Age Structured Models
Stock Synthesis in the U.S. Caribbean

SEDAR 103

Caribbean Application of Alternate Assessment Methods

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Species assessed in Caribbean SEDARs

Common Name	Scientific Name	Recommended as useful for management	Not recommended as useful for management
Caribbean Spiny Lobster	*Panulirus argus*	SEDAR 57, SEDAR 91	SEDAR 8, SEDAR 46
Queen Triggerfish	*Balistes vetula*	SEDAR 80	SEDAR 30, SEDAR 46
Yellowtail Snapper	*Ocyurus chrysurus*	-	SEDAR 8, SEDAR 46, SEDAR 84*
Stoplight Parrotfish	*Sparisoma viride*	-	SEDAR 84*
Hogfish	*Lachnolaimus maximus*	-	SEDAR 46
Red Hind	*Epinephelus guttatus*	-	SEDAR 35
Blue Tang	*Acanthurus coeruleus*	-	SEDAR 30
Queen Snapper	*Etelis oculatus*	-	SEDAR 26
Redtail Parrotfish	*Sparisoma chrysopterum*	-	SEDAR 26
Silk Snapper	*Lutjanus vivanus*	-	SEDAR 26
Mutton Snapper	*Lutjanus analis*	-	SEDAR 14
Queen Conch	*Lobatus gigas*	-	SEDAR 14
Yellowfin Grouper	*Mycteroperca venenosa*	-	SEDAR 14

Number of Species assessed at a time

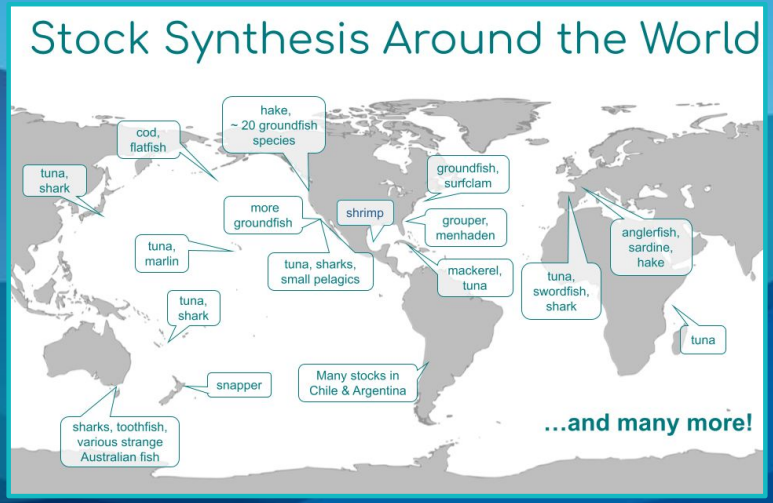
SEDARs #	SAR Year	Caribbean SEDARs (10)	# of Species	# of Stocks
SEDAR 8	2005	Caribbean Yellowtail Snapper, Caribbean and Southeast US Spiny Lobster	2	3
SEDAR 14	2007	Caribbean Yellowfin Grouper, Mutton Snapper, and Queen Conch	3	9
SEDAR 26	2011	Caribbean Queen Snapper, Silk Snapper, and Redtail Parrotfish	3	9
SEDAR 30	2013	US Caribbean Blue Tang and Queen Triggerfish	2	6
SEDAR 35	2014	Caribbean Red Hind	1	3
SEDAR 46	2016	US.Caribbean Data-Limited Species	6	6
SEDAR 57	2019	US Caribbean Spiny Lobster	1	3
SEDAR 80	2022	Caribbean Queen Triggerfish	1	3
SEDAR 84	2025	Caribbean Yellowtail Snapper and Stoplight Parrotfish	2	3
SEDAR 91	2025	US Caribbean Spiny Lobster	1	3

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Methods

SEDARs #	Term. Year	SEDAR DW Year	SAR Year	Methods
SEDAR 8	2002	2004	2005	Non-equilibrium production models (ASPIC)
SEDAR 14	2005	2007	2007	CPUE Models, Length Based Mortality Estimator, Habitat Model
SEDAR 26	2009	2011	2011	Length Based Mortality Estimator
SEDAR 30	2011	2012	2013	Length Based Mortality Estimator
SEDAR 35	2012	2014	2014	Gedamke-Hoenig Length-Based Estimator, Yield per recruit analysis
SEDAR 46	2014	2015	2016	Data-Limited Methods Toolkit (DLMtool)
SEDAR 57	2016	2018	2019	Stock Synthesis
SEDAR 80	2019	2022	2022	Stock Synthesis
SEDAR 84	2022	2024	2025	Stock Synthesis
SEDAR 91	2023	2024	2025	Stock Synthesis

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Age-Structured Modeling in the US Caribbean

SEDAR 103 Data Webinar 6

July 2026

Adyan Rios, Research Fisheries Ecologist

NOAA Fisheries, SEFSC, Sustainable Fisheries Division, Caribbean Fisheries Branch

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Stock Synthesis as an Age-Length Model

- Methot, 1989; Methot and Wetzel 2013
  - ADMB-based
  - Size & age based model with spatial structure, gender and growth-morphs
  - Density-dependence integrated through spawner-recruitment
- Integrated analysis - How it works:
  - Use population equations (mortality, growth, maturity, selectivity) to build a simulated reality.
  - Use Maximum Likelihood Estimation (MLE) to tune our parameters until our simulated data matches our observed data.
  - Balance a good statistical match with believable biology, choosing what to estimate vs. what to fix.

