Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission




CIAT
IATTC

Development of a flexible Ecological Risk Assessment (ERA) approach for quantifying the cumulative impacts of fisheries on bycatch species in the eastern Pacific Ocean

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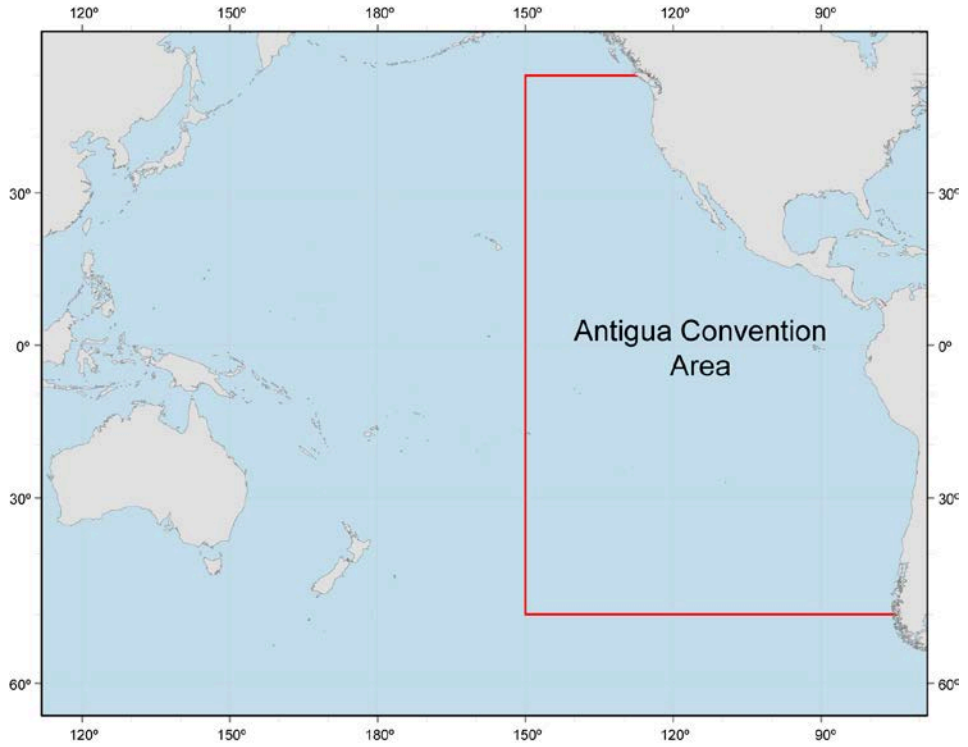
9th Meeting of the Scientific Advisory Committee La Jolla, California USA, 14-18 May 2018

Outline

- Inter-American Tropical Tuna Commission (IATTC) responsibilities
- The need to consider the ecological sustainability of fisheries
- Previous Ecological Risk Assessment (ERA) methods
- Description of a new ERA approach – “EASI-Fish”
- Application of EASI-Fish to EPO fisheries

Outline

- IATTC responsible for conservation and management of tuna, tuna-like and ‘associated species’ of fish in the EPO
- IATTC area covers ~55 million km^2 and several transitional areas
- Incorporates national jurisdictions and ABNJ



Ecological sustainability

- IATTC committed to ensuring ecologically sustainability
  - Antigua Convention, specific IATTC Resolutions (e.g. sharks, rays, turtles, dolphins)

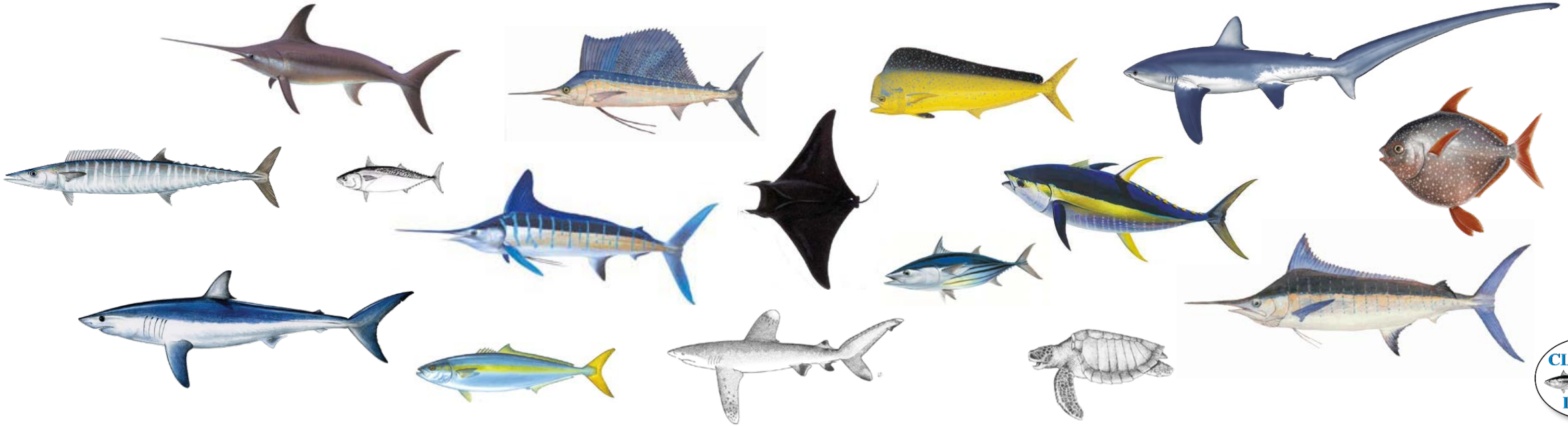
To ensure the "*long-term conservation and sustainable use of the stocks of tunas and tuna-like species and other associated species of fish taken by vessels fishing for tunas and tuna-like species in the eastern Pacific Ocean (EPO)*"

Article IV. "*Where the status of target stocks or non-target or associated or dependent species is of concern, the members of the Commission shall subject such stocks and species to enhanced monitoring in order to review their status and the efficacy of conservation and management measures.*"

Article VII. "…*adopt, as necessary, conservation and management measures and recommendations for species belonging to the same ecosystem and that are affected by fishing for, or dependent on or associated with, the fish stocks covered by this Convention, with a view to maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened*"

