3	1	4	4	1	2
CAL 1998	5	10	8	8	2	3	8	5	6
CAL 1999	5	8	6	9	8	19	12	10	15
CAL 2000	2	3	4	12	7	9	8	12	11
CAL 2001	8	7	13	22	17	24	23	24	20
CAL 2002	2	4	11	6	6	6	9	14	8
CAL 2003	4	6	11	11	13	9	7	7	8
CAL 2004	0	3	2	2	8	8	9	6	4
CAL 2005	3	1	6	5	5	6	7	8	5
CAL 2006	0	1	6	5	9	2	7	5	4
CAL 2007	3	1	1	1	5	7	6	3	5
CAL 2008	3	0	0	3	5	1	2	5	3
CAL 2009	3	8	6	8	12	13	8	14	18
CAL 2010	7	4	10	8	10	8	20	6	9
CAL 2011	6	7	3	8	5	12	9	15	28
CAL 2012	1	7	10	3	12	9	7	9	7
CAL 2013	5	4	6	6	8	7	7	5	5
CAL_bins	320	330	340	350	360	370	380	390	400
CAL 1983	1	2	1	1	0	0	0	0	1
CAL 1984	1	2	5	1	1	2	1	3	0
CAL 1985	0	2	2	0	5	0	3	2	1
CAL 1986	1	0	0	2	0	0	0	0	1
CAL 1987	2	1	2	4	1	1	2	1	0
CAL 1988	7	4	8	0	4	4	5	3	6
CAL 1989	7	3	2	8	6	6	8	8	6

CAL 1990	9	6	5	6	6	8	2	8	3
CAL 1991	8	9	7	8	5	3	8	7	7
CAL 1992	5	10	8	4	6	6	2	6	4
CAL 1993	2	4	2	2	4	4	1	1	3
CAL 1994	0	1	0	0	1	1	0	0	0
CAL 1995	5	0	0	2	2	0	1	1	1
CAL 1996	1	1	1	2	0	1	0	1	1
CAL 1997	2	2	1	1	3	3	1	3	2
CAL 1998	5	2	2	2	1	1	1	2	2
CAL 1999	3	6	8	7	11	4	4	2	3
CAL 2000	6	8	10	8	8	7	8	5	11
CAL 2001	15	13	15	14	8	10	7	8	6
CAL 2002	2	2	5	3	6	3	2	3	2
CAL 2003	7	9	8	2	6	3	1	6	1
CAL 2004	3	0	5	5	7	4	1	1	3
CAL 2005	3	4	6	4	6	1	2	2	3
CAL 2006	5	6	3	1	7	3	4	2	10
CAL 2007	0	5	3	3	1	5	1	2	4
CAL 2008	2	4	3	1	5	5	1	2	1
CAL 2009	16	12	10	13	12	13	7	9	10
CAL 2010	11	13	11	8	11	7	12	4	8
CAL 2011	14	9	13	9	13	12	10	17	8
CAL 2012	5	14	15	2	7	5	3	7	6
CAL 2013	4	8	7	3	7	9	3	3	2
CAL_bins	410	420	430	440	450	460	470	480	490
CAL 1983	3	0	0	0	0	0	0	0	1
CAL 1984	2	1	0	0	2	3	1	0	1
CAL 1985	2	4	1	5	1	0	6	1	1
CAL 1986	1	0	0	0	0	1	0	0	0
CAL 1987	2	1	1	1	2	2	1	0	1
CAL 1988	4	4	5	3	2	0	1	3	3
CAL 1989	2	5	2	4	9	3	7	1	5
CAL 1990	1	5	3	9	6	9	5	2	3
CAL 1991	0	4	4	4	2	3	5	1	2
CAL 1992	2	6	2	2	1	4	3	0	1
CAL 1993	2	2	3	1	4	1	2	3	4
CAL 1994	0	3	0	0	2	0	2	0	0
CAL 1995	1	0	0	2	0	1	1	2	1
CAL 1996	1	1	2	1	0	0	0	1	0
CAL 1997	2	2	1	1	0	0	0	0	1
CAL 1998	1	0	2	1	3	2	3	1	2
CAL 1999	8	8	2	1	0	2	1	4	3
CAL 2000	4	8	6	6	2	4	3	3	2
CAL 2001	10	15	5	6	4	3	3	5	4
CAL 2002	3	1	4	6	3	1	2	7	7
CAL 2003	6	4	2	3	3	3	1	1	3
CAL 2004	1	7	3	1	4	2	3	1	0
CAL 2005	5	2	1	3	3	1	5	3	6
CAL 2006	3	6	1	3	5	0	4	1	2
CAL 2007	3	3	4	0	1	1	0	2	1
CAL 2008	0	1	1	1	0	0	0	0	0
CAL 2009	14	12	4	2	8	13	3	5	5
CAL 2010	1	7	5	5	4	5	6	5	3
CAL 2011	11	16	14	5	8	9	7	6	7
CAL 2012	10	10	9	5	13	11	7	6	3
CAL 2013	3	3	2	2	9	0	3	1	2

CAL_bins	500	510	520	530	540	550	560	570	580
CAL 1983	0	3	0	0	0	0	3	0	1
CAL 1984	4	3	2	0	0	0	0	0	2
CAL 1985	2	4	0	3	4	0	1	0	1
CAL 1986	1	1	0	0	0	2	0	0	0
CAL 1987	3	0	2	1	1	0	0	0	1
CAL 1988	0	2	0	1	0	0	0	0	0
CAL 1989	5	6	4	8	3	4	2	2	2
CAL 1990	5	7	6	5	2	1	2	3	0
CAL 1991	6	2	4	3	1	3	3	0	0
CAL 1992	3	1	1	1	3	0	2	0	1
CAL 1993	0	2	2	0	2	4	1	0	0
CAL 1994	1	0	0	1	0	0	1	0	0
CAL 1995	1	2	0	0	0	0	1	1	0
CAL 1996	0	1	1	0	0	1	1	0	0
CAL 1997	1	1	0	0	0	1	0	0	0
CAL 1998	1	0	3	2	1	0	0	1	0
CAL 1999	4	2	3	2	1	0	0	0	0
CAL 2000	5	3	2	0	0	1	0	1	1
CAL 2001	1	1	0	1	2	2	0	0	0
CAL 2002	1	0	1	1	0	3	0	0	0
CAL 2003	2	3	3	3	0	1	0	1	0
CAL 2004	2	2	4	0	1	1	0	1	2
CAL 2005	2	0	0	1	0	1	2	1	0
CAL 2006	1	3	0	1	1	3	4	4	0
CAL 2007	2	0	2	1	0	0	0	0	0
CAL 2008	0	2	1	0	0	0	1	0	0
CAL 2009	6	5	3	3	4	2	1	1	2
CAL 2010	5	4	2	2	3	2	2	1	1
CAL 2011	5	9	3	5	4	5	5	2	2
CAL 2012	4	6	7	6	2	5	5	1	5
CAL 2013	3	2	1	2	2	6	2	3	0
CAL_bins	590	600	610	620	630	640	650	660	670
CAL 1983	0	0	0	0	0	0	0	0	0
CAL 1984	0	1	1	0	0	0	0	0	0
CAL 1985	0	0	0	0	0	0	0	0	0
CAL 1986	0	0	0	0	0	0	0	0	0
CAL 1987	0	0	1	0	0	0	0	0	0
CAL 1988	0	1	1	0	1	0	0	1	0
CAL 1989	1	1	0	0	2	0	0	0	0
CAL 1990	1	0	0	1	0	0	0	0	0
CAL 1991	0	3	0	0	0	0	0	0	0
CAL 1992	2	1	0	0	2	1	0	0	0
CAL 1993	0	0	0	0	0	0	0	0	0
CAL 1994	1	0	0	0	0	0	0	0	0
CAL 1995	1	0	0	0	1	0	0	0	0
CAL 1996	0	0	0	0	0	0	0	0	0
CAL 1997	0	0	0	0	0	0	1	0	0
CAL 1998	0	0	0	0	0	0	0	0	0
CAL 1999	0	0	0	0	1	0	1	0	0
CAL 2000	1	0	0	0	0	0	0	0	0
CAL 2001	0	2	0	0	0	0	0	0	0
CAL 2002	0	0	0	0	0	0	0	0	0
CAL 2003	0	1	0	1	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0
CAL 2005	0	1	0	0	0	0	1	0	0

CAL 2006	2	0	0	0	0	0	0	0	0
CAL 2007	0	1	1	1	0	0	0	0	0
CAL 2008	0	0	0	0	0	1	0	0	1
CAL 2009	0	0	1	0	0	0	0	0	0
CAL 2010	1	3	1	1	1	2	0	1	0
CAL 2011	6	3	1	2	1	1	1	0	1
CAL 2012	1	0	2	1	2	2	1	1	2
CAL 2013	0	0	0	1	0	0	0	0	0
CAL_bins	680	690	700	710	720	730	740	750	760
CAL 1983	0	0	0	0	0	0	0	0	0
CAL 1984	0	0	0	0	0	0	0	0	0
CAL 1985	0	0	0	0	0	0	0	0	0
CAL 1986	0	0	0	0	0	0	0	0	0
CAL 1987	0	0	0	0	0	0	0	0	0
CAL 1988	0	0	0	0	0	0	0	0	0
CAL 1989	0	0	0	0	0	0	0	0	0
CAL 1990	0	0	0	0	0	0	0	0	0
CAL 1991	0	0	0	0	0	0	0	0	0
CAL 1992	0	0	0	0	0	0	0	0	0
CAL 1993	0	0	0	0	0	0	0	0	0
CAL 1994	0	0	0	0	0	0	0	0	0
CAL 1995	0	0	0	0	0	0	0	0	0
CAL 1996	0	0	0	0	0	0	0	0	0
CAL 1997	0	0	0	0	0	0	0	0	0
CAL 1998	0	0	0	0	0	0	0	0	0
CAL 1999	0	0	0	0	0	0	0	0	0
CAL 2000	0	0	0	0	0	0	0	0	0
CAL 2001	0	0	0	0	0	0	0	0	0
CAL 2002	0	0	0	0	0	0	0	0	0
CAL 2003	0	1	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0
CAL 2005	0	0	0	0	0	0	0	0	0
CAL 2006	0	0	0	0	0	0	0	0	0
CAL 2007	0	0	0	0	0	0	0	0	0
CAL 2008	0	0	0	0	0	0	0	0	0
CAL 2009	0	0	0	0	0	0	0	0	0
CAL 2010	0	0	0	0	0	0	0	0	0
CAL 2011	2	0	0	0	0	0	0	0	0
CAL 2012	0	1	1	0	0	0	1	0	0
CAL 2013	1	0	0	0	0	0	0	0	0
CAL_bins	770	780	790	800	810	820	830	840	850
CAL 1983	0	0	0	0	0	0	0	0	0
CAL 1984	0	0	0	0	0	0	0	0	0
CAL 1985	0	0	0	0	0	0	0	0	0
CAL 1986	1	0	0	0	0	0	0	0	0
CAL 1987	0	0	0	0	0	0	0	0	0
CAL 1988	0	0	0	0	0	0	0	0	0
CAL 1989	0	0	0	0	0	0	0	0	0
CAL 1990	0	0	0	0	0	0	0	0	0
CAL 1991	0	0	0	0	0	0	0	0	0
CAL 1992	0	0	0	0	0	0	0	0	0
CAL 1993	0	0	0	0	0	0	0	0	0
CAL 1994	0	0	0	0	0	0	0	0	0
CAL 1995	0	0	0	0	0	0	0	0	0
CAL 1996	0	0	0	0	0	0	0	0	0
CAL 1997	0	0	0	0	0	0	0	0	0

CAL 1998	0	0	0	0	0	0	0	0	0
CAL 1999	0	0	0	0	0	0	0	0	0
CAL 2000	0	0	0	0	0	0	0	0	0
CAL 2001	0	0	0	0	0	0	0	0	0
CAL 2002	0	0	0	0	0	0	0	0	0
CAL 2003	0	0	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0
CAL 2005	0	0	0	0	0	0	0	0	0
CAL 2006	0	0	0	0	0	0	0	0	0
CAL 2007	0	0	0	0	0	0	0	0	0
CAL 2008	0	0	0	0	0	0	0	0	0
CAL 2009	0	0	0	0	0	0	0	0	0
CAL 2010	0	0	0	0	0	0	0	0	0
CAL 2011	0	0	0	0	0	0	0	0	0
CAL 2012	0	0	0	0	1	1	0	0	0
CAL 2013	0	0	0	0	0	0	0	0	0
CAL_bins	860	870	880	890					
CAL 1983	0	0	0	0					
CAL 1984	0	0	0	0					
CAL 1985	0	0	0	0					
CAL 1986	0	0	0	0					
CAL 1987	0	0	0	0					
CAL 1988	0	0	0	0					
CAL 1989	0	0	0	0					
CAL 1990	0	0	0	0					
CAL 1991	0	0	0	0					
CAL 1992	0	0	0	0					
CAL 1993	0	0	0	0					
CAL 1994	0	0	0	0					
CAL 1995	0	0	0	0					
CAL 1996	0	0	0	0					
CAL 1997	0	0	0	0					
CAL 1998	0	0	0	0					
CAL 1999	0	0	0	0					
CAL 2000	0	0	0	0					
CAL 2001	0	0	0	0					
CAL 2002	0	0	0	0					
CAL 2003	0	0	0	0					
CAL 2004	0	0	0	0					
CAL 2005	0	0	0	0					
CAL 2006	0	1	0	0					
CAL 2007	0	0	0	0					
CAL 2008	0	0	0	0					
CAL 2009	0	0	0	0					
CAL 2010	0	0	0	0					
CAL 2011	0	0	0	0					
CAL 2012	0	0	0	0					
CAL 2013	0	0	0	0					

Appendix 4.3.2 Puerto Rico yellowtail snapper data and parameter inputs available for use in calculating total allowable catch with DLMtool (Source: SEDAR 46 DW/AW Workshop). NA = not available.

Name	Yellowtailsnapper_PR_Handline								
Year	1983	1984	1985	1986	1987	1988	1989	1990	1991
	1992	1993	1994	1995	1996	1997	1998	1999	2000
	2001	2002	2003	2004	2005	2006	2007	2008	2009
	2010	2011	2012	2013	2014				
Catch	274597	227422	250598	124996	122999	137918	178461	209873	291165
	248488	304925	291047	409607	383049	349869	322532	356577	663675
	498566	363681	341668	381243	688908	281022	231993	393731	239705
	225039	159830	225201	134502	200667				
Abundance index	NA	NA	NA	NA	NA	NA	NA	1.57	1.18
	0.93	0.99	1.17	1.48	1.15	1.12	1.22	1.13	1.18
	1.33	1.10	0.78	0.84	0.72	0.72	0.86	0.69	0.61
	0.63	0.75	0.87	0.95	1.01				
Duration t	32								
Average catch over time t	297299								
Depletion over time t	0.33								
M	0.1889								
FMSY/M	0.75								
BMSY/B0	0.35								
Cref	NA								
Bref	NA								
Length at 50% maturity	248								
Length at 95% maturity	315								
Length at first capture	206								
Length at full selection	406								
CAA	NA								
Current stock depletion	0.33								
Current stock abundance	1E+06								
Von Bertalanffy t0 parameter	-0.955								
Von Bertalanffy K parameter	0.139								
Von Bertalanffy Linf parameter	502.53								
Length-weight parameter a	3.54E-05								
Length-weight parameter b	2.859								
Steepness	0.79								
Maximum age	19								
CV Catch	0.46								
CV Depletion over time t	0.5								
CV Average catch over time t	0.46								
CV Abundance index	0.26								
CV M	0.083								
CV FMSY/M	0.5								
CV BMSY/B0	0.5								
CV_MSY	NA								
CV_BMSY	NA								
CV current stock depletion	0.5								
CV current stock abundance	0.5								
CV von B. K parameter	0.16								
CV von B. Linf parameter	0.05								
CV von B. t0 parameter	0.45								
CV Length at 50% maturity	0.15								
CV Length at 95% maturity	0.17								
CV Length at first capture	0.2								
CV Length at full selection	0.2								

CV Length-weight parameter a	0.05								
CV Length-weight parameter b	0.05								
CV Steepness	0.2								
Sigma length composition	0.2								
Units	pounds								
Reference TAC	NA								
Reference TAC type	NA								
CAL_bins	100	110	120	130	140	150	160	170	180
CAL 1983	0	0	0	0	0	0	0	0	0
CAL 1984	0	0	0	0	0	1	2	3	11
CAL 1985	0	0	0	0	0	0	1	1	2
CAL 1986	0	0	0	0	0	0	0	1	3
CAL 1987	0	0	0	0	0	0	0	1	4
CAL 1988	0	0	0	0	0	2	3	4	6
CAL 1989	0	0	0	0	0	0	1	1	1
CAL 1990	0	0	0	0	0	0	1	1	3
CAL 1991	1	0	0	0	2	1	6	17	23
CAL 1992	0	0	0	1	0	6	28	46	92
CAL 1993	0	0	0	0	0	0	5	11	29
CAL 1994	0	0	0	0	0	1	0	0	4
CAL 1995	0	0	0	0	1	0	1	6	13
CAL 1996	0	0	0	0	0	0	0	0	0
CAL 1997	0	0	0	0	1	2	2	5	4
CAL 1998	0	0	0	1	1	0	0	1	1
CAL 1999	3	0	0	1	0	0	1	4	147
CAL 2000	12	6	2	4	1	11	8	13	60
CAL 2001	0	1	0	1	0	4	0	1	28
CAL 2002	1	0	0	0	0	0	0	3	19
CAL 2003	2	1	0	0	1	0	0	1	115
CAL 2004	0	0	0	0	0	0	0	2	3
CAL 2005	0	1	1	2	2	0	5	7	5
CAL 2006	2	2	1	0	0	2	4	8	14
CAL 2007	0	0	1	0	3	4	3	4	2
CAL 2008	0	0	0	0	1	0	0	0	1
CAL 2009	0	0	0	0	0	1	0	2	4
CAL 2010	0	0	0	0	0	0	0	0	0
CAL 2011	0	0	0	0	0	0	0	0	0
CAL 2012	0	0	0	0	0	0	0	0	0
CAL 2013	0	0	0	0	0	0	0	0	0
CAL_bins	190	200	210	220	230	240	250	260	270
CAL 1983	2	7	14	6	10	3	4	4	1
CAL 1984	10	26	48	53	68	71	77	84	89
CAL 1985	0	5	12	17	33	55	78	93	119
CAL 1986	7	9	10	15	24	42	27	41	37
CAL 1987	10	27	17	34	37	36	27	19	21
CAL 1988	12	17	28	44	47	92	85	62	73
CAL 1989	3	9	19	26	29	41	29	41	34
CAL 1990	11	23	60	67	102	79	69	84	89
CAL 1991	63	131	225	333	432	661	650	772	841
CAL 1992	180	295	441	596	681	794	829	692	633
CAL 1993	71	167	285	410	592	577	582	538	573
CAL 1994	12	32	66	127	208	300	390	463	447
CAL 1995	33	45	105	140	190	230	258	296	258
CAL 1996	1	3	19	47	30	37	35	36	53
CAL 1997	13	11	30	38	35	41	51	40	36
CAL 1998	3	2	13	33	71	90	95	117	110

CAL 1999	22	84	324	253	293	476	282	345	288
CAL 2000	6	35	140	126	170	290	273	271	321
CAL 2001	3	21	75	49	70	124	73	82	77
CAL 2002	17	39	138	137	149	167	148	167	192
CAL 2003	7	39	234	113	120	215	124	167	164
CAL 2004	8	11	39	34	75	92	156	193	171
CAL 2005	3	8	14	29	46	63	86	118	120
CAL 2006	15	34	41	42	43	38	36	55	77
CAL 2007	7	3	11	33	26	77	106	188	218
CAL 2008	2	1	14	24	35	44	46	67	120
CAL 2009	2	5	19	37	38	68	98	125	192
CAL 2010	0	2	9	6	9	24	29	51	95
CAL 2011	0	0	0	2	4	18	34	37	64
CAL 2012	0	6	2	4	13	41	103	109	124
CAL 2013	0	0	3	5	15	14	27	31	48
CAL_bins	280	290	300	310	320	330	340	350	360
CAL 1983	1	1	3	3	3	2	2	0	2
CAL 1984	63	55	53	61	52	38	21	17	7
CAL 1985	118	108	100	85	53	63	30	23	27
CAL 1986	24	39	33	27	20	17	14	9	14
CAL 1987	16	7	4	3	3	2	0	0	2
CAL 1988	67	51	38	41	35	24	26	18	15
CAL 1989	19	27	18	15	10	10	12	7	5
CAL 1990	96	97	79	66	55	31	39	28	24
CAL 1991	729	734	643	569	364	308	274	211	180
CAL 1992	597	612	519	491	305	280	228	190	113
CAL 1993	553	470	324	267	200	173	108	129	100
CAL 1994	410	342	305	226	139	113	72	70	61
CAL 1995	218	208	223	178	150	148	122	121	104
CAL 1996	41	23	29	31	6	10	8	7	8
CAL 1997	37	28	12	31	23	20	11	16	6
CAL 1998	113	114	97	79	87	61	64	61	21
CAL 1999	209	251	141	206	172	134	107	121	65
CAL 2000	341	308	241	252	213	125	138	149	107
CAL 2001	90	114	109	101	88	95	98	87	68
CAL 2002	212	211	118	252	229	166	151	159	162
CAL 2003	234	212	184	286	279	252	178	207	136
CAL 2004	192	152	130	139	175	103	98	93	73
CAL 2005	165	140	125	137	154	155	104	118	94
CAL 2006	108	113	145	220	243	161	109	96	145
CAL 2007	235	198	252	235	245	205	163	137	144
CAL 2008	116	120	103	157	193	147	108	107	100
CAL 2009	195	165	159	170	140	113	117	76	82
CAL 2010	146	181	150	143	124	85	109	90	82
CAL 2011	78	86	68	45	60	41	25	21	21
CAL 2012	151	123	82	67	59	33	29	26	16
CAL 2013	51	37	31	26	29	17	11	11	8
CAL_bins	370	380	390	400	410	420	430	440	450
CAL 1983	0	1	0	0	0	0	1	0	0
CAL 1984	7	1	4	0	0	1	3	0	0
CAL 1985	16	7	7	14	4	4	3	4	3
CAL 1986	6	8	3	3	2	4	3	1	3
CAL 1987	1	1	2	1	0	0	0	1	0
CAL 1988	10	9	7	5	3	3	7	1	2
CAL 1989	6	7	3	2	2	2	1	0	0
CAL 1990	21	18	13	13	7	2	2	2	0

CAL 1991	143	97	89	66	55	26	25	21	13
CAL 1992	97	70	59	42	34	26	14	12	6
CAL 1993	63	45	41	31	17	16	10	4	7
CAL 1994	22	30	15	19	16	9	8	5	1
CAL 1995	69	59	51	33	27	10	19	16	8
CAL 1996	3	6	3	4	2	1	2	0	2
CAL 1997	10	9	17	11	8	5	2	2	5
CAL 1998	40	49	46	56	29	27	32	25	52
CAL 1999	83	96	125	58	61	57	29	23	36
CAL 2000	99	86	93	75	67	41	34	25	37
CAL 2001	58	69	62	43	31	23	32	22	22
CAL 2002	144	119	114	57	83	41	25	17	15
CAL 2003	143	178	141	81	167	122	61	53	54
CAL 2004	62	65	60	58	37	40	28	23	10
CAL 2005	81	81	73	53	55	36	24	23	9
CAL 2006	90	99	81	60	59	45	38	31	27
CAL 2007	126	98	88	101	63	41	32	20	16
CAL 2008	108	73	56	47	57	45	18	11	9
CAL 2009	79	57	61	56	53	24	24	7	12
CAL 2010	65	73	57	57	55	25	13	13	7
CAL 2011	22	13	9	10	7	4	3	2	2
CAL 2012	11	14	16	9	9	9	3	5	6
CAL 2013	11	11	11	5	4	6	0	2	0
CAL_bins	460	470	480	490	500	510	520		
CAL 1983	0	0	0	0	0	0	0		
CAL 1984	0	0	1	0	0	0	0		
CAL 1985	4	1	0	1	0	0	1		
CAL 1986	1	1	0	0	0	0	1		
CAL 1987	0	1	0	0	0	0	0		
CAL 1988	2	1	0	2	0	0	0		
CAL 1989	1	0	0	0	1	0	0		
CAL 1990	2	2	1	0	1	0	1		
CAL 1991	12	17	13	6	2	3	3		
CAL 1992	4	10	5	6	4	1	2		
CAL 1993	6	2	4	0	0	2	0		
CAL 1994	1	0	2	0	0	2	0		
CAL 1995	3	4	2	6	2	2	9		
CAL 1996	1	1	0	0	0	0	0		
CAL 1997	0	0	4	0	1	4	1		
CAL 1998	16	10	19	24	12	0	0		
CAL 1999	11	6	4	11	5	6	3		
CAL 2000	21	17	23	27	15	7	5		
CAL 2001	8	11	5	8	5	6	5		
CAL 2002	18	7	4	13	6	1	11		
CAL 2003	51	23	29	17	4	17	22		
CAL 2004	12	9	4	2	9	8	5		
CAL 2005	10	4	6	9	5	5	4		
CAL 2006	27	11	19	6	5	9	1		
CAL 2007	16	14	7	11	8	4	3		
CAL 2008	9	16	5	2	7	11	8		
CAL 2009	3	7	2	3	1	1	0		
CAL 2010	8	6	9	1	5	3	2		
CAL 2011	2	1	2	0	1	0	1		
CAL 2012	0	2	4	2	2	3	1		
CAL 2013	0	0	1	0	0	0	0		

Appendix 4.3.3 St. Thomas queen triggerfish data and parameter inputs available for use in calculating total allowable catch with DLMtool (Source: SEDAR 46 DW/AW Workshop). NA = not available.

Name	Queen Trigger_STT_Trap							
Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
	2007	2008	2009	2010	2011	2012	2013	2014	
Catch	46518	66594	69963	80248	94666	98528	84841	74207	68051
	70499	81649	77125	77209	54857	44835	43762	44107	
Abundance index	NA	NA	1.05	1.02	1.13	1.04	0.87	1.07	1.06
	0.96	0.94	0.94	1.40	0.91	0.98	0.79	0.85	
Duration t	17								
Average catch over time t	63367								
Depletion over time t	0.125								
M	0.2568								
FMSY/M	0.75								
BMSY/B0	0.35								
Cref	NA								
Bref	NA								
Length at 50% maturity	215								
Length at 95% maturity	275								
Length at first capture	213								
Length at full selection	386								
CAA	NA								
Current stock depletion	0.125								
Current stock abundance	229008								
Von Bertalanffy t0 parameter	0								
Von Bertalanffy K parameter	0.214		`						
Von Bertalanffy Linf parameter	605.3								
Length-weight parameter a	8.64E-05								
Length-weight parameter b	2.784								
Steepness	0.84								
Maximum age	14								
CV Catch	0.28								
CV Depletion over time t	0.5								
CV Average catch over time t	0.28								
CV Abundance index	0.14								
CV M	0.083								
CV FMSY/M	0.5								
CV BMSY/B0	0.5								
CV_MSY	NA								
CV_BMSY	NA								
CV current stock depletion	0.5								
CV current stock abundance	0.5								
CV von B. K parameter	0.35								
CV von B. Linf parameter	0.12								
CV von B. t0 parameter	0.5								
CV Length at 50% maturity	0.15								
CV Length at 95% maturity	0.2								
CV Length at first capture	0.2								
CV Length at full selection	0.2								
CV Length-weight parameter a	0.05								
CV Length-weight parameter	0.05								

b									
CV Steepness	0.2								
Sigma length composition	0.2								
Units	pounds								
Reference TAC	NA								
Reference TAC type	NA								
CAL_bins	140	150	160	170	180	190	200	210	220
CAL 2002	0	0	0	0	0	1	0	2	4
CAL 2003	0	0	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	1	0	1
CAL 2005	0	0	0	0	0	2	4	4	4
CAL 2006	0	0	0	5	9	12	27	18	5
CAL 2008	0	0	0	0	0	0	0	0	2
CAL 2009	0	0	0	0	0	1	2	13	9
CAL 2010	0	0	1	0	0	2	3	8	19
CAL 2011	0	0	0	0	0	0	6	19	32
CAL 2012	0	0	0	0	0	0	1	2	8
CAL_bins	230	240	250	260	270	280	290	300	310
CAL 2002	10	5	10	19	14	20	20	25	9
CAL 2003	0	0	4	4	0	5	6	4	2
CAL 2004	1	1	2	0	1	4	4	4	7
CAL 2005	10	6	6	8	10	17	9	17	17
CAL 2006	10	9	12	11	19	25	21	27	7
CAL 2008	1	0	1	3	4	0	3	1	1
CAL 2009	22	36	25	43	28	35	28	34	36
CAL 2010	35	53	56	71	107	92	108	106	110
CAL 2011	33	45	58	66	62	58	52	58	73
CAL 2012	15	22	21	26	42	36	51	55	44
CAL_bins	320	330	340	350	360	370	380	390	400
CAL 2002	11	21	21	19	18	12	19	7	3
CAL 2003	5	4	2	11	1	5	2	8	4
CAL 2004	3	3	0	3	0	4	0	1	0
CAL 2005	9	14	15	15	11	7	8	4	0
CAL 2006	20	14	11	15	9	6	6	10	5
CAL 2008	6	2	3	1	0	0	1	0	0
CAL 2009	46	60	44	41	51	28	30	26	17
CAL 2010	122	106	107	115	75	75	57	35	21
CAL 2011	53	69	65	59	52	39	30	19	16
CAL 2012	48	44	34	33	37	33	20	14	9
CAL_bins	410	420	430	440	450	460	470	480	490
CAL 2002	0	3	0	0	0	0	2	0	1
CAL 2003	0	1	0	0	0	0	0	0	0
CAL 2004	1	0	0	0	0	0	0	0	0
CAL 2005	1	1	1	0	0	0	0	0	0
CAL 2006	5	5	1	2	1	0	0	1	0
CAL 2008	0	0	0	0	0	0	0	0	0
CAL 2009	9	4	0	1	1	0	0	0	0
CAL 2010	18	8	7	1	0	1	0	0	0
CAL 2011	16	12	2	2	2	1	0	2	0
CAL 2012	6	4	1	0	1	0	0	0	0
CAL_bins	500	510	520	530	540	550	560	570	580
CAL 2002	0	0	0	0	0	0	0	0	0
CAL 2003	0	0	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0
CAL 2005	0	0	0	0	0	0	0	0	0
CAL 2006	0	0	0	0	0	0	0	0	0

CAL 2008	0	0	0	0	0	0	0	0	0
CAL 2009	0	0	0	0	0	0	0	0	0
CAL 2010	0	0	0	0	0	0	1	0	0
CAL 2011	0	0	0	0	0	0	0	0	0
CAL 2012	0	0	0	0	0	0	0	0	0
CAL_bins	590	600	610	620	630	640	650	660	670
CAL 2002	0	0	0	0	0	0	0	0	0
CAL 2003	0	0	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0
CAL 2005	0	0	0	0	0	0	0	0	0
CAL 2006	0	0	0	0	0	0	1	0	0
CAL 2008	0	0	0	0	0	0	0	0	0
CAL 2009	0	0	0	0	0	0	0	0	0
CAL 2010	0	0	0	0	0	0	0	0	0
CAL 2011	0	0	0	0	0	0	0	0	0
CAL 2012	0	0	0	0	0	0	0	0	0

Appendix 4.3.4 St. Thomas spiny lobster data and parameter inputs available for use in calculating total allowable catch with DLMtool (Source: SEDAR 46 DW/AW Workshop). NA = not available.

Name	Spiny Lobster_STT_Trap							
Year	1975	1976	1977	1978	1979	1980	1981	1982	1983
	1984	1985	1986	1987	1988	1989	1990	1991	1992
	1993	1994	1995	1996	1997	1998	1999	2000	2001
	2002	2003	2004	2005	2006	2007	2008	2009	2010
	2011	2012	2013	2014					
Catch	6796	6742	19462	58432	29385	36088	38068	36661	36141
	35979	30141	23637	40667	54682	58858	77837	54800	86451
	83261	61773	67390	88037	95097	74077	75828	76153	89711
	115972	135292	133982	124643	136027	119641	110465	115762	114577
	84302	83157	84233	89092					
Abundance index	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	NA	0.64	0.62
	0.80	0.97	0.92	0.88	1.09	1.10	1.20	1.11	1.27
	0.96	0.99	1.11	1.35					
Duration t	40								
Average catch over time t	72232								
Depletion over time t	0.26								
M	0.35								
FMSY/M	0.75								
BMSY/B0	0.35								
Cref	NA								
Bref	NA								
Iref	NA								
Length at 50% maturity	65.8								
Length at 95% maturity	73.8								
Length at first capture	73								
Length at full selection	133								
CAA	NA								
Current stock depletion	0.26								
Current stock abundance	339396								
Von Bertalanffy t0 parameter	0.44								
Von Bertalanffy K parameter	0.24		`						
Von Bertalanffy Linf parameter	183								
Length-weight parameter a	9.21E-03								
Length-weight parameter b	2.48								
Steepness	0.5								
Maximum age	20								
CV Catch	0.5								
CV Depletion over time t	0.5								
CV Average catch over time t	0.5								
CV Abundance index	0.21								
CV M	0.14								
CV FMSY/M	0.5								
CV BMSY/B0	0.5								
CV_MSY	NA								
CV_BMSY	NA								
CV current stock depletion	0.5								
CV current stock abundance	0.5								
CV von B. K parameter	0.21								
CV von B. Linf parameter	0.08								

CV von B. t0 parameter	1.14								
CV Length at 50% maturity	0.15								
CV Length at 95% maturity	0.17								
CV Length at first capture	0.2								
CV Length at full selection	0.2								
CV Length-weight parameter a	0.05								
CV Length-weight parameter b	0.05								
CV Steepness	0.2								
Sigma length composition	0.2								
Units	pounds								
Reference TAC	NA								
Reference TAC type	NA								
CAL_bins	50	60	70	80	90	100	110	120	
CAL 1980	0	0	1	21	63	61	60	22	
CAL 1981	1	2	6	46	114	117	96	90	
CAL 1983	0	0	0	0	8	6	10	12	
CAL 1984	0	0	6	49	73	153	145	137	
CAL 1985	0	0	2	69	106	189	124	145	
CAL 1986	5	9	5	12	35	58	52	51	
CAL 1987	0	0	0	30	58	87	59	90	
CAL 1988	0	0	1	64	76	176	81	89	
CAL 1992	0	0	0	17	34	54	40	25	
CAL 1993	0	0	1	48	42	45	29	26	
CAL 1994	0	0	0	15	23	24	15	11	
CAL 1995	0	0	5	3	0	1	11	1	
CAL 1996	0	0	0	16	27	36	17	17	
CAL 2002	1	0	0	31	37	109	58	75	
CAL 2003	0	1	0	37	17	100	78	101	
CAL 2004	1	24	30	80	23	58	21	28	
CAL 2005	0	2	31	80	69	70	43	14	
CAL 2006	0	33	56	131	194	164	227	117	
CAL 2008	0	0	0	10	18	37	14	15	
CAL 2009	0	1	2	119	153	270	117	115	
CAL 2010	0	4	6	92	161	315	154	175	
CAL 2011	0	1	0	86	125	245	104	93	
CAL 2012	1	3	0	43	68	165	69	98	
CAL 2013	0	0	0	50	54	92	37	60	
CAL_bins	130	140	150	160	170	180	190		
CAL 1980	17	5	2	0	0	0	0		
CAL 1981	78	40	37	10	6	1	2		
CAL 1983	6	2	2	4	1	0	0		
CAL 1984	81	31	28	12	25	0	7		
CAL 1985	94	32	39	7	11	4	0		
CAL 1986	36	17	13	5	5	1	0		
CAL 1987	59	15	37	2	7	0	0		
CAL 1988	46	6	12	6	0	0	0		
CAL 1992	27	10	3	0	0	0	0		
CAL 1993	18	9	4	2	3	0	1		
CAL 1994	3	0	0	0	0	0	0		
CAL 1995	4	2	4	1	2	0	2		
CAL 1996	11	2	2	1	0	0	0		
CAL 2002	23	6	8	1	0	0	0		
CAL 2003	42	7	6	3	0	0	0		
CAL 2004	6	4	0	0	0	0	0		
CAL 2005	6	1	0	0	0	0	0		
CAL 2006	47	29	11	4	4	1	0		

CAL 2008	6	0	0	0	0	0	0		
CAL 2009	52	12	14	3	2	0	0		
CAL 2010	80	22	19	2	0	0	1		
CAL 2011	34	5	11	1	0	1	0		
CAL 2012	30	4	3	0	0	0	0		
CAL 2013	23	12	1	0	0	0	0		

Appendix 4.3.5 St. Croix spiny lobster data and parameter inputs available for use in calculating total allowable catch with DLMtool (Source: SEDAR 46 DW/AW Workshop). NA = not available.