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Stock Synthesis Observation Model

Capable of producing expected value for these types of data

Catches	Indices of abundance
Assumed stock depletion	Index of random effect
Discards	Absolute abundance
Effort	Average weight
Tagging	Average length

Composition Data from catch, discard, survey: Length; Age (with ageing error)

Weight or Length composition with flexible binning

Age-conditional-on-length

Average length-at-age, average weight-at-age (with ageing error)

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The US Caribbean Landscape

- Successfully implemented Stock Synthesis for complex data-limited stocks, specifically **Spiny Lobster** and **Queen Triggerfish** (SEDARs 57, 57U, 91, and 80).
  - Developed OFLs and ABCs paired with the Caribbean Fishery Management Council's ABC Control Rule
- Attempted **Yellowtail Snapper** and **Stoplight Parrotfish** (SEDAR 84).

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Tier 2: Data Moderate	
Condition for Use, MSY, SDC	Data-moderate approaches where two of the three time series (catch, stage composition, and index of abundance) are deemed informative by the assessment process, and the assessment can provide MSST, MFMT, and PDF of OFL.
ABC	Same as Tier 1, but variation of the PDF of OFL (σ) must be greater than 1.5 σ_{min} (in principle there should be more uncertainty with data-moderate approaches than data-rich approaches).
Tier 3: Data Limited: Accepted Assessment Available	
Condition for Use	Relatively data-limited or out-of-date assessments
MSY	MSY proxy = long-term yield at proxy for F_{MSY}
SDC	MFMT = F_{MSY} proxy MSST = 0.75* SSB_{MFMT} or proxy OFL = Catch at MFMT
ABC	ABC determined from OFL as reduced (buffered) by scientific uncertainty[4] and reflecting the acceptable probability of overfishing[2] a. Where the buffer is applied to the PDF of OFL when the PDF is determined from the assessment (with $\sigma \geq 2\sigma_{min}$) **OR** b. Where ABC = buffer * OFL, where buffer must be ≤ 0.9



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Summary of SEDAR 80

- Discussions with stakeholders and the SSC guided **dome-shaped selectivity and steepness inputs**
- Reference model diagnostics stable but we are unable to estimate **MSY and stock status** with confidence
  - Conflicting signals across the data sources
  - Sensitivity to inputs of growth, mortality, and data component reweighting
  - Correlated key parameters
  - There are relatively few sources of data



STTJ Data Overview

- Commercial landings (annual) and composite length composition
- RVC index and observed length composition by year

Estimated Parameters

- **Unfished recruitment (R0)**
- **Selectivity parameters**
- **Initial F (2000)**

Fixed Parameters

- Growth
- Natural Mortality
- Maturity
- **Steepness (0.99)**
- **Sigma R (0.6)**

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Characterizing Uncertainty



Diagnostics

- Residual patterns
- Jitter
- Retrospective

Sensitivity

- Life history growth (higher CV)
- Run alternative growth (higher Lmax)
- Run alternative natural mortality (lower M)
- Run with reweighting (Dirichlet multinomial)
- Runs with a higher equilibrium catch (60 and 80 mt)

Profiles

- Steepness and RVC domed selectivity
- Initial equilibrium catch
- R0

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Steepness and Domed Selectivity Profile

Profile Result Total Likelihood	Final selectivity parameter NCRMP Reef Visual Census Survey				
Steepness	0.97	0.93	0.88	0.83	0.79
0.4	528.286	525.386	522.537	519.749	517.04
0.5	524.44	521.65	518.912	516.24	513.649
0.6	522.18	519.465	516.804	514.21	511.7
0.7	520.961	518.297	515.689	513.149	510.694
0.8	520.579	517.95	515.378	512.876	510.458
0.9	521.262	518.658	516.112	513.636	511.245
0.99	526.252	523.665	521.136	518.677	516.304

Profile Result Survey Likelihood	Final selectivity parameter NCRMP Reef Visual Census Survey				
Steepness	0.97	0.93	0.88	0.83	0.79
0.4	46.5911	46.5735	46.5596	46.5495	46.5434
0.5	46.7585	46.7325	46.7089	46.6888	46.6724
0.6	46.8602	46.8307	46.8038	46.7802	46.76
0.7	46.9381	46.908	46.8802	46.8553	46.8335
0.8	47.0051	46.9738	46.9458	46.9199	46.8977
0.9	47.0622	47.0311	47.0025	46.9768	46.9536
0.99	47.1073	47.0764	47.0475	47.0211	46.9975

Profile Result R0	Final selectivity parameter NCRMP Reef Visual Census Survey				
Steepness	0.97	0.93	0.88	0.83	0.79
0.4	6.8609	6.88022	6.9011	6.92363	6.94798
0.5	6.84883	6.86686	6.88606	6.90688	6.9294
0.6	6.83288	6.85003	6.86841	6.88834	6.90993
0.7	6.81676	6.83366	6.85176	6.87132	6.8925
0.8	6.80247	6.81907	6.83716	6.8565	6.87765
0.9	6.79	6.80672	6.82473	6.84427	6.86534
0.99	6.78049	6.79737	6.81545	6.83496	6.8561