Ecological sustainability

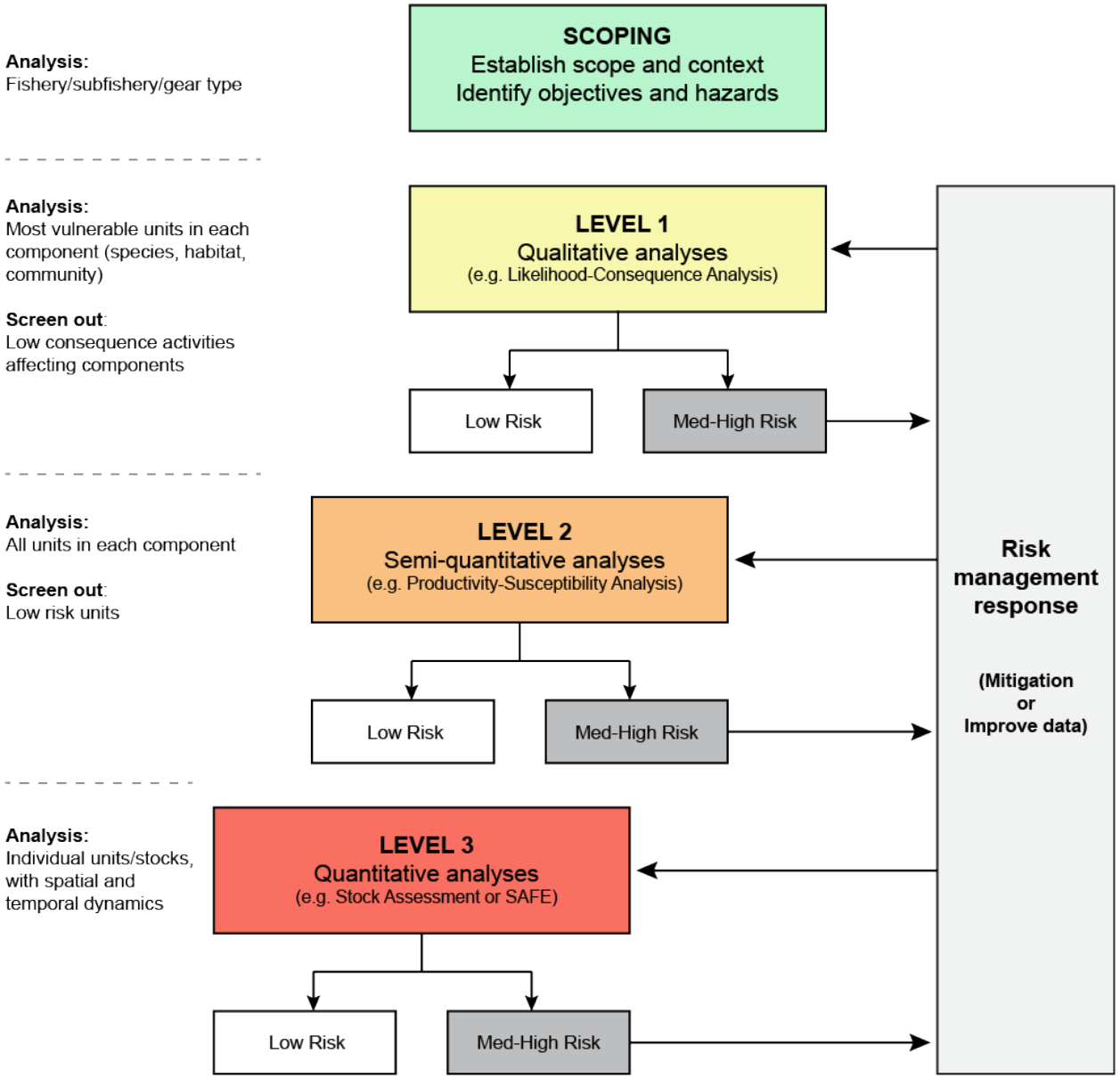
- But many species interactions across EPO fisheries
- Many caught incidentally - “bycatch” & “byproduct”
- Some caught infrequently, many have little value, poor reporting or recorded in broad taxonomic groups (e.g. “sharks”).
- Lack basic biological and ecological data for traditional assessment



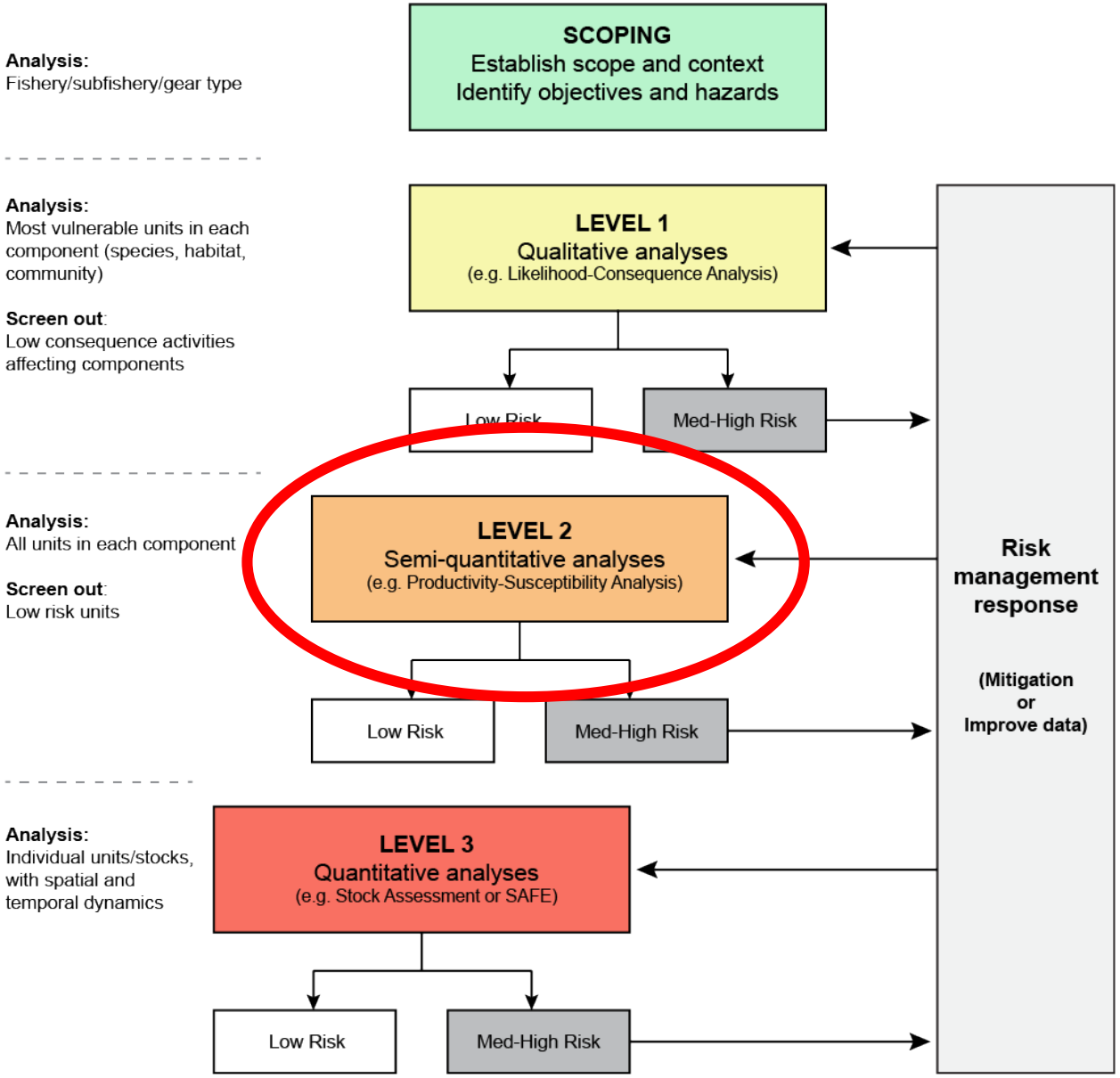
Ecological Risk Assessment (ERA)

- Pursuing EBFM is necessary, but a long and expensive process
- IATTC staff cannot study/monitor every species with existing resources
- But, IATTC committed through its 5-year IATTC strategic science plan to a long-term strategy to continue to fill data gaps and develop methods to assess ecological sustainability
- As a starting point, the ecosystem group has adopted the Ecological Risk Assessment for the Effects of Fishing (ERAEF) framework, proposed by Hobday et al. (2011)