Name	SpinyLobster_STX_Dive								
Year	1976	1977	1978	1979	1980	1981	1982	1983	1984
	1985	1986	1987	1988	1989	1990	1991	1992	1993
	1994	1995	1996	1997	1998	1999	2000	2001	2002
	2003	2004	2005	2006	2007	2008	2009	2010	2011
	2012	2013	2014						
Catch	2218	8166	4981	3078	1288	2104	2692	4480	7564
	4426	5970	13032	8012	2207	19472	37246	21132	37176
	29790	25029	28843	35949	42718	53329	89020	116619	116273
	106039	125415	120929	146592	168005	148003	149908	139685	109751
	86997	59398	39681						
Abundance index	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	0.69	0.71	0.70
	0.73	0.88	0.83	0.78	1.30	1.45	1.44	1.64	1.43
	0.79	0.79	0.85						
Duration t	39								
Average catch over time t	54441.46								
Depletion over time t	0.24								
M	0.35								
FMSY/M	0.75								
BMSY/B0	0.35								
Cref	NA								
Bref	NA								
Iref	NA								
Length at 50% maturity	65.79								
Length at 95% maturity	73.8								
Length at first capture	81								
Length at full selection	120								
CAA	NA								
Current stock depletion	0.24								
Current stock abundance	151165.7								
Von Bertalanffy t0 parameter	0.44								
Von Bertalanffy K parameter	0.24		`						
Von Bertalanffy Linf parameter	183								`
Length-weight parameter a	9.21E-03								
Length-weight parameter b	2.48								
Steepness	0.5								
Maximum age	20								
CV Catch	1.02								
CV Depletion over time t	0.5								
CV Average catch over time t	1.02								
CV Abundance index	0.34								
CV M	0.14								
CV FMSY/M	0.5								
CV BMSY/B0	0.5								
CV_MSY	NA								
CV_BMSY	NA								
CV current stock depletion	0.5								
CV current stock abundance	0.5								
CV von B. K parameter	0.21								
CV von B. Linf parameter	0.08								

CV von B. t0 parameter	1.14								
CV Length at 50% maturity	0.15								
CV Length at 95% maturity	0.17								
CV Length at first capture	0.2								
CV Length at full selection	0.2								
CV Length-weight parameter a	0.05								
CV Length-weight parameter b	0.05								
CV Steepness	0.2								
Sigma length composition	0.2								
Units	pounds								
Reference TAC	NA								
Reference TAC type	NA								
CAL_bins	60	70	80	90	100	110	120	130	140
CAL 1981	0	0	1	15	15	41	30	21	8
CAL 1982	0	0	6	22	20	17	13	2	1
CAL 1983	0	0	20	25	22	17	8	7	5
CAL 1984	0	0	42	54	19	28	9	14	6
CAL 1985	0	0	2	1	2	2	1	0	0
CAL 1986	0	0	1	6	2	1	0	0	0
CAL 1987	0	0	19	82	63	49	22	22	3
CAL 1988	0	6	29	142	128	97	50	16	6
CAL 1989	0	0	15	113	94	60	35	22	1
CAL 1990	0	0	14	90	110	35	36	8	4
CAL 1991	0	0	10	35	29	20	4	4	0
CAL 1992	0	0	0	11	4	8	5	1	0
CAL 1993	0	0	11	79	65	56	16	1	2
CAL 1994	0	0	10	107	83	42	33	13	3
CAL 1995	0	0	16	94	90	52	28	7	2
CAL 1996	0	0	7	70	59	46	14	8	0
CAL 1997	1	0	12	115	98	49	19	12	1
CAL 1998	0	0	20	219	165	122	45	19	2
CAL 1999	0	0	18	226	164	123	35	12	1
CAL 2000	0	0	16	155	112	109	39	12	4
CAL 2002	0	0	4	148	116	116	50	3	1
CAL 2005	0	0	3	109	123	101	25	2	0
CAL 2006	0	0	29	199	166	173	78	21	6
CAL 2008	0	0	31	158	102	69	47	19	1
CAL 2009	0	0	20	150	100	68	39	14	2
CAL 2010	0	0	22	201	194	96	52	19	7
CAL 2011	0	0	1	4	4	5	1	0	0
CAL_bins	150	160	170	180	190				
CAL 1981	4	0	2	1	0				
CAL 1982	0	0	0	0	0				
CAL 1983	2	2	0	0	0				
CAL 1984	0	0	1	0	0				
CAL 1985	0	0	0	0	0				
CAL 1986	0	0	0	0	0				
CAL 1987	1	0	0	0	0				
CAL 1988	1	0	1	0	0				
CAL 1989	0	1	0	0	0				
CAL 1990	0	0	0	0	0				
CAL 1991	0	0	0	0	0				
CAL 1992	0	0	0	0	0				
CAL 1993	0	0	0	0	0				
CAL 1994	0	0	1	1	1				
CAL 1995	1	0	0	0	0				

CAL 1996	2	1	0	1	0				
CAL 1997	0	0	1	0	0				
CAL 1998	2	2	0	1	0				
CAL 1999	1	2	0	0	0				
CAL 2000	0	0	0	0	0				
CAL 2002	1	0	0	0	0				
CAL 2005	1	0	0	0	0				
CAL 2006	3	1	0	0	0				
CAL 2008	2	0	1	0	0				
CAL 2009	1	0	1	0	0				
CAL 2010	4	1	0	0	0				
CAL 2011	0	0	0	0	0				

Appendix 4.3.6 St. Croix stoplight parrotfish data and parameter inputs available for use in calculating total allowable catch with DLMtool (Source: SEDAR 46 DW/AW Workshop). NA = not available.

Name	Stoplight Parrotfish STX Dive									
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Catch	24958	69035	81147	89627	98980	110389	116884	99740	121315	143028
	164576	157662	134899	120116	61797	20152	41869	33773	21750	
Abundance index	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	1.20	1.12	0.68	
Duration t	19									
Average catch over time t	90089									
Depletion over time t	0.15									
M	0.2998									
FMSY/M	0.75									
BMSY/B0	0.35									
Cref	NA									
Bref	NA									
Length at 50% maturity	205									
Length at 95% maturity	235									
Length at first capture	220									
Length at full selection	338									
CAA	NA									
Current stock depletion	0.15									
Current stock abundance	96731									
Von Bertalanffy t0 parameter	0									
Von Bertalanffy K parameter	0.2496		`							
Von Bertalanffy Linf parameter	631.6									
Length-weight parameter a	3.70E-05									
Length-weight parameter b	2.9051									
Steepness	0.84									
Maximum age	12									
CV Catch	0.51									
CV Depletion over time t	0.5									
CV Average catch over time t	0.51									
CV Abundance index	0.28									
CV M	0.084									
CV FMSY/M	0.5									
CV BMSY/B0	0.5									
CV_MSY	NA									
CV_BMSY	NA									
CV current stock depletion	0.5									
CV current stock abundance	0.5									
CV von B. K parameter	0.3									
CV von B. Linf parameter	0.12									
CV von B. t0 parameter	0.5									
CV Length at 50% maturity	0.15									
CV Length at 95% maturity	0.2									
CV Length at first capture	0.2									
CV Length at full selection	0.2									
CV Length-weight parameter a	0.05									
CV Length-weight parameter b	0.05									
CV Steepness	0.2									
Sigma length composition	0.2									
Units	pounds									
Reference TAC	NA									
Reference TAC type	NA									
CAL_bins	190	200	210	220	230	240	250	260	270	280
CAL 1996	0	0	0	1	0	0	1	1	0	2
CAL 1998	0	0	2	4	6	4	11	3	6	5
CAL 2002	0	0	0	2	1	3	1	8	10	11
CAL 2003	0	0	0	0	2	2	2	6	4	10

CAL 2004	0	0	0	0	2	2	3	4	7	4
CAL 2007	0	0	4	10	23	27	46	43	44	34
CAL 2008	0	2	12	21	28	29	58	70	74	73
CAL 2009	0	2	4	15	21	36	37	59	66	63
CAL 2010	2	6	13	34	19	52	65	74	99	96
CAL 2011	0	0	0	0	0	0	0	0	0	0
CAL_bins	290	300	310	320	330	340	350	360	370	380
CAL 1996	0	0	0	1	1	0	0	0	0	0
CAL 1998	4	12	21	8	8	2	2	0	0	0
CAL 2002	12	9	4	9	5	1	0	1	0	0
CAL 2003	10	5	5	8	2	7	2	5	3	1
CAL 2004	6	6	14	1	1	3	0	1	0	0
CAL 2007	31	16	14	13	10	9	5	2	1	2
CAL 2008	55	39	45	35	19	18	11	4	3	0
CAL 2009	60	49	51	28	22	16	12	10	2	9
CAL 2010	85	65	61	46	40	11	18	4	3	2
CAL 2011	0	0	0	0	0	1	0	0	0	0
CAL_bins	390	400	410	420	430	440	450	460	470	480
CAL 1996	0	0	0	0	0	0	0	0	0	0
CAL 1998	0	0	0	0	0	0	0	0	0	0
CAL 2002	0	0	0	0	0	0	0	0	0	0
CAL 2003	1	0	0	0	0	0	0	0	0	0
CAL 2004	0	0	0	0	0	0	0	0	0	0
CAL 2007	0	1	0	0	0	0	0	0	0	0
CAL 2008	0	0	0	0	0	0	0	0	0	0
CAL 2009	1	0	0	0	0	0	0	0	0	0
CAL 2010	2	0	0	1	0	0	0	0	0	0
CAL 2011	0	0	0	0	0	0	0	0	0	0
CAL_bins	490	500								
CAL 1996	0	0								
CAL 1998	0	0								
CAL 2002	0	0								
CAL 2003	0	0								
CAL 2004	0	0								
CAL 2007	0	0								
CAL 2008	0	1								
CAL 2009	0	0								
CAL 2010	0	0								
CAL 2011	0	0								

Appendix 4.4 DLMtool methods applicable to SEDAR 46

Reference method

1.) Reference FMSY method (FMSYref) (Carruthers 2015b)

Definition: uses perfect information about FMSY within management strategy evaluation.

$$\mathrm{TAC}_{y+1} = \mathrm{A\,x}\,(1 - \exp^{-\mathrm{FMSY}})$$

Where:
TAC = total allowable catch,
y = year,
A = absolute abundance (biomass) updated in each management update of projection, and
FMSY = fishing mortality rate at maximum sustainable yield.

Pros	**Cons**
• Comes directly from operating model	• Not applicable on real world data

Catch-based methods

1.) Constant Catch (CC4) (Geromont and Butterworth 2014b, Carruthers et al. 2015)

Definition: constant catch linked to 70% of historical catches over the most recent 5 years.

$$\mathrm{TAC}_{y+1} = 0.7\ \mathrm{x}\ \frac{\sum_{y=t-4}^{y=t} \mathrm{Cat}_y}{5}$$

Where:
TAC = total allowable catch,
y = year,
Cat = catch, and
t = number of years with catch.

Pros	**Cons**
• Readily understood by all parties typically involved in the management of the resource	• Quality of information determines whether MP is reacting to real trends in biomass or simply following noise
• Does not require long time series	• No feedback control
	• May require an unacceptably large drop in TAC in the first year of implementation

2.) Surplus Production MSY (SPMSY) *(Martell and Froese 2012)*

Definition: uses the Martell and Froese (2012) method for estimating MSY, an approach which estimates stock trajectories based on catches and a rule for intrinsic rate of increase. The TAC is calculated using the surplus production model which predicts K, r and depletion and the Schaefer productivity curve.

$$\mathrm{TAC}_{y+1} = \mathrm{Dep}\ x\ (1 - \mathrm{Dep})\ x\ r\ x\ K\ x\ 2$$

Where:
TAC = total allowable catch,
y = year,
Dep = Depletion,
r = maximum rate of population increase, and
K = carrying capacity.

Pros	Cons
• Minimal data inputs	• Requires known catch time series

Caveats for applying Catch-based DLMs for Caribbean species

1.) ***Cat*** input: highly uncertain due to:

- Inconsistencies in recording on data sheets (prior to 2011) for yellowtail snapper, queen triggerfish, stoplight parrotfish
- Species misidentification or lack of identification: yellowtail snapper, queen triggerfish, and stoplight parrotfish
- Underreporting of catch: concern for all species chosen for assessment

Index-based methods

1.) Index slope (catch per unit of effort (CPUE) index of abundance) (Islope1) (Geromont and Butterworth 2014b; Carruthers et al. 2015)

Definition: incrementally adjusts the total allowable catch to maintain a constant CPUE / relative abundance index.

$$\mathrm{TAC}_{y+1}^{\mathrm{slope}} = \frac{0.8}{5}\sum\nolimits_{y-4}^{y} \mathrm{Cat}_y\ x\ (1 + 0.4\ x\ S_y)$$

Where:
TAC = total allowable catch,
y= year,
Cat = catch, and
S_y = CPUE slope (gradient of a log-linear regression) for the most recent 5 years.

Pros	Cons
• Readily understood by all parties typically involved in management	• Quality of information determines whether MP is reacting to real trends in biomass or simply following noise
• Does not require long time series	• Requires an index of abundance reflective of stock trends

2.) Index slope (catch per unit of effort (CPUE) index of abundance) (Islope4) (Geromont and Butterworth 2014b; Carruthers et al. 2015)

Definition: biologically precautionary MP that incrementally adjusts the total allowable catch to maintain a constant CPUE / relative abundance index.

$$\mathrm{TAC}_{\mathrm{y+1}}^{\mathrm{slope}} = \frac{0.6}{5}\sum_{\mathrm{y-4}}^{\mathrm{y}} \mathrm{Cat}_{\mathrm{y}}\ \mathrm{x}\,(1 + \ 0.2\ \mathrm{x}\ \mathrm{S}_{\mathrm{y}})$$

Where:
TAC = total allowable catch,
y= year,
Cat = catch, and
S_y = CPUE slope (gradient of a log-linear regression) for the most recent 5 years.

Pros	Cons
• Same as Islope1 but more conservative	• Same as Islope1

3.) ***Index Target (CPUE index of abundance) (Itarget1)*** (Geromont and Butterworth 2014b, Carruthers et al. 2015)

Definition: incrementally adjusts the TAC (starting from reference level that is a fraction of mean recent catches) to reach a target CPUE / relative abundance index.

$$\text{If } \mathrm{I}_{\mathrm{y}}^{\mathrm{recent}} \geq \mathrm{I}^{0}, \qquad \mathrm{TAC}_{\mathrm{y+1}} = 0.5\ \mathrm{x}\ \mathrm{C}^{\mathrm{ave}} \left[1 - \frac{(\mathrm{I}_{\mathrm{y}}^{\mathrm{recent}} - \mathrm{I}^{0})}{(\mathrm{I}^{\mathrm{target}} - \mathrm{I}^{0})}\right]$$

$$\text{If } \mathrm{I}_{\mathrm{y}}^{\mathrm{recent}} < \mathrm{I}^{0}, \qquad \mathrm{TAC}_{\mathrm{y+1}} = 0.5\ \mathrm{x}\ \mathrm{C}^{\mathrm{ave}} \left[\frac{\mathrm{I}_{\mathrm{y}}^{\mathrm{recent}}}{\mathrm{I}^{0}}\right]^{2}$$

Where:
$\mathrm{I}_{\mathrm{y}}^{\mathrm{recent}}$ = average CPUE for the most recent 5 years,
I^{ave} = historical average CPUE,
$I^{0} = 0.8\ I^{ave}$,
$\mathrm{C}^{\mathrm{ave}}$ = average catch for the most recent 5 years, and
$I^{target} = 1.5\ I^{ave}$.

Pros	Cons
• Same as Islope1	• Same as Islope1

4.) ***Index Target (CPUE index of abundance) (Itarget4)*** (Geromont and Butterworth 2014b, Carruthers et al. 2015)

Definition: biologically precautionary MP that incrementally adjusts the TAC (starting from reference level that is a fraction of mean recent catches) to reach a target CPUE / relative abundance index.

$$\text{If } \mathrm{I}_{\mathrm{y}}^{\mathrm{recent}} \geq \mathrm{I}^{0}, \qquad \mathrm{TAC}_{\mathrm{y+1}} = 0.5\ \mathrm{x}\ 0.7\ \mathrm{C}^{\mathrm{ave}} \left[1 - \frac{(\mathrm{I}_{\mathrm{y}}^{\mathrm{recent}} - \mathrm{I}^{0})}{(\mathrm{I}^{\mathrm{target}} - \mathrm{I}^{0})}\right]$$

$$\text{If } \mathrm{I}_{\mathrm{y}}^{\mathrm{recent}} < \mathrm{I}^{0}, \qquad \mathrm{TAC}_{\mathrm{y+1}} = 0.5\ \mathrm{x}\ 0.7\ \mathrm{C}^{\mathrm{ave}} \left[\frac{\mathrm{I}_{\mathrm{y}}^{\mathrm{recent}}}{\mathrm{I}^{0}}\right]^{2}$$

Where:
$\mathrm{I}_{\mathrm{y}}^{\mathrm{recent}}$ = average CPUE for the most recent 5 years,
I^{ave} = historical average CPUE,
$I^{0} = 0.8\ I^{ave}$,
$\mathrm{C}^{\mathrm{ave}}$ = average catch for the most recent 5 years, and

$I^{target} = 2.5\ I^{ave}$.

Pros	Cons
• Same as Itarget1 but more conservative	• Same as Itarget1

5.) ***Index Target 5 (IT5)*** (Carruthers 2015b)

Definition: the total allowable catch is modified according to current index levels (mean index over last 5 years) relative to a target level with the maximum annual changes set at 5%.

$$\mathrm{TAC}_{y+1} = \frac{\sum_{y-4}^{y} \mathrm{Ind}_y}{5\ \mathrm{x}\ \mathrm{Iref}}$$

Where:
TAC = total allowable catch,
y= year,
Ind = relative index of abundance, and
Iref = target relative abundance level (e.g., a proxy of a CPUE near BMSY)

Pros	Cons
• Does not require long time series	• Need a target reference level

6.) ***Index Target 10 (IT10)*** (Carruthers 2015b)

Definition: same as IT5 with the exception of maximum annual changes set at 10%.

7.) ***Index Target based on natural mortality rate (ITM)*** (Carruthers 2015b)

Definition: same as IT5 with the exception that the maximum fractional annual changes are set at mc where:

$$\mathrm{mc} = \frac{(5 + \mathrm{Mort\ x\ 25})}{100}$$

Where:
Mort = natural mortality rate.

Pros	Cons
• Does not require long time series	• Need a target reference level
	• Requires estimate of Mort

Caveats for applying index-based methods for Caribbean species

1.) **Cat** inputs: highly uncertain due to:
- Inconsistencies in recording on data sheets (prior to 2011): yellowtail snapper, queen triggerfish, and stoplight parrotfish
- Species misidentification or lack of identification: yellowtail snapper, queen triggerfish, and stoplight parrotfish
- Underreporting of catch: all species chosen for assessment

2.) **Ind** input: requires an index of abundance that is considered representative of trends in stock dynamics
3.) **Iref** input: some methods require a reference index level

Depletion-based methods

1.) Depletion-Corrected Average Catch (DCAC) (MacCall 2009; Carruthers et al. 2014)

Definition: calculates average catches accounting for the removal of the "windfall harvest" of less productive biomass that may have occurred as the stock became depleted.

$$\mathrm{TAC}_{\mathrm{y+1}} = \frac{\mathrm{C_{obs}}}{\mathrm{t} + (1 - \mathrm{D_t})/(0.4\ \mathrm{c\ Mort})}$$

Where:
TAC = total allowable catch,
y = year,
C_{obs} = trajectory of annual historical catches,
t = number of years of historical catches,
D_t = estimate of depletion over time t,
c = value for tuning adjustment which can have a value < 1 and equals FMSY/Mort, and
Mort = natural mortality rate.

Pros	**Cons**
• Performance robust across a wide range of scenarios (NMFS 2011)	• Not necessarily good MSY proxy - the use of DCAC as a method to estimate OFL should be regarded as a rough approximation
• Do not need to know full catch history	• Sensitive to assumptions about depletion
• Ability to run Monte Carlo simulations	• Does not work if Mort > 0.2
• Relatively robust to misspecification of Mort and F_{MSY}/Mort (Cummings et al. 2014)	• Provides a biased value of OFL; tends to overfish at biomass below B_{MSY}
• "Theoretically clear, technically sound, well implemented and tested and could be used with confidence (given understanding of limitations) to estimate sustainable yield or OFL, respectively" - (Stokes 2011)	• If the stock is assumed to be much less depleted than it actually is, the median of the distribution of DCAC is higher than the true OFL
	• Not meant to be updated regularly; provides a one-time estimate of a sustainable catch level for the stock
	• Not directly suitable for specifying catches in a stock-rebuilding plan

2.) ***Depletion-Corrected Average Catch with 40% Depletion (DCAC_40)*** (MacCall 2009, Carruthers et al. 2014)

Definition: Same as DCAC with the exception of assuming stock depletion is 40% of unfished levels.

3.) ***Depletion-Corrected Average Catch with a 40-10 Harvest Control Rule (DCAC4010)*** (MacCall 2009, Carruthers et al. 2014)

Definition: Same as DCAC with the exception of throttling back the TAC to zero at 10% of unfished stock size.

4.) ***Extra Depletion Corrected Average Catch (EDCAC)*** (MacCall 2009; Harford and Carruthers in prep)

Definition: simple modification to DCAC which better accounts for absolute stock depletion.

$$\mathrm{TAC_{y+1}} = \frac{\mathrm{C_{obs}}}{\mathrm{t} + (1 - \mathrm{D_t})/(0.4\ \mathrm{c\ Mort})}\ \mathrm{x}\ \frac{\mathrm{D_t}}{\mathrm{BMSY\_B0}}$$

Where:
TAC = total allowable catch,
y = year,
C_{obs} = trajectory of annual historical catches,
t = number of years of historical catches,
D_t = estimate of depletion over time t,
c = value for tuning adjustment which can have a value < 1 and equals FMSY/Mort,
Mort = natural mortality rate, and
BMSY_B0 = ratio of BMSY to unfished biomass (B_0).

Pros	Cons
• Same as DCAC with the exception of better performance when biomass is below B_{MSY}	• Same as DCAC

5.) ***Mean Catch Depletion (MCD)*** (Carruthers 2015b; Harford and Carruthers in prep)

Definition: simple average catch-depletion management procedure included in DLMtool to demonstrate the relative information impact on TAC estimation from an estimate of current stock depletion.

$$\mathrm{TAC_{y+1}} = 2\ \mathrm{x\ Dep\ x}\ \frac{\sum_{\mathrm{y=1}}^{\mathrm{y=t}} \mathrm{Cat_y}}{\mathrm{t}}$$

Where:
TAC = total allowable catch,
y = year,
Dep= estimate of current stock depletion,
Cat = catch, and
t = number of years with catch.

Pros	Cons
• Tends to perform well when depletion is	• Need reliable estimate of current stock

known	depletion
	- Catch time series known

Caveats for applying Depletion-based methods for Caribbean species

1.) **Cat** input: highly uncertain due to:
   - Inconsistencies in recording on data sheets (prior to 2011): yellowtail snapper, queen triggerfish, and stoplight parrotfish
   - Species misidentification or lack of identification: yellowtail snapper, queen triggerfish, and stoplight parrotfish
   - Underreporting of catch: all species chosen for assessment

2.) **Dep** input: Requires an estimate of current stock depletion or depletion over time which is one of the most difficult data inputs to obtain. The depletion estimates used within SEDAR46 are considered highly uncertain.

3.) **Mort** input: requires a reliable estimate of natural mortality

Abundance-based methods

1.) FMSY/M ratio method (Fratio) (Gulland 1971; Walters and Martell 2002; Martell and Froese 2012; Carruthers et al. 2014)

Definition: fixed FMSY to Mort ratio.

$$\mathrm{TAC_{y+1}} = \mathrm{Abun\ x\ Mort\ x\ FMSY\_M}$$

Where:
TAC = total allowable catch,
y = year,
Abun = current stock abundance,
Mort = natural mortality rate, and
FMSY_M = ratio of the fishing mortality rate at maximum sustainable yield to natural mortality rate.

Pros	**Cons**
- Does not require long time series of catch	- Need a current estimate of absolute stock size and Mort

2.) Beddington and Kirkwood life history method (BK) (Beddington and Kirkwood 2005; Carruthers et al. 2014)

Definition: uses growth parameters and length at first capture to estimate MSY and FMSY.

$$\mathrm{TAC_{y+1}} = \frac{\mathrm{Abun\ x\ 0.6\ x\ vbK}}{0.67 - \frac{\mathrm{LFC}}{\mathrm{vbLinf}}}$$

Where:
TAC = total allowable catch,
y = year,
Abun = current stock abundance,
vbK = Von Bertalanffy K parameter,

LFC = Length at first capture, and
vbLinf = Von Bertalanffy L∞ parameter.

Pros	Cons
• Does not require long time series of catch	• Need a current estimate of absolute stock size
	• Need information on selectivity (length at first capture)

3.) Yield-Per-Recruit analysis (YPR) (Beverton and Holt 1957)

Definition: derives F that maximizes the yield obtained per recruit using an approximation to FMSY (F0.1).

$$\mathrm{TAC_{y+1} = \ Abun\ x\ FMSY}$$

Where:
TAC = total allowable catch,
y = year,
Abun = current stock abundance, and
FMSY = fishing mortality rate at Maximum Sustainable Yield.

Pros	Cons
• Does not require long time series of catch	• Need a current estimate of absolute stock size

Caveats for applying abundance-based methods for Caribbean species

1.) **Abun** input: highly uncertain estimates of current stock abundance: concern for all species chosen for assessment
2.) **Mort** input: requires a reliable estimate of natural mortality

Data-moderate methods

1.) Delay-difference stock assessment model (DD) (Deriso 1980; Schnute 1985; Carruthers et al. 2014)

Definition: biomass dynamic model with biologically meaningful parameters that accounts for basic time delays due to growth and recruitment.

$$\mathrm{TAC_{y+1}} = \frac{\mathrm{Cat_y}}{1 - \mathrm{exp}^{-\mathrm{q_{DD}E_y}}}\ \mathrm{x}\ (1 - \mathrm{exp}^{-\mathrm{Mort\ x\ 0.5}})$$

Where
TAC = total allowable catch,
y = year,
Cat = catch,
q_{DD} = estimated catchability,
E_y = observed fishing effort, and
Mort = natural mortality rate.

Pros	Cons
• Considered data-moderate as it uses various data sources	• Data-moderate; requires auxiliary information regarding the form of the stock-recruit function, the fraction of mature fish-at-age, body growth rate, natural mortality rate, and the vulnerability-at-age curve
• Expected to perform better than the data-limited methods that only make use of catch data	• Subject to imperfect information regarding historical catches
	• A large quantity of data is no guarantee of reliable information on which to base decision making (data-rich stocks are often information poor)
	• Observation error only, does not estimate process error (recruitment deviations)
	• Extent to which dubious assumptions are violated tends to be the biggest driver of performance for this method

2.) Delay-difference stock assessment model with a 40-10 Harvest Control Rule (DD4010) (Deriso 1980, Schnute 1985, Carruthers et al. 2014)

Definition: same as DD with the exception of throttling back the TAC to zero at 10% of unfished stock size.

Caveats for applying Data-moderate assessment models for Caribbean species

1.) **Cat** input: highly uncertain due to:
- Inconsistencies in recording on data sheets (prior to 2011): yellowtail snapper, queen triggerfish, and stoplight parrotfish
- Species misidentification or lack of identification: yellowtail snapper, queen triggerfish, and stoplight parrotfish
- Underreporting of catch: all species chosen for assessment

2.) **Ind** input: requires an index of abundance that is considered representative of trends in stock dynamics

3.) **Life history** inputs: requires reliable estimate of life history parameters

Length-based methods

1.) Length target (Ltarget4) (Geromont and Butterworth 2014b, Carruthers et al. 2015)

Definition: biologically precautionary MP that incrementally adjusts the TAC to reach a target mean length in catches.

$$\text{If } L_y^{recent} \geq L^0, \qquad TAC_{y+1} = 0.5 \text{ x } 0.8\, C^{ave} \left[1 - \frac{(L_y^{recent} - L^0)}{(L^{target} - L^0)}\right]$$

$$\text{If } L_y^{recent} < L^0, \qquad TAC_{y+1} = 0.5 \text{ x } 0.8\, C^{ave} \left[\frac{L_y^{recent}}{L^0}\right]^2$$

Where:
TAC = total allowable catch,
y = year,
L_y^{recent}= average length for the most recent 5 years,
L^{ave} = historical mean length,
$L^0 = 0.9\ L^{ave}$,
C^{ave} = average catch for the most recent 5 years, and
$L^{target} = 1.15\ L^{ave}$.

Pros	Cons
• Unless there is a strong quantitative signal from the length data, the TAC is better left where it is so as to avoid the possibility of tracking noise rather than signal in a data-poor situation	• Requires length measurements which accurately reflect trends in the population

2.) Stepwise CC (length data) (LstepCC1) (Geromont and Butterworth 2014b, Carruthers et al. 2015)

Definition: incrementally adjusts the TAC according to the mean length of recent catches.

$$\mathrm{TAC}_{y+1} = \mathrm{TAC}_y \pm 5\% \left(\frac{\sum_{y=t-4}^{y=t} \mathrm{Cat}_y}{5} \right)$$

Where:
TAC = total allowable catch,
y = year,
Cat = catch, and
t = number of years with catch.

Pros	Cons
• Readily understood by all parties typically involved in the management of the resource	• Quality of information determines whether MP is reacting to real trends in biomass or simply following noise
• Does not require long time series	• No feedback control
	• May require an unacceptably large drop in TAC in the first year of implementation
	• Requires length measurements which accurately reflect trends in the population

3.) Stepwise CC (length data) (LstepCC4) (Geromont and Butterworth 2014b, Carruthers et al. 2015)

Definition: Biologically precautionary MP that incrementally adjusts the TAC according to the mean length of recent catches.

$$\mathrm{TAC_{y+1}} = \mathrm{TAC_y} \ \pm 5\% \left(\frac{0.7 \ \sum_{\mathrm{y=t-4}}^{\mathrm{y=t}} \mathrm{Cat_y}}{5} \right)$$

Where:
TAC = total allowable catch,
y = year,
Cat = catch, and
t = number of years with catch.