Profile Result Composition Likehood	Final selectivity parameter NCRMP Reef Visual Census Survey				
Steepness	0.97	0.93	0.88	0.83	0.79
0.4	456.771	454.243	451.775	449.381	447.076
0.5	456.789	454.273	451.818	449.436	447.144
0.6	456.81	454.295	451.841	449.461	447.17
0.7	456.801	454.282	451.826	449.444	447.151
0.8	456.765	454.245	451.786	449.403	447.108
0.9	456.719	454.197	451.737	449.351	447.057
0.99	456.676	454.152	451.69	449.304	447.01

Profile Result Initial F	Final selectivity parameter NCRMP Reef Visual Census Survey				
Steepness	0.97	0.93	0.88	0.83	0.79
0.4	0.20	0.20	0.19	0.18	0.17
0.5	0.21	0.20	0.19	0.19	0.18
0.6	0.22	0.21	0.20	0.19	0.19
0.7	0.22	0.22	0.21	0.20	0.19
0.8	0.23	0.22	0.21	0.21	0.20
0.9	0.24	0.23	0.22	0.21	0.20
0.99	0.24	0.23	0.22	0.21	0.20

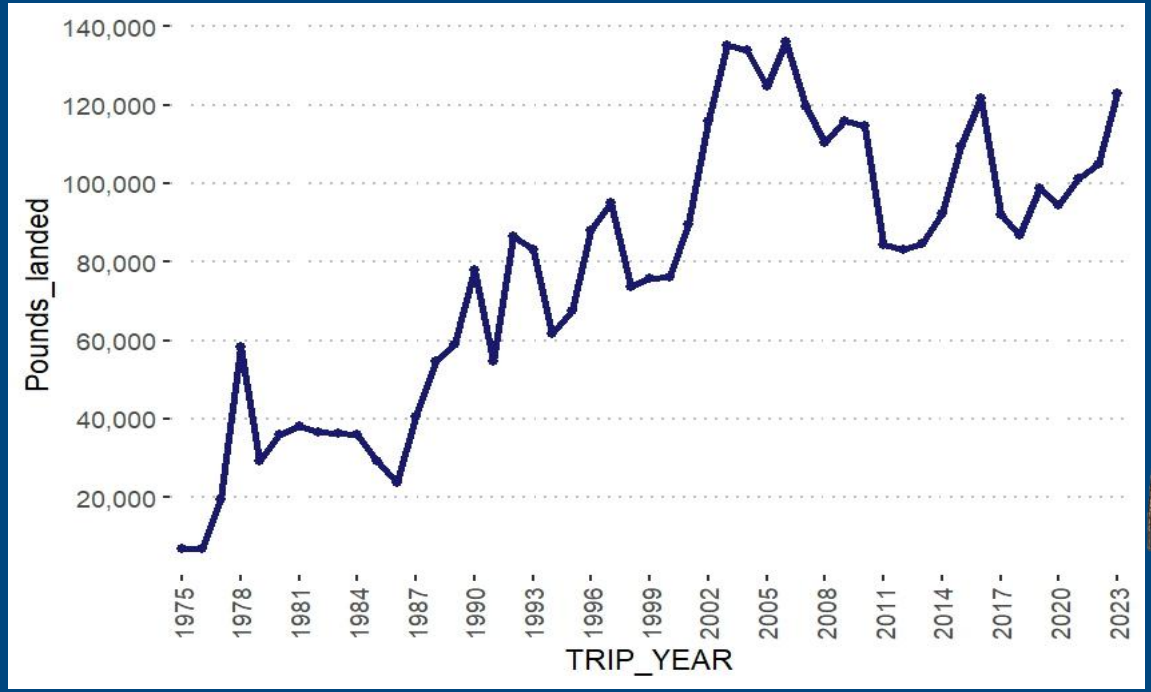
Profile Result Recruitment Likelihood	Final selectivity parameter NCRMP Reef Visual Census Survey				
Steepness	0.97	0.93	0.88	0.83	0.79
0.4	23.65	23.32	22.99	22.64	22.27
0.5	20.10	19.89	19.66	19.43	19.18
0.6	17.85	17.72	17.57	17.42	17.26
0.7	16.40	16.32	16.24	16.14	16.03
0.8	15.44	15.40	15.35	15.29	15.23
0.9	14.78	14.76	14.74	14.71	14.67
0.99	14.35	14.35	14.35	14.33	14.31