ERAEF Framework

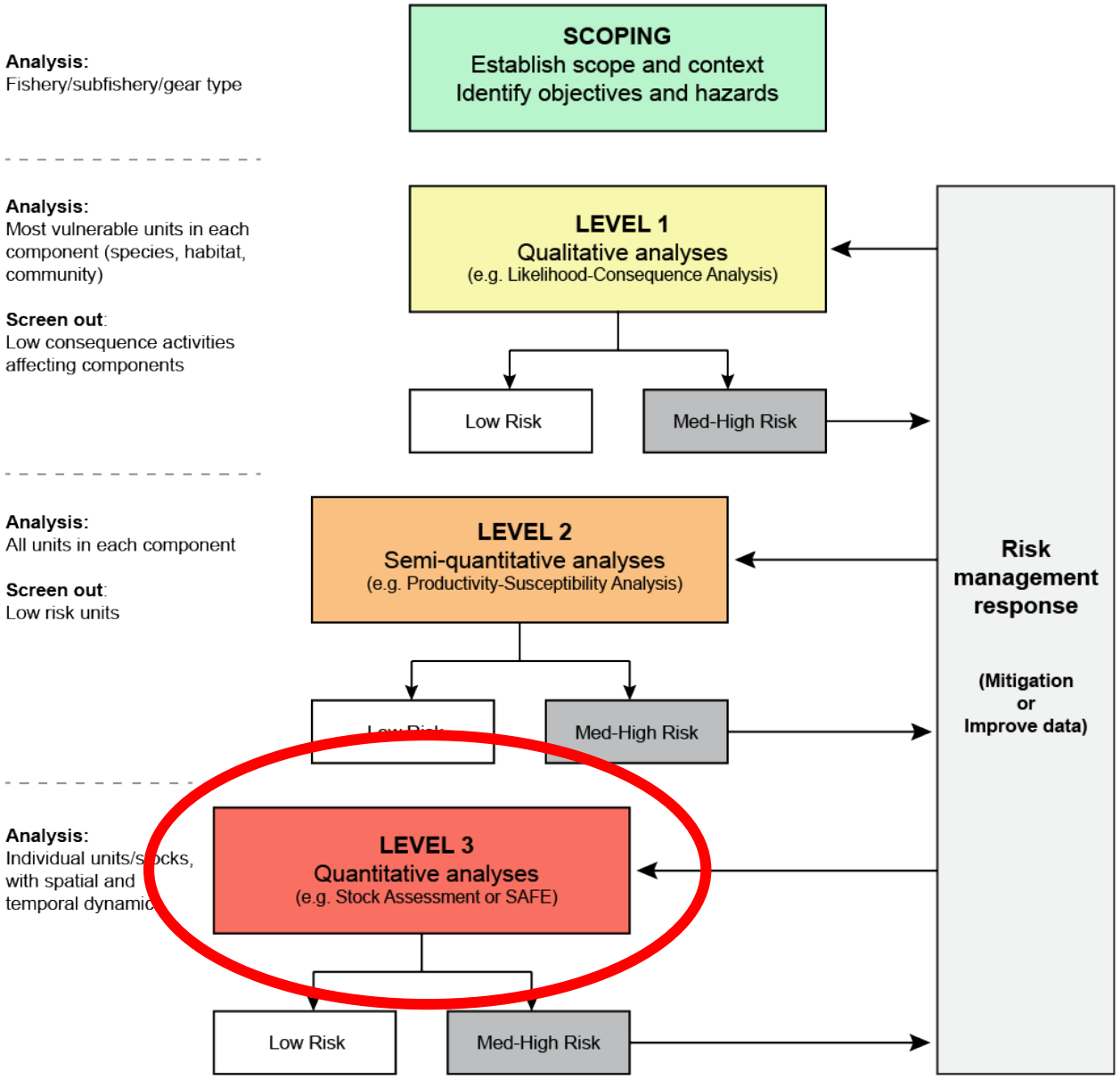


ERAEF Framework



- PSA for purse-seine (Class 6) and ‘industrial’ longline
- Other PSAs were planned but now superseded by EASI-Fish

ERAEF Framework



- PSA for purse-seine (Class 6) and 'industrial' longline
- Other PSAs were planned but now superseded by EASI-Fish
- EASI-Fish is a Level 3 analysis, similar to SAFE

Ecological Risk Assessment (ERA)

- Used in data-limited settings to prioritize species most vulnerable to fishing impacts
  - Implement immediate mitigation measures to reduce risk
  - Further data collection and research for future conventional assessment

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Ecological Risk Assessment (ERA)

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  - Implement immediate mitigation measures to reduce risk
  - Further data collection and research for future conventional assessment
- Qualitative ('expert opinion') to quantitative methods
- Semi-quantitative Productivity-Susceptibility Analysis (PSA)
  - Rapid
  - Inexpensive
  - Minimal data required
  - Widely used (e.g. WCPFC, IOTC, ICCAT, IATTC)
  - Preferred ERA method by MSC for fishery certification

Productivity-Susceptibility Analysis (PSA)

- **“Vulnerability”** – potential for the productivity of a stock to be diminished by direct and indirect fishing pressure.

1. **Susceptibility** – propensity of species to be captured by, and incur mortality from, a fishery (e.g. spatial overlap by fishery, gear selectivity - 6 attributes

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2. **Productivity** – capacity to recover if stock is depleted, function of life history attributes (e.g. longevity, maturity) – 5 attributes

Productivity-Susceptibility Analysis (PSA)