Appendix 4.5 *Relevant R code for the DLMtool functions used in the SEDAR 46 stock evaluation.*

Functions

```
TACfilter<-function(TAC) {
 TAC[TAC<0]<-NA
 TAC[TAC>(mean(TAC,na.rm=T)+5*sd(TAC,na.rm=T))]<-NA
 return(TAC)
}

cv<-function(x) {sd(x)/mean(x)}
sdconv<-function(m,sd) {(log(1+((sd^2)/(m^2))))^0.5}
mconv<-function(m,sd) {log(m)-0.5*log(1+((sd^2)/(m^2}
alphaconv<-function(m,sd) {m*(((m*(1-m))/(sd^2))-1)}
betaconv<-function(m,sd) {(1-m)*(((m*(1-m))/(sd^2))-1)}
trlnorm<-function(reps,mu,cv) {return(rlnorm(reps,mconv(mu,mu*cv),sdconv(mu,mu*cv)))}
```

Reference method

FMSYref

```
FMSYref<-function (x, DLM_data, reps = 100)
trlnorm(reps, DLM_data@OM$A[x] * (1 - exp(-DLM_data@OM$FMSY[x])), 0.01)
```

Catch-based

Constant catch linked to average catches (CC4)

```
CC4 <-function (x, DLM_data, reps = 100, yrsmth = 5, xx = 0.3)
{
   C_dat <- DLM_data@Cat[x, (length(DLM_data@Year) - (yrsmth -
      1)):length(DLM_data@Year)]
   TAC <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
   TACfilter(TAC)
}
```

Surplus production MSY (SPMSY)

```
SPMSY <-function (x, DLM_data, reps = 100)
{
   dependencies = "DLM_data@MaxAge, DLM_data@vbK, DLM_data@L50, DLM_data@Cat"
   maxage <- DLM_data@MaxAge
   nsamp <- reps * 200
   rule <- rep(4, 3)
   if (DLM_data@vbK[x] > 0.3) {
      rule[1] <- 1
   }
   else if (DLM_data@vbK[x] < 0.3 & DLM_data@vbK[x] > 0.16) {
      rule[1] <- 2
   }
   else if (DLM_data@vbK[x] < 0.16 & DLM_data@vbK[x] > 0.05) {
      rule[1] <- 3
   }
   AM <- iVB(DLM_data@vbt0[x], DLM_data@vbK[x], DLM_data@vbLinf[x],
```

```
    DLM_data@L50[x])
  if (AM < 1.5) {
    rule[2] <- 1
  }
  else if (AM < 4.5 & AM > 1.5) {
    rule[2] <- 2
  }
  else if (AM < 10 & AM > 4.5) {
    rule[2] <- 3
  }
  if (DLM_data@MaxAge < 4) {
    rule[1] <- 1
  }
  else if (DLM_data@MaxAge < 11 & DLM_data@MaxAge > 3) {
    rule[1] <- 2
  }
  else if (DLM_data@MaxAge < 31 & DLM_data@MaxAge > 10) {
    rule[1] <- 3
  }
  if (mean(rule) < 1.5)
    rsamp <- runif(nsamp, 0.6, 1.5)
  if (mean(rule) > 1.5 & mean(rule) < 2.5)
    rsamp <- runif(nsamp, 0.2, 1)
  if (mean(rule) > 2.5 & mean(rule) < 3.5)
    rsamp <- runif(nsamp, 0.05, 0.5)
  if (mean(rule) > 3.5)
    rsamp <- runif(nsamp, 0.015, 0.1)
  Ksamp <- runif(nsamp, mean(DLM_data@Cat[x, ])/rsamp, (10 *
    mean(DLM_data@Cat[x, ]))/rsamp)
  nyears <- length(DLM_data@Cat[x, ])
  B <- array(NA, dim = c(nsamp, nyears))
  if (DLM_data@Cat[x, 1] < (0.5 * max(DLM_data@Cat[x, ]))) {
    B[, 1] <- Ksamp * runif(nsamp, 0.5, 0.9)
  }
  else {
    B[, 1] <- Ksamp * runif(nsamp, 0.3, 0.6)
  }
  if (DLM_data@Cat[x, nyears] < (0.5 * max(DLM_data@Cat[x,
    ]))) {
    LB <- 0.01
    UB <- 0.4
  }
  else {
    LB <- 0.3
    UB <- 0.7
  }
  for (i in 2:nyears) {
    B[, i] <- B[, i - 1] - DLM_data@Cat[x, i - 1]
```

```
    B[, i] <- B[, i] + rsamp * B[, i] * (1 - B[, i]/Ksamp)
  }
  B <- B/rep(Ksamp, nyears)
  cond <- (B[, nyears] >= LB) & (B[, nyears] <= UB)
  if (sum(cond) < 1) {
    B[B[, nyears] >= UB, nyears] <- UB
    cond <- (B[, nyears] >= LB) & (B[, nyears] <= UB)
  }
  dep <- B[cond, nyears][1:reps]
  MSY <- rsamp[cond][1:reps] * Ksamp[cond][1:reps]/4
  Kc <- Ksamp[cond][1:reps]
  rc <- rsamp[cond][1:reps]
  TAC <- Kc * dep * rc/2
  if (sum(!is.na(TAC)) < ceiling(reps/10)) {
    cond <- (B[, nyears] >= 0.01) & (B[, nyears] <= 0.7)
    dep <- B[cond, nyears][1:reps]
    MSY <- rsamp[cond][1:reps] * Ksamp[cond][1:reps]/4
    Kc <- Ksamp[cond][1:reps]
    rc <- rsamp[cond][1:reps]
    TAC <- Kc * dep * rc/2
  }
  TACfilter(TAC)
}
```

Index-based

CPUE slope (Islope1)

```
Islope1<- function (x, DLM_data, reps = 100, yrsmth = 5, lambda = 0.4, xx = 0.2)
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
  if (is.na(DLM_data@MPrec[x])) {
    TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  }
  else {
    TACstar <- rep(DLM_data@MPrec[x], reps)
  }
  I_hist <- DLM_data@Ind[x, ind]
  yind <- 1:yrsmth
  slppar <- summary(lm(I_hist ~ yind))$coefficients[2, 1:2]
  Islp <- rnorm(reps, slppar[1], slppar[2])
  TAC <- TACstar * (1 + lambda * Islp)
  TACfilter(TAC)
}
```

CPUE slope (Islope4)

```
Islope4<-function (x, DLM_data, reps = 100, yrsmth = 5, lambda = 0.2, xx = 0.4)
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
```

```
  if (is.na(DLM_data@MPrec[x])) {
    TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  }
  else {
    TACstar <- rep(DLM_data@MPrec[x], reps)
  }
  I_hist <- DLM_data@Ind[x, ind]
  yind <- 1:yrsmth
  slppar <- summary(lm(I_hist ~ yind))$coefficients[2, 1:2]
  Islp <- rnorm(reps, slppar[1], slppar[2])
  TAC <- TACstar * (1 + lambda * Islp)
  TACfilter(TAC)
}
```

Index Target (cpue index of abundance) (Itarget1)

```
Itarget1<-function (x, DLM_data, reps = 100, yrsmth = 5, xx = 0, Imulti = 1.5)
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
  TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  Irecent <- mean(DLM_data@Ind[x, ind])
  Iave <- mean(DLM_data@Ind[x, (length(DLM_data@Year) - (yrsmth *
    2 - 1)):length(DLM_data@Year)])
  Itarget <- Iave * Imulti
  I0 <- 0.8 * Iave
  if (Irecent > I0) {
    TAC <- 0.5 * TACstar * (1 + ((Irecent - I0)/(Itarget -
      I0)))
  }
  else {
    TAC <- 0.5 * TACstar * (Irecent/I0)^2
  }
  TACfilter(TAC)
}
```

Index Target (cpue index of abundance) (Itarget4)

```
Itarget4 <-function (x, DLM_data, reps = 100, yrsmth = 5, xx = 0.3, Imulti = 2.5)
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
  TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  Irecent <- mean(DLM_data@Ind[x, ind])
  Iave <- mean(DLM_data@Ind[x, (length(DLM_data@Year) - (yrsmth *
    2 - 1)):length(DLM_data@Year)])
  Itarget <- Iave * Imulti
  I0 <- 0.8 * Iave
  if (Irecent > I0) {
    TAC <- 0.5 * TACstar * (1 + ((Irecent - I0)/(Itarget -
```

```
         I0)))
   }
   else {
      TAC <- 0.5 * TACstar * (Irecent/I0)^2
   }
   TACfilter(TAC)
}
```

Index Target 5 (IT5)

```
IT5<-function (x, DLM_data, reps = 100, yrsmth = 5, mc = 0.05)
{
   ind <- max(1, (length(DLM_data@Year) - yrsmth + 1)):length(DLM_data@Year)
   deltaI <- mean(DLM_data@Ind[x, ind])/DLM_data@Iref[x]
   if (deltaI < (1 - mc))
      deltaI <- 1 - mc
   if (deltaI > (1 + mc))
      deltaI <- 1 + mc
   TAC <- DLM_data@MPrec[x] * deltaI * trlnorm(reps, 1, DLM_data@CV_Ind[x])
   TAC
}
```

Index Target 10 (IT10)

```
IT10<-function (x, DLM_data, reps = 100, yrsmth = 10, mc = 0.05)
 {
   ind <- max(1, (length(DLM_data@Year) - yrsmth + 1)):length(DLM_data@Year)
   deltaI <- mean(DLM_data@Ind[x, ind])/DLM_data@Iref[x]
   if (deltaI < (1 - mc))
      deltaI <- 1 - mc
   if (deltaI > (1 + mc))
      deltaI <- 1 + mc
   TAC <- DLM_data@MPrec[x] * deltaI * trlnorm(reps, 1, DLM_data@CV_Ind[x])
   TAC
}
```

Index Target based on natural mortality rate (ITM)

```
ITM<-function (x, DLM_data, reps = 100)
{
   mc <- (5 + DLM_data@Mort[x] * 25)/100
   if (mc > 0.2)
      mc <- 0.2
   yrsmth <- floor(4 * (1/DLM_data@Mort[x])^(1/4))
   ind <- max(1, (length(DLM_data@Year) - yrsmth + 1)):length(DLM_data@Year)
   deltaI <- mean(DLM_data@Ind[x, ind])/DLM_data@Iref[x]
   if (deltaI < (1 - mc))
      deltaI <- 1 - mc
   if (deltaI > (1 + mc))
      deltaI <- 1 + mc
```

```
   TAC <- DLM_data@MPrec[x] * deltaI * trlnorm(reps, 1, DLM_data@CV_Ind[x])
   TAC
}
```

Depletion-based

Depletion-Corrected Average Catch (DCAC)

```
DCAC<-function (x, DLM_data, reps = 100)
{
   C_tot <- DLM_data@AvC[x] * DLM_data@t[x]
   Mdb <- trlnorm(reps, DLM_data@Mort[x], DLM_data@CV_Mort[x])
   FMSY_M <- trlnorm(reps, DLM_data@FMSY_M[x], DLM_data@CV_FMSY_M[x])
   Bt_K <- trlnorm(reps, DLM_data@Dt[x], DLM_data@CV_Dt[x])
   BMSY_K <- rbeta(reps, alphaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]),
      betaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]))
   TACfilter(C_tot/(DLM_data@t[x] + ((1 - Bt_K)/(BMSY_K * FMSY_M *
      Mdb))))
}
```

Depletion-Corrected Average Catch assuming stock depletion is 40% of unfished levels (DCAC_40)

```
DCAC_40<-function (x, DLM_data, reps = 100)
{
   C_tot <- DLM_data@AvC[x] * DLM_data@t[x]
   Mdb <- trlnorm(reps, DLM_data@Mort[x], DLM_data@CV_Mort[x])
   FMSY_M <- trlnorm(reps, DLM_data@FMSY_M[x], DLM_data@CV_FMSY_M[x])
   Bt_K <- 0.4
   BMSY_K <- rbeta(reps, alphaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]),
      betaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]))
   TACfilter(C_tot/(DLM_data@t[x] + ((1 - Bt_K)/(BMSY_K * FMSY_M *
      Mdb))))
}
```

Depletion-Corrected Average Catch with a 40-10 Harvest Control Rule (DCAC4010)

```
DCAC4010<-function (x, DLM_data, reps = 100)
```

```
{
 C_tot <- DLM_data@AvC[x] * DLM_data@t[x]
   Mdb <- trlnorm(reps, DLM_data@Mort[x], DLM_data@CV_Mort[x])
   FMSY_M <- trlnorm(reps, DLM_data@FMSY_M[x], DLM_data@CV_FMSY_M[x])
   Bt_K <- trlnorm(reps, DLM_data@Dt[x], DLM_data@CV_Dt[x])
   BMSY_K <- rbeta(reps, alphaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]),
      betaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]))
   TAC <- C_tot/(DLM_data@t[x] + ((1 - Bt_K)/(BMSY_K * FMSY_M *
      Mdb)))
   cond1 <- Bt_K < 0.4 & Bt_K > 0.1
   cond2 <- Bt_K < 0.1
   if (length(cond1) > 0)
      TAC[cond1] <- TAC[cond1] * (Bt_K[cond1] - 0.1)/0.3
   if (length(cond2) > 0)
      TAC[cond2] <- TAC[cond2] * tiny
   if (length(cond1) < 1 & length(cond2) < 1)
      return(NA)
   TACfilter(TAC)
}
```

Extra Depletion-Corrected Average Catch (EDCAC)

```
EDCAC<- function (x, DLM_data, reps = 100)
{
   C_tot <- DLM_data@AvC[x] * DLM_data@t[x]
   Mdb <- trlnorm(reps, DLM_data@Mort[x], DLM_data@CV_Mort[x])
   FMSY_M <- trlnorm(reps, DLM_data@FMSY_M[x], DLM_data@CV_FMSY_M[x])
   Bt_K <- trlnorm(reps, DLM_data@Dt[x], DLM_data@CV_Dt[x])
   BMSY_K <- rbeta(reps, alphaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]),
      betaconv(DLM_data@BMSY_B0[x], DLM_data@CV_BMSY_B0[x]))
   dcac <- C_tot/(DLM_data@t[x] + ((1 - Bt_K)/(BMSY_K * FMSY_M *
      Mdb)))
   TAC <- dcac * Bt_K/BMSY_K
   TACfilter(TAC)
}
```

Mean Catch Depletion (MCD)

```
MCD<-function (x, DLM_data, reps = 100)
{
   depo <- max(0.01, min(0.99, DLM_data@Dep[x]))
   Bt_K <- rbeta(reps * 100, alphaconv(depo, min(depo * DLM_data@CV_Dep[x],
      (1 - depo) * DLM_data@CV_Dep[x])), betaconv(depo, min(depo *
      DLM_data@CV_Dep[x], (1 - depo) * DLM_data@CV_Dep[x])))
   Bt_K <- Bt_K[Bt_K > 0.00999 & Bt_K < 0.99001][1:reps]
   AvC <- rlnorm(reps, log(mean(DLM_data@Cat[x, ], na.rm = T)),
      DLM_data@CV_Cat[x])
   TAC <- AvC * 2 * Bt_K
   TACfilter(TAC)
}
```

Abundance-based

Fratio(FMSY/M)

```
Fratio<-function (x, DLM, reps = 100)
{
  Ac <- trlnorm(reps, DLM@Abun[x], DLM@CV_Abun[x])
  OFLfilter(Ac * trlnorm(reps, DLM@Mort[x], DLM@CV_Mort[x]) *
    trlnorm(reps, DLM@FMSY_M[x], DLM@CV_FMSY_M[x]))
}
```

Beddington and Kirkwood life history method (BK)

```
BK <-function (x, DLM, reps = 100)
{
  Lc <- trlnorm(reps * 10, DLM@LFC[x], 0.2)
  Linfc <- trlnorm(reps * 10, DLM@vbLinf[x], DLM@CV_vbLinf[x])
  Ac <- trlnorm(reps * 10, DLM@Abun[x], DLM@CV_Abun[x])
  Kc <- trlnorm(reps * 10, DLM@vbK[x], DLM@CV_vbK[x])
  OFL <- Ac * (0.6 * Kc)/(0.67 - (Lc/Linfc))
  OFLfilter(OFL[OFL > 0][1:reps])
}
```

Yield-Per-Recruit Analysis (YPR)

```
YPR<-function (x, DLM, reps = 100)
{
  Linfc <- trlnorm(reps, DLM@vbLinf[x], DLM@CV_vbLinf[x])
  Kc <- trlnorm(reps, DLM@vbK[x], DLM@CV_vbK[x])
  t0c <- -trlnorm(reps, -DLM@vbt0[x], DLM@CV_vbt0[x])
  Mdb <- trlnorm(reps, DLM@Mort[x], DLM@CV_Mort[x])
  LFS <- trlnorm(reps, DLM@LFS[x], DLM@CV_LFS[x])
  a <- DLM@wla[x]
  b <- DLM@wlb[x]
  Ac <- trlnorm(reps, DLM@Abun[x], DLM@CV_Abun[x])
  FMSY <- YPRopt(Linfc, Kc, t0c, Mdb, a, b, LFS, DLM@MaxAge,
    reps)
  OFL <- Ac * FMSY
  OFLfilter(OFL)
}
```

Data-moderate

Delay-difference (DD)

```
DD<-function (x, DLM_data, reps = 100)
{
  Linfc <- trlnorm(reps, DLM_data@vbLinf[x], DLM_data@CV_vbLinf[x])
  Kc <- trlnorm(reps, DLM_data@vbK[x], DLM_data@CV_vbK[x])
  t0c <- -trlnorm(reps, -DLM_data@vbt0[x], DLM_data@CV_vbt0[x])
  Mdb <- trlnorm(reps, DLM_data@Mort[x], DLM_data@CV_Mort[x])
  a <- DLM_data@wla[x]
  b <- DLM_data@wlb[x]
```

```
  Winf = DLM_data@wla[x] * DLM_data@vbLinf[x]^DLM_data@wlb[x]
  age <- 1:DLM_data@MaxAge
  la <- DLM_data@vbLinf[x] * (1 - exp(-DLM_data@vbK[x] * ((age -
    DLM_data@vbt0[x]))))
  wa <- DLM_data@wla[x] * la^DLM_data@wlb[x]
  a50V <- iVB(DLM_data@vbt0[x], DLM_data@vbK[x], DLM_data@vbLinf[x],
    DLM_data@L50[x])
  yind <- (1:length(DLM_data@Cat[x, ]))[!is.na(DLM_data@Cat[x,
    ] + DLM_data@Ind[x, ])]
  C_hist <- DLM_data@Cat[x, yind]
  E_hist <- C_hist/DLM_data@Ind[x, yind]
  E_hist <- E_hist/mean(E_hist)
  ny_DD <- length(C_hist)
  params <- log(c(DLM_data@Mort[x], mean(C_hist, na.rm = T),
    DLM_data@Mort[x]))
  k_DD <- ceiling(a50V)
  k_DD[k_DD > DLM_data@MaxAge/2] <- ceiling(DLM_data@MaxAge/2)
  Rho_DD <- (wa[k_DD + 2] - Winf)/(wa[k_DD + 1] - Winf)
  Alpha_DD <- Winf * (1 - Rho_DD)
  So_DD <- exp(-DLM_data@Mort[x])
  wa_DD <- wa[k_DD]
  UMSYprior <- c(1 - exp(-DLM_data@Mort[x] * 0.5), 0.3)
  opt <- optim(params, DD_R, opty = 1, So_DD = So_DD, Alpha_DD = Alpha_DD,
    Rho_DD = Rho_DD, ny_DD = ny_DD, k_DD = k_DD, wa_DD = wa_DD,
    E_hist = E_hist, C_hist = C_hist, UMSYprior = UMSYprior,
    method = "L-BFGS-B", lower = log(exp(params)/20), upper = log(exp(params) *
      20), hessian = TRUE)
  TAC <- rep(NA, reps)
  samps <- cbind(rnorm(reps, opt$par[1], ((opt$par[1])^2)^0.5 *
    0.1), rnorm(reps, opt$par[2], ((opt$par[2])^2)^0.5 *
    0.1), rnorm(reps, opt$par[3], ((opt$par[3])^2)^0.5 *
    0.1))
  if (reps == 1)
    samps <- matrix(c(opt$par[1], opt$par[2], opt$par[3]),
      nrow = 1)
  for (i in 1:reps) TAC[i] <- DD_R(samps[i, ], opty = 2, So_DD = So_DD,
    Alpha_DD = Alpha_DD, Rho_DD = Rho_DD, ny_DD = ny_DD,
    k_DD = k_DD, wa_DD = wa_DD, E_hist = E_hist, C_hist = C_hist,
    UMSYprior = UMSYprior)
  TACfilter(TAC)
}
```

Delay-difference stock assessment model with a 40-10 Harvest Control Rule (DD4010)

```
DD4010 <-function (x, DLM_data, reps = 100)
{
  Linfc <- trlnorm(reps, DLM_data@vbLinf[x], DLM_data@CV_vbLinf[x])
  Kc <- trlnorm(reps, DLM_data@vbK[x], DLM_data@CV_vbK[x])
  t0c <- -trlnorm(reps, -DLM_data@vbt0[x], DLM_data@CV_vbt0[x])
```

```
Mdb <- trlnorm(reps, DLM_data@Mort[x], DLM_data@CV_Mort[x])
a <- DLM_data@wla[x]
b <- DLM_data@wlb[x]
Winf = DLM_data@wla[x] * DLM_data@vbLinf[x]^DLM_data@wlb[x]
age <- 1:DLM_data@MaxAge
la <- DLM_data@vbLinf[x] * (1 - exp(-DLM_data@vbK[x] * ((age -
   DLM_data@vbt0[x]))))
wa <- DLM_data@wla[x] * la^DLM_data@wlb[x]
a50V <- iVB(DLM_data@vbt0[x], DLM_data@vbK[x], DLM_data@vbLinf[x],
   DLM_data@L50[x])
yind <- (1:length(DLM_data@Cat[x, ]))[!is.na(DLM_data@Cat[x,
   ] + DLM_data@Ind[x, ])]
C_hist <- DLM_data@Cat[x, yind]
E_hist <- DLM_data@Ind[x, yind]
E_hist <- C_hist/E_hist
E_hist <- E_hist/mean(E_hist)
ny_DD <- length(C_hist)
params <- log(c(DLM_data@Mort[x], mean(C_hist, na.rm = T),
   DLM_data@Mort[x]))
k_DD <- ceiling(a50V)
k_DD[k_DD > DLM_data@MaxAge/2] <- ceiling(DLM_data@MaxAge/2)
Rho_DD <- (wa[k_DD + 2] - Winf)/(wa[k_DD + 1] - Winf)
Alpha_DD <- Winf * (1 - Rho_DD)
So_DD <- exp(-DLM_data@Mort[x])
wa_DD <- wa[k_DD]
UMSYprior <- c(1 - exp(-DLM_data@Mort * 0.5), 0.3)
opt <- optim(params, DD_R, opty = 1, So_DD = So_DD, Alpha_DD = Alpha_DD,
   Rho_DD = Rho_DD, ny_DD = ny_DD, k_DD = k_DD, wa_DD = wa_DD,
   E_hist = E_hist, C_hist = C_hist, UMSYprior = UMSYprior,
   method = "L-BFGS-B", lower = log(exp(params)/20), upper = log(exp(params) *
      20), hessian = TRUE)
TAC <- rep(NA, reps)
dep <- rep(NA, reps)
samps <- cbind(rnorm(reps, opt$par[1], ((opt$par[1])^2)^0.5 *
   0.1), rnorm(reps, opt$par[2], ((opt$par[2])^2)^0.5 *
   0.1), rnorm(reps, opt$par[3], ((opt$par[3])^2)^0.5 *
   0.1))
if (reps == 1)
   samps <- matrix(c(opt$par[1], opt$par[2], opt$par[3]),
      nrow = 1)
for (i in 1:reps) TAC[i] <- DD_R(samps[i, ], opty = 2, So_DD = So_DD,
   Alpha_DD = Alpha_DD, Rho_DD = Rho_DD, ny_DD = ny_DD,
   k_DD = k_DD, wa_DD = wa_DD, E_hist = E_hist, C_hist = C_hist,
   UMSYprior = UMSYprior)
for (i in 1:reps) dep[i] <- DD_R(samps[i, ], opty = 3, So_DD = So_DD,
   Alpha_DD = Alpha_DD, Rho_DD = Rho_DD, ny_DD = ny_DD,
   k_DD = k_DD, wa_DD = wa_DD, E_hist = E_hist, C_hist = C_hist,
   UMSYprior = UMSYprior)
```

```
  cond1 <- !is.na(dep) & dep < 0.4 & dep > 0.1
  cond2 <- !is.na(dep) & dep < 0.1
  TAC[cond1] <- TAC[cond1] * (dep[cond1] - 0.1)/0.3
  TAC[cond2] <- TAC[cond2] * tiny
  TACfilter(TAC)
}
```

Length-based

Target length MP (Ltarget4)

```
Ltarget4<-function (x, DLM_data, reps = 100, yrsmth = 5, xx = 0.2, xL = 1.15)
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
  TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  binval <- DLM_data@CAL_bins[1:(length(DLM_data@CAL_bins) -
    1)] + (DLM_data@CAL_bins[2] - DLM_data@CAL_bins[1])/2
  CALdat <- DLM_data@CAL[x, , ] * rep(binval, each = dim(DLM_data@CAL)[2])
  avCAL <- apply(CALdat, 1, sum)/apply(DLM_data@CAL[x, , ],
    1, sum)
  Lrecent <- mean(avCAL[ind])
  Lave <- mean(avCAL[(length(DLM_data@Year) - (yrsmth * 2 -
    1)):length(DLM_data@Year)])
  L0 <- 0.9 * Lave
  Ltarget <- xL * Lave
  if (Lrecent > L0) {
    TAC <- 0.5 * TACstar * (1 + ((Lrecent - L0)/(Ltarget -
      L0)))
  }
  else {
    TAC <- 0.5 * TACstar * (Lrecent/L0)^2
  }
  TACfilter(TAC)
}
```

Stepwise CC (length data) (LstepCC1)

```
LstepCC1<-function (x, DLM_data, reps = 100, yrsmth = 5, xx = 0, stepsz = 0.05,
  llim = c(0.96, 0.98, 1.05))
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
  if (is.na(DLM_data@MPrec[x])) {
    TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  }
  else {
    TACstar <- rep(DLM_data@MPrec[x], reps)
  }
  step <- stepsz * TACstar
  binval <- DLM_data@CAL_bins[1:(length(DLM_data@CAL_bins) -
```

```
    1)] + (DLM_data@CAL_bins[2] - DLM_data@CAL_bins[1])/2
  CALdat <- DLM_data@CAL[x, , ] * rep(binval, each = dim(DLM_data@CAL)[2])
  avCAL <- apply(CALdat, 1, sum)/apply(DLM_data@CAL[x, , ],
    1, sum)
  Lrecent <- mean(avCAL[ind])
  Lave <- mean(avCAL[(length(DLM_data@Year) - (yrsmth * 2 -
    1)):length(DLM_data@Year)])
  rat <- Lrecent/Lave
  if (rat < llim[1]) {
    TAC <- TACstar - 2 * step
  }
  else if (rat < llim[2]) {
    TAC <- TACstar - step
  }
  else if (rat > llim[3]) {
    TAC <- TACstar + step
  }
  else {
    TAC <- TACstar
  }
  TACfilter(TAC)
}
```

Stepwise CC (length data) (LstepCC4)

```
LstepCC4<-function (x, DLM_data, reps = 100, yrsmth = 5, xx = 0.3, stepsz = 0.05,
  llim = c(0.96, 0.98, 1.05))
{
  ind <- (length(DLM_data@Year) - (yrsmth - 1)):length(DLM_data@Year)
  C_dat <- DLM_data@Cat[x, ind]
  if (is.na(DLM_data@MPrec[x])) {
    TACstar <- (1 - xx) * trlnorm(reps, mean(C_dat), DLM_data@CV_Cat/(yrsmth^0.5))
  }
  else {
    TACstar <- rep(DLM_data@MPrec[x], reps)
  }
  step <- stepsz * TACstar
  binval <- DLM_data@CAL_bins[1:(length(DLM_data@CAL_bins) -
    1)] + (DLM_data@CAL_bins[2] - DLM_data@CAL_bins[1])/2
  CALdat <- DLM_data@CAL[x, , ] * rep(binval, each = dim(DLM_data@CAL)[2])
  avCAL <- apply(CALdat, 1, sum)/apply(DLM_data@CAL[x, , ],
    1, sum)
  Lrecent <- mean(avCAL[ind])
  Lave <- mean(avCAL[(length(DLM_data@Year) - (yrsmth * 2 -
    1)):length(DLM_data@Year)])
  rat <- Lrecent/Lave
  if (rat < llim[1]) {
    TAC <- TACstar - 2 * step
  }
```

```
  else if (rat < llim[2]) {
    TAC <- TACstar - step
  }
  else if (rat > llim[3]) {
    TAC <- TACstar + step
  }
  else {
    TAC <- TACstar
  }
  TACfilter(TAC)
}
```

SEDAR

Southeast Data, Assessment, and Review

SEDAR 46

U.S. Caribbean Data-limited Species

SECTION III: Research Recommendations

SEDAR
4055 Faber Place Drive, Suite 201
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1. DATA RESEARCH RECOMMENDATIONS

Species Selection:

- Investigate additional data sets and re-evaluate species selection criteria for future stock evaluations.
- For example, consider the information available for queen conch (*Strombus gigas*) in the National Ocean Service's Biogeography visual surveys (Menza et al. 2006) and in data collected by universities in the region.
- Mesophotic reef surveys in western Puerto Rico (García-Sais et al. 2012), visual surveys and passive acoustic monitoring in western Puerto Rico and Mona Island (Scharer-Umpierre et al., 2014), and
- SEAMAP-C (Pagan 2002, Ingram 2014).

To the extent possible, these (and any other datasets) should be integrated and comprehensively summarized to facilitate comparisons and explorations in future analyses.

Life History:

- Representative sampling across size/age spectra for under-sampled US Caribbean stocks.
- Updated studies of life history and demographic characteristics are needed that focus on sampling under-represented size classes, particularly large (old) fishes to provide more accurate estimates of asymptotic length, and small (young) fishes to more accurately estimate the rate at which fishes approach asymptotic length. This recommendation stems from a concern that maximum lengths were too often considerably longer than L_∞ estimates. This observation could stem from inadequate sampling of the largest length classes, region-specific differences in asymptotic growth (where parameters were borrowed from other regions), or where exploitation has dramatically modified stock structure.
- Additional sampling is also necessary for improving stock-specific maturity schedules, and these data should be fit via modern logistic regressions methods to obtain the most robust estimates of length at maturity.
- Research efforts be put into compilation of various datasets of life history demographic parameters for all exploited species in the tropical western Atlantic, through a Regional Expert Demographic Workshop.

Fishery Statistics:

Commercial research recommendations

- Evaluate the efficacy of existing commercial landings expansion factors used in Puerto Rico; provide recommendations for improved methods to calculate expansion factors; examine the impact on landings estimates due to methodological changes implemented in 2003 for calculating expansion factors

- Verify, using port samplers or other appropriate methods, self-reported landings in the US Virgin Islands and Puerto Rico
- Obtain species-specific estimates of discards from the commercial sector in Puerto Rico and in the US Virgin Islands
- Quantify the sizes and discard conditions of fish discarded by commercial fisheries in Puerto Rico and in the US Virgin Islands

Recreational research recommendations

- Increase representative sampling of the recreational sector in Puerto Rico and expand to collect recreational data in the US Virgin Islands
- Include spiny lobster and conch in the MRIP in order to estimate recreational catch for these important Caribbean species
- Explore changes in the Puerto Rico recreational catch estimates as a result of the change in intercept protocols and estimation methodologies from MRFSS to MRIP in 2014

Measures of Fishery Abundance:

- Conduct additional examinations to identify auxiliary variables that could be informative in standardization
- Begin the spiny lobster nominal and standardized index further back in time
- Invest in regional scale fisheries-independent surveys to estimate relative (or absolute) abundance
- Investigate methods for subsetting to trips targeting the target species
- Account for change in regulations that may affect CPUE
- Obtain supplementary information and evaluate the use of aggregation of data over gears. The recommendation for SEDAR 46 was to group gear types that were assumed to have similar selectivity's. Additional efforts could help determine when it is or is not appropriate to use gear groups.

Fishing Effort:

- Investigate issue associated with fishers not reporting effort information in St. Croix
- Review any caveats/concerns such as species having more than one dominant fishery or noted changes in fishing behavior
- Extend the data-limited approaches to allow two fisheries, or a single fishery with two distinct types of selectivity/catchability

Length Frequency Distributions:

- The TIP sampling operational framework in Puerto Rico and in the USVI should be reviewed to ensure sampling is representative of the primary fisheries.

- Conduct review of supplemental information on size from data series not readily available for these evaluations.
- Evaluate the use of aggregation of length samples over gears. The recommendation by the SEDAR 46 DW Panel was to group gear types that were assumed to have similar selectivities.
- Address difficulty in assigning the fishing areas to develop a continuous series for the USVI. Develop a consistent time series of area assignments for St. Thomas and St. John. Consider if alternative approaches to aggregating the fishing area information in the TIP data may be feasible.

2. ASSESSMENT RESEARCH RECOMMENDATIONS

A number of research recommendations are identified throughout the SEDAR 46 stock evaluation. These arise from the perspective of information content (i.e., data availability, quantity, and quality and information content) and also the modeling approach. Within this context the following discussion and recommendations are made.

Regarding data availability, continued explorations are warranted on the following topics to address uncertainty within key data inputs for data-limited stock assessment models:

1. A statistical review of existing fishery independent surveys to identify an optimum sampling design for development of fishery independent abundance indices. Fishery independent surveys can contribute critical information regarding trends in stock abundance, which can be applied in relatively simple management procedures.

2. Develop indices of abundance for spiny lobster using all available data since 1970s with focus on a fishery independent survey.

3. Investigate more justifiable estimates of stock depletion (Dep) and depletion over time (Dt), such as through Productivity-Susceptibility Analysis (e.g., Cope et al. 2015) or using methods such as mean length estimators.

4. Investigate more justifiable estimates of current stock abundance.

5. Enhanced catch at length by gear sampling is needed to better inform selectivity at age.

6. Investigate fleet dynamics to more accurately capture fishery characteristics.

7. Identify target catch or index levels which could be used in conjunction with catch and index time series.

8. Identify target length levels which could be used in conjunction with catch and a length frequency series.

9. Develop a weighting scheme for length composition and multiple gear fisheries reflective of the stock.

10. Consider organizing species into species complexes for assessment based on similar life history, market characteristics, and vulnerability. This could help streamline the stock assessment process in a data-limited context.

Within the modeling framework used in SEDAR 46, many limitations are acknowledged within an MSE approach. Pragmatically, results are a product of the specific conditions of the simulation, which are assumed to be as simplistic as possible but contain sufficient complexity to reflect the system in a representative way. Methods tend to perform poorly when fundamental assumptions are invalid or inputs are strongly miss-specified. Detecting model misspecficiation for data-limited scenarios offers additional challenges including evaluating incongruency between data sources. As well, within the implementation model, assumed management target recommendations (i.e., TACs) were taken as catch with no implementation error simulated. Further, no uncertainty was considered in determining TACs via buffers to account for multiple sources of uncertainty (catch reporting, assessment procedure violations, etc). Thus, additional considerations towards confirmation of the stock and fleet subclass components of the operating models explored in SEDAR 46 are warranted. In particular, assumptions regarding the selectivity pattern of fleets should be further examined.

Recommendations for enhancing the practical use of the DLMtool from the analytical team.

- Revisions of the DLMtool software to enhance the model functionality to allow multiple indices of abundance.

- Revision of the DLMtool software to allow age varying M.

- Allow for implementation error of the harvest control rule (e.g., TAC overages) within the implementation model in the MSE.

Recommendations for enhancing the practical use of the DLMtool from the developer (Carruthers (2015a) that the SEDAR 46 analytical team considers of practical relevance to US Caribbean fisheries application of the toolkit:

- Idealized observation models for catch composition data

"Currently, DLMtool simulates catch-composition data from the true simulated catch composition data via a multinomial distribution and some effective sample size. This observation model may be unrealistically well-behaved and favor those approaches that use these data. Harvest control rules must be integrated into data-limited MPs".

- Harvest control rules

"In the version of DLMtool applied in SEDAR 46 (version 2.1.2), harvest control rules (e.g., the 40-10 rule) must be written into a data-limited MP. There is currently no ability to do a factorial comparison of say 4 harvest controls rules against 3 MPs (the user must describe all 12 combinations). The reason for this is that it would require further subclasses. For example the 40-10 rule may be appropriate for the output of DBSRA but it would not be appropriate for some of the simple management procedures such as DynF that already incorporate throttling of TAC recommendations according to stock depletion."