Fixed Parameters
in Reference Model
Steepness = 0.99
RVC Sel Final = 0.90



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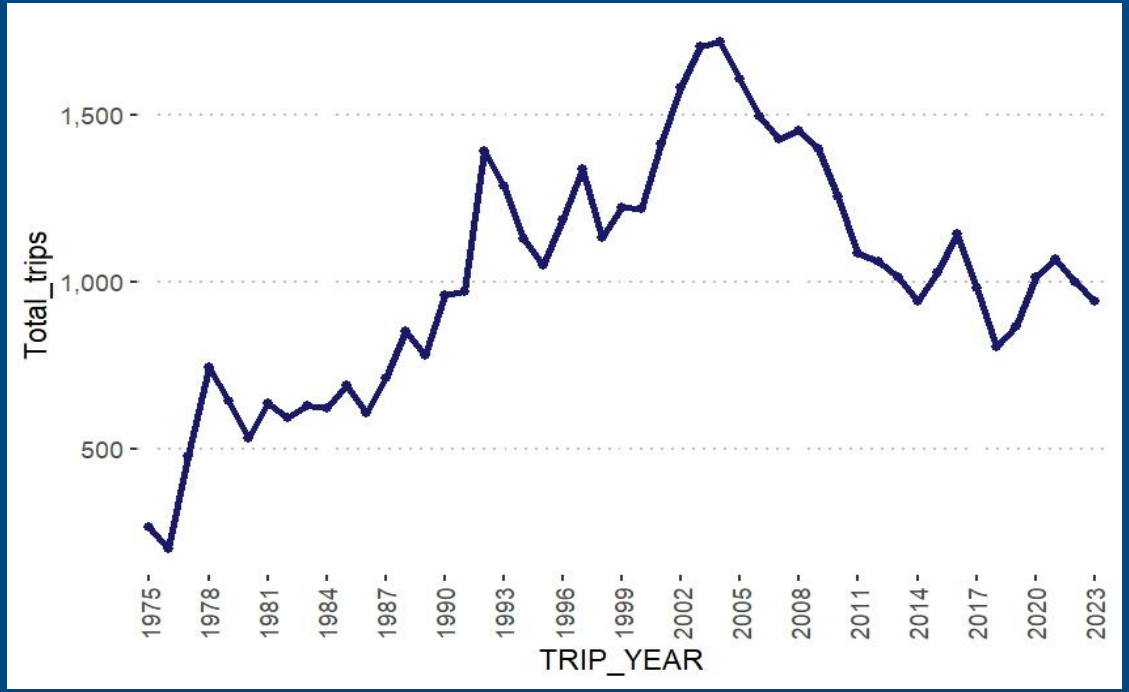
STTJ Spiny Lobster Commercial Landings
SEDAR 91





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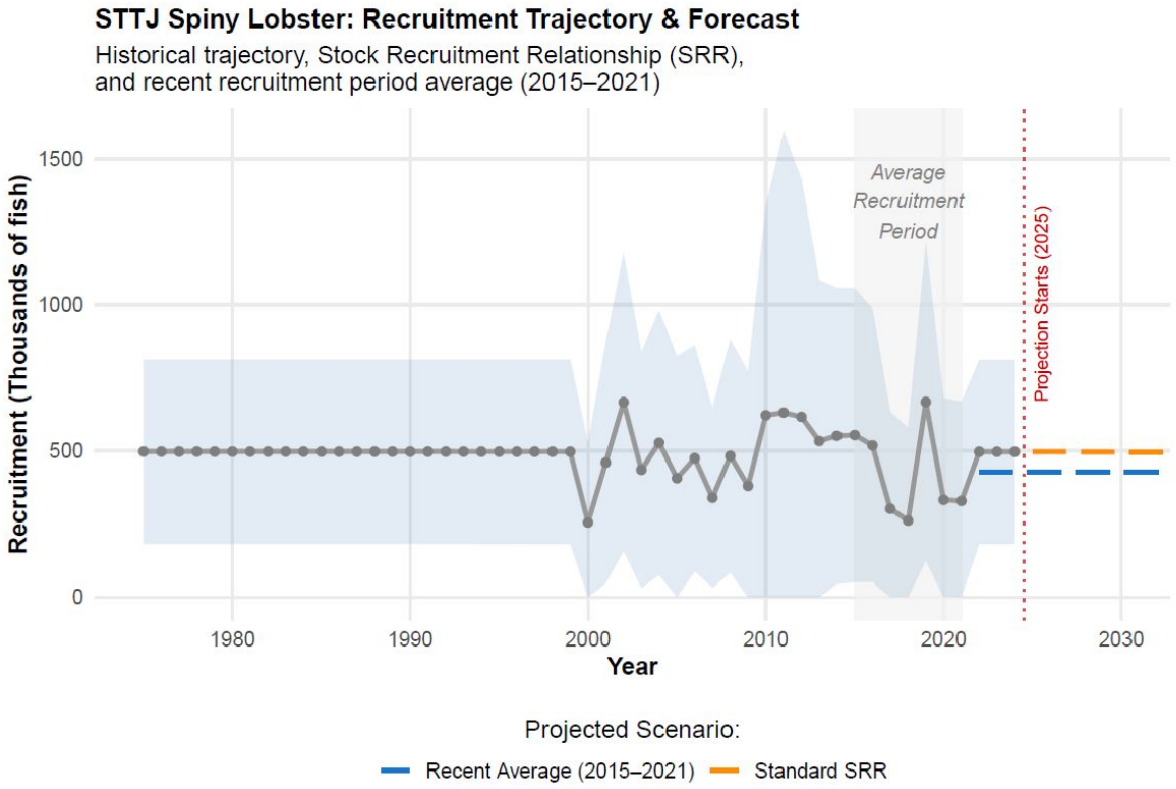
STTJ Spiny Lobster Commercial Trips
SEDAR 91





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Challenges and Opportunities

- Rigid growth curves estimated outside the model rather than letting SS dynamically estimate them.
- A necessary over-reliance on fixed parameters.
- Lack of long-term abundance indices.
- Relatively short species-specific landings time series, requiring estimation of initial fishing mortality.
- Very low sample sizes in our length composition data, leading to conflicting signals.

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Challenges and Opportunities

- To make these models work under data limitations, we cannot just look at a single model run. We have to evaluate model performance and stability.
- We use techniques like Jittering to ensure our models converge, Likelihood Profiles to check parameter sensitivity, and Uncertainty Grids to capture structural doubt.