- Precise or ‘borrowed’ parameter values reduced to a 1-3 score

growth co-efficient K = 0.43 yr^{-1}

	Low	Medium	High
Value range	<0.1	0.1-0.4	>0.4
PSA Score	1	2	3

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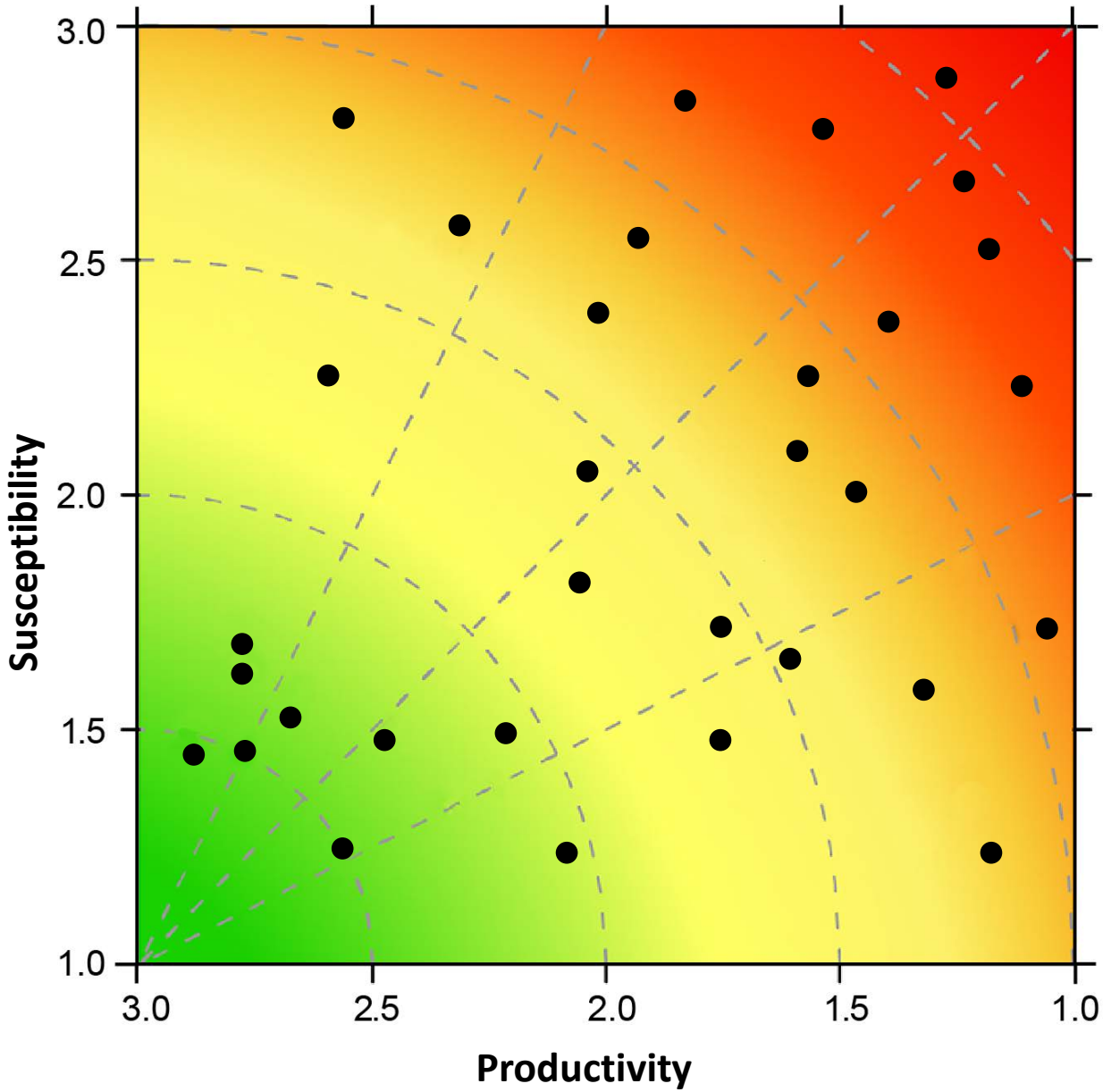
- Scores for all attributes averaged to provide a vulnerability score (v)

Productivity-Susceptibility Analysis (PSA)



Vulnerability (*v*) is measured as Euclidean distance from plot origin

$$v = \sqrt{(p-3)^2 + (s-1)^2}$$

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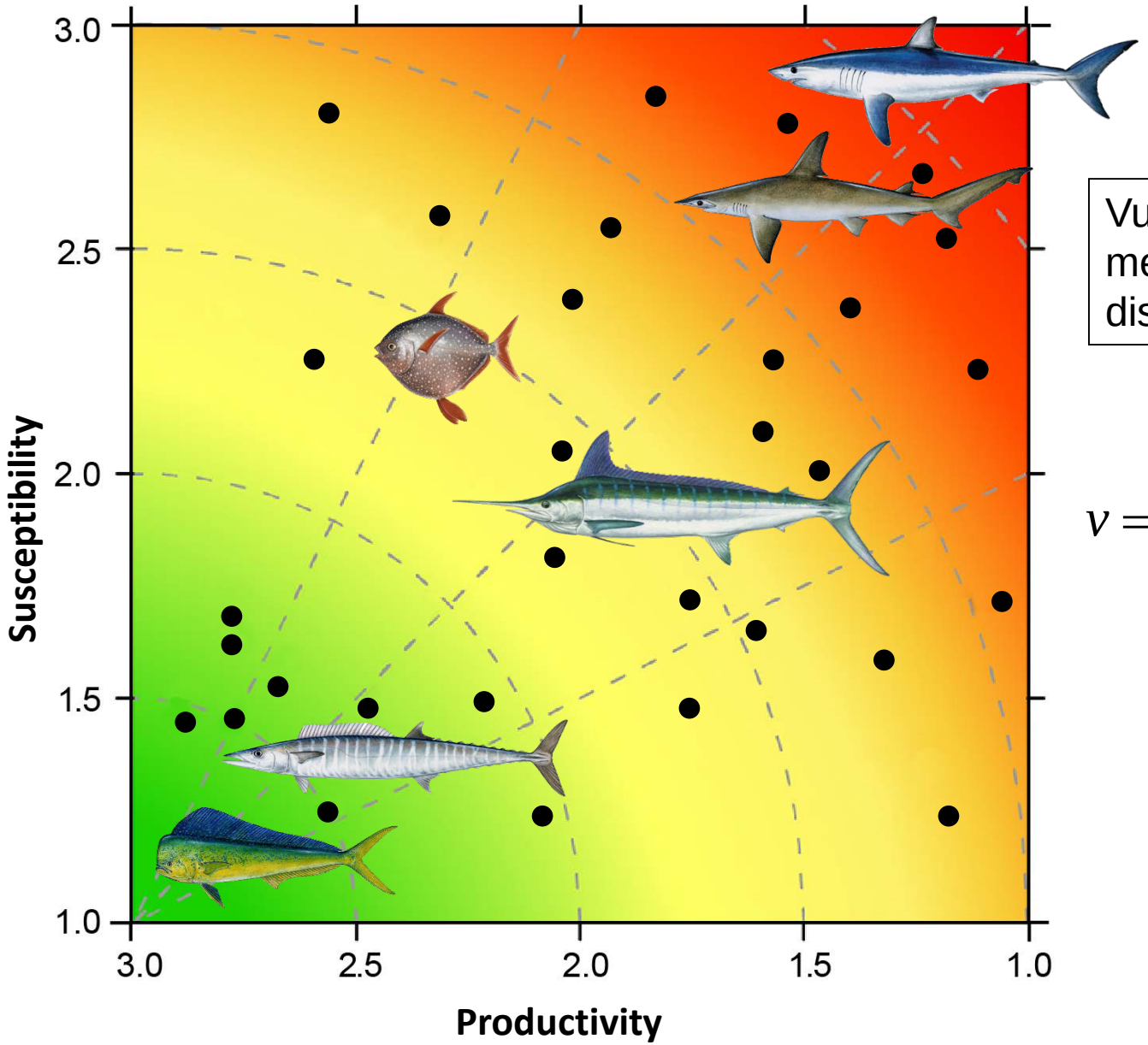