- Implementation error

"In this edition of DLMtool there is no implementation error. The only imperfection between a management recommendation and the simulated TAC comes in the form of the MaxF argument that limits the maximum fishing mortality rate on any given age-class in the operating model. The default is 0.8 which is high for all but the shortest living fish species."

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

This section considers the research recommendations initially provided by the DW and AW that were then considered by the SEDAR 46 Review Panel. The Review Panel generally supported the recommendations from the DW and AW, and those from the assessment team. However, the Review Panel extended these recommendations as outlined below. Recommendations fell into two general categories: (1) data; and, (2) model.

Data

One of the fuzziest aspects of the data-limited process was how exactly data reliability was qualified or quantified. We discovered that fishery data precision (e.g., coefficient of variation, CV) was not able to be determined from the current fishery catch sampling methodologies that are employed in the Caribbean. While this was probably a topic of conversation at the DW, there was insufficient discussion of these critical issues in the SEDAR 46 DW/AW report (AW). There needs to be a solid focus on data design strategies as the data-limited process moves forward in the region to establish ACLs for a range of species presently not under consideration.

Thus, two aspects of model inputs must be addressed: (1) life history demographics; and, (2) fishery-dependent data (size-structured catch and fishing effort). Research into what defines the "best" demographic parameters for DLM model inputs, for example, most accurate and precise growth (length-at-age) curve, maximum age (i.e., natural mortality rate), size at first capture (selectivity ogive), size at first sexual maturity (maturation ogive), etc. There seemed to be insufficient attention to these issues in the workshop, and arbitrary (non-estimated) CVs were applied to data inputs. Perhaps the number one priority is to refine the life history demographic parameters identified by the DW across the region, and to improve accuracy and precision of those basic data. This strategy would likely be facilitated by a workshop of technical experts convened, in the near future, to review and analyse existing life history demographic data for all relevant exploited species in the U.S. Caribbean, Southeast U.S. and Gulf of Mexico. When joint parameter variance-covariance is not available, how will estimates of uncertainty for life history demographic parameters, for example, be provided? This would include quantitative justifications for error variances and CVs.

A focus on design-based strategies for ensuring collection of accurate and precise fisheries-dependent commercial and recreational data should be advanced in the region. This would greatly improve fishery-dependent mean (and variance) estimates of landings, discards and the effort required to obtain them. The sampling protocols must be optimized to ensure representative sampling across size-age spectra over time and space. If precise estimates were obtained in the most recent years, then a data-limited analysis could identify current exploitation rates and resource sustainability. In addition, it makes sense to conduct a statistical review, analysis and optimal sampling design of complimentary fishery-independent surveys as these could provide extremely important spatially-integral, accurate and precise information on exploitation effects by measuring what is left in the water after fishing has occurred.

More work must be done on evaluation of species selection criteria. The adequacy of the choice of species suitable for these pilot species analyses was generally successful. However, a couple of those species provided little guidance on model performance. These analyses revealed issues in three areas: (1) appropriate models and benchmarks; (2) reliable life history demographic data; and, (3) adequate fishery-dependent data.

Model

A review of appropriate data-limited methods should be conducted as soon as possible, under the auspices of SEDAR, to allow evaluation of which methods should really be used in the DLM process for evaluation. Such a technical review would consider: (1) model theoretical basis and assumptions; (2) data requirements; (3) robustness of model to departures from assumptions and data requirements; and, (4) model responses (i.e., biases) to model uncertainty. This would include a systematic analysis of the sources of variability and how they influence OM dynamics. This was nearly impossible to discern in the way that the materials were presented at SEDAR 46, which was no fault of the analysts.

Some of the model estimates produced during SEDAR 46 were very troubling due to either: (1) application of an inappropriate or an inapplicable model(s) or MP; and/or, (2) very wide ranges of error variances, while unknown, that were applied to the input data. As a result, some MPs produced forecasts of unrealistic catch levels, suggesting that their usefulness is highly dubious. Not surprisingly, when appropriate variances and covariances were applied, the median of the output distribution do not change, but the range of model output metrics were substantially reduced. Nevertheless, that did not lead to any material change in the findings of the assessment with regard to MPs that performed better. The argument that this tested the MPs with greater uncertainty and therefore could still be used as a test of robustness was only partially accepted by the review panel.

While this AW was an examination of the potential efficacy of the approach due to its "newness", and the fact that it was 3rd party application not fully controlled by the analytical team, we believe that in future workshops the analysts should more clearly specify what is desired as an outcome of model simulations, so that the simulations can be more finely tuned to answer specific questions. Generally, feasibility and limitations of MPs to real world applications is largely determined by data sufficiency and model adequacy. Additionally, there was no guarantee that the sampling algorithms in the OM reflected reality, and to some extent particular methodologies were difficult to assess given the information available to the Panel. In general, the AW would have run more smoothly if more attention were paid to the accuracy and precision of the basic data, and adherence to the assumptions required by the applicable MPs.

A better description and explanation of what is actually going on in the DLMtool OM at the outset would have been useful and clarifying to the Review Panel. As it was, application of methodologies at times appeared quite *ad hoc*, particularly as related to application of means, variances and coefficients of variations of model parameters. The parameters were treated as independent random variables, when we know they are dependent. But this is in fact the DLMtool default as it tries to cover a very wide range of uncertainties. There were a number of unclear definitions, such as “model stability”, which roughly translated to how many simulation runs were required for an input level of variation where for some unspecified reason, all model parameters seemed to be varying simultaneously. This would suggest that some further attention to model sensitivity is highly warranted. Concepts as straight-forward as the number of required model runs to achieve stationarity were not well substantiated.

The apparent uncertainty in both data and models for U.S. Caribbean species suggests caution when selecting MPs intended to provide management advice. Selection of a particular MP for providing catch allocation strategies for management should consider: (1) MP sensitivity to parameters; (2) satisfying model assumptions; and, (3) information quality.

Recommendations

More precise and clearer descriptions and rationales for model thresholds and benchmarks used in the DLM process are needed. Analyses presented at the AW focused heavily on fishery yields (i.e., catches) which made it difficult to discern the rationale for what constituted a particular preferred choice of the MPs. A broader perspective might be entertained when setting OFLs and other appropriate benchmarks. This would likely include yield risks as they relate, in addition, to benchmarks specific to both economic and ecological risks. Adherence to this philosophy would require that model thresholds are set at more conservative resource use levels than are presently considered, and this in turn would avoid theoretical searches of infeasible or impractical model decision space. It is probably not useful to go too far into the weeds in trying to assess the full complexity of a fishery at first, rather the assessment needs to focus on distinguishing sustainable from non-sustainable rates of exploitation, and then identify the appropriate annual catches required to sustain the resource(s). If multiple MPs or a subset of tools are used, then some consideration must be given to model averaging. It would appear from the AW that many of the proposed estimation methods and MPs are non-starters from the outset. This seems an opportune time to conduct a thorough analysis of DLMtool efficacy. The Panel feels that the approaches presented could have broad potential for use in the Caribbean, but still require deeper, more thoughtful consideration to determine what avenues of application allow one to achieve the greatest utility of the tool.

SEDAR
Southeast Data, Assessment, and Review

SEDAR 46

U.S. Caribbean Data-Limited Species

SECTION IV: Review Workshop Report

April 2016

SEDAR
4055 Faber Place Drive, Suite 201
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Table of Contents

1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 46 Review Workshop was held February 23-25, 2016 in Miami, Florida.

1.2 TERMS OF REFERENCE

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
   a) Are data decisions made by the DW and AW sound and robust?
   b) Are data uncertainties acknowledged, reported, and within normal or expected levels?
   c) Are data applied properly within the assessment model?
   d) Are input data series reliable and sufficient to support the assessment approach and findings?
2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and considering the following:
   a) Are the data-limited methods scientifically sound and robust?
   b) Are the methods appropriate given the available data?
   c) Are the data-limited models configured properly and used in a manner consistent with standard practices?
   d) Are the quantitative estimates produced reliable? Does the method produce management metrics (e.g. MSY, ABC, ACL) or other indicators (e.g. trends in F or Z, probability of overfishing) that may be used to inform managers about stock trends and conditions?
3. Consider how uncertainties in the assessment, and their potential consequences, are addressed.

  - Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.
  - Ensure that the implications of uncertainty in technical conclusions are clearly stated.

4. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
   - Clearly denote research and monitoring that could improve the reliability of future assessments.
   - Provide recommendations on possible ways to improve the SEDAR process.
4. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.
6. Provide guidance on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.
7. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference.

1.3 LIST OF PARTICIPANTS

Workshop Panel

Vance P. Vicinte, Chair	Chair, SSC
Panayiota Apostolaki	CIE Reviewer
Jerald S. Ault	Council Appointee
Cathy Dichmont	CIE Reviewer
John Hoenig	SSC
Paul Medley	CIE Reviewer

Analytic Representation

Nancie Cummings	SEFSC, Miami
Adyan Rios	SEFSC, Miami
Skyler Sagarese	SEFSC, Miami

Appointed Observers

Winston Ledee	Industry Representative – St. Thomas
Roberto Silva	Industry Representative – Puerto Rico

Observers

Molly Adams	Univ. of Miami
Meaghan Bryan	SEFSC, Miami

Quang Huynh	VIMS
Jeff Isley	SEFSC, Miami
Bill Harford	RSMAS/SEFSC
Michael Larkin	SERO
Vivian Matter	SEFSC, Miami
Daniel Matos-Caraballo	PRDNER
Kevin McCarthy	SEFSC, Miami
Clay Porch	SEFSC, Miami

Staff

Julie Neer	SEDAR
Julie O'Dell	SAFMC Staff
Kate Quigley	CFMC Staff

1.4 LIST OF REVIEW WORKSHOP WORKING PAPERS AND DOCUMENTS

Documents Prepared for the Review Workshop			
SEDAR46-RW-01	Estimating total mortality rates and calculating overfishing limits from length observations for six U.S. Caribbean stocks	Quang C. Huynh	14 Jan 2016
SEDAR46-RW-02	Management strategy evaluations for mean length-based management procedures using DLMtool	Quang C. Huynh	22 Feb 2016
SEDAR46-RW-03	An alternative approach to setting annual catch limits for data-limited fisheries: Use of the DLMtool and mean length estimator for six US Caribbean stocks	Nancie Cummings, Skyler Sagarese and Quang C. Huynh	22 Feb 2016

Reference Documents Submitted during the Review Workshop		
SEDAR46-RD04	Evaluating methods for setting catch limits in data-limited fisheries	Thomas R. Carruthers, André E. Punt, Carl J. Walters, Alec MacCall, Murdoch K. McAllister, Edward J. Dick, Jason Cope
SEDAR46-RD05	Evaluating methods for setting catch limits in data-limited fisheries: Supplemental Appendix A	Thomas R. Carruthers, André E. Punt, Carl J. Walters, Alec MacCall, Murdoch K. McAllister, Edward J. Dick,

		Jason Cope
SEDAR46-RD06	DLMtool: Data-Limited Methods Toolkit (v2.1.1)	Tom Carruthers and Adrian Hordyk
SEDAR46-RD07	Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico	Jerald S. Ault, Steven G. Smith, Jiangang Luo, Mark E. Monaco, and Richard S. Appeldoorn
SEDAR46-RD08	Data Limited Techniques for Tier 4 Stocks: An alternative approach to setting harvest control rules using closed loop simulations for management strategy evaluation	Jason McNamee, Gavin Fay, and Steven Cadrin
SEDAR46-RD09	Application of Data-Poor Harvest Control Rules to Atlantic Mackerel	John Wiedenmann
SEDAR46-RD10	September 2015 Mid-Atlantic SSC Meeting Report – Black Sea Bass Review	Mid-Atlantic SSC
SEDAR46-RD11	Stock assessment of protogynous fish: evaluating measures of spawning biomass used to estimate biological reference points	Elizabeth N. Brooks, Kyle W. Shertzer, Todd Gedamke, and Douglas S. Vaughan

2. REVIEW PANEL REPORT

PANEL REPORT

SEDAR 46 U.S. Caribbean Data-Limited Species Assessment Terms of Reference (ToR)

Vance Vincente (Chair), Panayiota Apostolaki, Jerald S. Ault, Catherine M. Dichmont, John M. Hoenig, and Paul A.H. Medley

Panel Overview

The overall Data Limited Method (DLM) approach presented to the SEDAR 46 Review Panel appeared appropriate, as was the general method of selecting species for these assessments. The DLM methods presented at SEDAR 46 appeared to have been applied correctly and the analysts successfully came up with a set of candidate Management Procedures (MPs). However, the Panel felt strongly that the analysts still need to refine their approach based on several principal suggestions, such as:

- The analysis should develop a more sophisticated approach to developing and assigning parameter and input data variances in the Operating Model (OM). For example, reference to the actual variance-covariance relationships for growth models would be far more appropriate than simply selecting growth parameters independently from uniform distributions.
- There is need to examine the numerical performance of the OM in much more detail. Some of the estimation procedures and MPs appeared grossly *ad hoc*.
- We recommend tuning of the candidate MPs to the specific species-island unit cases that are to be examined.

We are generally satisfied that the new candidate MPs outperformed the current MP, and furthermore, that the current MPs failed to meet the performance criteria used to evaluate all of the other MPs. The Panel also noted that, with regard to the current MP, *ad hoc* assignment of “averaged catches over the past *x* years” as the target ACL has no theoretical or empirical basis for selection. This type of ACL designation makes no specific reference to the actual exploitation rate required to achieve those catches or the status of the stock under that catch regime. The findings of the assessment are appropriate to guide management discussions and provide enough evidence that the candidate MPs could be used for setting annual catch limits.

Finally, the Panel agreed that the assessment team did a great deal of original work in the process of development of their SEDAR 46 analyses and presentations, and in addition, responded fully to every panel request made for additional clarifying analyses. The assessment team is congratulated by the Panel for a job very well done!

ToR 1: ***Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following: (a) Are data decisions made by the DW and AW sound and robust?; (b) Are data uncertainties acknowledged, reported, and within normal or expected levels?; (c) Are data applied properly within the assessment model?; and, (d) Are input data series reliable and sufficient to support the assessment approach and findings?***

The ToR uses "assessment" – a word we interpret as being a determination of whether the MP is sustainable over the long term or not; whereas, stock assessment implies stock status as being sustainable or non-sustainable at a particular time (which is not an option in these analyses).

The panel supports the assessors that, overall, the data were constrained such that they were not appropriate for use in a conventional stock assessment model, but they were adequate if used with the appropriate MPs (Note: the analysts did not undertake a stock assessment *per se*, but used the data to set up the needed parameters for the OM and MP, and then used a small subset of the MPs). Broadly the analytical approach was good, given the available data. The assessors clearly acknowledged the weaknesses of these analyses and assembled the best scientific data available. They also evaluated and addressed uncertainties in a Management Strategy Evaluation (MSE). The Data Workshop (DW) chose the test species-island units well: 5 with the best data and the 6th unit was perhaps the worst data available to them (but could still have enough data to apply an MP).

In general, variances were applied in the OM assuming uniform distributions which is questionable given the inherent Gaussian variance-covariance relationships for many of the parameters, such as life history.

- Specifically, the mean responses of the life history (LH) parameters are generally appropriate for use in the OM and MPs, with some exceptions. The mean lengths are the most reliable data sources, whereas the catch data quality was highly variable. There was no apparent statistical substance for expansion factors that have been applied to these data, and which prevented computation of specific estimate variances. Again, there were largely no variance estimates provided for these types of data, and as a result the CV was chosen in an somewhat *ad hoc* manner, simply because the estimates were not derived from a design-based approach.

  The data design and collection is weak in many respects. Unfortunately, there was not much the assessment team could do about this. Current data systems put serious limitations on broader-based analyses for a while.

Recommendations

- Concentrate future efforts on key data for these analyses. These would include robust measures of CPUE, catch and fishery-independent length frequency distributions, accurate and precise LH parameters for the entire range of key fisheries. In that regard, there should be a refined focus on specific MPs.
- The currently used MP (averaged catches over several recent years) performed poorly in comparison to a number of alternative methodologies considered in this workshop.

Future efforts could be greatly improved by refining and clarifying a range of certain data and model inputs. These actions would result in a smaller solution space in OM and key MPs.

- The feedback control should be used as an incentive to get better data, which for example a constant catch approach tends not to do.
- L_c, length at first capture, was set up incorrectly in the model. We recommend using a default as either the mode of the size-frequency distribution, or perhaps even a smaller size to account for variability of length at ages. Use the mode when there is presumed knife-edged selectivity. At the same time, a test for dome-shaped selectivity would be important.

ToR 2: ***Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data, and considering the following: (A) Are the data-limited methods scientifically sound and robust? (B) Are the methods appropriate given the available data? (C) Are the data-limited models configured properly and used in a manner consistent with standard practices? (D) Are the quantitative estimates produced reliable? Does the method produce management metrics (e.g. MSY, ABC, ACL) or other indicators (e.g. trends in F or Z, probability of overfishing) that may be used to inform managers about stock trends and conditions?***

Responses:

(A) Are the data-limited methods scientifically sound and robust?
Yes, the DLM Toolkit and the management procedures have been peer reviewed.

(B) Are the methods appropriate given the available data?
Yes, this is a data limited set of fisheries and this toolbox and Management Procedures have been created for this specific purpose.

(C) Are the data-limited models configured properly and used in a manner consistent with standard practices?
Yes, there are no substantial issues (after further within-workshop runs were undertaken), although there are suggested future refinements to the DLM Toolbox and management procedure process.

(D) Are the quantitative estimates produced reliable? Does the method produce management metrics (e.g. MSY, ABC, ACL) or other indicators (e.g. trends in F or Z, probability of overfishing) that may be used to inform managers about stock trends and conditions?
Yes, within the context of data limited approaches (i.e., one would not expect many of the above list to be estimated by these methods), they produce the necessary information from which to produce an overfishing limit (OFL).

Summary:
The DLM tool developed by Caruthers and co-workers (Carruthers *et al.* 2014; Carruthers & Hordyk 2015) were applied to the six species-island units. The DLM tool is an R package that contains the normal MSE components of an OM and data-limited management procedures. The MSE facilitates simulation testing of uncertainties and biases in the data and life history parameters/assumptions. A sub-set of the available MPs was utilised. These have been used elsewhere in the world. This toolkit and management procedures are freely available and the different components of the model have been peer reviewed through the journal publications process, for example Gedamke and Hoenig (2006); Carruthers *et al.* (2014); Geromont and Butterworth (2014).

A subset of the DLM tool MPs was tested for these cases – these were selected from a set based on whether they apply, whether they provide a good reference set and how a more data rich method would perform. The MPs all require a different mix of information, thereby being variously sensitive to the species-specific pros and cons of the data and parameters. For example, the catch only methods require a catch series and information on depletion, whereas the index-based method mostly needs a recent index of abundance, in this case CPUE. The mean length estimation MP (Huynh 2016) was tested externally to the MSE (although it was integrated during the workshop). In addition, a reference MP that assumed perfect information was included. Not all the MPs tested can be used in actuality, but the tested selection of MPs was appropriate and highlighted the sensitivities to data and underlying assumptions.

During the workshop, the MPs currently being used were tested. These do not perform well relative to the other candidate MPs and mostly do not satisfy the Performance Measure criteria as applied to the other MPs.

The toolbox includes a set of Performance Measures for comparing the different management procedures. The four Performance Measures chosen by the Assessment Panel are appropriate, being (a) the probability of not overfishing, (b) probability of being overfished, (c) the inter-annual catch variability, and (d) the long term yield. Unlike many other MSEs elsewhere in the world, there are no target reference point Performance Measures. The overfished and overfishing Performance Measures would be seen as limit reference point Performance Measures and so define the outside extreme of OFL space. The MSE is implementing the Management Procedure value as the final TAC set in the process i.e. the MP was assumed to deliver the ABC/TAC, yet the Performance Measure cut offs were set up so as to conform to an OFL. Care should therefore be taken with final MP choice.

Good MP diagnostics were provided. This information, together with additional sensitivity tests were extremely helpful in reducing the full set of MPs to a sub-set of candidate MPs. However, short-term transitional Performance Measures were not tested prior to the workshop. Work during and after the review shows that these transitional statistics are important.

In addition to the MSE tests, the MPs were tested using real world data. This means that only MPs that could be undertaken in the real world would be highlighted here. These were appropriately implemented.

The operating model in the DLM tool needs further refining. The DLMtool OM is provided with extensive input parameters and their associated uncertainty to simulate an age-based population. The OM samples parameter settings where upper and lower bounds have been provided and assumed a uniform distribution, i.e., they are uninformative priors. Also, these priors are assumed to act independently of each other, which means that uncertainty is over-specified and some life-history combinations may not describe the species-island unit. The toolkit also does not include implementation uncertainty which means that it assumed that all management decisions are implemented without any error. Despite these potential weaknesses, the toolbox is an appropriate tool to apply to these data limited applications.

Only convergence statistics of the OM were investigated – guidance as to further review of the OM performance was provided during the workshop and these were provided during the review process. These highlight a few inconsistent behaviours and the value of these tests.

ToR 3: ***Consider how uncertainties in the assessment, and their potential consequences, are addressed.***

Uncertainties in an assessment can arise from multiple sources: problems of data quality, the need to make assumptions in the assessment, and uncertainty about model formulation and stock population dynamics. Some of these problems can be handled individually, e.g., providing a range of possible values for an input parameter to the assessment model, fitting alternative models and using model diagnostics to look for problems in model formulation. The assessment team did all this in their pilot data-limited analyses of Caribbean fisheries.

The potential consequences of uncertainties in the assessment can be, and was, studied through MSE simulations. The assessment team relied heavily on this approach to choose MPs and evaluate their likely performance under different assumptions about uncertainty in the data and its sources (i.e. error/data inaccuracy or bias). In order to do this, they had to specify an OM for each stock to simulate what the stock might do if managed a certain way. The OM generates observations on the stock which are then fed into the assessment and management model to generate an impact on the stock. The OM is then updated, providing new observations that are fed into the assessment and management models, and so forth.

The review team felt that the use of MSE simulations was appropriate. This was a new initiative for the assessment team and it involved evaluation of a large number of scenarios. For the most part the MSE were handled very well.

Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.

The review team felt a critical element of MSE is the construction of the OM model. The assessment team made a good effort to develop realistic operating models; however, these models should be substantially refined in the future assessments. In particular, there was some confusion about how selectivity in the fishery was modeled and this requires further investigation.

The assessment team devoted a great deal of attention to the unbiased and precise data scenario, and treated this as the base case. They then considered numerous variations on this theme by introducing biases and imprecision in various places. The review Panel questioned the choice of the unbiased and precise data as the base case and considered whether biased and imprecise data scenario should be the base case since this SEDAR is envisioned as a template for data poor stock assessments. Unbiased and precise data should only be considered if there is reason to believe that this is a plausible scenario for a particular data-poor stock.

The assessment team initially focused on specific metrics from the MSE simulations. The review team expressed the opinion that there are additional performance metrics that should be considered, specifically related to model diagnostics and transitional characteristics of the model. The assessment team responded by providing additional metrics.

The review team is satisfied that the assessment team evaluated the significant sources of uncertainty in the population, data sources, and assessment methods through a careful evaluation of each source of data, and through a combination of management strategy evaluation simulations, sensitivity analyses, and examination of model diagnostics.

Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The review panel felt the implications of uncertainty were clearly stated. However, the basis of those conclusions depends very much on the MSE simulations, and the nature of those simulations, i.e., the construction of the operating models and the alternative scenarios, needs to be documented fully in a technical report.

ToR 4: *Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted. These recommendations should: (a) clearly denote research and monitoring that could improve the reliability of future assessments; and, (b) provide recommendations on possible ways to improve the SEDAR process.*

This section considers the research recommendations initially provided by the DW and AW that were then considered by the SEDAR 46 Review Panel. The Review Panel generally supported the recommendations from the DW and AW, and those from the assessment team. However, the Review Panel extended these recommendations as outlined below. Recommendations fell into two general categories: (1) data; and, (2) model.

Data

One of the fuzziest aspects of the data-limited process was how exactly data reliability was qualified or quantified. We discovered that fishery data precision (e.g., coefficient of variation, CV) was not able to be determined from the current fishery catch sampling methodologies that are employed in the Caribbean. While this was probably a topic of conversation at the DW, there was insufficient discussion of these critical issues in the SEDAR 46 DW/AW report (AW). There needs to be a solid focus on data design strategies as the data-limited process moves forward in the region to establish ACLs for a range of species presently not under consideration.

Thus, two aspects of model inputs must be addressed: (1) life history demographics; and, (2) fishery-dependent data (size-structured catch and fishing effort). Research into what defines the "best" demographic parameters for DLM model inputs, for example, most accurate and precise growth (length-at-age) curve, maximum age (i.e., natural mortality rate), size at first capture (selectivity ogive), size at first sexual maturity (maturation ogive), etc. There seemed to be insufficient attention to these issues in the workshop, and arbitrary (non-estimated) CVs were applied to data inputs. Perhaps the number one priority is to refine the life history demographic parameters identified by the DW across the region, and to improve accuracy and precision of those basic data. This strategy would likely be facilitated by a workshop of technical experts convened, in the near future, to review and analyse existing life history demographic data for all relevant exploited species in the U.S. Caribbean, Southeast U.S. and Gulf of Mexico. When joint parameter variance-covariance is not available, how will estimates of uncertainty for life history demographic parameters, for example, be provided? This would include quantitative justifications for error variances and CVs.

A focus on design-based strategies for ensuring collection of accurate and precise fisheries-dependent commercial and recreational data should be advanced in the region. This would greatly improve fishery-dependent mean (and variance) estimates of landings, discards and the effort required to obtain them. The sampling protocols must be optimized to ensure representative sampling across size-age spectra over time and space. If precise estimates were obtained in the most recent years, then a data-limited analysis could identify current exploitation rates and resource sustainability. In addition, it makes sense to conduct a statistical review, analysis and optimal sampling design of complimentary fishery-independent surveys as these could provide extremely important spatially-integral, accurate and precise information on exploitation effects by measuring what is left in the water after fishing has occurred.

More work must be done on evaluation of species selection criteria. The adequacy of the choice of species suitable for these pilot species analyses was generally successful. However, a couple of those species provided little guidance on model performance. These analyses revealed issues in three areas: (1) appropriate models and benchmarks; (2) reliable life history demographic data; and, (3) adequate fishery-dependent data.

Model

A review of appropriate data-limited methods should be conducted as soon as possible, under the auspices of SEDAR, to allow evaluation of which methods should really be used in the DLM process for evaluation. Such a technical review would consider: (1) model theoretical basis and assumptions; (2) data requirements; (3) robustness of model to departures from assumptions and data requirements; and, (4) model responses (i.e., biases) to model uncertainty. This would include a systematic analysis of the sources of variability and how they influence OM dynamics. This was nearly impossible to discern in the way that the materials were presented at SEDAR 46, which was no fault of the analysts.

Some of the model estimates produced during SEDAR 46 were very troubling due to either: (1) application of an inappropriate or an inapplicable model(s) or MP; and/or, (2) very wide ranges of error variances, while unknown, that were applied to the input data. As a result, some MPs produced forecasts of unrealistic catch levels, suggesting that their usefulness is highly dubious. Not surprisingly, when appropriate variances and covariances were applied, the median of the output distribution do not change, but the range of model output metrics were substantially reduced. Nevertheless, that did not lead to any material change in the findings of the assessment with regard to MPs that performed better. The argument that this tested the MPs with greater uncertainty and therefore could still be used as a test of robustness was only partially accepted by the review panel.

While this AW was an examination of the potential efficacy of the approach due to its "newness", and the fact that it was 3rd party application not fully controlled by the analytical team, we believe that in future workshops the analysts should more clearly specify what is desired as an outcome of model simulations, so that the simulations can be more finely tuned to answer specific questions. Generally, feasibility and limitations of MPs to real world applications is largely determined by data sufficiency and model adequacy. Additionally, there was no guarantee that the sampling algorithms in the OM reflected reality, and to some extent particular methodologies were difficult to assess given the information available to the Panel. In general, the AW would have run more smoothly if more attention were paid to the accuracy and precision of the basic data, and adherence to the assumptions required by the applicable MPs.

A better description and explanation of what is actually going on in the DLMtool OM at the outset would have been useful and clarifying to the Review Panel. As it was, application of methodologies at times appeared quite *ad hoc*, particularly as related to application of means, variances and coefficients of variations of model parameters. The parameters were treated as independent random variables, when we know they are dependent. But this is in fact the DLMtool default as it tries to cover a very wide range of uncertainties. There were a number of unclear definitions, such as "model stability", which roughly translated to how many simulation runs were required for an input level of variation where for some unspecified reason, all model parameters seemed to be varying simultaneously. This would suggest that some further attention to model sensitivity is highly warranted. Concepts as straight-forward as the number of required model runs to achieve stationarity were not well substantiated.

The apparent uncertainty in both data and models for U.S. Caribbean species suggests caution when selecting MPs intended to provide management advice. Selection of a particular MP for providing catch allocation strategies for management should consider: (1) MP sensitivity to parameters; (2) satisfying model assumptions; and, (3) information quality.

Recommendations

More precise and clearer descriptions and rationales for model thresholds and benchmarks used in the DLM process are needed. Analyses presented at the AW focused heavily on fishery yields (i.e., catches) which made it difficult to discern the rationale for what constituted a particular preferred choice of the MPs. A broader perspective might be entertained when setting OFLs and other appropriate benchmarks. This would likely include yield risks as they relate, in addition, to benchmarks specific to both economic and ecological risks. Adherence to this philosophy would require that model thresholds are set at more conservative resource use levels than are presently considered, and this in turn would avoid theoretical searches of infeasible or impractical model decision space. It is probably not useful to go too far into the weeds in trying to assess the full complexity of a fishery at first, rather the assessment needs to focus on distinguishing sustainable from non-sustainable rates of exploitation, and then identify the appropriate annual catches required to sustain the resource(s). If multiple MPs or a subset of tools are used, then some consideration must be given to model averaging. It would appear from the AW that many of the proposed estimation methods and MPs are non-starters from the outset. This seems an opportune time to conduct a thorough analysis of DLMtool efficacy. The Panel feels that the approaches presented could have broad potential for use in the Caribbean, but still require deeper, more thoughtful consideration to determine what avenues of application allow one to achieve the greatest utility of the tool.

ToR 5: ***Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.***

The assessment, both the process and findings, represents the best scientific knowledge about the stocks and their exploitation that is currently available. As this approach has been used for the first time for these stocks and given the data-limited nature of the stocks, there is clearly, additional work that needs to be done both on the data and model side to refine the approach. However, this assessment constitutes an improvement over previous approaches and has successfully made progress with developing scientific advice to support management.

The MSE approach that the assessment has adopted to overcome challenges associated with data-limited species is a relevant and transparent way to assess the performance of different management procedures. It has been used widely to assess fisheries and management approaches and its strengths and weaknesses are well documented (Holland 2010, Butterworth and Punt, 1999). The software used (DLMtool) and many of the MPs have been peer-reviewed and includes a wide range of methods that can be applied to data-poor species so, its choice is appropriate and relevant.

The assessment has made use of biological information compiled from a range of relevant studies to inform the selection of the model parameter values. It also considered both fishery dependent and fishery independent information to describe exploitation and made use of indirect ways to improve accuracy (expert knowledge, expansion factors, etc.). This reflects the team's efforts to include all relevant information to respond to the knowledge gaps that characterize the stocks assessed. However, despite the considerable work done, the accuracy of input data remains low; the Panel has recommended additional research to improve the accuracy of data and/or the overall robustness of the analysis (see previous ToR)

The main source of information to define the values of biological parameters was peer-reviewed papers and both life history and fisheries information was reviewed as part of the Data and Assessment workshops which included scientists, fisheries experts, and fishermen so, there has been a good level of scrutiny. Furthermore, the assessment team conducted additional analysis to address key issues identified during the review meeting and those findings also increased the robustness of the overall approach.

Although some improvements have been recommended, the assessment captures the uncertainty in input parameters well and the metrics used were appropriate to reflect the level of uncertainty in the results.

The mean length estimator which was used in previous assessments was also one of the Management Procedures (MPs) included in this analysis and that maintains continuity. The assessment also used a range of other methods to test their performance for the 6 species-island units and provide preliminary TAC distributions and that offers additional assurance and a comprehensive picture of the assessment options available.

As this was not a conventional stock assessment *per se*, it was not possible to produce all the management metrics that are often calculated in conventional assessments (e.g. B_{MSY}) and those that were calculated (i.e. TAC) were characterized by high uncertainty. However, the criteria used to assess the performance of different MPs and presentation of the outcomes were relevant and provided objective and robust insight that can inform management decisions.

ToR 6: *Provide guidance on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.*

The following is a list of key improvements for further development of the assessment methodology. These should lead to improvements in identifying the best performing Management Procedures (MPs). This recognises that the approach is a work-in-progress, and further development is desirable for Caribbean fisheries.

The main recommendation for the data is to ensure that sufficient data are collected to apply the data-limited MPs selected. Reasonably precise data, such as total catches and length sampling, are required to implement the recommended MPs. Current results suggest that TIP collection of species composition, lengths and CPUE will be most important to monitor these fisheries, while total catch data will be needed to implement the catch limits. For the modeling, the following recommendations are made for the next assessment.

- Strong correlations between parameters, notably L_∞ and K, and the length-weight parameters a and b, should be accounted for in the parameter density functions. Joint parameter probability density functions should result in projections that are less variable than currently simulated. For example, strong correlations that are known to occur between L_∞ and K could be parameterised in a bivariate normal, rather than treating these parameters as independent. This should provide better performance measures for identifying the best MPs.

- Projections need to be more constrained to reflect possible scenarios. Currently, some projections used to assess MPs would appear to be highly unlikely (e.g. projecting catches much higher than any previously observed). While it is important to measure MP robustness, and noting the performance measures themselves are robust to uncertainty, including excessive highly unlikely projections as part of that assessment could still distort the apparent performance of MPs. Improved parameter selection might be achieved by conditioning the operating model on the available past observations, adding a rejection probability to outcomes or improving the joint parameter probability densities as above.

- If the data or information that are required for an MP are not available or not reliable, the MP should be rejected at an earlier stage in the assessment. Including these MPs in performance reports, while assuming the information they require is known, may give a misleading impression from the results.

- The performance measure of Short Term Yield requested during the review should be used to evaluate MPs. More generally, performance indicators for the MPs should cover all the requirements of MPs as they are identified, so that MPs can be rejected based on performance criteria rather than for additional external reasons.