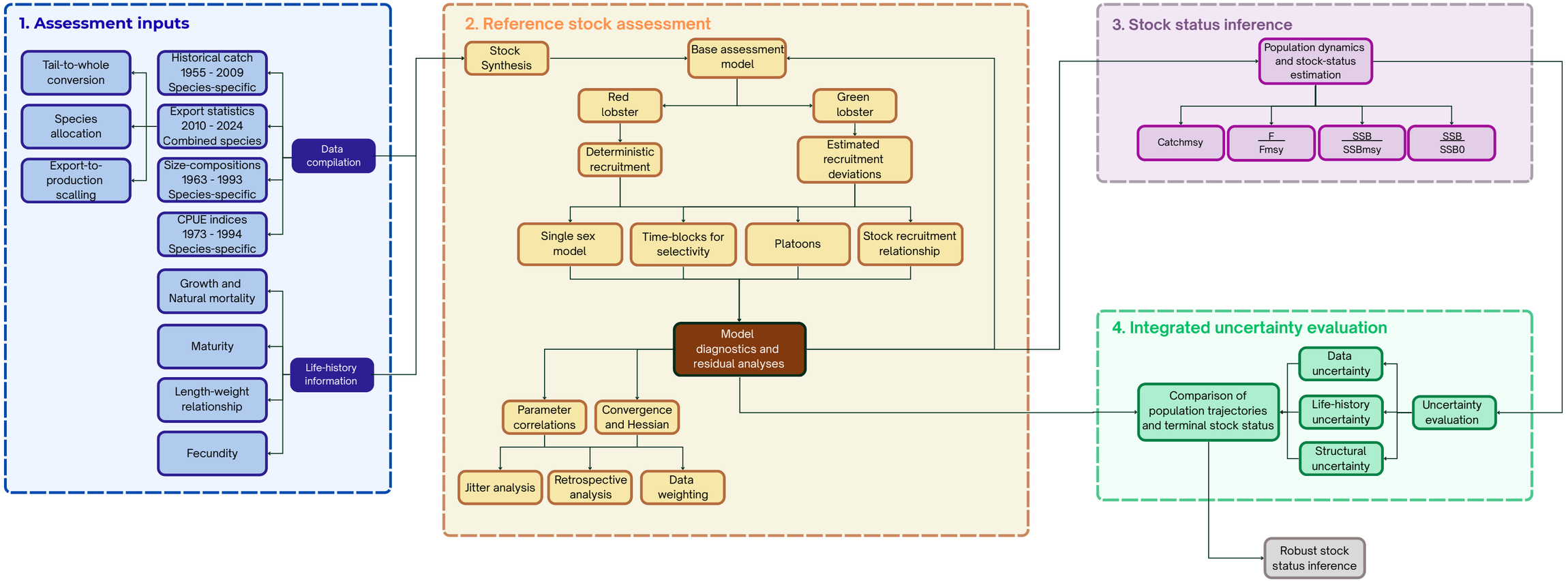
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A structured framework for uncertainty evaluation in data-limited stock assessments: application to Brazilian spiny lobsters