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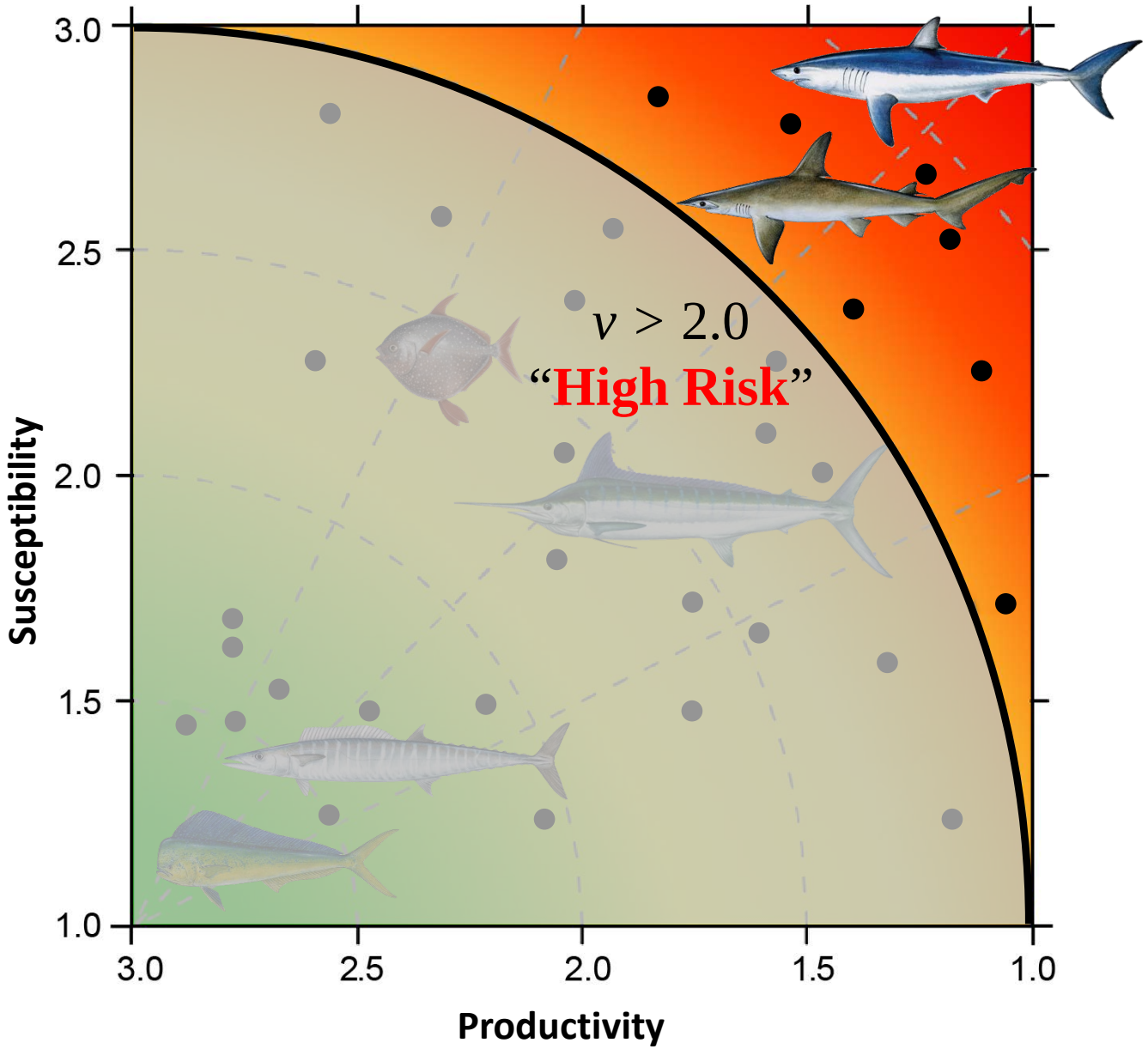

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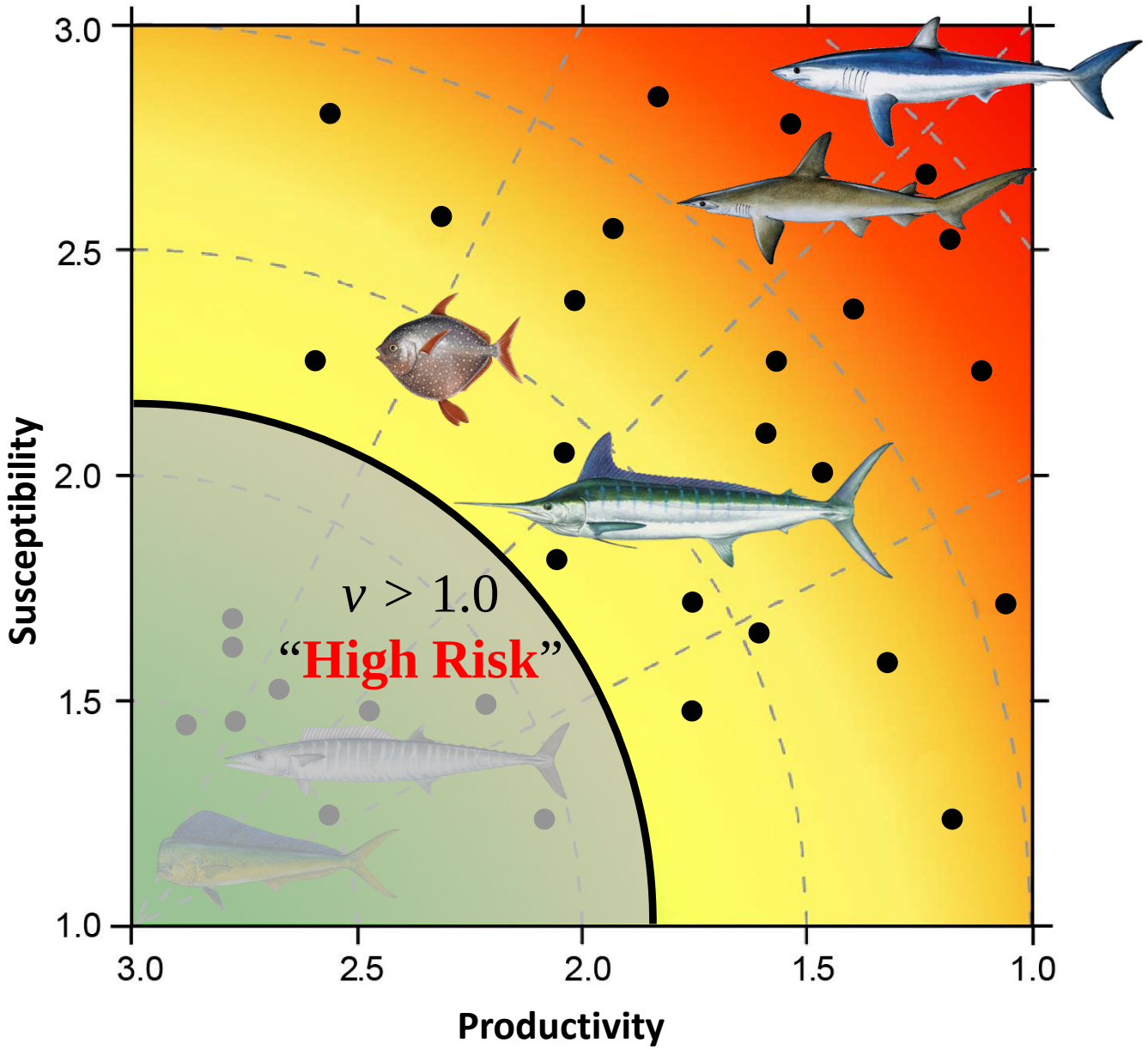


Need for improved ERA methods

- PSA produces only a relative measure of vulnerability
- Arbitrary threshold value has no biological meaning
- Potential for false positives and false negatives
- Cannot assess the cumulative impacts of multiple fisheries
  - An ongoing request from some IATTC Members
  - Eric Gilman's talk at IATTC Bycatch WG (Friday)