- MSE projection diagnostics should be routinely reported. The Review Panel requested example individual TAC projections. In addition, the range of key statistics from the MSE, such as TAC, biomass, mean length and fishing mortality, would be useful for review to check the projections are valid.

- The selectivity parameter, Lc, should be set to the mode of the observed length frequency by default. This would correspond to the point of full selection when assuming knife-edge selectivity.

- The simulated data for the management procedures should, by default, reflect the properties of real data (i.e. be imprecise and biased).

- Natural mortality estimates obtained from size dependent on age information should follow typical procedures (e.g., Then et al. 2015), but probably should not sample uniform-random around the mean of the probability distribution, since of maximum age means that animals live to no less than that particular age..

For the longer term, and not necessarily for the next assessment, the method might be enhanced, particularly for Caribbean fisheries.

- It should be possible to supply parameter vectors to the DLMtool operating model rather than parameters for parametric probability density functions.

- Alternative operating models to cover different life history characteristics should be provided. Specifically, sex differentiation in growth, and protogynous or protandrous hermaphroditism could be covered.

- The method to obtain a sufficiently precise estimate of the performance indicators should be made more efficient. The current number of projections is more than sufficient, but makes the assessments time consuming. The projection length and number of simulations should be tested to ensure they are as efficient as possible but sufficient for their use. This could be achieved by a statistical test for convergence at the start of simulations rather than relying on graphical output. Unless there is a need to contrast replicates (a random draw of time dependent parameters) with simulations (a random draw of all parameters), only simulations may be required, which again could increase the analysis efficiency.

- Although data limited methods provide an important transitional solution to management for sustainability of these presently "data-limited" fisheries, longer-term objectives should focus on improved accuracy and precision of the basic fishery catch-and-effort and length-structured abundance data and key demographic parameters (i.e., lifetime growth, lifespan and mortality, recruitment indices, etc.) and associated biological and economic information for the fisheries being assessed. The DLM tool provides a starting point for a "value of information" analysis that could be used to help identify priority research.

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SEDAR

Southeast Data, Assessment, and Review

SEDAR 46

U.S. Caribbean Data-limited Species

SECTION V: Addenda and Post-Review Workshop Updates

March 2016

SEDAR
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Addendum A:

The SEDAR 46 Review Workshop (RW) took place23-25 February 2016. Results of applying (1) the DLMtool (Carruthers et al. 2014) and (2) the mean length estimator were presented for six species-island units selected by the SEDAR 46 Data/Assessment Workshop Panel herein referred to as "S46 DW/AW Panel". During the RW, the Panel requested additional analyses of the analytical team for both modeling frameworks. These additional analyses included changes to several of the base operating models (stock, fleet, and observation components) and also additional sensitivity analyses. The results of those analyses are presented in this addendum report. The structure of the material presented in this addendum report follows the order of the S46 RW requests (i.e., DLMtool- Day 1-Homework 1, Day 2-Homework, Day 3-Homework 3).

Homework relating to the DLMtool (Carruthers et al. 2014) application for six US Caribbean species-island units.

Day 1-Homework 1 (Tuesday February 23, 2016)

The S46 RW Panel requested the following five analyses on Day 1:

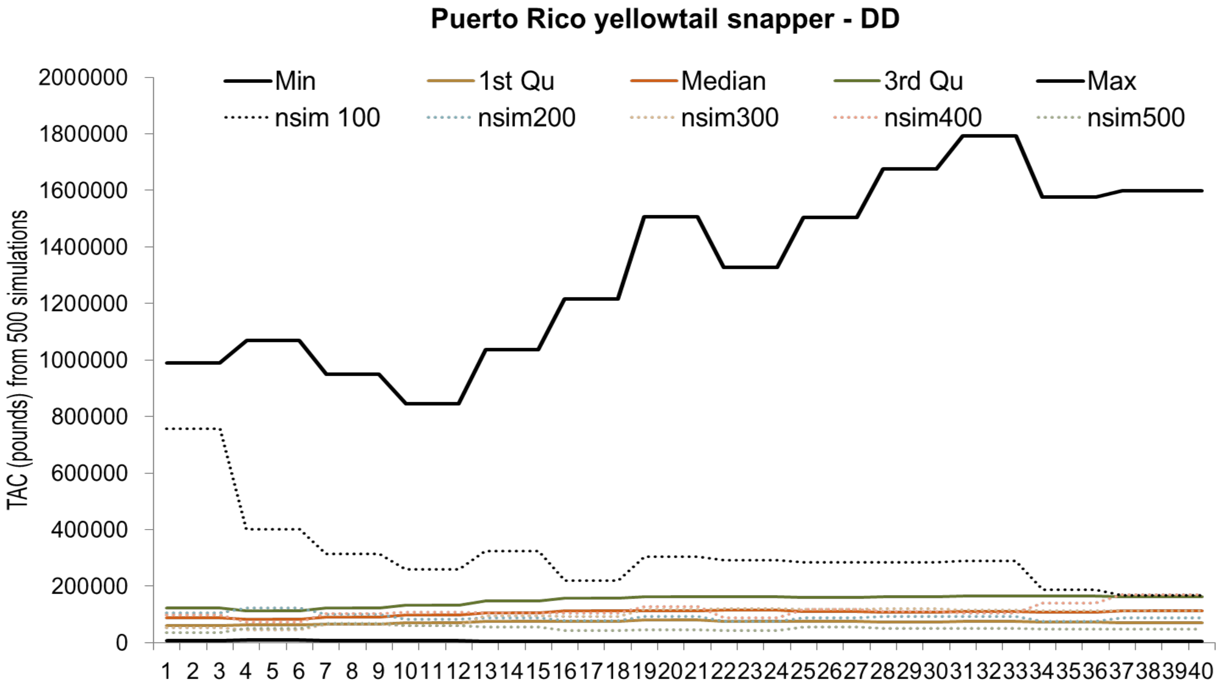
1. Provide a time series of TACs across the 40 year projection interval from the DLMtool MSE for one species-island unit (yellowtail snapper was selected by the RW Panel)
2. Conduct a comparison of management procedure (MP) performance metrics (using S46 DW/AW performance metrics specified at the November 2015 workshop) against the current Council (Caribbean Fishery Management Council -CFMC) method used to set annual catch limits; results are presented in detail in Homework 2 as this work continued into day 2
3. Compile short-term yield from the MSE results for each base model
4. Conduct catch sensitivity – increase total removals by 30% to explore the impact of catch bias on TACs
5. Rerun hogfish with dome-shaped selectivity as the base model assumed asymptotic selectivity. Much discussion ensued during the DLMtool application results presentation relating to common practice in Puerto Rico that fishers typically avoid the larger hogfish due to consumer market preferences.

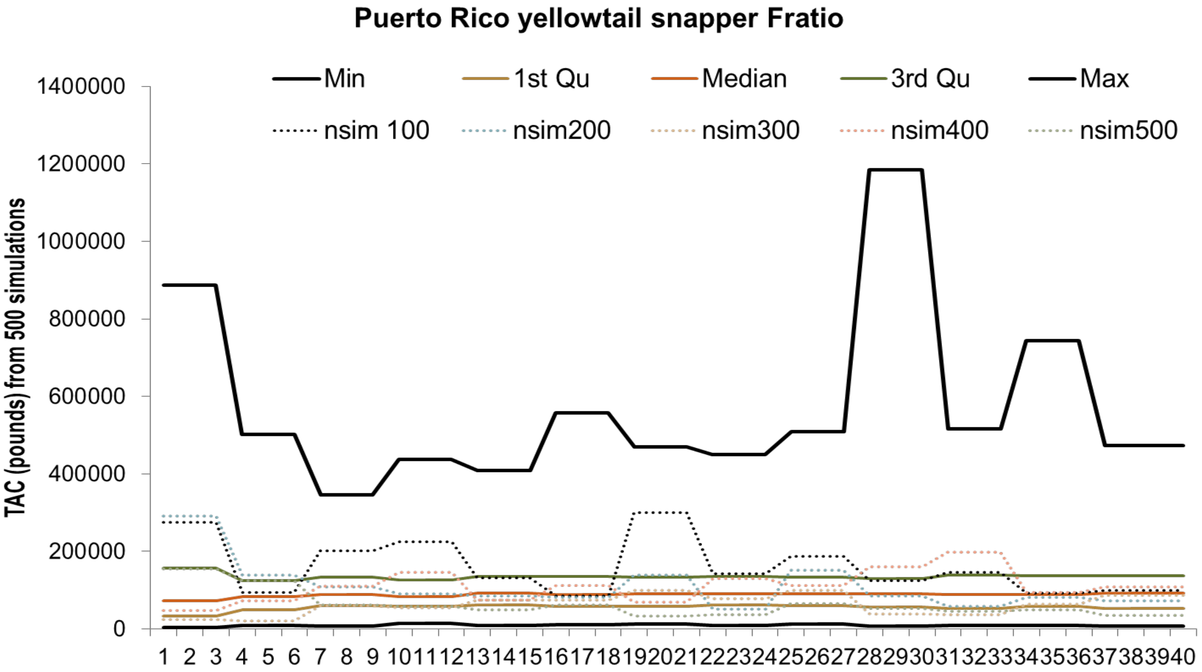
An additional question from the commercial industry representative in Puerto Rico was posed during the public comment period relating to trends in effort used in the MSEs. This was considered as question 6 by the analytical team.

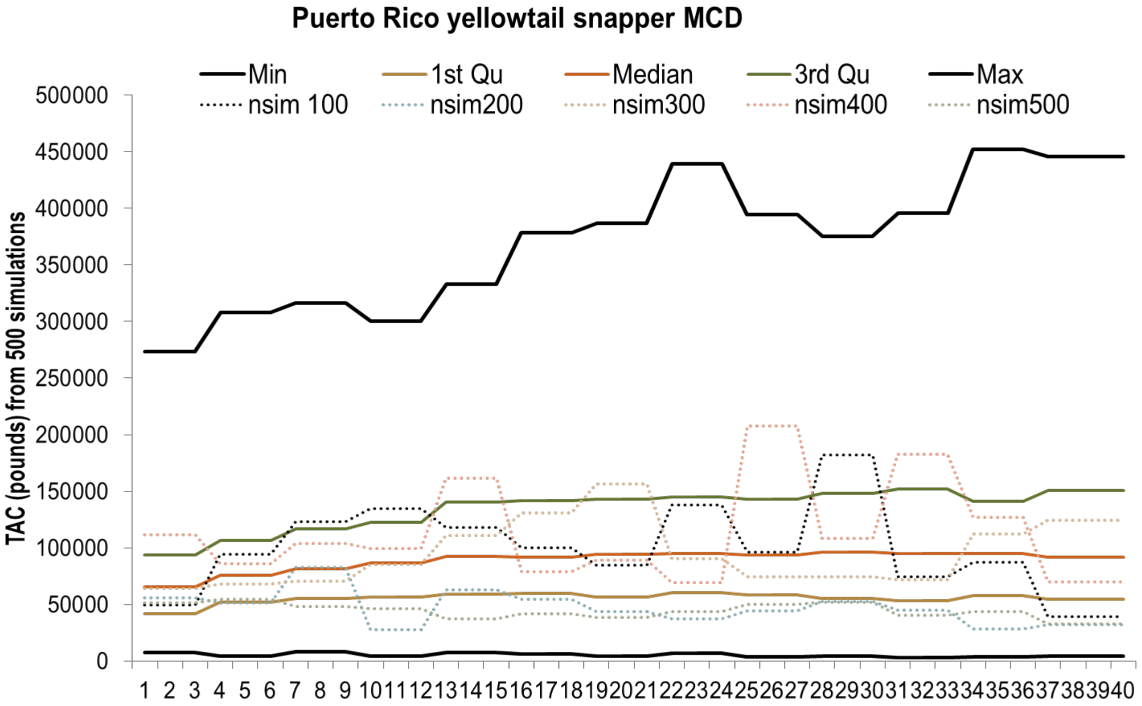
1. *Homework 1, Request 1: Provide a time series of TACs across the 40 year projection interval from the DLMtool MSE for one species-island unit (yellowtail snapper was selected by the RW Panel). Provide the results by individual simulation for MPs meeting the performance criteria specified by the S46 DW/AW Panel.*

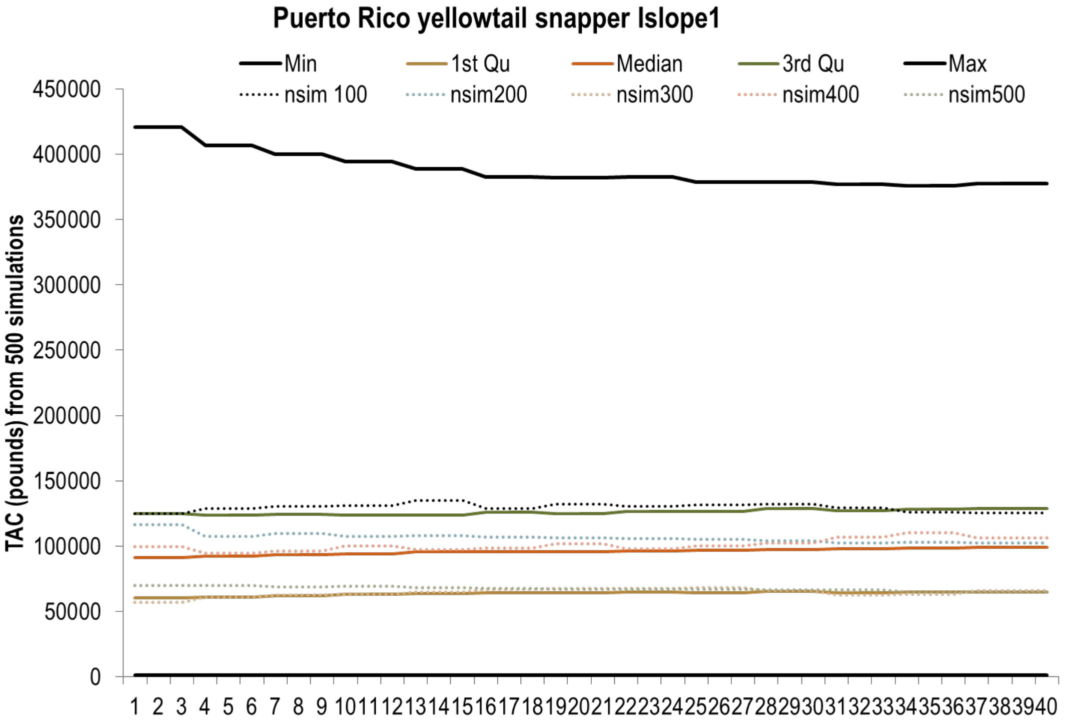
The analytical team was requested to further investigate the results from the DLMtool management strategy evaluation (MSE) for one (1) species-island unit (e.g., Puerto Rico (PR) yellowtail snapper) to further examine the results from the individual simulations. This request was in response to the results for the data-moderate management procedures (MPs) (e.g., Delay Difference [DD] and Delay Difference 4010 [DD4010]) which yielded very broad TAC distributions and large TAC recommendations, often exceeding observed catches.

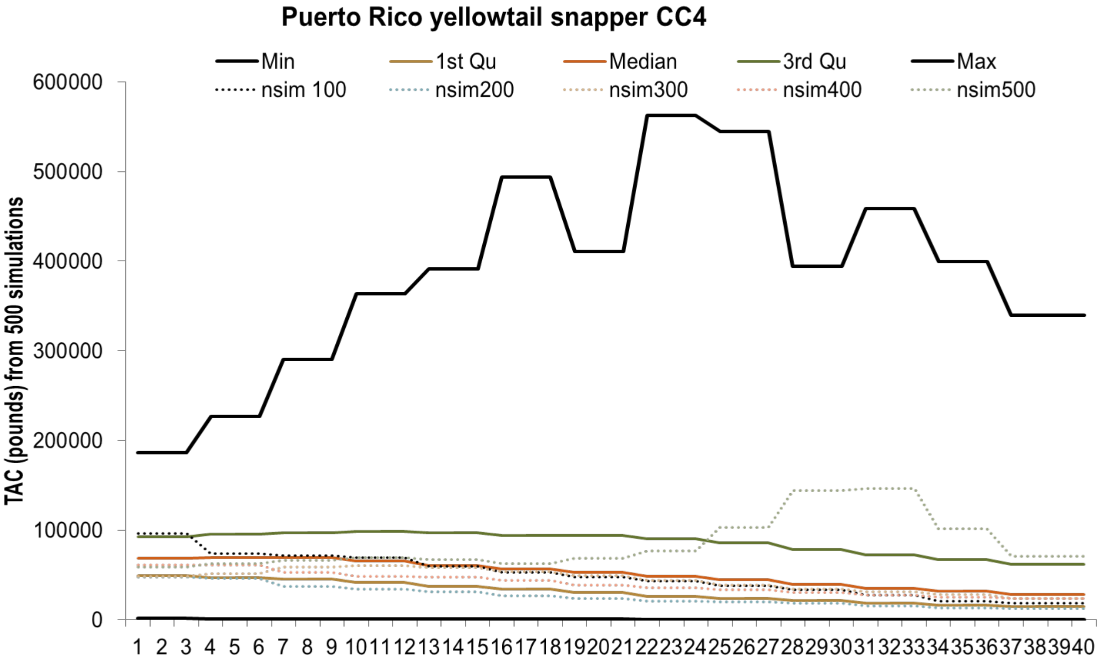
Analytical team response: The team extracted TAC statistics from within the MSE for selected MPs (DD, Fratio, MCD, Islope1, and CC4). These five MPs were selected for this examination as they frequently met the performance criteria across all species-island units. Summary statistics (minimum, 25% percentile [1st Qu], median, 75th percentile [3rd Qu], maximum) are provided for the TACs (*y* axis) by MP along with 5 individual simulations within each MP (i.e., the 100th [nsim 100], 200th [nsim200], 300th nsim300], 400th [nsim400], and 500th simulations [nsim500]) for the 40 year projection period (*x* axis).






Puerto Rico yellowtail snapper MCD
Min
1st Qu
Median
3rd Qu
Max
nsim 100
nsim200
nsim300
nsim400
nsim500
TAC (pounds) from 500 simulations
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40


Puerto Rico yellowtail snapper Islope1
Min
1st Qu
Median
3rd Qu
Max
nsim 100
nsim200
nsim300
nsim400
nsim500
TAC (pounds) from 500 simulations
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40



2. *Homework 1, Request 2: Include the Council's current method of setting annual catch limits in the Caribbean within the MSE to determine its performance in relation to other MPs.*

Please see Homework 2 for details as visualization of these results was improved during Homework 2.

3. *Homework 1, Request 3: Provide short-term yield performance metrics for each MSE*

The RW Panel also requested the team to provide performance metrics relating to short-term yield for each MP which met the S46 DW/AW performance criteria. This question was in response to a RW Panel concern that long-term results for yield (i.e., that the TACs from the last ten years of the 40 year projection) could be much higher than during the short-term transition phase of the projections (i.e., the TACs from the early years of the 40 year projection).

Analytical team response: The analytical team compiled the short-term yield metric for the base MSEs, defined as the fraction of simulations achieving over half FMSY yield over the first 10 years of the projection. Performance metrics including the probability of not overfishing (PNOF), long term yield (during last 10 years of the 40 year projection = LTY), and the short term yield (STY) are provided in the following table for each of the six species-island units. All performance statistics are relative to the performance of the FMSYref MP.

Table. Performance metrics for probability of not overfishing (PNOF), long term yield (during last 10 years of the 40 year projection = LTY), and short term yield (STY; during first 10 years of the 40 year projection) for the six species-island units evaluated in S46. All performance statistics are relative to the performance of the FMSYref MP.

Puerto Rico hogfish	Puerto Rico yellowtail snapper	St. Thomas queen triggerfish

MP	PNOF	LTY	STY	MP	PNOF	LTY	STY	MP	PNOF	LTY	STY
DD4010	93.2	99.0	51.2	DD4010	75.3	97.5	77.3	DD	80.6	95.9	61.8
DD	76.8	98.9	75.0	DD	55.7	96.7	90.7	DD4010	93.8	92.3	48.7
MCD	79.0	96.8	68.2	MCD	71.6	94.0	83.4	MCD	79.5	91.2	58.3
Fratio	61.8	95.3	66.3	Fratio	59.5	93.9	79.2	Fratio	59.2	89.5	62.3
BK	79.0	93.6	54.0	Islope1	60.9	81.9	89.5	Islope1	58.0	88.9	64.4
Islope1	55.6	83.6	83.5	Islope4	61.1	79.9	89.1	Islope4	60.5	84.0	75.1
Islope4	57.3	80.9	82.5	SPMSY	72.6	60.9	72.0	Itarget1	52.9	78.8	73.8
SPMSY	80.5	63.6	69.1	CC4	77.6	34.2	82.6	CC4	58.2	65.1	66.6
CC4	73.9	31.7	73.1	Itarget1	87.3	25.3	77.9	SPMSY	80.1	58.7	64.7
Itarget1	78.4	29.2	72.4								

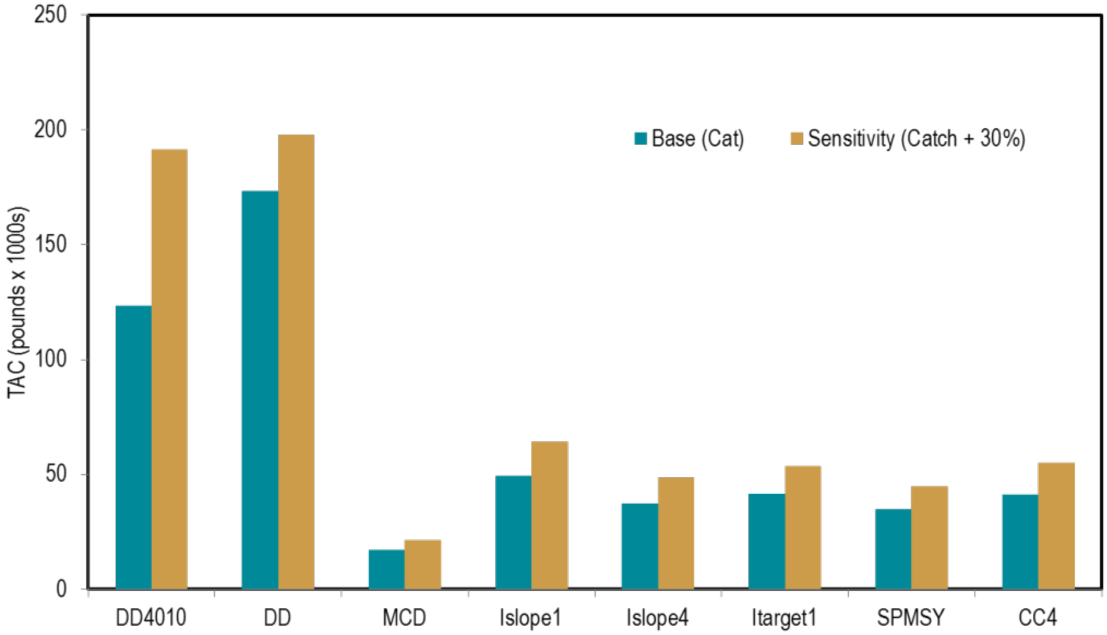
St. Thomas spiny lobster				St. Croix spiny lobster				St. Croix stoplight parrotfish			
MP	PNOF	LTY	STY	MP	PNOF	LTY	STY	MP	PNOF	LTY	STY
Fratio	56.1	84.9	71.6	DD	66.9	84.4	66.8	DD	89.0	85.9	35.9
MCD	66.5	83.7	65.9	MCD	66.3	84.3	64.9	MCD	82.3	79.8	35.7
DD	67.7	83.4	68.1	DD4010	75.9	80.0	56.7	Fratio	57.8	79.5	47.1
DD4010	77.1	80.3	56.8	Islope1	67.9	66.8	64.0	DD4010	96.7	78.3	30.6
Islope1	65.6	67.1	65.2	Islope4	68.7	63.2	63.8	Islope1	59.8	73.0	50.6
Islope4	66.3	62.4	64.9	CC4	54.7	60.3	60.4	Islope4	64.2	62.4	48.5
Itarget1	60.1	57.8	58.4	Itarget1	59.9	58.9	57.3	SPMSY	81.0	34.2	33.8
CC4	56.1	56.6	61.6	SPMSY	66.8	50.4	58.6	Itarget4	97.9	0.0	3.4
SPMSY	67.5	46.9	59.5	Itarget4	98.8	0.0	16.1				
Itarget4	98.8	0.2	16.2								

4. *Homework 1, Request 4: Conduct sensitivity of TAC calculation to data inputs including time series of total removals (i.e., catch) – explore +30% catch. For each of the six species-island units, sensitivities of the TAC to catch levels (+30% catch) were run to address bias in catch.*

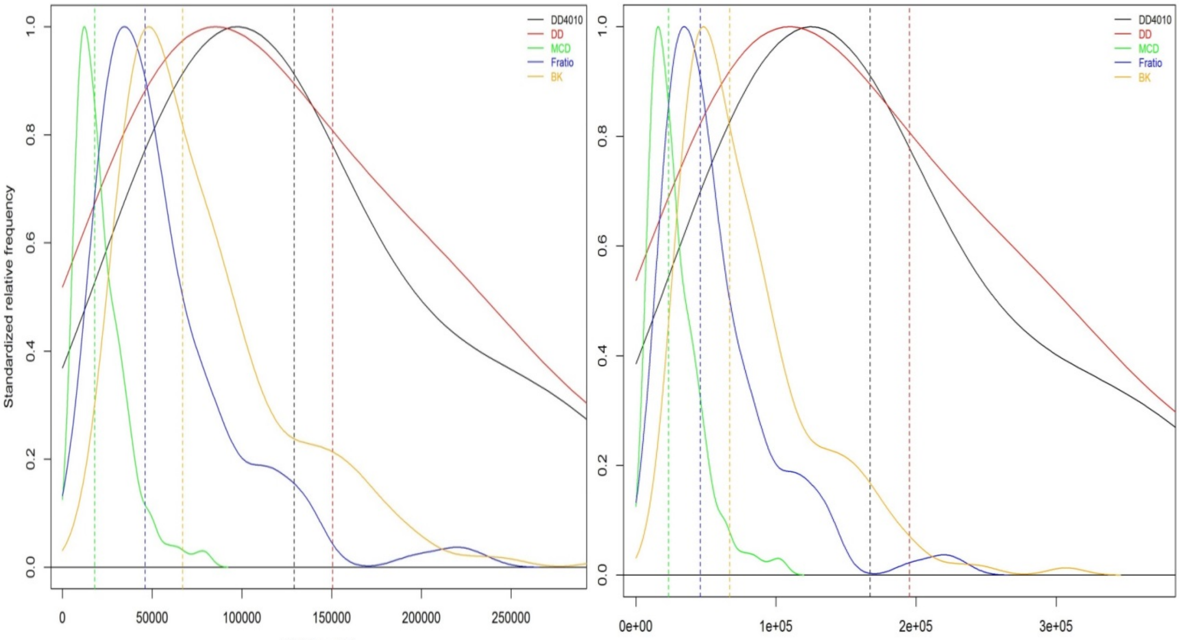
The RW Panel requested a sensitivity run to determine how bias in catch could impact the catch (TAC) recommendations.

Analytical team response: A sensitivity analysis was conducted for each species-island unit where the time series of total removals (i.e., catch) was inflated each year by 30% (inferring a negative bias in total catch). Catch recommendations are compared between the 'base' and each 'sensitivity run (+30% catch)' for each species-island unit below in the graphical summaries. Results are presented in terms of a) histograms of expected catch by MP and b) distributions of catch recommendations (total allowable catch) by MP for the MPs meeting the S46 DW/AW performance metrics and displaying the largest relative long-term yield compared to FMSYref.

Puerto Rico Hogfish Catch Sensitivity

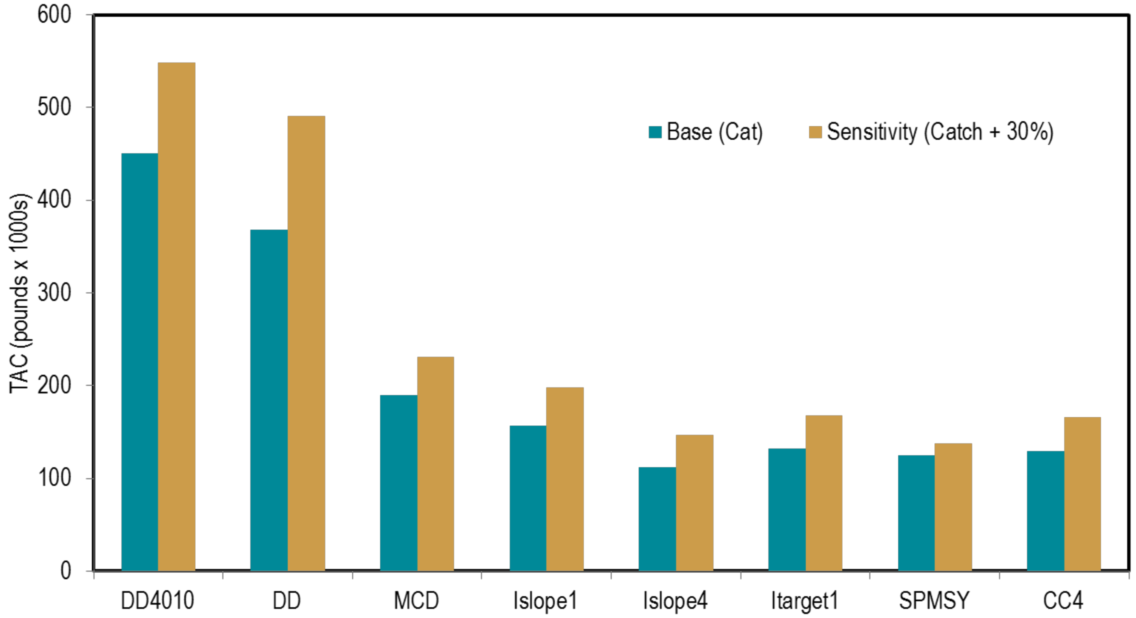


Results a: Impact of greater total removals (+ 30%) on catch (TAC) recommendations for each management procedure for Puerto Rico hogfish

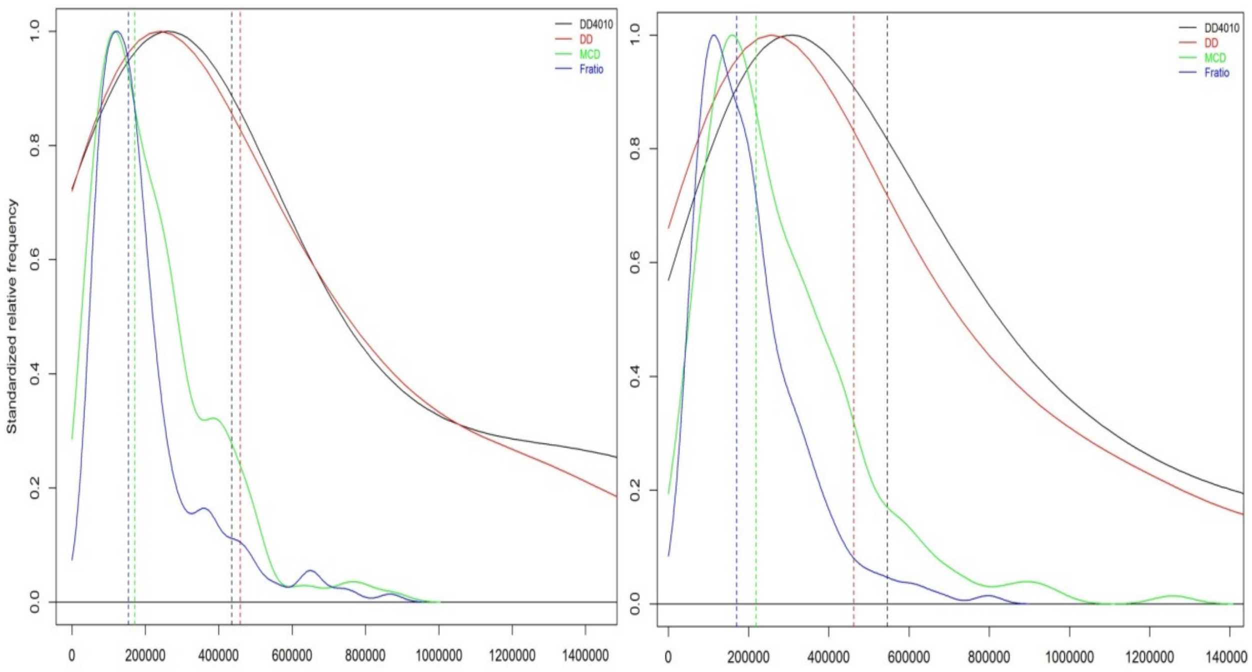


Results b: Impact of greater total removals (+ 30%; right) on TAC distributions for each management procedure compared to base run (left) for Puerto Rico hogfish

Puerto Rico Yellowtail Snapper Catch Sensitivity

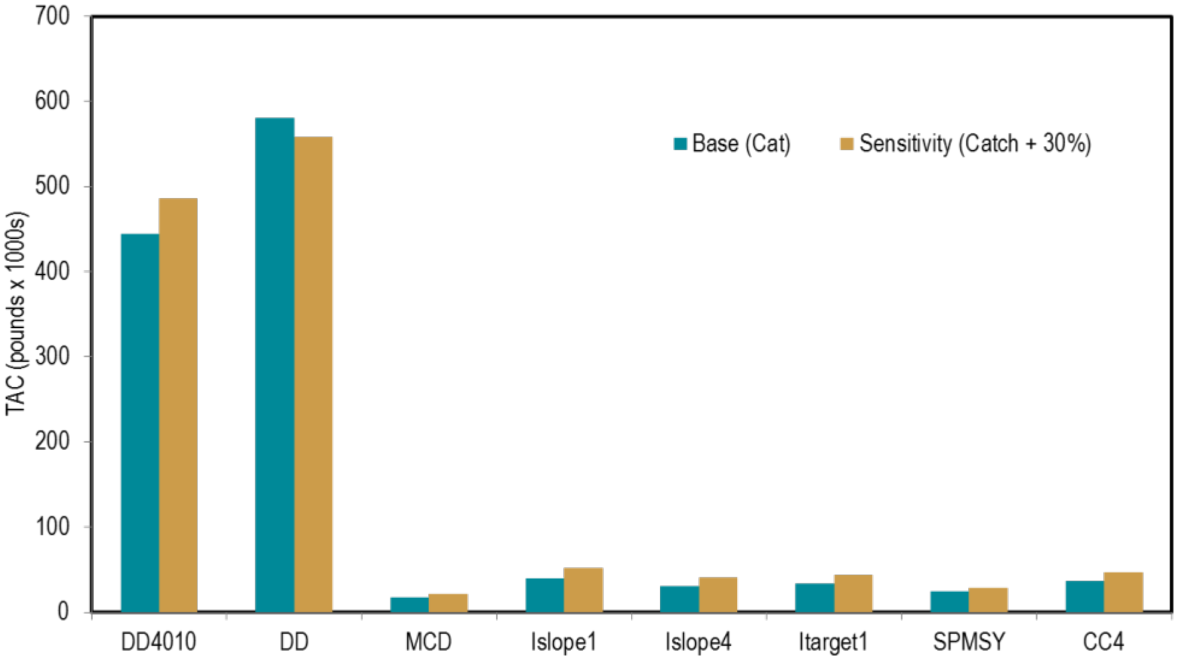


Results a: Impact of greater total removals (+ 30%) on catch (TAC) recommendations for each management procedure for Puerto Rico yellowtail snapper