Lucas Silva – UFRPE
Jason Cope – NOAA
Humber Andrade – UFRPE

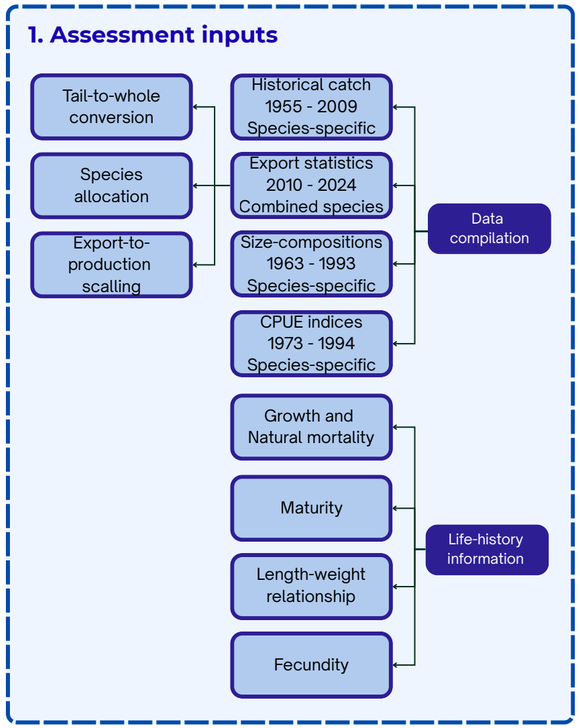
Miami, 2026

Integrated modelling framework

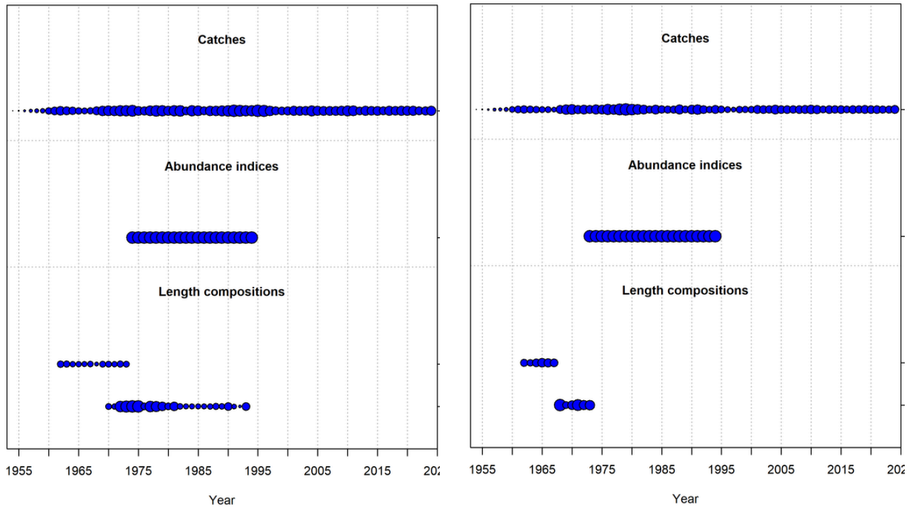


Integrated modelling framework

1. Assessment inputs



1.1. Data compilation



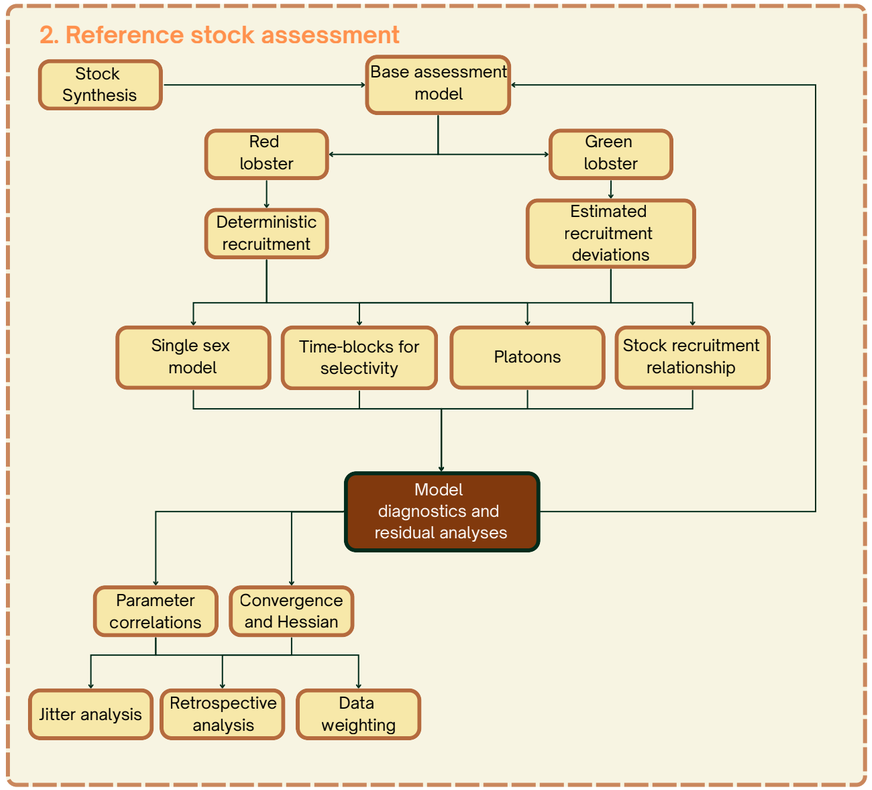
a) catch: 1955 to 2009 - Silva and Fonteles-Filho (2011);
b) export data: 2010 to 2024 - ComexStat database
c) size-composition: 1963 to 1973 - Paiva and Costa (1964 – 1974) for both species
d) size-composition: 1970 to 1993 - Ivo and Pereira (1996) for red lobster
e) catch per unit effort: 1973 to 1994 - Ivo and Pereira (1996)

1.2. Life-history

Natural mortality (M)
Growth ($L\infty$, K, and t0)
Maturity (L50 and L95)
Length-weight relationship (a and b)
Fecundity (a and b)

Integrated modelling framework

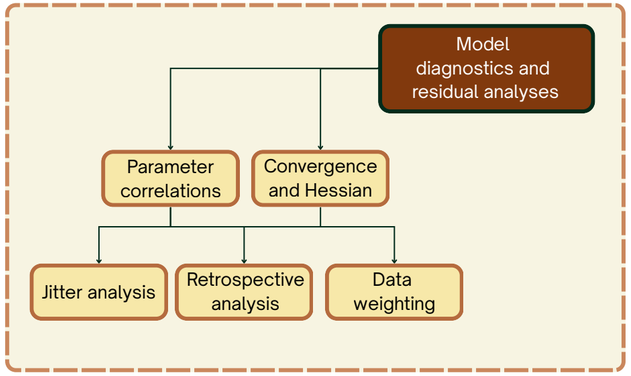
2. Reference stock assessment



Stock Synthesis (Methot and Wetzel, 2013)
SACTool (Cope, 2020)

Steepness (h =0.7)
Recruitment deviation (σR = 0.6)
Autocorrelation (ρ = 0)
Selectivity (Dome-shaped / Time block)

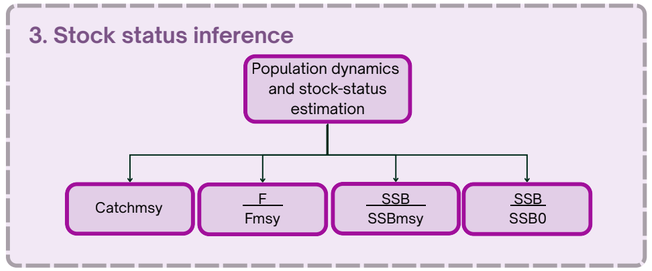
2.1. Model diagnostics and residual analysis