Need for improved ERA methods

	PSA
Productivity attribute	
Intrinsic rate of population increase (r)	X
Maximum age (t_m)	X
Maximum size (L_{max})	X
Length-at-infinity (L_∞)	
von Bertalanffy growth coefficient (K)	X
Natural mortality (M)	X
Fecundity	X
Breeding strategy	X
Recruitment pattern	X
Age at maturity (t_m)	X
Length-at-maturity (L_m or L_{50})	
Mean trophic level	X
Susceptibility attribute	
Areal overlap	X
Geographic concentration	X
Fishing season duration	
Vertical overlap (i.e. encounterability)	X
Seasonal availability	X
Schooling, aggregation, and behavioral responses	X
Morphological characteristics affecting capture	X
Gear selectivity	
Desirability or value of the fishery	X
Management strategy	X
Fishing rate relative to M (equivalent to F-based RPs)	X
Biomass of spawners (SSB) or other proxies (equivalent to spawning biomass-based RPs)	X
Survival after capture and release	X
Impact of fisheries on essential fish habitat	X

- Designed for data-limited fisheries
- But, many parameters require estimation
- Data resolution lost in conversion to 1-3

Need for improved ERA methods

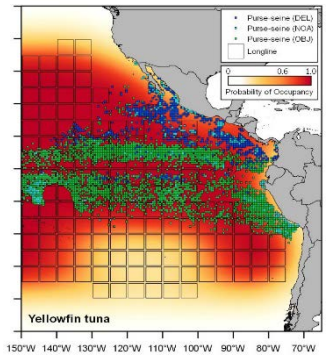
- Managers need a quantitative method to more reliably identify vulnerable species
- Rapid, inexpensive, and repeatable, especially in data-limited settings
- Spatially explicit for moving fishing effort, specify existing closures, but also to explore ‘what if’ scenarios as mitigation measures.

EASI-Fish

- **E**cological **A**ssessment of the **S**ustainable **I**mpacts by **Fish**eries (EASI-Fish)
- Similar PSA “Productivity” and “Susceptibility” components
- Susceptibility component estimates the proportion of the population that is potentially impacted by fishery *x*.
  - Exploitation rate converted to instantaneous fishing mortality (*F*)
- Productivity component is a length-based per-recruit model
- Vulnerability status determined using biological reference points
- Designed to be user-friendly and flexible for data-poor fisheries

EASI-Fish

Susceptibility - “Volumetric overlap”



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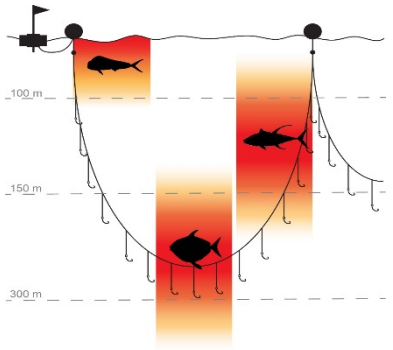

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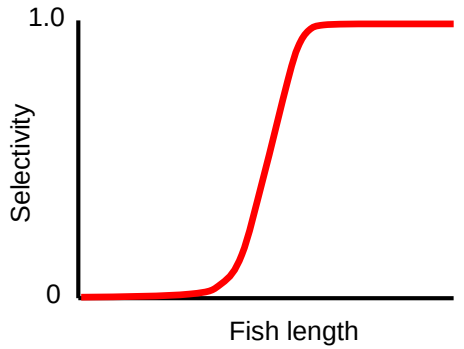

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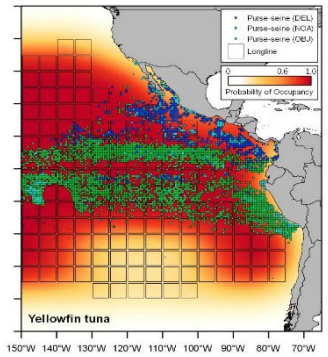
Fishing Mortality (***F***)

EASI-Fish

Susceptibility - “Volumetric overlap”



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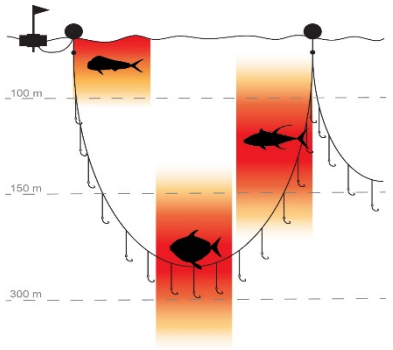

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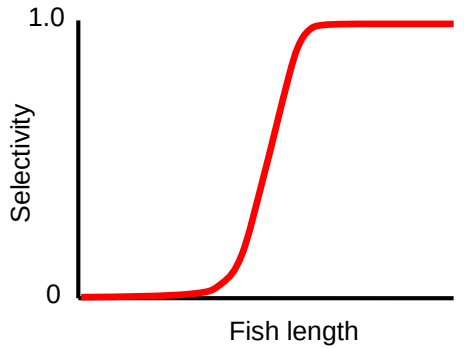

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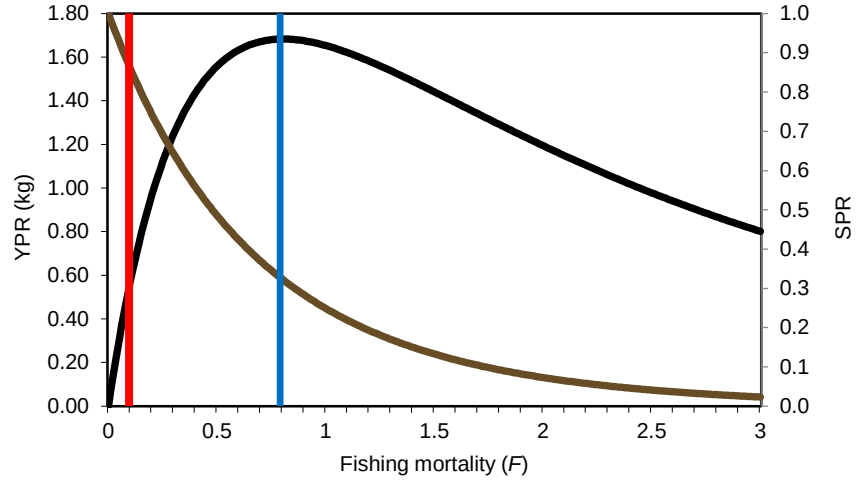
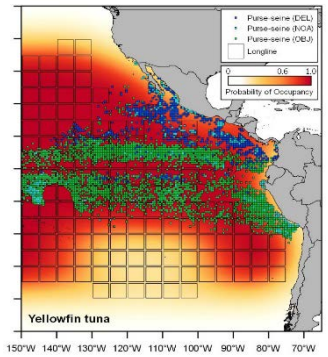
Fishing Mortality (***F***)

Productivity - YPR



EASI-Fish

Susceptibility - “Volumetric overlap”



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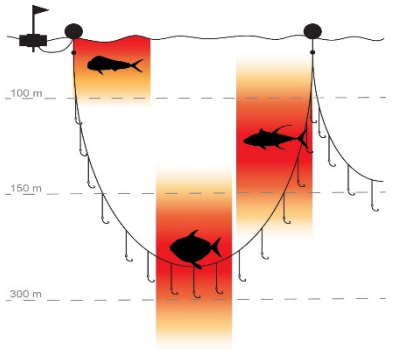