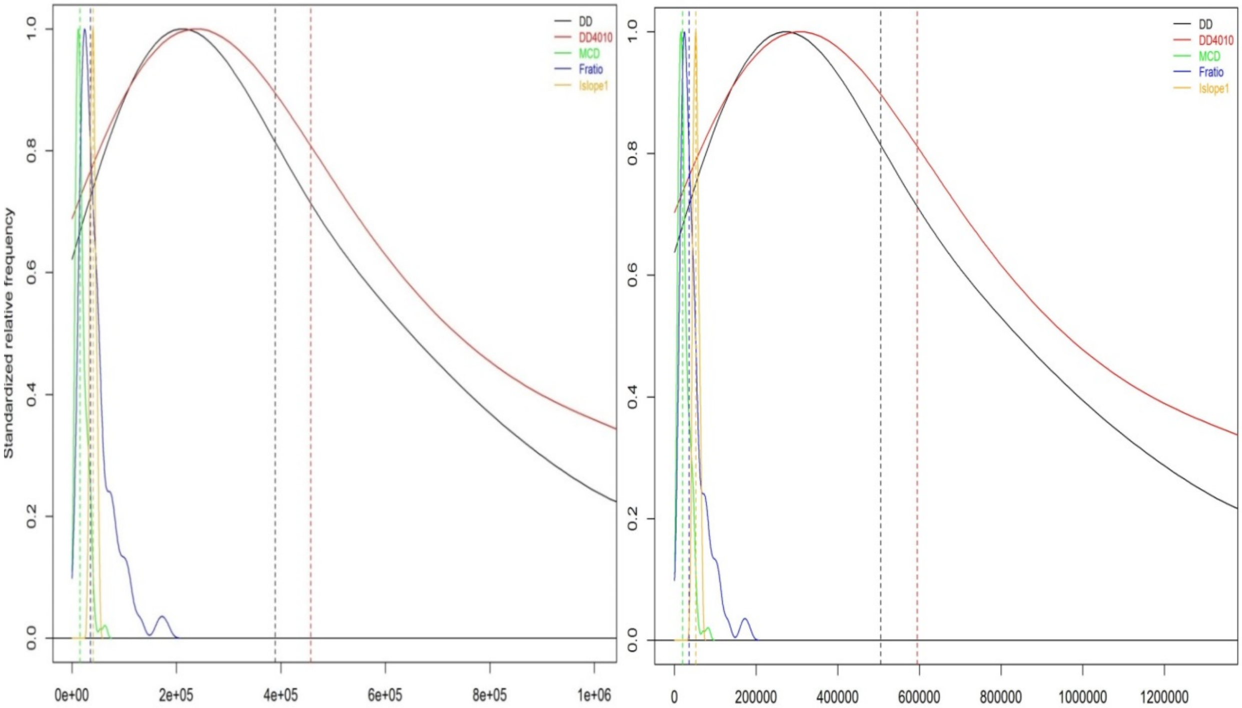


Results b: Impact of greater total removals (+ 30%; right) on TAC distributions for each management procedure compared to base run (left) for Puerto Rico yellowtail snapper

St. Thomas Queen Triggerfish Catch Sensitivity

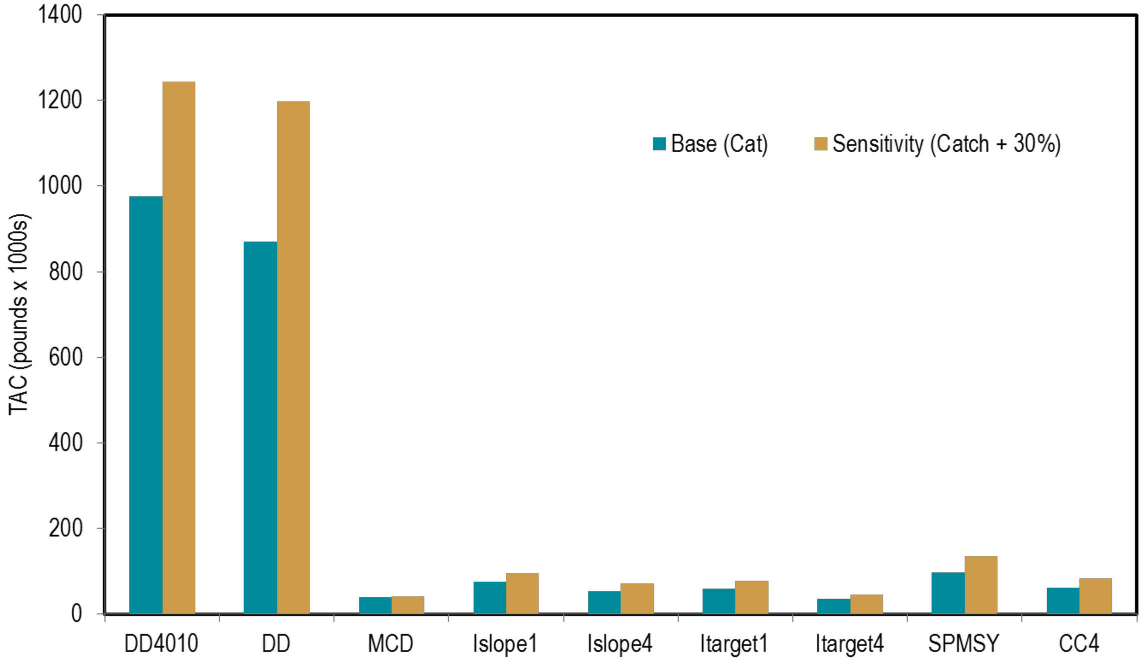


Results a: Impact of greater total removals (+ 30%) on catch (TAC) recommendations for each management procedure for St. Thomas queen triggerfish

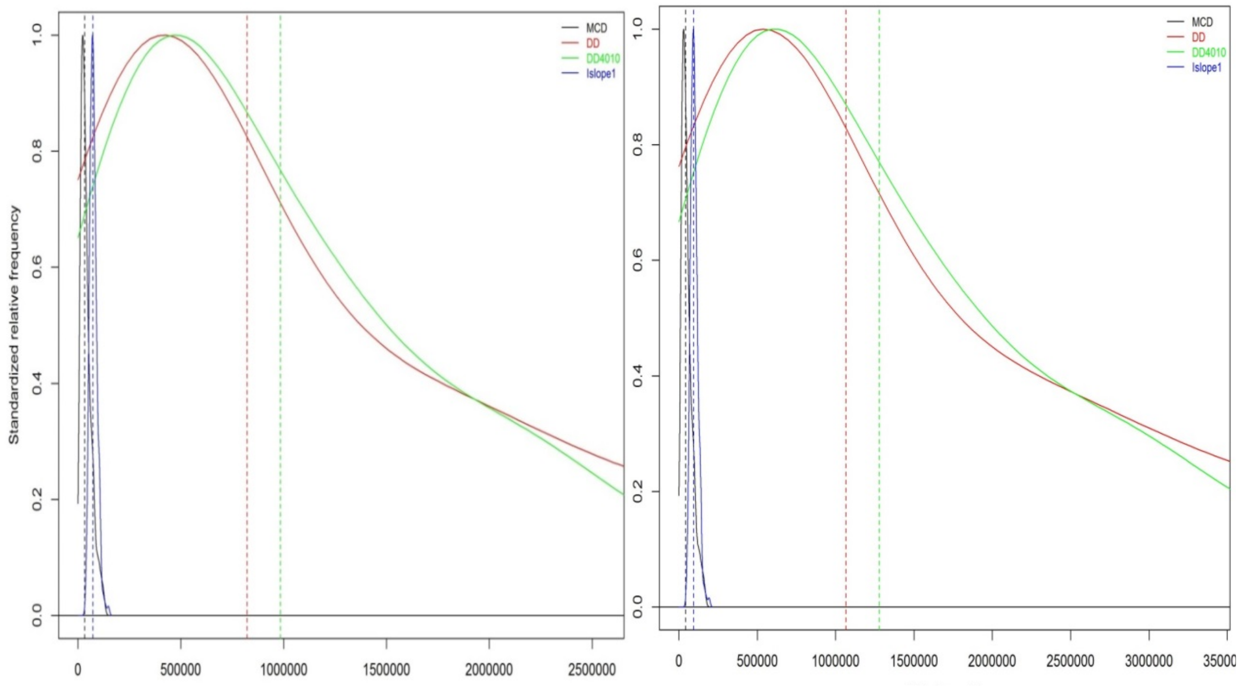


Results b: Impact of greater total removals (+ 30%; right) on TAC distributions for each management procedure compared to base run (left) for St. Thomas queen triggerfish

STT Spiny Lobster Catch Sensitivity

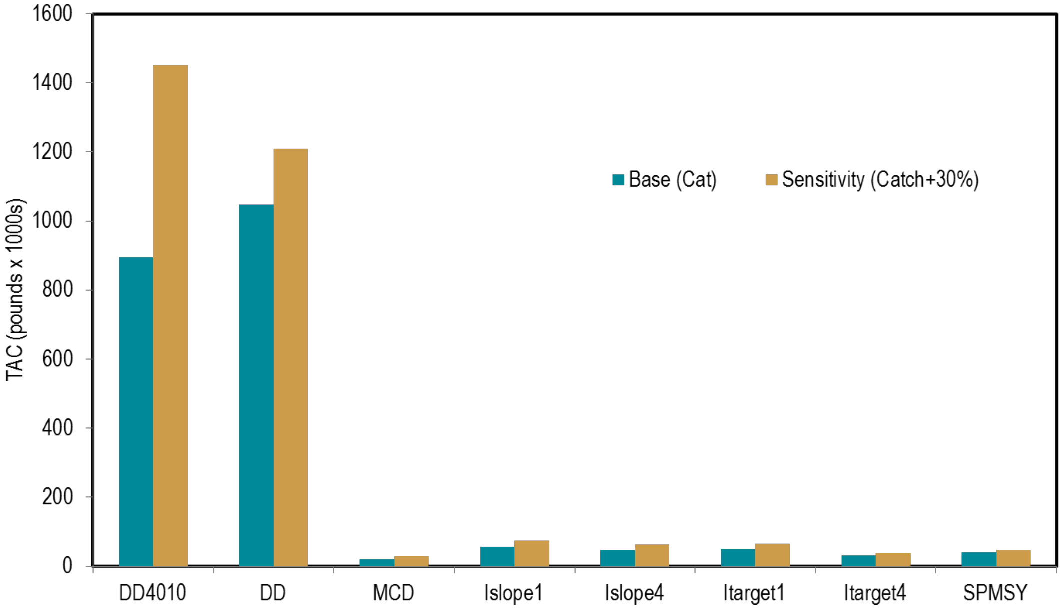


Results a: Impact of greater total removals (+ 30%) on catch (TAC) recommendations for each management procedure for St. Thomas spiny lobster

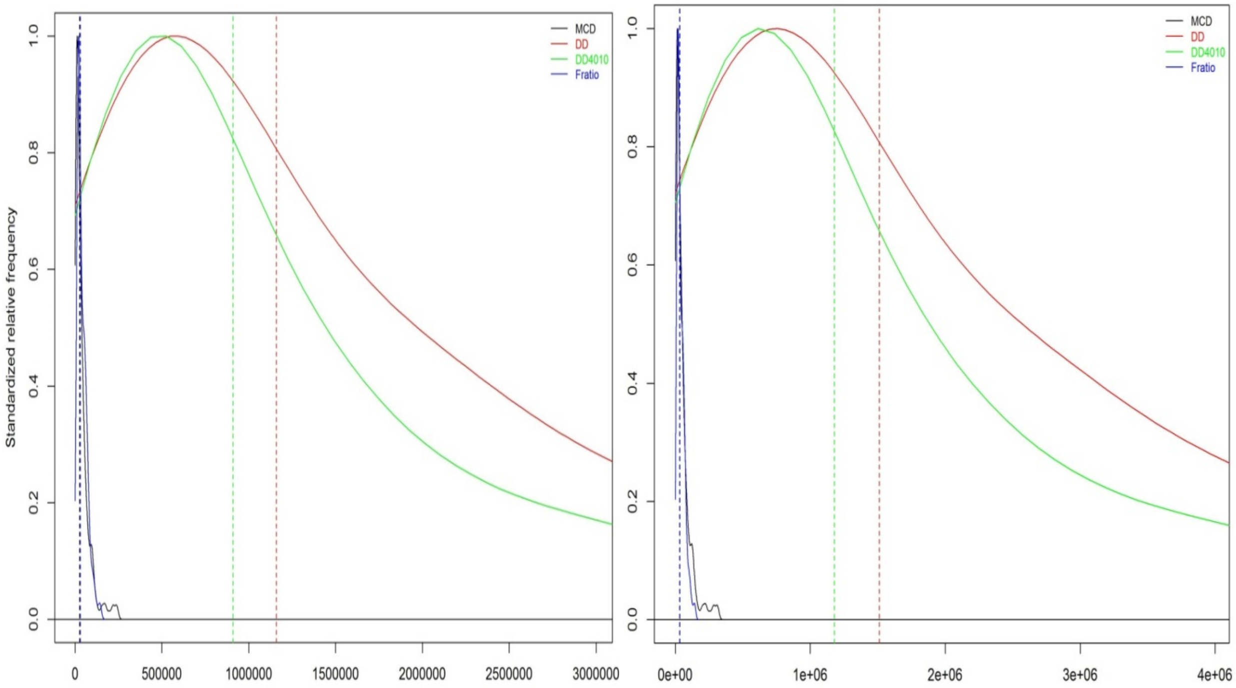


Results b: Impact of greater total removals (+ 30%; right) on TAC distributions for each management procedure compared to base run (left) for St. Thomas spiny lobster

STX Spiny Lobster Catch Sensitivity

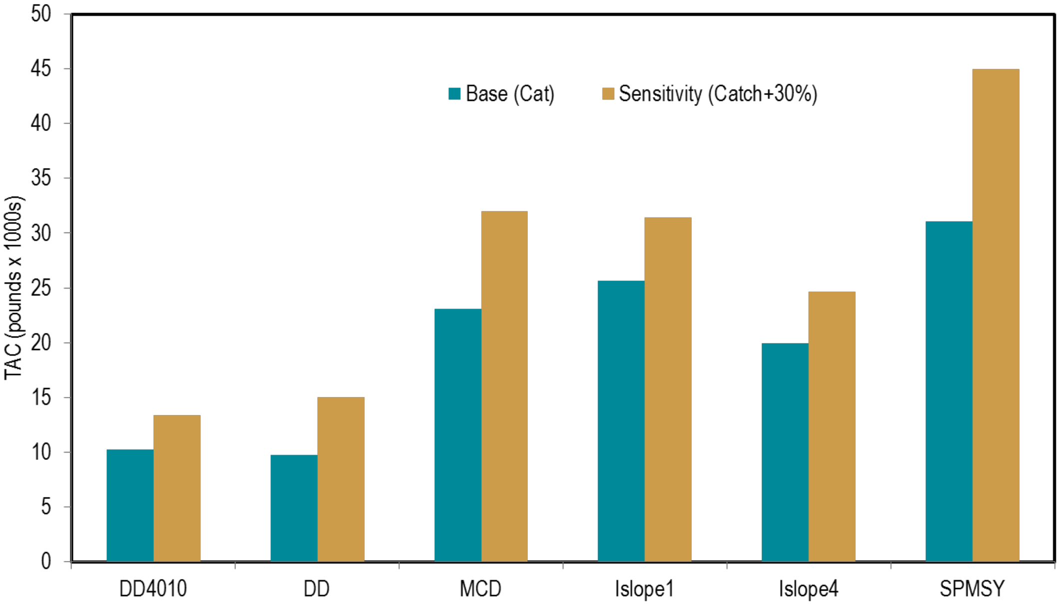


Results a: Impact of greater total removals (+ 30%) on catch (TAC) recommendations for each management procedure for St. Croix spiny lobster

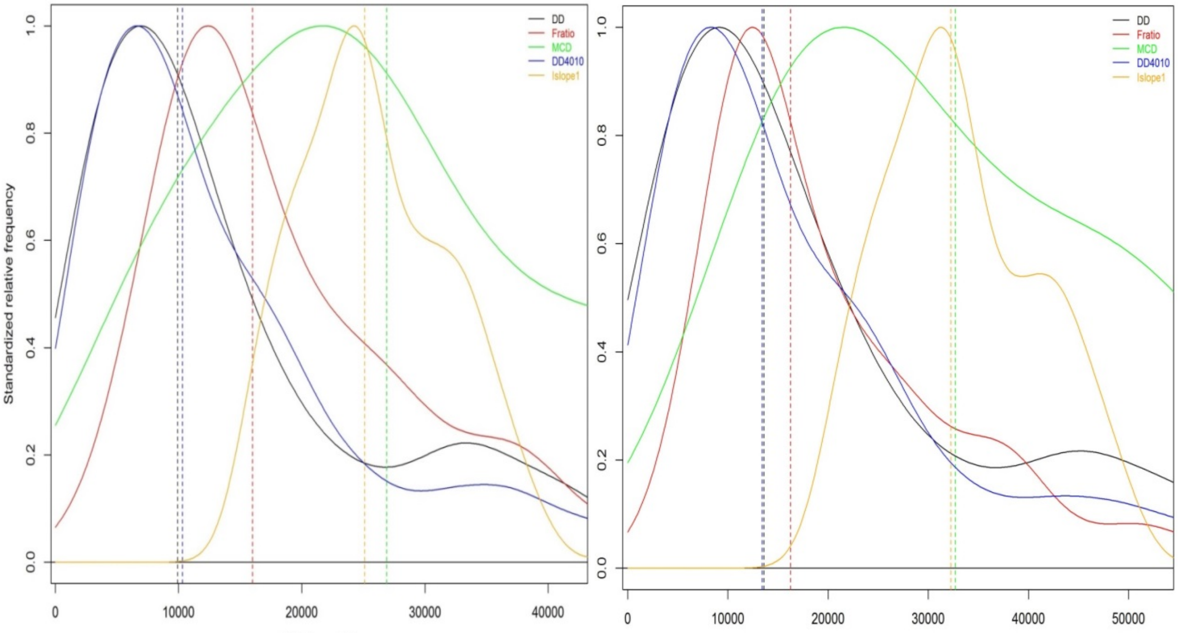


Results b: Impact of greater total removals (+ 30%; right) on TAC distributions for each management procedure compared to base run (left) for St. Croix spiny lobster

STX stoplight parrotfish Catch Sensitivity



Results a: Impact of greater total removals (+ 30%) on catch (TAC) recommendations for each management procedure for St. Croix stoplight parrotfish



Results b: Impact of greater total removals (+ 30%; right) on TAC distributions for each management procedure compared to base run (left) for St. Croix stoplight parrotfish

5. *Homework 1, Request 5:* Sensitivity of MSE results to the fleet characterization for Puerto Rico Hogfish, assuming a more dome-shaped selectivity pattern.

A question and comment from the RW panel and also the public comment period from the Puerto Rican commercial fishery representative was raised as to the selectivity assumption. The fishery representative described the common practice of fishers to avoid larger individuals due to preference by consumers for smaller/more plate-sized fish.

Analytical team response: The team reran the MSE for PR hogfish assuming dome-shaped selectivity. Result are presented in the following table for the base OM (left panel) and an alternative OM assuming high-dome selectivity (right panel) for all MPs meeting the S46 DW/AW perfomance criteria. Results are shown for both the base observation model (precise, unbiased – top two tables) and also the alternative observation model (imprecise, biased – bottom two tables).

Puerto Rico hogfish: Dome-shaped selectivity sensitivity run

15%LH, **asymptotic**, precise, unbiased

MP	PNOF	B50	LTY	AAVY
FMSYref	95.2	98.6	100.0	100.0
EDCAC	57.9	96.9	97.4	58.4
MCD	79.0	98.2	96.6	75.8
Fratio	61.8	94.9	96.0	52.0
BK	79.0	95.1	93.5	59.2
DCAC4010	92.0	98.6	91.5	68.4
Islope1	55.6	82.2	83.0	96.2
Islope4	57.3	82.1	80.2	96.2
IT10	69.1	91.5	79.8	98.8
ITM	68.8	91.0	78.3	98.8
IT5	67.0	88.5	77.4	97.0
LstepCC1	59.4	83.3	74.2	96.2
LstepCC4	59.1	83.2	74.1	96.2
SPMSY	80.5	92.1	63.8	98.2
CC4	73.9	92.0	30.4	100.0
Itarget1	78.4	94.9	26.3	100.0
Ltarget4	92.6	97.5	2.4	99.8

15%LH, **high-dome**, precise, unbiased

MP	PNOF	B50	LTY	VY
FMSYref	96.7	98.4	99.4	100.0
MCD	83.1	98.1	95.8	74.2
EDCAC	58.9	97.5	95.4	67.4
YPR	56.3	91.0	92.7	53.6
Fratio	58.2	92.7	92.1	56.4
DCAC4010	93.0	98.5	90.1	72.0
BK	78.3	95.5	89.7	56.8
Islope1	53.7	82.4	80.5	97.2
IT5	65.5	88.1	79.9	98.2
ITM	69.6	91.0	78.8	99.0
IT10	70.2	91.7	78.4	99.0
Islope4	56.2	82.2	76.9	97.0
LstepCC1	58.0	83.7	71.6	98.0
LstepCC4	57.9	83.7	70.8	97.6
Itarget1	72.4	93.0	31.8	100.0
CC4	70.9	90.1	28.7	100.0
Ltarget4	90.6	96.8	3.1	100.0

Puerto Rico hogfish: Dome-shaped selectivity sensitivity run.

15%LH, **asymptotic**, imprecise, unbiased

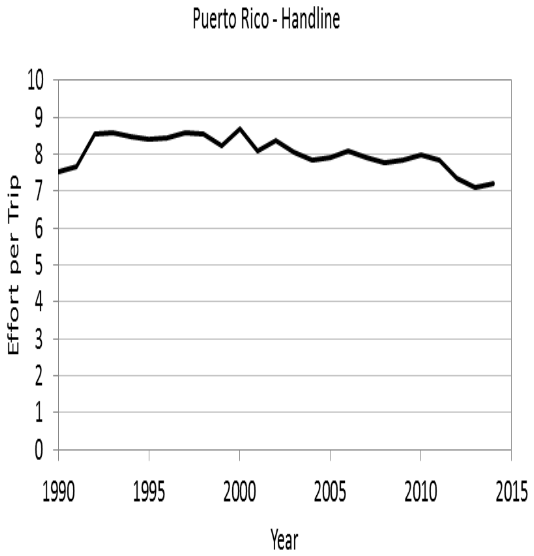
MP	PNOF	B50	LTY	VY
FMSYref	95.5	97.3	100.0	100.0
Islope1	55.2	76.8	71.2	93.4
Islope4	56.3	76.8	65.0	93.0
LstepCC4	57.9	78.1	61.8	95.2
LstepCC1	57.9	78.3	59.8	95.6
SPMSY	75.2	88.2	59.8	97.0
IT5	64.1	82.5	57.2	96.8
IT10	67.1	85.5	56.4	98.2
ITM	66.9	85.0	54.5	97.8
Itarget1	67.9	83.8	28.3	71.2
CC4	62.1	79.6	26.9	84.2
Ltarget4	77.9	89.2	17.2	65.6

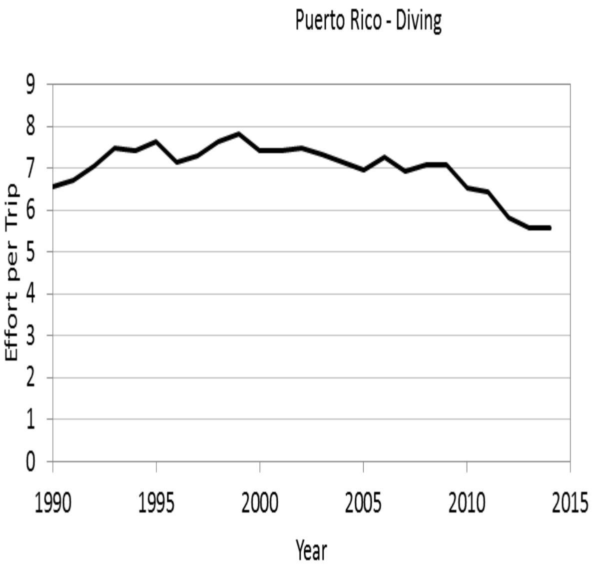
15%LH, **high-dome**, imprecise, unbiased

MP	PNOF	B50	LTY	VY
FMSYref	96.4	98.2	99.8	100.0
Islope1	57.3	79.7	63.9	91.4
IT5	62.3	83.3	62.3	96.6
Islope4	59.2	79.7	61.5	94.8
ITM	62.7	83.9	61.1	97.0
LstepCC4	61.3	81.7	59.8	96.8
LstepCC1	61.4	81.4	59.6	96.6
IT10	63.1	84.4	59.2	97.4
Itarget1	68.2	86.1	26.7	73.2
CC4	63.8	82.0	25.2	83.4
Ltarget4	79.3	91.3	16.3	64.0

6. *Homework 1, Request 6: Question from the Puerto Rican commercial fishery representative as to assumptions of fishing effort trend. The representative noted that fishing effort in PR had recently declined both in numbers of traps and also in number of fishers.*

Analytical team response: The team noted that the two Puerto Rico fisheries involved in the S46 evaluation were the dive and handline fisheries, thus the comment relating to a decline in trap was not an issue with the S46 modeling. In addition, the team provided visual representation of the effort trends assumed in the two species-island units noting that the decline in effort for the hogfish fishery was in agreement with the fisher representative. Similarly, a declining effort trend was assumed since ~ 2010 in the handline fishery. The graphs are provided below.





Day 2- Homework 2 (Wednesday February 24, 2016)

There were three main requests of the team relating to application of the DLMtool on Day 2. These related to 1) the appropriateness of the assumption using the 95% percentile to indicate the length at full selection, which was noted by the Review Panel to exclude a substantial portion of the population from the exploitation as opposed to using the mode of the length distribution; 2) the assumption of precise and unbiased data inputs within the observation model; 3) continuing to explore the TAC results on a simulation by simulation basis; and 4) the need to provide MSE performance results for the current management procedure used by the Council (CFMC).

1. Rerun the MSE with the CFMC's current harvest control rule for setting the annual catch limit for yellowtail snapper
2. Run with 1 simulation and 1 repetition at a time for a stock
3. Rerun MSE with LFS correction for PR hogfish and PR yellowtail snapper for both precise and unbiased and imprecise and biased data inputs within the observation model

The analytical team responses are provided below:

1. *Homework Day 2, Request 1: Rerun the MSE with the CFMC's current harvest control rule for setting the annual catch limit for yellowtail snapper.*

Analytical team response: The team responded by rerunning the MSE with the current CFMC fixed catch (assumed = ACL) and also offered results for three additional constant catch scenarios which could be considered: (1) median catch over the most recent 3 years (MCThree); (2) median catch over the most recent 10 years (MCTen); and (3) the third highest catch over the entire time series (THC). In addition, the MSE results would be shown for 500 simulations and one single replicate from the MSE, and the assumptions of imprecise and biased data inputs within the observation model would be evaluated.

The following was assumed for the runs:

Yellowtail snapper current ACL:

- ***Commercial landings = 373,295 lbs ww***
    - ***Average landings during 1999-2005, then reduced by 15% to account for an undefined aspect of uncertainty***
- ***Recreational landings = 28,509 lbs ww***
    - ***Average landings during 2000-2005 (data start in 2000)***
- ***TOTAL landings = 401,804 lbs ww***

Within the DLMtool, the current CFMC MP (fixed catch) was implemented by defining two new MP's, one with no variability and one with a small (0.1) standard deviation as follows:

```
#Test current method –CFMC ACL WITH no SD
CFMC_NoSD<-function(x,DLM_data,reps){rlnorm(reps,log(401804),0)}
class(CFMC_NoSD)<-"DLM_output"
environment(CFMC_NoSD)<-asNamespace('DLMtool')
sfExport("CFMC_NoSD")
```

```
#Test current method – 0.1 SD
CFMC<-function(x,DLM_data,reps){rlnorm(reps,log(401804),0.1)}
class(CFMC)<-"DLM_output"
environment(CFMC)<-asNamespace('DLMtool')
sfExport("CFMC")
```

Within the DLMtool, the MCThree, MCTen, and THC were implemented as follows:

```
#Median catch over last 3 years
MCThree<-function(x,DLM_data,reps){three<-c(DLM_data@Cat[(length(DLM_data@Cat)-
2)],DLM_data@Cat[(length(DLM_data@Cat)-1)], DLM_data@Cat[length(DLM_data@Cat)])
rlnorm(reps,log(median(three,na.rm=T)),0.1)}
class(MCThree)<-"DLM_output"
environment(MCThree)<-asNamespace('DLMtool')
sfExport("MCThree")
```

```
#Median catch over last 10 years
MCTen<-function(x,DLM_data,reps){ten<-c(DLM_data@Cat[(length(DLM_data@Cat)-
9)],DLM_data@Cat[(length(DLM_data@Cat)-8)],DLM_data@Cat[(length(DLM_data@Cat)-
```

```
7)],DLM_data@Cat[(length(DLM_data@Cat)-6)],DLM_data@Cat[(length(DLM_data@Cat)-
5)],DLM_data@Cat[(length(DLM_data@Cat)-4)],DLM_data@Cat[(length(DLM_data@Cat)-
3)],DLM_data@Cat[(length(DLM_data@Cat)-2)],DLM_data@Cat[(length(DLM_data@Cat)-
1)],DLM_data@Cat[length(DLM_data@Cat)])
rlnorm(reps,log(median(ten,na.rm=T)),0.1)}
class(MCTen)<-"DLM_output"
environment(MCTen)<-asNamespace('DLMtool')
sfExport("MCTen")
```

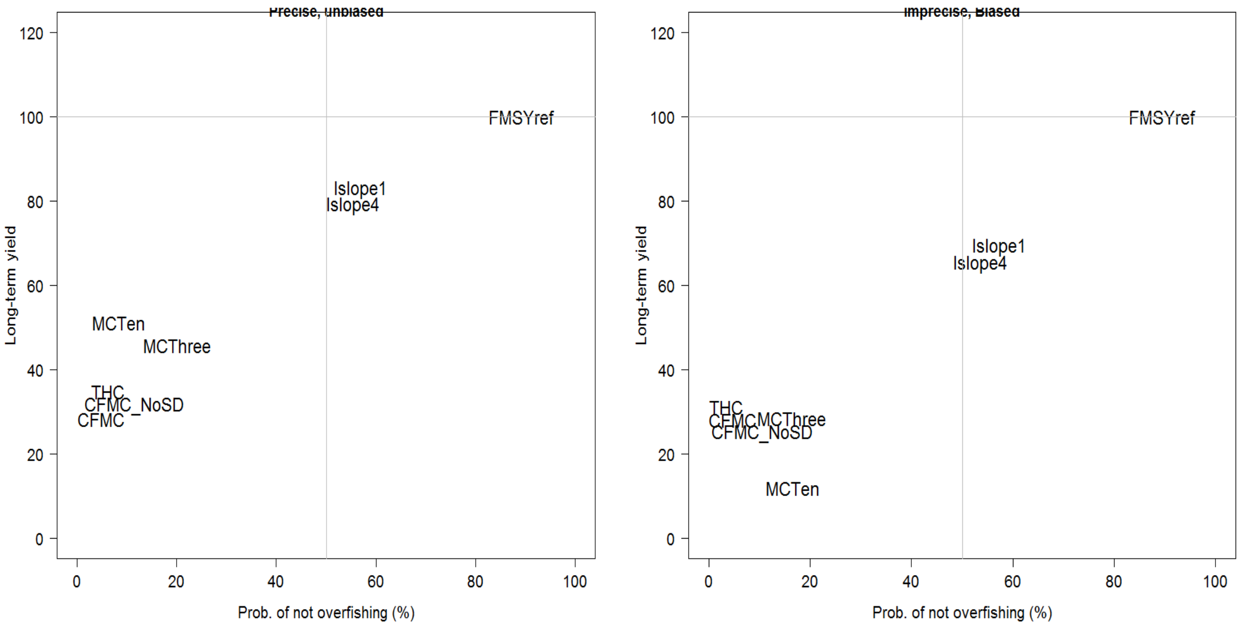
```
#Third-highest catch
THC<-function(x,DLM_data,reps){rlnorm(reps,log(DLM_data@Cat[x,order(DLM_data@Cat[x,],
decreasing=T)[3]]),0.1)}
class(THC)<-"DLM_output"
environment(THC) <- asNamespace('DLMtool')
sfExport("THC")
```

A review of the performance metrics specified by the S46 DW/AW panel at the November 2-4 workshop was provided by the team for the RW panel and other participants, as these metrics were important in examining the results from the fixed catch MPs.