Carvalho et al., 2021

Integrated modelling framework

3. Stock-status inference



MSY

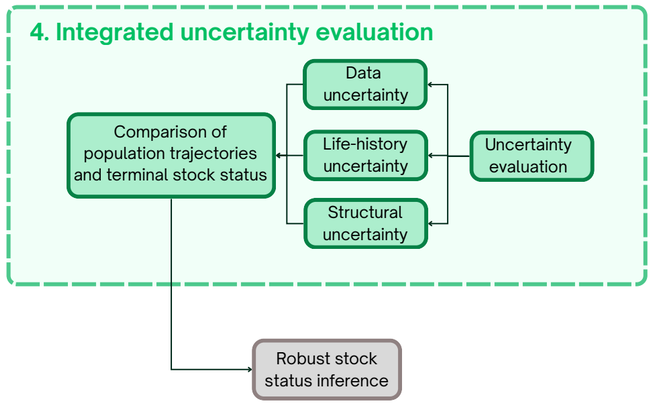
- Not overfished: SSB/SSBMSY ≥ 1
- Overfished: SSB/SSBMSY < 1
- Not experiencing overfishing: F/FMSY < 1
- Experiencing overfishing: F/FMSY ≥ 1

SSB0

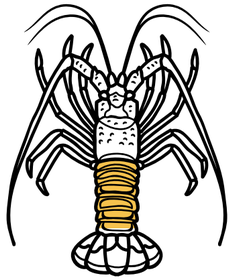
- Underexploited: SSB/SSB0 > 0.40
- Transitional or recovering state: 0.25 < SSB/SSB0 ≤ 0.40
- Overexploited: SSB/SSB0 ≤ 0.25

Integrated modelling framework

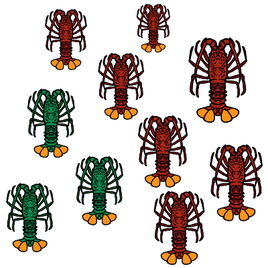
4. Uncertainty evaluation



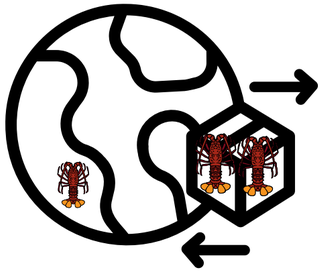
4.1. Data uncertainty



Tail-to-whole
(0.3, 0.33, 0.346)



Species-composition
(63.9%, 70%, 73.1%)



Export-to-production
(80%, 90%, 95%)

4.2. Life-history uncertainty

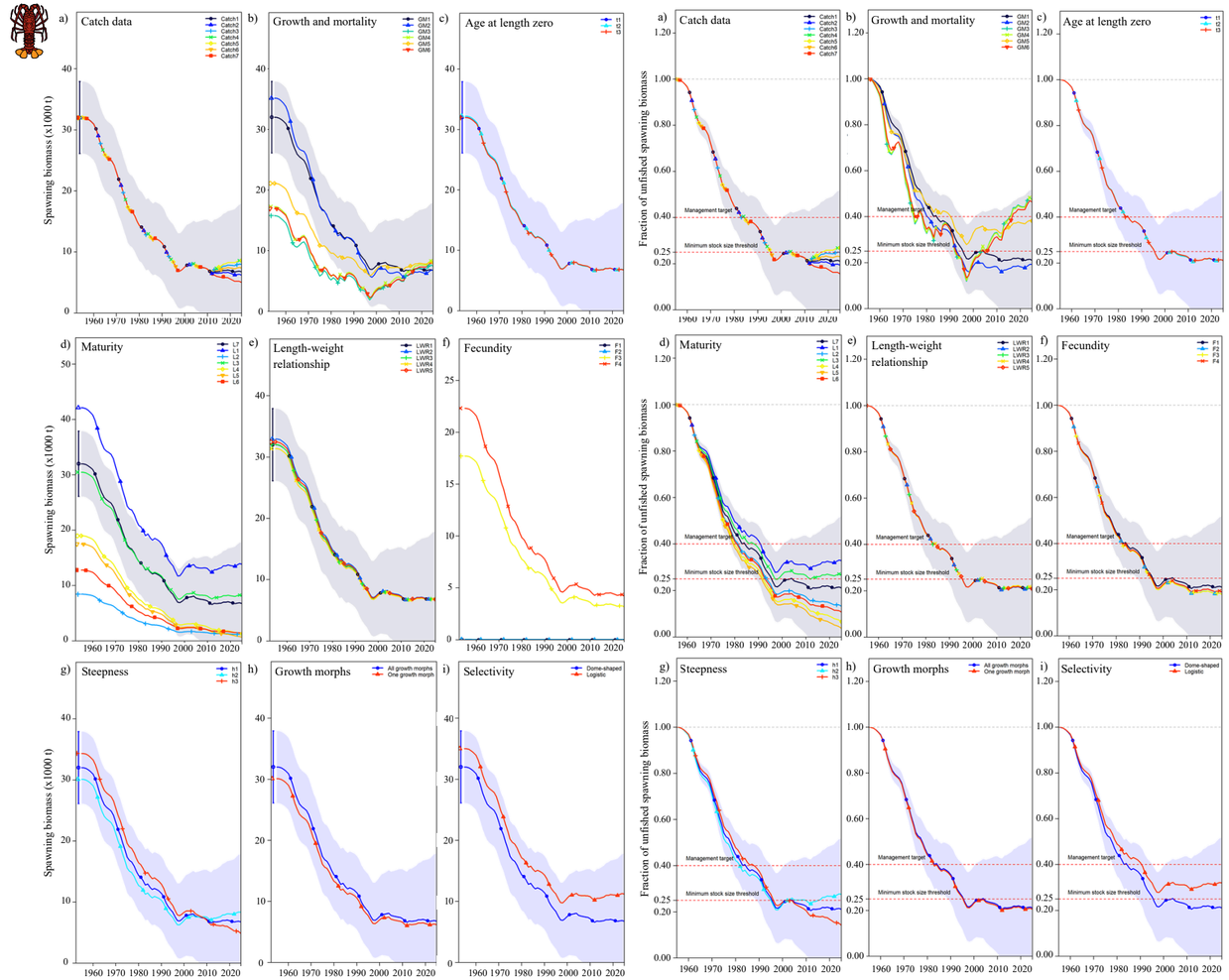
Growth (L∞, K, t0)
Mortality (M)
Maturity (L50, L95)
Length-weight relationship (LWRa, LWRb)
Fecundity (F)