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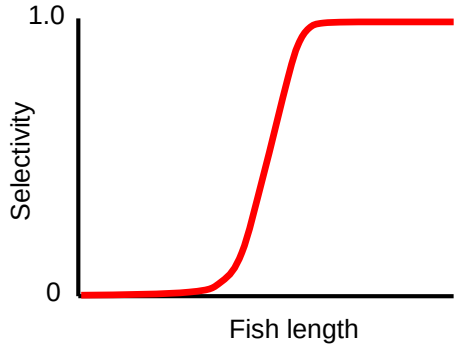
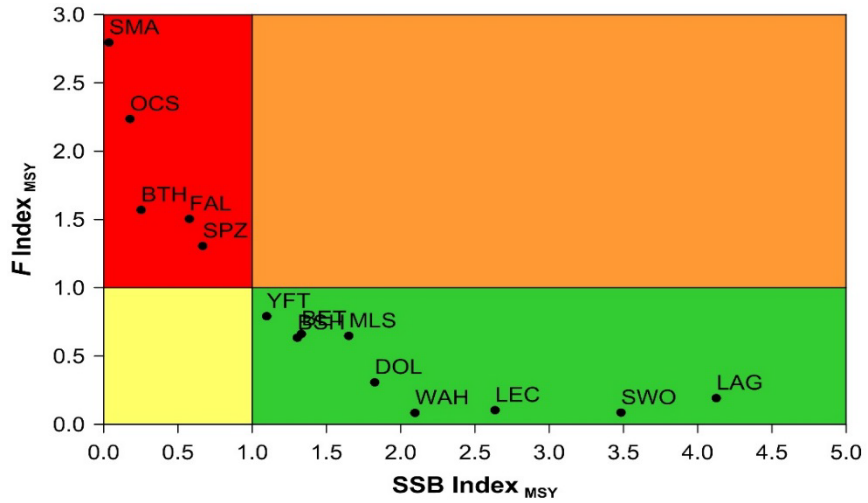


= Fishing Mortality (***F***)

Vulnerability status - BRPs



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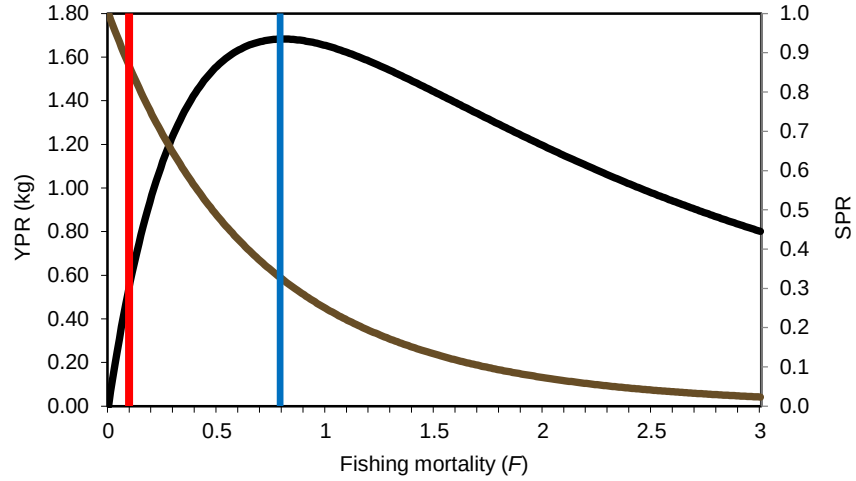

Susceptibility

- Susceptibility comprised of 6 components:
  - Areal overlap (*G*) - proportion of the species' distribution exposed to fishery *x*
  - Duration of the fishing season (*D*) – proportion of the year exposed to a fishery
  - Seasonal availability (*A*) – proportion of the year available for capture in a fishery
  - Encounterability (*N*) - proportion of species' vertical habitat exposed to a fishery
  - Contact selectivity (*C*) - proportion of fish encountering the gear that is caught
  - Post-release mortality (*P*) - proportion of released fish that die
- Susceptibility is estimated by fishery (*x*) by length class (*j*)