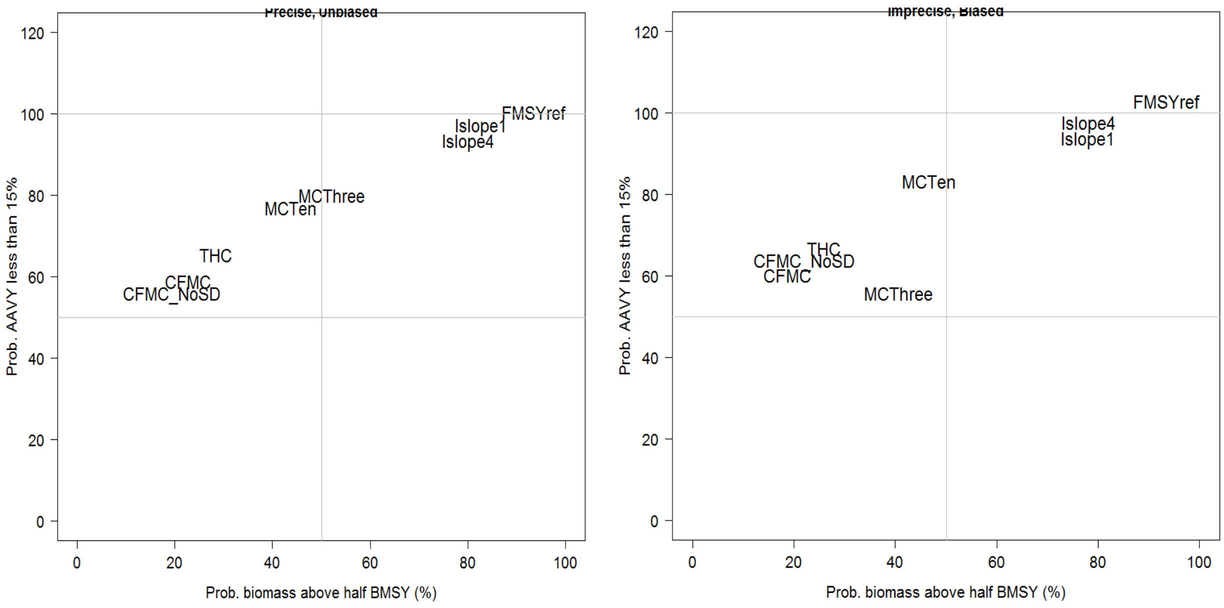
Performance metrics were:

- ***Long-term yield (LTY) = fraction of simulations achieving over 50% FMSY yield over the final ten years of the projection***
- ***Probability of not overfishing (PNOF) = fraction of simulation years in which F < FMSY***
- ***Average annual variability in yield (AAVY) = fraction of simulations achieving <15% average annual variability in yield***
- ***Probability of the biomass being above 50% BMSY (B50) = probability of the biomass being > 50%*** B_{MSY} ***over the entire projection***

Day 2 Homework Results 1a: MSE evaluation (500 simulations) of the current harvest control rule from CFMC for Puerto Rico yellowtail snapper. Performance metrics shown include the Probability of not overfishing (*x* axis) vs the long term yield (LTY) relative to FMSYref (*y* axis). The left panel is assuming precise, unbiased data inputs within the observation model and the right panel is assuming imprecise, biased data inputs.

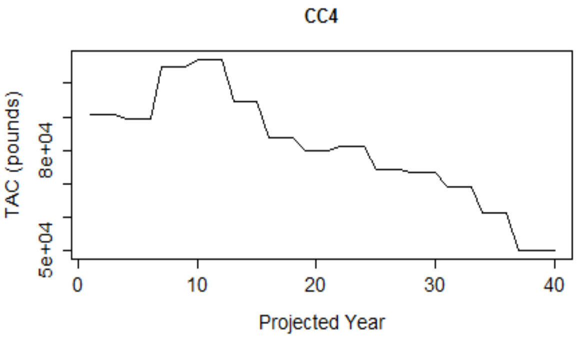


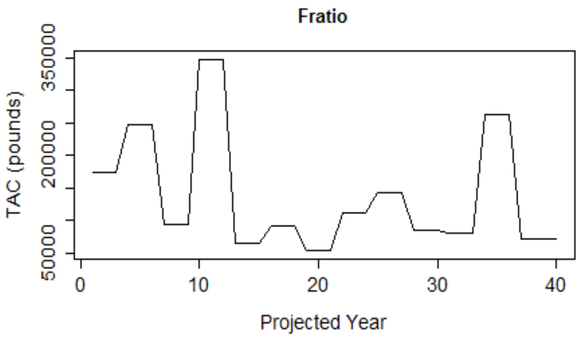
Day 2 Homework Results 1b: MSE evaluation (500 simulations) of the current harvest control rule from CFMC for Puerto Rico yellowtail snapper. Performance metrics shown include the Probability that the Biomass > 50% BMSY (*x* axis) vs the average annual variability in yield (*y* axis). The left panel is assuming precise, unbiased data inputs within the observation model and the right panel is assuming imprecise, biased data inputs.

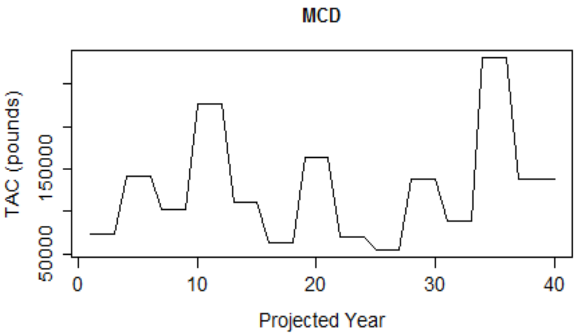


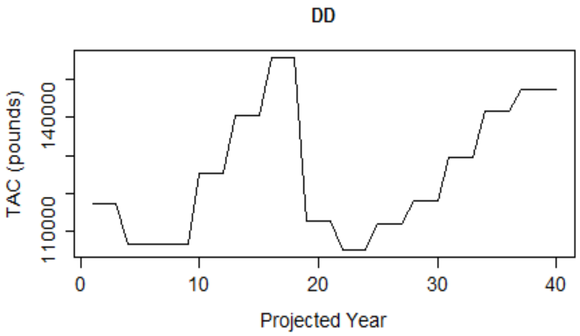
2. *Homework 2, Request 2: Run with 1 simulation and 1 repetition at a time for a stock.*

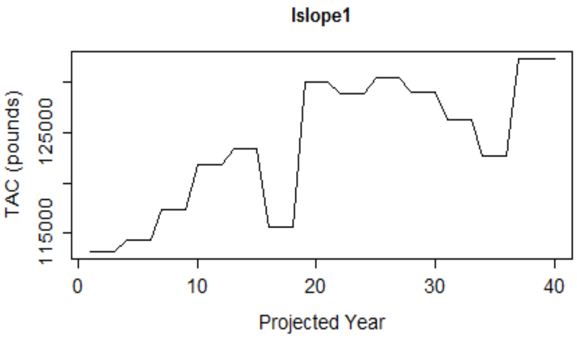
The Review Panel requested an MSE run for only 1 simulation and 1 repetition for a stock (yellowtail snapper) to see how the TACs were performing within the MSE. The results are provided below for each of the successful MPs meeting the performance criteria.











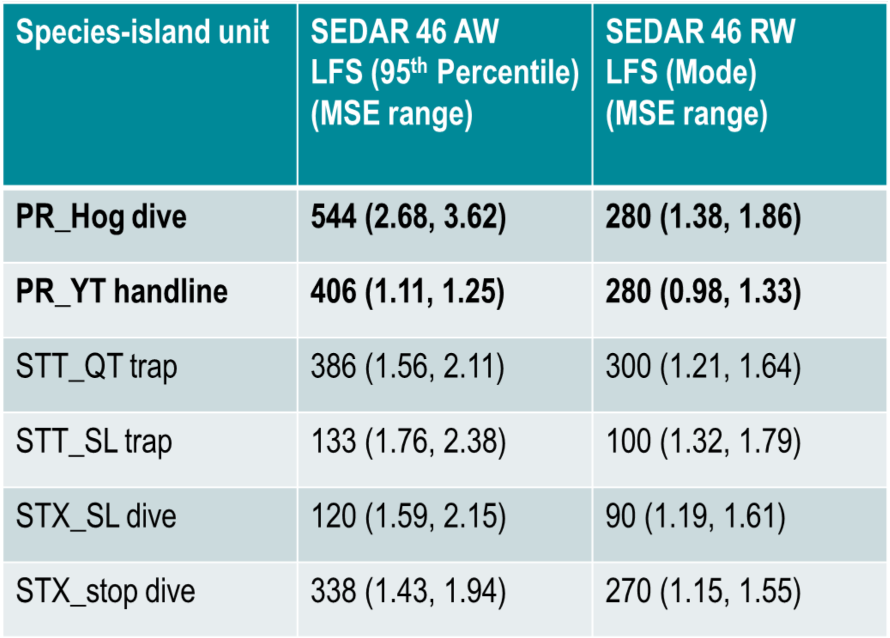
3. *Homework Day 2, Request 3: Rerun the MSEs for PR hogfish and PR yellowtail snapper with the revised length at full selectivity (LFS) parameter. Rerun both precise, unbiased and imprecise, biased data inputs for the observation models.*

It was noted by the RW Panel that the value for LFS assumed by the analytical team was – quite far to the right of the mode of length distribution (as shown in the data triage overview, Presentation 1 of the analytical team entitled "Data Overview"). Compared to the original estimate of LFS, the mode of the length distribution was located further to the left for all six species-island units. The question of "why not take the mode" was posed to the team. The original recommendation was to use the length class which was fully selected to the fishery, and was based on the 95th percentile of the frequency distribution of lengths.

A follow up question to the DLMtool developer later on Day 1 via email, indicated that the 95th percentile selection was arbitrary. Thus, the team was asked by the RW to examine this assumption by conducting a sensitivity MSE run using the mode of the length distribution to represent the length at full selection for two species (PR hogfish and yellowtail snapper).

Analytical team response: The team responded by revisiting the LFS data input and rerunning the requested MSEs. The following was assumed relating to LFS, "the size at which individuals are fully (100%) vulnerable (available) to the fishing unit".

The following table provides the AW base fleet model LFS assumption that assumed the 95th percentile and the revised LFS assumption using the mode as the definition for defining the LFS range for the MSE.



Species-island unit	SEDAR 46 AW LFS (95th Percentile) (MSE range)	SEDAR 46 RW LFS (Mode) (MSE range)
PR_Hog dive	**544 (2.68, 3.62)**	**280 (1.38, 1.86)**
PR_YT handline	**406 (1.11, 1.25)**	**280 (0.98, 1.33)**
STT_QT trap	386 (1.56, 2.11)	300 (1.21, 1.64)
STT_SL trap	133 (1.76, 2.38)	100 (1.32, 1.79)
STX_SL dive	120 (1.59, 2.15)	90 (1.19, 1.61)
STX_stop dive	338 (1.43, 1.94)	270 (1.15, 1.55)

Results of the sensitivity to the base model assumption regarding LFS are shown below for two of the species-island units (Puerto Rico hogfish and yellowtail snapper). Results within each species are organized by type of observation model (precise, unbiased- top row and imprecise, biased –bottom set of tables. Bolded text highlights MPs where results change between MSEs (bolded red = method no longer selected using revised LFS; bolded black = method now selected using revised LFS). The results also include re-runs for the mean length estimator with revised LFS provided by Huynh.

Puerto Rico hogfish:

AW LFS (95th Percentile) (MSE range)	RW LFS (Mode) (MSE range)
544 (2.68, 3.62)	280 (1.38, 1.86)

PR hogfish: Precise, unbiased

AW Base				
MP	PNOF	B50	LTY	AAVY
FMSYref	95	99	100	100
DD4010	93	99	99	98
DD	77	97	99	100
EDCAC	58	97	97	58
MCD	79	98	97	76
Fratio	62	95	96	52
BK	79	95	94	59
DCAC4010	92	99	92	68
Islope1	56	82	83	96
Islope4	57	82	80	96
IT10	69	92	80	99
ITM	69	91	78	99
IT5	67	89	77	97
LstepCC1	59	83	74	96
LstepCC4	59	83	74	96
SPMSY	81	92	64	98
YPR_ML	58	77	63	88
SPR40_ML	65	70	38	74
CC4	74	92	30	100
Itarget1	78	95	26	100
Ltarget4	93	98	2	100

Revised LFS				
MP	PNOF	B50	LTY	AAVY
FMSYref	84	96	100	100
MCD	81	96	91	77
EDCAC	63	93	89	62
DCAC4010	97	97	82	73
Fratio	58	79	80	63
YPR	53	74	80	58
YPR_ML	70	84	63	78
IT10	69	79	58	97
ITM	69	78	56	97
Islope1	58	69	56	92
IT5	65	75	55	95
Islope4	59	70	50	93
LstepCC4	61	71	45	94
LstepCC1	61	71	45	94
CC4	85	88	7	99
Itarget1	88	92	7	100
Ltarget4	96	95	0	100

**DD and DD4010 produced errors, SPMSY, BK and SPR40_ML drop out of DW/AW performance criteria, YPR is included

PR hogfish: Imprecise, biased

Alt Observation				
MP	PNOF	B50	LTY	AAVY
FMSYref	96	97	100	100
Islope1	55	77	71	93
Islope4	56	77	65	93
LstepCC4	58	78	62	95
LstepCC1	58	78	60	96
SPMSY	75	88	60	97
IT5	64	83	57	97
IT10	67	86	56	98
ITM	67	85	55	98
Itarget1	68	84	28	71
CC4	62	80	27	84
Ltarget4	78	89	17	66

**DD and DD4010 produced errors

Revised LFS (RW Base)				
MP	PNOF	B50	LTY	AAVY
FMSYref	84	93	100	100
Islope1	59	65	40	89
IT10	68	72	36	94
SPR40_ML	62	74	36	86
Islope4	61	66	36	91
ITM	68	71	36	94
YPR_ML	79	87	34	85
IT5	66	69	33	93
LstepCC4	64	68	30	93
LstepCC1	64	68	28	93
Ltarget1	51	57	17	82
Itarget1	74	76	12	70
CC4	69	71	9	77
Ltarget4	85	85	6	65

*DD and DD4010 produced errors, SPMSY drops out of DW/AW performance metric criteria; Ltarget1 now present (**bolded**)

Puerto Rico yellowtail snapper

AW LFS (95th Percentile) (MSE range)	RW LFS (Mode) (MSE range)
406 (1.11, 1.25)	**280 (0.98, 1.33)**

PR yellowtail snapper: Precise, unbiased

AW Base				
MP	PNOF	B50	LTY	AAVY
FMSYref	89	99	100	100
DD4010	75	98	97	96
DD	56	93	96	100
MCD	72	98	94	66
Fratio	60	92	94	51
DCAC4010	94	99	90	79
DCAC	62	85	87	97
IT5	63	86	87	99
IT10	56	85	87	99
ITM	56	85	86	99
DCAC_40	62	83	83	97
Islope1	61	83	81	99
Islope4	61	82	79	98
LstepCC4	63	84	79	99
LstepCC1	64	84	78	99
YPR_ML	65	77	64	94
SPMSY	73	85	61	98
CC4	78	90	32	100
Itarget1	87	95	22	100
Ltarget4	97	99	1	100

Revised LFS				
MP	PNOF	B50	LTY	AAVY
FMSYref	89	99	100	100
DD4010	68	96	97	96
DD	52	89	95	100
MCD	71	99	92	73
DCAC4010	92	99	91	80
DCAC	60	86	85	97
IT5	52	82	84	97
DCAC_40	60	85	82	96
Islope1	57	82	82	97
Islope4	57	82	81	97
LstepCC1	59	83	79	98
LstepCC4	59	83	79	98
YPR_ML	54	73	60	95
CC4	77	91	36	100
Itarget1	88	96	25	100
Ltarget4	97	99	1	100

*Fratio, IT10, ITM, SPMSY drops out of DW/AW performance metric criteria

PR yellowtail snapper: Imprecise, biased

Alt Observation				
MP	PNOF	B50	LTY	AAVY
FMSYref	90	99	100	100
DCAC	57	79	77	91
Islope1	58	78	73	94
DCAC_40	58	79	72	96
Islope4	58	78	71	94
IT5	61	80	69	97
IT10	57	80	69	97
ITM	57	80	69	97
LstepCC4	60	79	68	96
LstepCC1	61	79	67	96
SPMSY	80	88	53	97
CC4	65	79	28	83
Itarget1	73	86	26	73
Ltarget4	84	91	15	68

Revised LFS (RW Base)				
MP	PNOF	B50	LTY	AAVY
FMSYref	89	99	100	100
DCAC	57	79	78	92
IT5	56	77	73	96
DCAC_40	58	78	72	96
IT10	53	77	71	97
Islope1	57	77	70	94
ITM	53	77	70	97
Islope4	59	77	67	95
LstepCC4	61	79	67	96
LstepCC1	61	79	66	97
SPR40_ML	59	71	39	96
YPR_ML	71	81	38	94
CC4	64	78	28	84
Itarget1	72	85	27	74
Ltarget4	83	91	16	68

*SPMSY drops out of DW/AW performance metric criteria

Day 3 Homework (Thursday February 25, 2016)

The analytical team was requested at the end of the RW on Day 3, to also provide results of the MSE sensitivity examination to the assumption of LFS for the remaining species not yet examined. These runs were made subsequent to the RW as the meeting adjourned shortly after this request. These results are shown below and thus provide the full suite of MSEs using revised LFS for the species-island units.

An additional request of the team was to provide the results of the mean length estimator (see Huynh) within the re-runs.

Results include:

1. MSE results for revised LFS inputs for both precise, unbiased and imprecise, biased data inputs within the observation model for the remaining 4 species-islands units.
2. Length-based results within these tables. Note that length-based methods were not simulation tested using imprecise, biased data observations for the Assessment Workshop.

St. Thomas queen triggerfish

AW LFS (95th Percentile) (MSE range)	RW LFS (Mode) (MSE range)
386 (1.56, 2.11)	300 (1.21, 1.64)

STT queen triggerfish: Precise, unbiased

AW Base				
MP	PNOF	B50	LTY	AAVY
FMSYref	94	98	96	100
DD	82	97	91	100
EDCAC	54	97	89	64
DD4010	95	99	87	83
MCD	79	98	85	66
Fratio	58	94	84	51
Islope1	60	86	78	100
DCAC4010	95	99	76	74
ITM	73	94	74	100
IT10	73	94	73	100
Islope4	62	86	71	100
IT5	73	91	66	100
LstepCC4	64	87	64	100
LstepCC1	64	87	64	100
Itarget1	53	88	61	100
CC4	58	85	52	100
SPMSY	79	90	47	99
YPR_ML	80	85	44	96
Ltarget4	91	97	9	100

Revised LFS				
MP	PNOF	B50	LTY	AAVY
FMSYref	92	98	89	100
DD	72	96	84	100
DD4010	89	98	81	86
MCD	78	98	73	69
Fratio	53	89	68	56
IT10	65	91	67	100
ITM	64	91	67	100
Islope1	55	85	66	99
DCAC4010	94	99	65	72
IT5	65	89	62	100
Islope4	58	85	60	99
YPR_ML	68	83	57	92
LstepCC4	61	87	52	99
LstepCC1	61	87	52	99
Itarget1	55	88	49	100
CC4	58	86	47	100
Ltarget4	93	97	5	100

*EDCAC and SPMSY drop out of DW/AW performance metric criteria

STT queen triggerfish: Imprecise, biased

Alt Observation				
MP	PNOF	B50	LTY	AAVY
FMSYref	94	99	97	100
DD	68	92	83	76
Islope1	64	85	64	97
Islope4	66	85	61	98
ITM	70	89	56	100
IT10	71	89	56	100
LstepCC1	68	86	54	99
LstepCC4	68	86	53	100
IT5	72	89	51	100
SPMSY	80	90	40	99
Itarget1	63	85	36	78
CC4	60	80	33	91
Ltarget4	79	90	20	77

Revised LFS (RW Base)				
MP	PNOF	B50	LTY	AAVY
FMSYref	92	98	89	100
DD	60	88	74	76
IT10	62	86	50	99
Islope4	62	84	49	99
ITM	62	85	49	99
Islope1	59	84	49	95
IT5	63	85	46	99
LstepCC1	66	86	43	100
LstepCC4	66	86	43	100
SPR40_ML	57	74	39	96
YPR_ML	75	87	32	94
CC4	60	81	30	91
Itarget1	63	85	29	77
Ltarget4	79	91	17	76

*SPMSY drops out of DW/AW performance metric criteria

St. Thomas spiny lobster

AW LFS (95th Percentile) (MSE range)	RW LFS (Mode) (MSE range)
133 (1.76, 2.38)	100 (1.32, 1.79)

STT spiny lobster: Precise, unbiased

AW Base				
MP	PNOF	B50	LTY	AAVY
FMSYref	71	93	85	99
EDCAC	53	96	73	64
MCD	64	96	72	71
DD	67	92	69	98
DD4010	78	95	67	76
DCAC4010	82	98	62	67
Islope1	63	88	53	96
Islope4	64	88	52	96
LstepCC4	66	88	49	96
LstepCC1	66	88	49	96
ITM	68	93	49	99
IT5	71	91	48	97
Itarget1	60	89	48	100
IT10	69	92	46	99
CC4	54	82	44	95
SPMSY	68	86	39	93
Ltarget4	88	96	12	100
Itarget4	99	98	0	64

Revised LFS				
MP	PNOF	B50	LTY	AAVY
FMSYref	61	93	69	100
MCD	63	97	56	76
DD	59	91	55	99
DD4010	72	95	52	80
Fratio	50	84	48	54
DCAC4010	82	98	47	68
IT5	64	88	40	99
IT10	63	90	40	99
ITM	62	90	38	99
Islope1	63	86	38	98
Islope4	65	86	36	98
CC4	55	84	36	97
Itarget1	61	90	32	99
LstepCC1	67	86	32	98
LstepCC4	67	86	31	98
Ltarget4	90	96	8	100
Itarget4	99	98	0	66

*EDCAC and SPMSY drop out of DW/AW performance metric criteria; Fratio is included

STT spiny lobster: Imprecise, biased

Alt Observation				
MP	PNOF	B50	LTY	AAVY
FMSYref	71	93	85	99
DD	61	86	62	73
Islope1	65	86	45	94
Islope4	65	86	44	94
IT10	70	89	40	96
ITM	69	89	40	97
IT5	71	88	39	95
LstepCC1	67	87	39	95
LstepCC4	68	87	39	94
SPMSY	73	87	35	92
CC4	62	80	25	87
Itarget1	69	86	22	79
Ltarget4	78	89	13	81

Revised LFS (RW Base)				
MP	PNOF	B50	LTY	AAVY
FMSYref	62	94	69	100
DCAC	50	78	37	91
DCAC_40	52	77	34	92
IT10	69	88	33	97
ITM	67	88	33	97
Islope1	69	86	30	94
IT5	70	87	30	97
Islope4	70	86	27	95
YPR_ML	52	72	25	97
LstepCC4	72	87	24	96
LstepCC1	72	87	23	96
CC4	62	82	19	88
Itarget1	68	86	17	79
Ltarget4	80	91	11	83

*DD and SPMSY drop out of DW/AW performance metric criteria; DCAC and DCAC_40 are included

St. Croix spiny lobster

AW LFS (95th Percentile) (MSE range)	RW LFS (Mode) (MSE range)
120 (1.59, 2.15)	**90 (1.19, 1.61)**

STX spiny lobster: Precise, unbiased

AW Base				
MP	PNOF	B50	LTY	AAVY
FMSYref	72	91	81	99
EDCAC	55	94	73	69
MCD	66	94	71	73
DD	72	92	70	99
DD4010	84	96	67	75
Fratio	60	87	64	52
DCAC4010	84	96	57	60
Islope1	61	85	51	97
Itarget1	52	85	48	99
Islope4	62	85	47	97
LstepCC1	63	85	44	97
LstepCC4	63	85	44	97
IT10	72	91	43	99
ITM	72	92	43	99
SPMSY	63	83	41	94
IT5	71	89	40	98
Ltarget4	84	93	17	100
Itarget4	99	96	0	72

Revised LFS				
MP	PNOF	B50	LTY	AAVY
FMSYref	53	90	58	99
EDCAC	52	93	54	68
DD	64	90	51	98
MCD	64	94	51	77
DD4010	78	95	48	81
Fratio	51	81	42	56
DCAC4010	83	96	41	65
CC4	53	82	36	94
Itarget1	60	87	36	98
IT5	65	83	33	95
Islope1	60	80	32	92
ITM	67	88	31	97
IT10	66	86	31	97
Islope4	61	80	30	92
LstepCC4	64	81	29	93
LstepCC1	63	81	28	93
Ltarget4	88	94	10	99
Itarget4	99	97	0	72

*SPMSY drops out of DW/AW performance metric criteria; CC4 is included

STX spiny lobster: Imprecise, biased

Alt Observation				
MP	PNOF	B50	LTY	AAVY
FMSYref	72	91	81	99
DD	64	87	63	76
Islope1	62	84	44	96
Islope4	63	84	41	96
LstepCC4	65	85	38	96
ITM	71	89	38	98
LstepCC1	65	85	38	96
IT10	71	89	37	98
SPMSY	68	83	37	94
IT5	70	87	36	97
CC4	57	80	28	89
Itarget1	63	85	26	79
Ltarget4	74	88	17	82

Revised LFS (RW Base)				
MP	PNOF	B50	LTY	AAVY
FMSYref	53	90	58	99
DD	55	82	44	75
IT10	66	83	27	94
YPR_ML	55	74	27	99
IT5	67	81	26	93
ITM	66	83	26	94
Islope4	66	80	26	91
Islope1	65	80	26	89
LstepCC1	68	81	22	93
LstepCC4	68	81	22	93
CC4	60	79	20	84
Itarget1	67	84	18	77
Ltarget4	79	89	11	78

*SPMSY drops out of DW/AW performance metric criteria

St. Croix stoplight parrotfish

AW LFS (95th Percentile) (MSE range)	RW LFS (Mode) (MSE range)
338 (1.43, 1.94)	**270 (1.15, 1.55)**

STX stoplight parrotfish: Precise, unbiased

AW Base				
MP	PNOF	B50	LTY	AAVY
FMSYref	88	95	99	100
DD	89	94	88	97
EDCAC	62	93	87	56
Fratio	58	84	82	54
MCD	82	95	82	70
DD4010	97	96	80	56
Islope1	60	78	74	100
DCAC4010	97	96	64	73
Islope4	64	78	63	100
ITM	76	88	62	100
IT10	77	87	58	100
LstepCC4	66	79	51	100
LstepCC1	66	79	49	100
IT5	77	85	44	100
SPMSY	81	86	35	100
Ltarget4	86	91	13	100
Itarget4	98	95	0	65

Revised LFS				
MP	PNOF	B50	LTY	AAVY
FMSYref	82	93	99	100
DD	79	90	89	98
EDCAC	58	90	83	54
DD4010	93	95	81	63
MCD	79	94	79	69
Fratio	52	78	76	53
ITM	73	85	68	99
Islope1	60	75	65	99
IT10	73	85	65	99
YPR_ML	52	72	60	96
DCAC4010	94	96	59	69
IT5	72	82	54	100
Islope4	64	76	53	99
LstepCC1	66	77	42	99
LstepCC4	66	77	40	99
Ltarget4	87	89	12	100
Itarget4	98	95	0	64

*SPMSY drops out of DW/AW performance metric criteria

STX stoplight parrotfish: Imprecise, biased

Alt Observation				
MP	PNOF	B50	LTY	AAVY
FMSYref	88	95	99	100
Islope1	62	76	55	99
Islope4	65	77	48	99
ITM	72	84	46	100
IT10	73	84	41	100
LstepCC4	68	78	40	100
Itarget1	54	72	40	83
LstepCC1	68	78	39	100
CC4	55	70	38	93
IT5	74	82	36	100
SPMSY	77	83	35	100
Ltarget4	73	82	24	82

Revised LFS (RW Base)				
MP	PNOF	B50	LTY	AAVY
FMSYref	82	93	99	100
DD	65	81	74	70
YPR_ML	67	81	52	98
Islope1	60	72	48	93
ITM	67	77	47	99
Islope4	63	74	47	98
IT10	68	77	45	99
IT5	67	76	41	99
LstepCC1	66	75	38	99
LstepCC4	66	75	36	99
CC4	57	69	34	91
Itarget1	58	70	34	81
Ltarget4	75	80	19	81

*SPMSY drops out of DW/AW performance metric criteria; DD is included

In light of the revised MSE runs, the analytical team updated: (1) the summary table suggesting which MPS to exclude based on data concerns and MP performance; and (2) the table of MPs recommended for setting catch advice. These tables were originally provided to the S46 RW Panel (on Day 1 of the S46 RW) in the supplemental Synthesis overview reference document ("An alternative approach to setting annual catch limits for data-limited stocks in the US Caribbean: A Synthesis of the SEDAR 46 US Caribbean stock evaluation"). These tables provided recommendations from the analytical team of which MPs to discourage from use in setting annual catches at this time due to data limitations and also identified potential MPs that could be considered for use in setting annual catches using the DLMtool. The updated tables take into account considerations from the results of the additional runs and sensitivity examinations requested by the RW panel. The tables of MPs to exclude and MPs to consider for use in setting ACLs are presented separately according to assumptions of the observation models (set 1-precise, unbiased and set 2- imprecise, biased) and follow below.

Table-Precise, Unbiased MSE observation model assumption: Identification and relevant support for exclusion of MPs for further use in recommending catch levels based on MSE results assuming revised length at full selectin (LFS) and the MSE observation model of precise, unbiased data inputs. Strikethrough indicates exclusion of method. Asterisks identify MPs which could be applied if a lower long-term yield criterion (i.e., < 50% acceptable) was selected by managers.

Acceptance Issue	**PR_Hog**	**PR_YT**	**STT_QT**	**STT_SL**	**STX_SL**	**STX_Stop**	**Research Recommendations**
Data quality							
Depletion uncertain	~~MCD~~	~~MCD~~	~~MCD~~	~~MCD~~	~~MCD~~	~~MCD~~	Convene expert team to develop estimates of depletion, explore Productivity-Susceptibility Analysis (see NMFS 2011)
Current Abundance uncertain	~~Fratio, YPR~~		~~Fratio~~	~~Fratio~~	~~Fratio~~	~~Fratio~~	Convene expert team to develop estimates of current abundance using better estimates of F (e.g., from mean length approaches)
Life history							Convene workshop to characterize LH demographics and uncertainty estimates
Uncertain maximum Age and/or Mort			~~DD, DD4010~~	~~DD, DD4010~~	~~DD, DD4010~~		
Protogyny							
Uncertain growth Parameters			~~YPR_ML~~			~~DD, DD4010, YPR_ML~~	
Index of abundance restricted						~~Islope1, Islope4, Itarget4~~	Develop statistically robust fishery-independent surveys
Unrealistic results							
Catch recommendations exceeding or near largest observed catches		~~DD, DD4010~~	~~DD, DD4010~~	~~DD, DD4010~~	~~DD, DD4010~~		Further investigation into discard estimates, catch reporting and verification
Unacceptable performance in MSE							
Long-term yield < 50% relative to FMSYref	~~Itarget1, CC4~~	~~Itarget1, CC4~~	~~Itarget1, CC4~~	~~Islope1*,~~ ~~Islope4,~~ ~~Itarget1,~~ ~~Itarget4,~~ ~~CC4~~	~~Islope1,~~ ~~Islope4,~~ ~~Itarget1*,~~ ~~Itarget4,~~ ~~CC4*~~	~~Itarget4~~	Convene methods workshop to develop framework for assessing data limited stocks (e.g., NMFS 2011)

Table-Imprecise, Biased MSE observation model assumption: Identification and relevant support for exclusion of MPs for further use in recommending catch levels based on MSE results assuming revised LFS and imprecise, biased data inputs within the observation model. Strikethrough indicates exclusion of method. An asterisk identifies MPs which could be applied if a lower long-term yield criterion (i.e., < 50% acceptable) was used by the analysts.

Acceptance Issue	**PR_Hog**	**PR_YT**	**STT_QT**	**STT_SL**	**STX_SL**	**STX_Stop**	**Research Recommendations**
Data quality							
Depletion uncertain							Convene expert team to develop estimates of depletion, explore Productivity-Susceptibility Analysis (see NMFS 2011)
Current Abundance uncertain							Convene expert team to develop estimates of current abundance using better estimates of F (e.g., from mean length approaches)
Life history							Convene workshop to characterize LH demographics and uncertainty estimates
Uncertain maximum Age and/or Mort			~~DD~~		~~DD~~		
Protogyny							
Uncertain growth parameters			~~YPR_ML, SPR40_ML~~			~~DD, YPR_ML~~	
Index of abundance restricted						~~Islope1, Islope4, Itarget1~~	Develop statistically robust fishery-independent surveys
Concerns over catch						~~CC4~~	Revisit landings
Unrealistic results							
Catch recommendations exceeding or near largest observed catches			~~DD~~		~~DD~~		Further investigation into discard estimates, catch reporting and verification
Unacceptable performance in MSE							
Long-term yield < 50% relative to FMSYref	~~Islope1*, Islope4*, Itarget1, CC4, YPR_ML, SPR40_ML*~~	~~Itarget1, CC4, YPR_ML*, SPR40_ML*~~	~~Islope1*, Islope4*, Itarget1, CC4~~	~~Islope1*, Islope4*, YPR_ML*, Itarget1, CC4~~	~~Islope1*, Islope4*, YPR_ML*, Itarget1, CC4~~	~~Islope1, Islope4, CC4, Itarget1~~	Convene methods workshop to develop framework for assessing data limited stocks (e.g., NMFS 2011)

Table. Precise, Biased MSE observation model assumption: Potential methods for setting catch recommendations based on sufficiency and quality of data, model assumptions, and performance metrics for the MSE using the revised LFS assumption and assuming precise and unbiased data inputs within the observation model. - Indicates no recommendations made.

Recommended methods	**PR_Hog**	**PR_YT**	**STT_QT**	**STT_SL**[1]	**STX_SL**[2]	**STX_Stop**
Index-based	Islope1, Islope4	Islope1, Islope4	Islope1, Islope4	Islope1	Itarget1	**-**
Catch-based	-	**-**	**-**	-	CC4	**-**
Length-based	YPR_ML	YPR_ML	-	-	-	-

[1] Note that for St. Thomas spiny lobster, the inclusion criterion for long-term yield of 50%, as used by the analysts, would result in no recommended MPs. The relative long-term yields for applicable methods ranking from highest to lowest are: Islope1 (38.0%), Islope4 (35.9%), CC4 (35.8%), Itarget1 (32.4%), and Itarget4 (0%). Islope1 could be applied if a lower relative long-term yield would be acceptable.

[2] Note that for St. Croix spiny lobster, the inclusion criterion for long-term yield of 50%, as used by the analysts, would result in no recommended MPs. The relative long-term yields for applicable methods ranking from highest to lowest are: CC4 (36%), Itarget1 (35.8%), Islope1 (31.8%), Islope4 (30.3%), and Itarget4 (0%). CC4 and Itarget1 could be applied if a lower relative long-term yield would be acceptable.

Table. Imprecise, Biased MSE observation model assumption: Potential methods for setting catch recommendations based on sufficiency and quality of data, model assumptions, and performance metrics for the MSE using the revised LFS assumption and assuming imprecise and biased data inputs within the observation model. - Indicates no recommendations made.