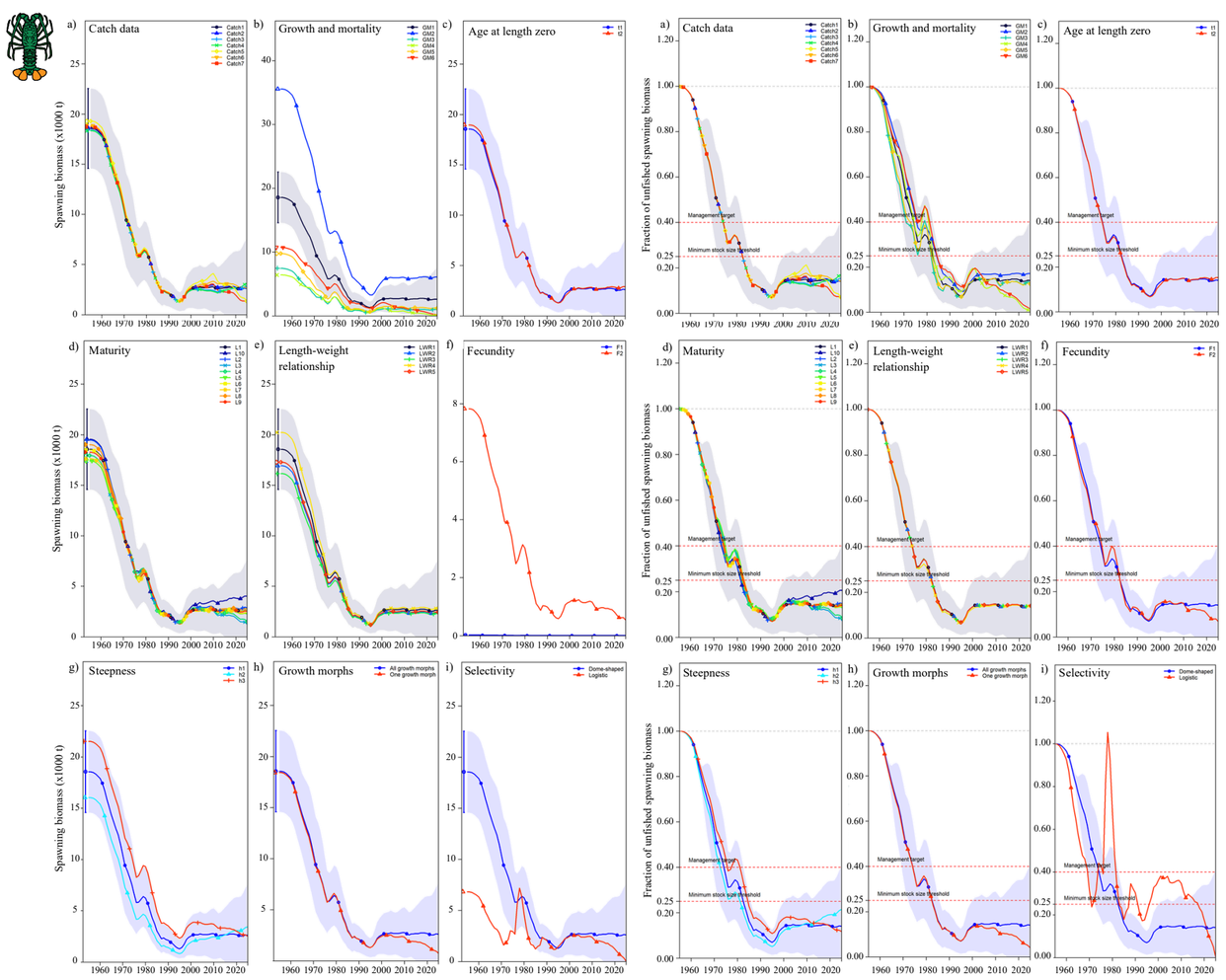
4.3. Structural uncertainty

Selectivity
Growth morphs
Steepness (h)

Red lobster - 25 scenarios
Green lobster - 29 scenarios

Uncertainty evaluation





Conclusions

Data

- Recent stock dynamics are informed mainly by reconstructed catches and historical biological data: growth, mortality and maturity
- Historical data can still support robust qualitative inference
- Lack of contemporary length compositions and abundance indices increases uncertainty in terminal estimates

Uncertainty evaluation

- Biological and structural assumptions were the main sources of uncertainty
- Catch reconstruction had a comparatively smaller effect
- Sensitivity differed between species
- Uncertainty affected population scale and stock status differently
- Identifying which assumptions change biomass magnitude versus management conclusions is critical for robust data-limited stock assessments.

Acknoledgements