Recommended methods	**PR_Hog[1]**	**PR_YT[2]**	**STT_QT[3]**	**STT_SL[4]**	**STX_SL[5]**	**STX_Stop**
Index-based	Islope1, Islope4	Islope1, Islope4	Islope1, Islope4	Islope1, Islope4	Islope4, Islope1	**-**
Length-based	SPR40_ML	YPR_ML, SPR40_ML	-	YPR_ML	YPR_ML	-

[1] Note that for Puerto Rico hogfish, the inclusion criterion for long-term yield of 50%, as used by the analysts, would result in no recommended MPs. The relative long-term yields for applicable methods ranking from highest to lowest are: Islope1 (39.8%), SPR40_ML (36%), Islope4 (35.9%), YPR_ML (34%), Itarget1 (12%), and CC4 (9%). Islope1, Islope4 and SPR40_ML could be applied if a lower relative long-term yield would be acceptable.

[2] Note that for Puerto Rico yellowtail snapper, if a lower relative long-term yield would be acceptable, both SPR40_ML (39%) and YPR_ML (38%) could be applied.

[3] Note that for St. Thomas queen triggerfish, the inclusion criterion for long-term yield of 50%, as used by the analysts, would result in no recommended MPs. The relative long-term yields for applicable methods from highest to lowest are: Islope1 (48.9%), Islope4 (49.2%), CC4 (29.9%), and Itarget1 (29.1). Islope1 and Islope4 could be applied if a lower relative long-term yield would be acceptable.

[4] Note that for St. Thomas spiny lobster, the inclusion criterion for long-term yield of 50%, as used by the analysts, would result in no recommended MPs. The relative long-term yields for applicable methods from highest to lowest include Islope1 (29.8%), Islope4 (26.8%), YPR_ML (25%), CC4 (18.5%), and Itarget1 (16.8%). Islope1, Islope4 and YPR_ML could be applied if a lower relative long-term yield would be acceptable.

[5] Note that for St. Croix spiny lobster, the inclusion criterion for long-term yield of 50%, as used by the analysts, would result in no recommended MPs. The relative long-term yields for applicable methods from highest to lowest include YPR_ML (27%), Islope4 (25.8%), Islope1 (25.6%), CC4 (20.2%), and Itarget1 (18.3%). YPR_ML, Islope4 and Islope1 could be applied if a lower relative long-term yield would be acceptable.

ADDEDNDUM B:

1. Puerto Rico hogfish spawning potential ratio (SPR)

The spawning potential ratio analysis for Puerto Rico hogfish was modeled taking into account the protogynous life history of the species. The sex ratio p_t (i.e. the proportion male at age t) was modeled as a logistic function of age t:

$$p_t = [1 + \exp\{-\log 19\left(\frac{t - t_{50}}{t_{95} - t_{50}}\right)\}]^{-1} \qquad (1)$$

where t_{50} and t_{95} are the ages at which 50% and 95% of the population are male, respectively. The population abundance N_t and the abundance of males N_t^m and females N_t^f are given as:

$$\begin{aligned} N_t &= N_{t-1}\exp(-Z_t) \\ N_t^m &= N_t p_t \\ N_t^f &= N_t(1 - p_t) \end{aligned} \qquad (2)$$

The spawning stock biomass of males (SSB^m) and females (SSB^f) are:

$$\begin{aligned} SSB^m &= \sum_{t=1}^{t_{\max}} N_t^m w_t \\ SSB^f &= \sum_{t=1}^{t_{\max}} N_t^f w_t mat_t \end{aligned} \qquad (3)$$

where w_t is the weight and mat_t is the percent mature at age t and t_{max} is the maximum age. It was assumed that all males are mature. Maturity of females and selectivity were assumed to be knife-edge. Growth and selectivity were assumed to be the same between sexes. From equations 1-3 and life history information, the fishing mortality rate reference point $F_{SPR\%}$ from the spawning stock biomass (SSB) of males only and females only can be obtained at the desired threshold.

For Puerto Rico hogfish, the sex ratio ogive was derived using the results from Collins and McBride (2011). They reported separate sex ratios for Florida hogfish by nearshore (<30 m depth) and offshore (>30 m depth) habitat. An analysis of the Trip Interview Program (TIP) database indicated that Puerto Rico hogfish was fished at both depths. Thus, the mean of the two sex ratio ogives was used for this analysis with t_{50} = 7 years and t_{95} = 11 years.

Fishing mortality reference points at SPR threshold of 30% and 40% are reported in Table 1 and Figure 1. The reference point considering the SSB of both sexes is slightly higher than when only that of males are considered. In turn, the reference point is much higher when SSB of only females is considered.

Brooks et al. (2008) reported that in general the reference point used to assess protogynous species should be obtained from the SSB of both sexes. Sex-specific reference points should be used only if there is strong evidence that fertilization potential is reduced or is unaffected by exploitation. Thus, the SPR reference points used in the mean length management procedures were sex-independent for Puerto Rico hogfish.

2. Performance metrics of mean length-based management procedures

Performance metrics of the mean length-based management procedures (MPs) from the DLMtool management strategy evaluations (MSEs) are updated in Table 2 with long-term yield (LTY) and short-term yield (STY) metrics obtained from the summary() function output in the DLMtool package. Using imprecise, biased observations (and assuming the length of full selectivity to be the mode of the observed length distribution) in the MSEs, the management criteria were met in the MSEs of all 6 stocks when $F_{0.1}$ was used as the reference point in the mean length-based management procedures. When $F_{30\%}$ was used as the reference point, the management criteria was only met for Puerto Rico yellowtail snapper, Puerto Rico hogfish, and St. Thomas queen triggerfish. Distributions of the OFLs obtained from mean length MPs which met the management criteria are provided in Table 3.

3. Sensitivity of L_c and L_∞ in queen triggerfish

In the application of the mean length estimator, an increasing trend in the estimated mortality rate concurrent with increasing value of L_c was observed for St. Thomas queen triggerfish. Such a trend can occur if there is dome selectivity or if L_∞ specified in the model is an overestimate of that in the population. In both cases, as the value of L_c increases, the abundance of large animals missing in the data (due to either dome selectivity of the gear or overestimate of L_∞) becomes a larger proportion of the length distribution > L_c resulting in a higher estimate of total mortality. To differentiate between dome selectivity of the gear or overestimate of L_∞ and to analyze their effects on the mean length MPs, a grid of L_c and L_∞ values was used to estimate mortality rates and reference points ($F_{0.1}$) for queen triggerfish. If estimated mortality rates are stable at an alternative (smaller) value of L_∞, this would suggest an overestimate of L_∞ whereas a trend in mortality with L_c at many values of L_∞ would suggest dome-shaped selectivity.

For queen triggerfish, four values of L_∞ (415, 500, 605.3, 700 mm) were examined with five values of L_c (280, 300, 320, 340, 360 mm). The benchmark F_{recent} was obtained from using the mean length estimator to obtain the total mortality rate and subtracting the natural mortality rate of 0.26 (Table 4). The F_{ratio} was obtained as the ratio of the reference point $F_{0.1}$ and F_{recent}. The u_{ratio} was calculated as well by converting the two instantaneous mortality rates into annual exploitation rates and then taking the ratios. For an annual OFL, u_{ratio} may be used if instantaneous rates are very high.

Although there was no trend in the estimated F_{recent} at L_∞ = 415 mm with increasing L_c, the magnitude of the mortality rate is very low for the expected exploitation of the stock and the value of

L_∞ = 415 mm is low given the distribution of observed lengths in the stock. Other (larger) values of L_∞ produced trends in estimated mortality with increasing L_c, suggesting dome-shaped selectivity. The slope of the trend appeared to decrease when calculating the F_{ratio} and the trend was further decreased when u_{ratio} was used. Thus, for the mean length management procedures, the OFL estimates that are relatively insensitive to L_c for a given value of L_∞. However, a good estimate of growth for St. Thomas queen triggerfish is needed to obtain the appropriate u_{ratio} and OFL estimates.

4. Sensitivity analysis of OFL

Sensitivity analysis of life history input parameters in the mean length management procedures assumes independent sampling in DLMtool. Further sensitivity analysis was done by incorporating correlation in the estimates of von Bertalanffy parameters L_∞ and K for Puerto Rico yellowtail snapper and hogfish (using $F_{0.1}$ and $F_{40\%}$ as the reference points). A variance-covariance matrix was created for L_∞ and K using the coefficients of variation (CVs) from the life history information and a correlation coefficient of -0.9.

First, a Monte Carlo procedure with 2,000 replicates was done with only stochasticity in von Bertalanffy parameters. For yellowtail snapper, there appeared to be no trend in the OFL with either L_∞ and K (Figures 2, 3). For Puerto Rico hogfish, the OFL is negatively correlated with L_∞ and positively correlated with K (although L_∞ and K are themselves negatively correlated as well) (Figures 4, 5). In this case, the estimates of F_{recent}, and thus the mean length estimator, appear to be sensitive to von Bertalanffy parameters with a negative and positive correlation to L_∞ and K, respectively. The estimates of the reference points, on the other hand, do not have a trend.

Second, the OFL estimation procedure in DLMtool was modified to incorporate correlated stochasticity in L_∞ and K. All other stochastic parameters (natural mortality, catch) were assumed to be independent. Generally, the interquartile range of the OFL did not considerably vary with correlated L_∞ and K. In 3 out of 4 cases, the range of the OFL decreased (Table 5). This behavior would be expected from the correlated sampling procedure, which produces a narrower parameter space for values L_∞ and K to reduce the range of OFLs. The stochastic sampling of correlated L_∞ and K parameters identified different sensitivity trends to the calculated OFL with respect to the growth parameters between yellowtail snapper and hogfish, which was not readily apparent in the Sense() function in DLMtool.

References

Brooks, E.N., Shertzer, K.W., Gedamke, T., and Vaughan, D.S. 2008. Stock assessment of protogynous fish: evaluating measures of spawning biomass used to estimate biological reference points. Fisheries Bulletin 106:12-23.

Collins, A.B. and McBride, R.S. 2011. Demographics by depth: spatially explicit life-history dynamics of a protogynous reef fish. Fisheries Bulletin 109:232-242.

Table 1. SPR reference points for hogfish from the spawning stock biomass of both sexes, males only, and females only.

Reference point	**Both**	**Males**	**Females**
F30%	0.17	0.12	0.55
F40%	0.12	0.09	0.37

Table 2. Performance metrics of the management procedures from the MSEs of the 6 Caribbean stocks: the probability of not overfishing (PNOF), the probability of biomass above half B_{MSY} (B50), the probability of achieving long term yield (LTY) and short term yield (STY), and the probability of annual variability in yield to remain within 15% (AAVY). Base stock and fleet dynamics were considered with an unbiased and biased observation dynamics.

	Unbiased Observation					Biased Observation				
MP	PNOF	B50	LTY	STY	AAVY	PNOF	B50	LTY	STY	AAVY
Yellowtail snapper										
FMSYref	91	98	100	79	100	90	98	100	79	100
YPR_ML*	54	73	60	45	95	71	81	38	36	94
SPR30_ML	15	41	53	72	96	40	55	42	59	94
SPR40_ML*	40	62	57	56	94	59	71	39	45	96
Hogfish										
FMSYref	96	96	100	58	100	96	97	100	60	100
YPR_ML*	70	84	63	13	78	79	87	34	16	85
SPR30_ML	24	48	42	51	82	44	59	37	42	87
SPR40_ML*	49	70	58	29	77	62	74	36	29	86
Queen triggerfish										
FMSYref	93	97	96	66	100	94	98	95	67	100
YPR_ML*	68	83	57	20	92	75	87	32	20	94
SPR30_ML	23	50	52	52	96	38	59	45	46	97
SPR40_ML*	46	68	62	36	93	57	74	39	35	96
Spiny lobster STT										
FMSYref	73	94	85	65	100	70	93	85	62	100
YPR_ML*	25	56	32	59	99	52	72	25	41	97
SPR30_ML	2	26	12	68	91	12	36	16	63	93
SPR40_ML	7	36	19	68	93	26	48	18	57	95
Spiny lobster STX										
FMSYref	72	91	79	52	100	72	90	78	54	100
YPR_ML*	35	63	35	48	99	55	74	27	36	99

SPR30_ML	3	35	19	62	96	15	44	23	57	96
SPR40_ML	9	43	25	60	97	29	55	26	50	97
Stoplight parrotfish										
FMSYref	86	97	97	71	100	86	96	97	73	100
YPR_ML*	52	72	60	36	96	67	81	52	29	98
SPR30_ML	14	40	59	62	98	26	49	73	56	98
SPR40_ML	31	56	64	51	97	47	66	64	43	98

* Indicates the MPs which met management criteria (PNOF > 50%, B50 > 50%, and AAVY > 50%) from the MSEs using the biased observations.

Table 3. Summary of the distribution of OFLs for the 6 stocks from the MPs which met management criteria (from the MSEs with biased, imprecise observations) for the respective stock.

	Quantile (x 1000 pounds)				
MP	Min	25%	Median	75%	Max
Yellowtail snapper					
YPR_ML	31.9	109.1	166.0	241.2	734.1
SPR40_ML	29.6	114.1	176.2	293.7	1506.3
Hogfish					
YPR_ML	4.2	26.1	40.2	72.8	890.7
SPR40_ML	9.1	31.2	50.7	86.9	1575.2
Queen triggerfish					
YPR_ML	4.7	13.0	18.9	30.2	189.3
SPR40_ML	6.3	18.0	30.2	56.1	1611.0
STT Spiny lobster					
YPR_ML	14.2	45.5	69.4	111.5	3726.5
STX Spiny lobster					
YPR_ML	0.9	9.8	17.5	32.6	2607.2
Stoplight parrotfish					
YPR_ML	1.0	3.8	5.6	8.2	27.7

Table 4. Estimated mortality rates F_{recent} and ratios of $F_{0.1}$ and F_{recent} in instantaneous and annual exploitation rates for St. Thomas queen triggerfish from a grid of values for L_c and L_∞.

	Linf			
Lc	**415**	**500**	**605.3**	**700**
	F_{recent}			
280	0.03	0.35	0.74	1.09
300	0.04	0.42	0.89	1.31
320	0.04	0.50	1.08	1.59
340	0.02	0.58	1.27	1.89
360	-0.04	0.62	1.44	2.18
	F_{ratio}			
280	11.67	0.83	0.31	0.17
300	10.25	0.69	0.28	0.18
320	11.25	0.70	0.27	0.14
340	25.50	0.60	0.23	0.12
360	-	0.66	0.20	0.11
	u_{ratio}			
280	9.99	0.85	0.39	0.25
300	8.58	0.73	0.38	0.28
320	9.24	0.75	0.38	0.26
340	20.18	0.67	0.35	0.24
360	-	0.73	0.33	0.23

Table 5. Summary of the distribution of OFLs for yellowtail snapper and hogfish using either independent values of Linf and K or correlated values, with a correlation of -0.9.

	Quantile (x 1000 pounds)				
	Min	25%	Median	75%	Max
Yellowtail snapper					
F0.1					
Independent Linf/K	31.9	109.1	166.0	241.2	734.1
Correlated Linf/K	30.6	113.3	153.2	218.7	595.4
F40%					
Independent Linf/K	29.6	114.1	176.2	293.7	1506.3
Correlated Linf/K	29.1	136.8	196.7	279.4	891.8
Hogfish					
F0.1					
Independent Linf/K	4.2	26.1	40.2	72.8	890.7
Correlated Linf/K	8.4	30.1	43.1	62.5	1884.7
F40%					
Independent Linf/K	9.1	31.2	50.7	86.9	1575.2
Correlated Linf/K	13.8	36.7	51.0	83.8	717.5

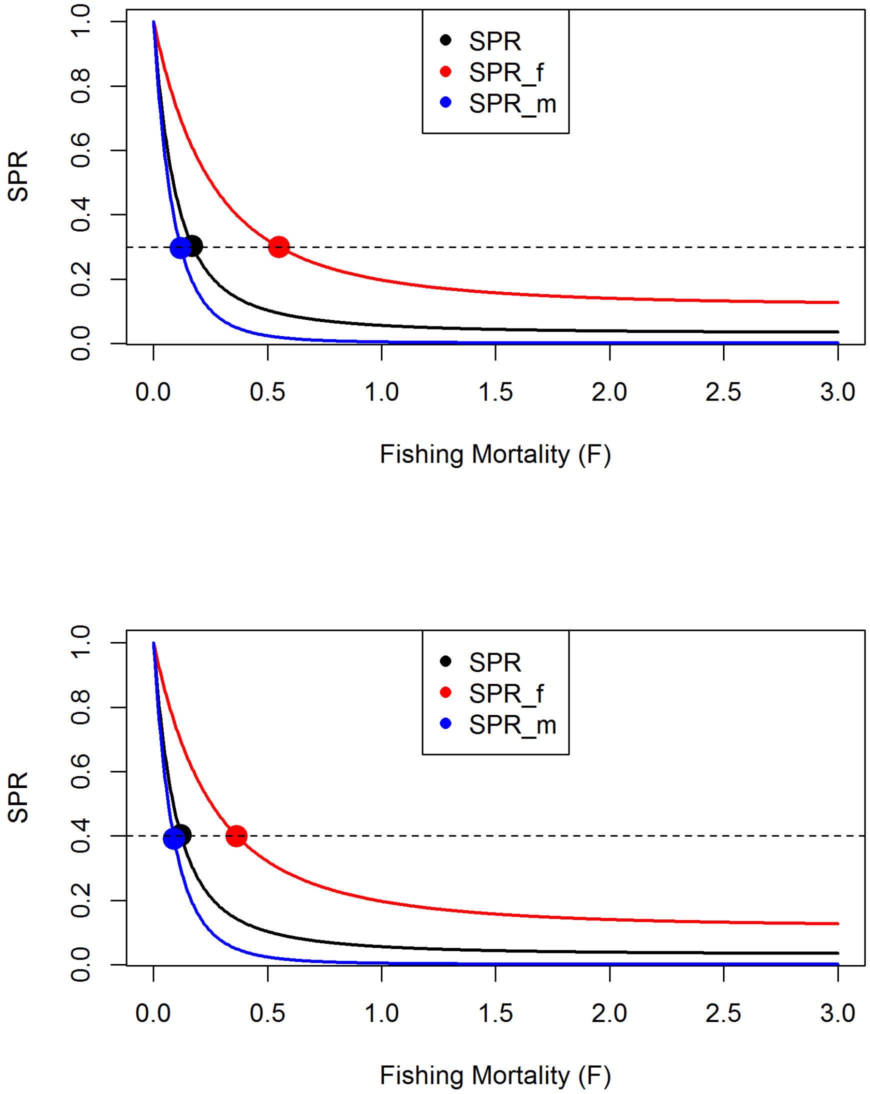


Figure 1. The spawning potential ratio curves for Puerto Rico hogfish from the abundance and maturity of both sexes (black), females only (red), and males only (blue). Top figure indicates reference points at SPR = 30% and bottom figure indicate those at SPR = 40%.

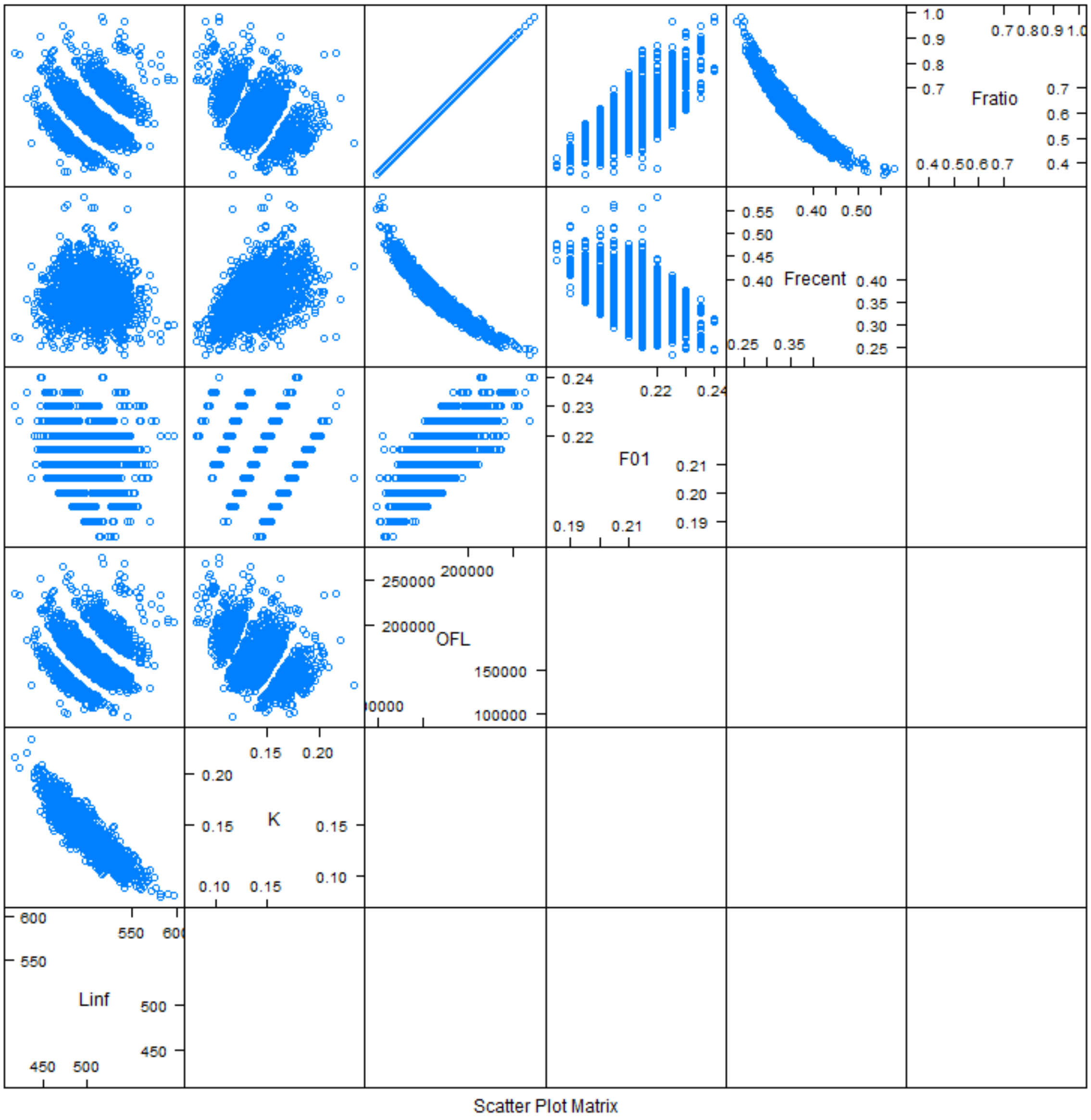


Figure 2. Scatterplot matrix of the sensitivity of the OFL to Linf and K for yellowtail snapper using $F_{0.1}$ as the reference point. Fratio is the ratio of $F_{0.1}$ and F_{recent}.

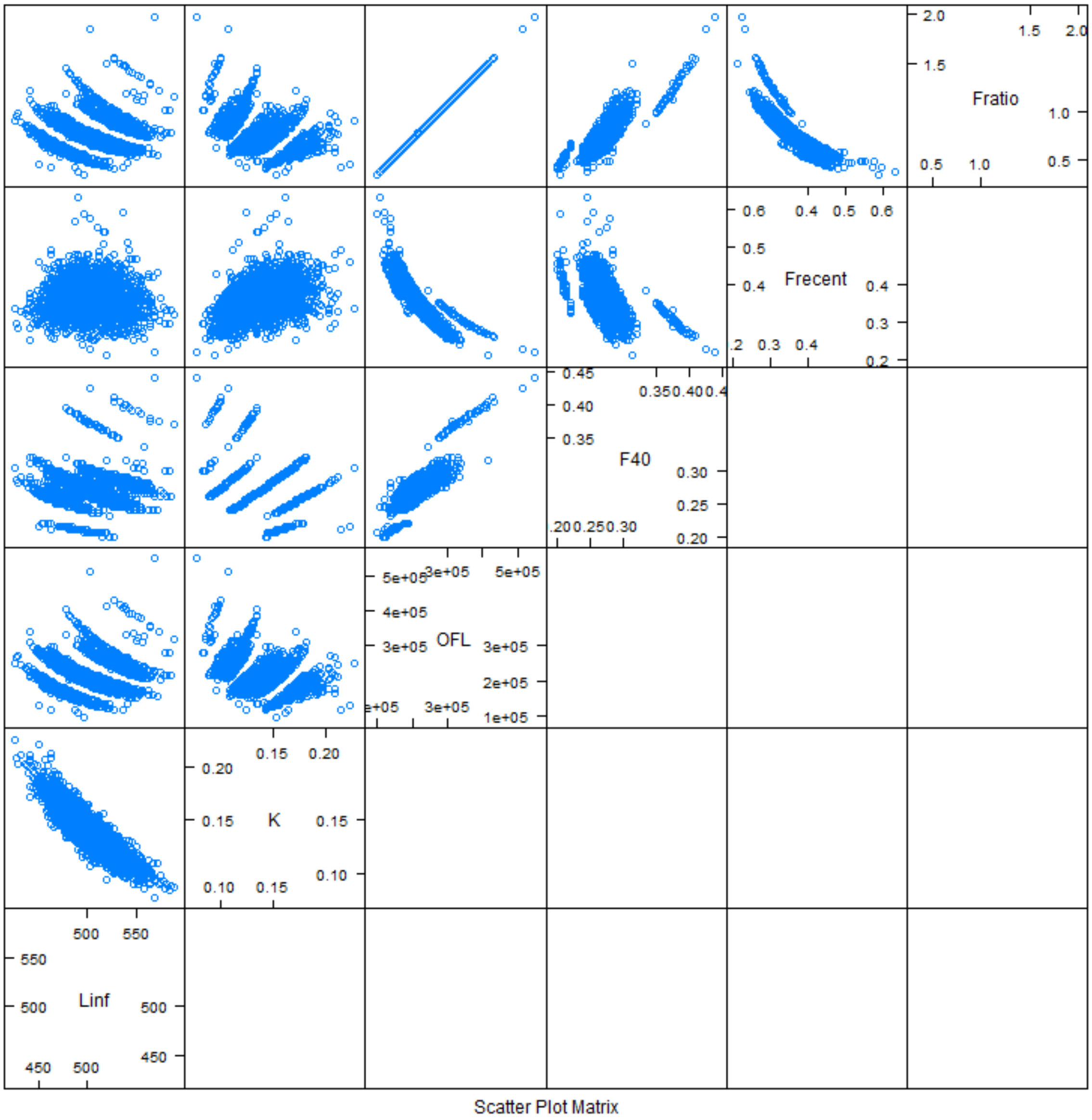


Figure 2. Scatterplot matrix of the sensitivity of the OFL to Linf and K for yellowtail snapper using $F_{40\%}$ as the reference point. Fratio is the ratio of $F_{40\%}$ and F_{recent}.

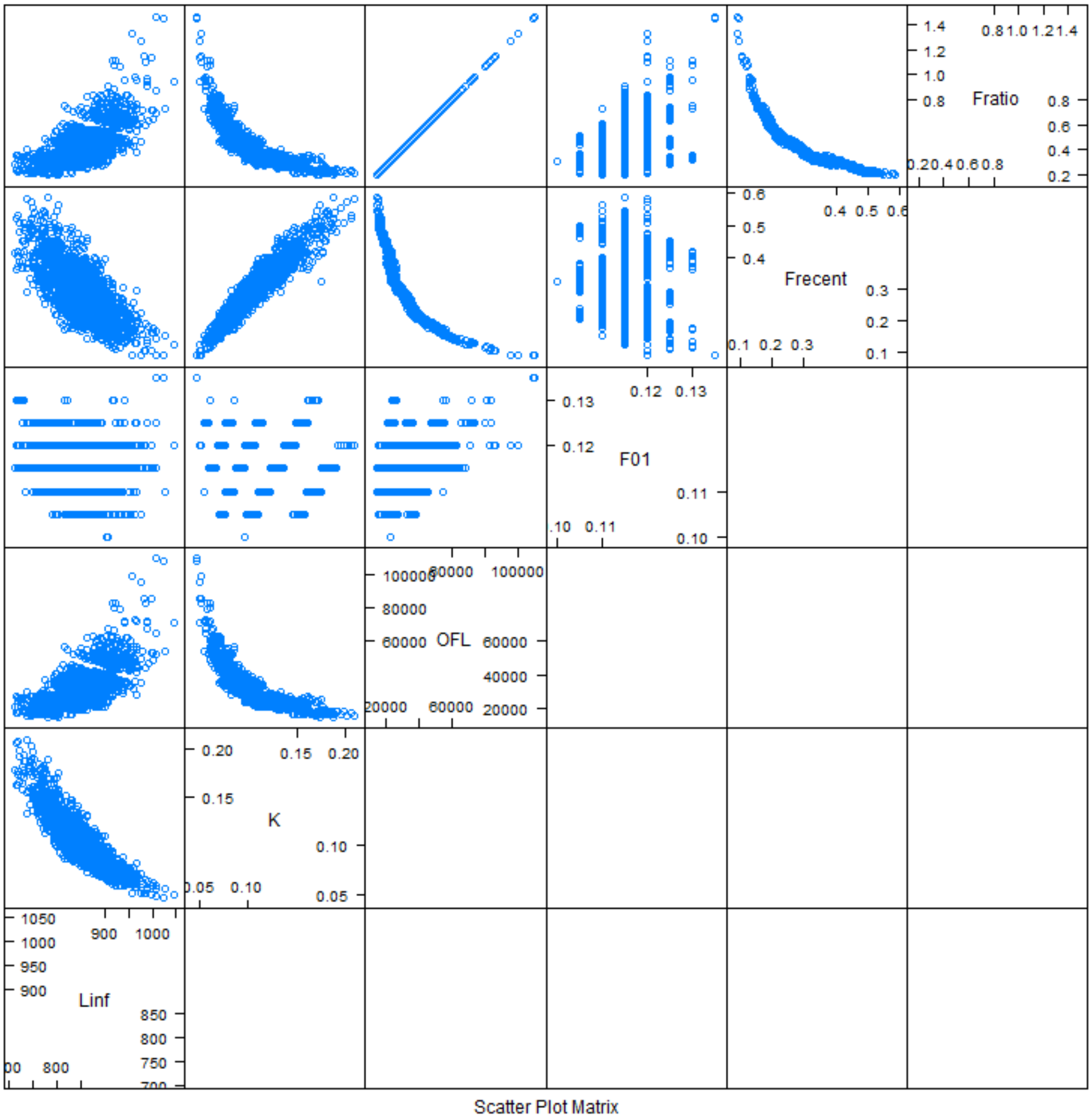


Figure 3 Scatterplot matrix of the sensitivity of the OFL to Linf and K for hogfish using $F_{0.1}$ as the reference point. Fratio is the ratio of $F_{0.1}$ and F_{recent}.

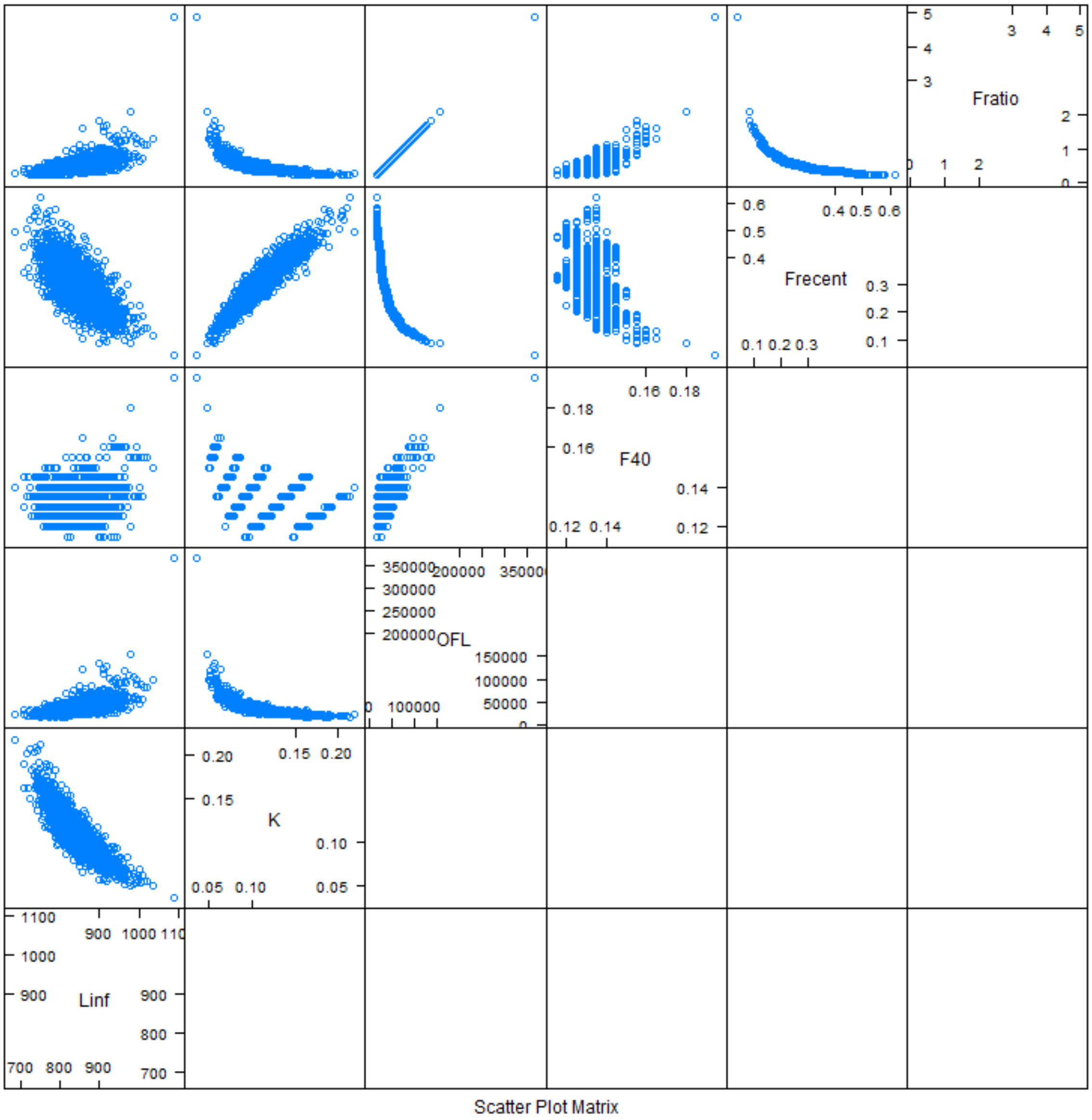


Figure 5. Scatterplot matrix of the sensitivity of the OFL to Linf and K for hogfish using $F_{40\%}$ as the reference point. Fratio is the ratio of $F_{40\%}$ and $F_{recent.}$