$$S_{xj} = \frac{G_x}{G}\left(D_x A_{xj} N_{xj} C_{xj} P_{xj}\right)$$

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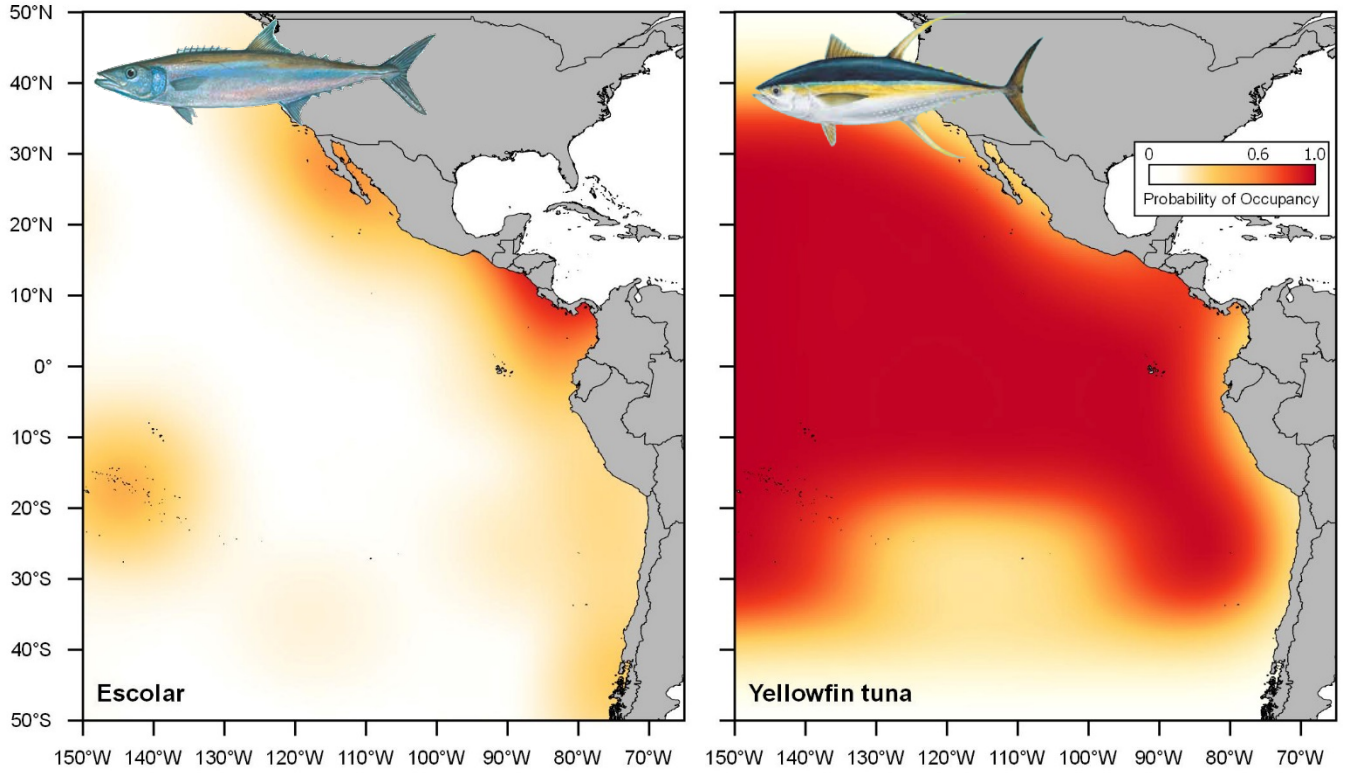
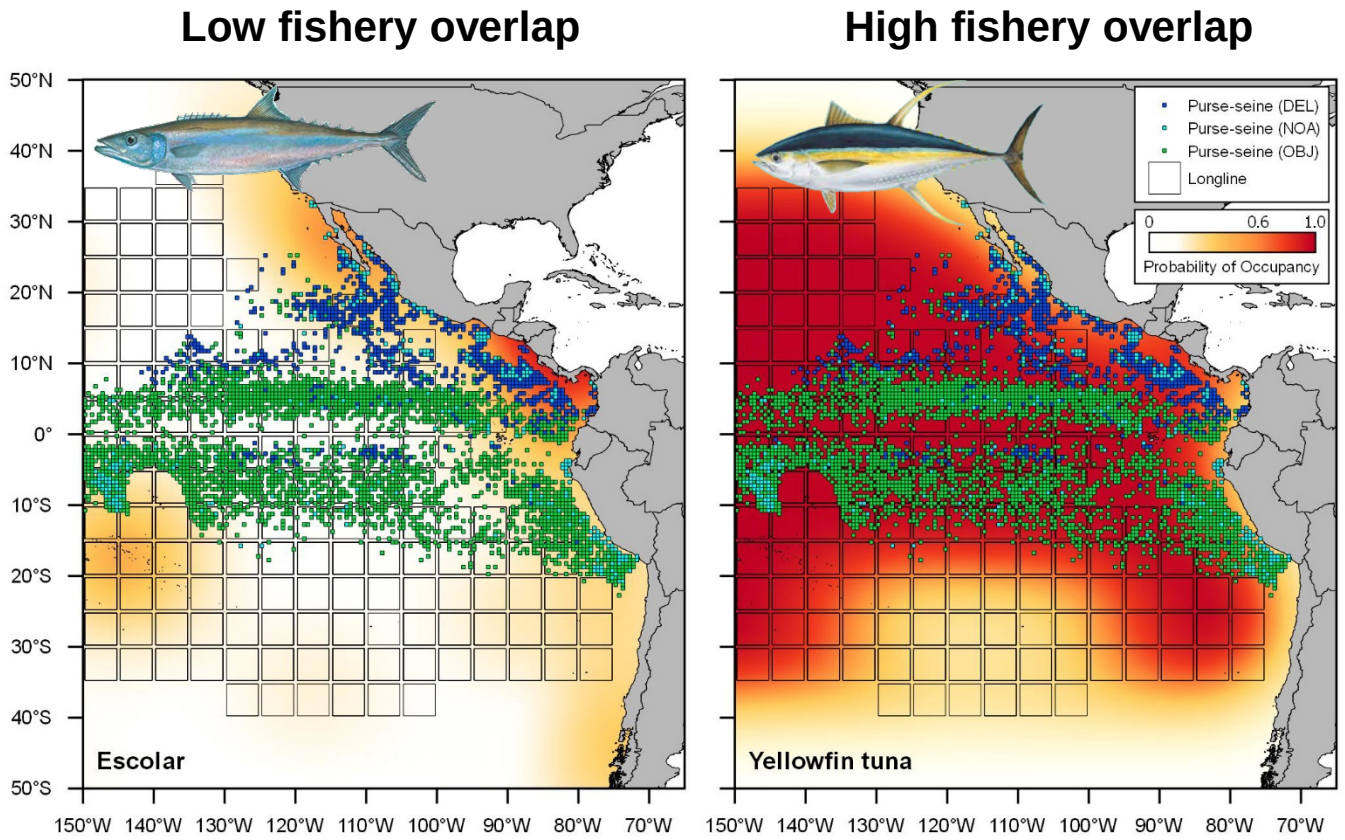
Areal overlap

- Species habitat modeled using environmental envelope model



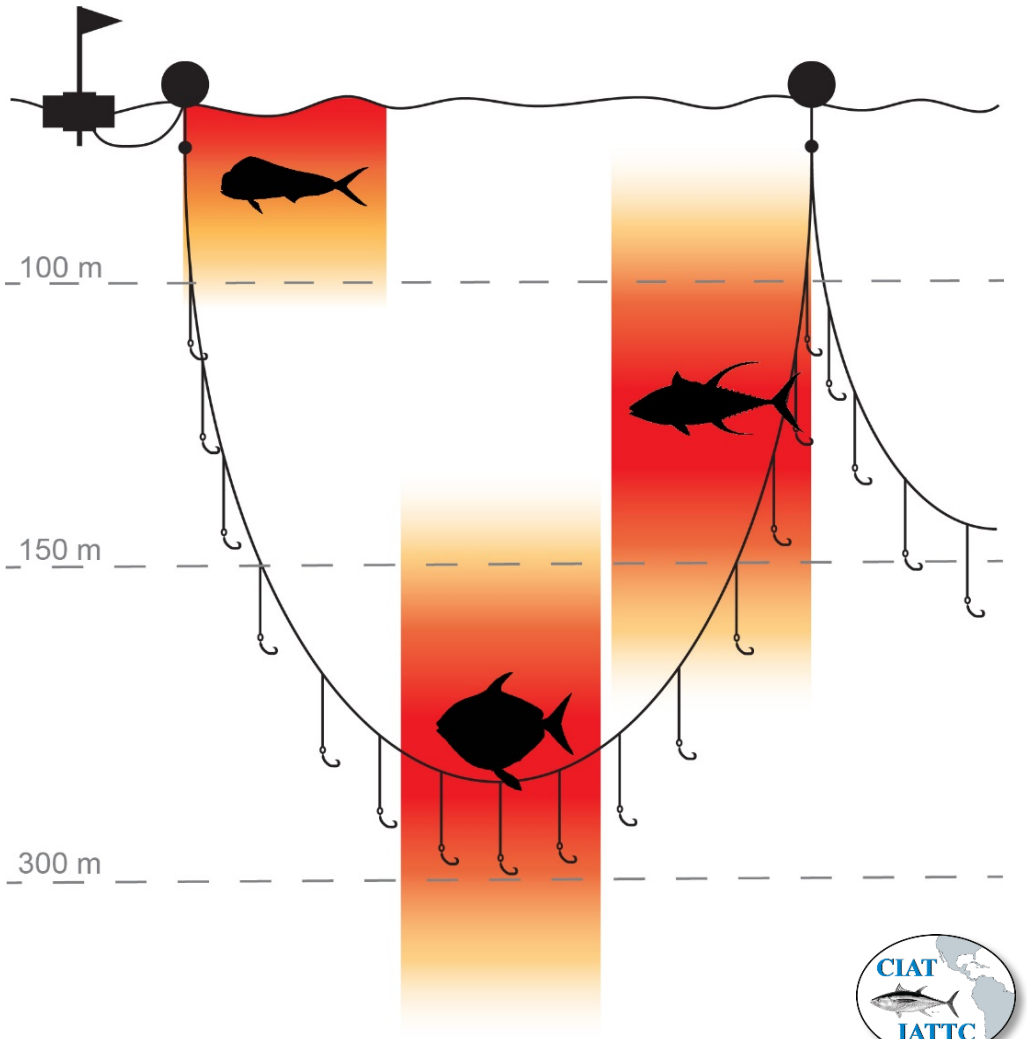
Areal overlap

- Species habitat modeled using environmental envelope model
- Areal overlap - no. grids occupied (G) that are fished (G_x)
- Target species overlap high (0.76 for LL), bycatch lower (0.48)



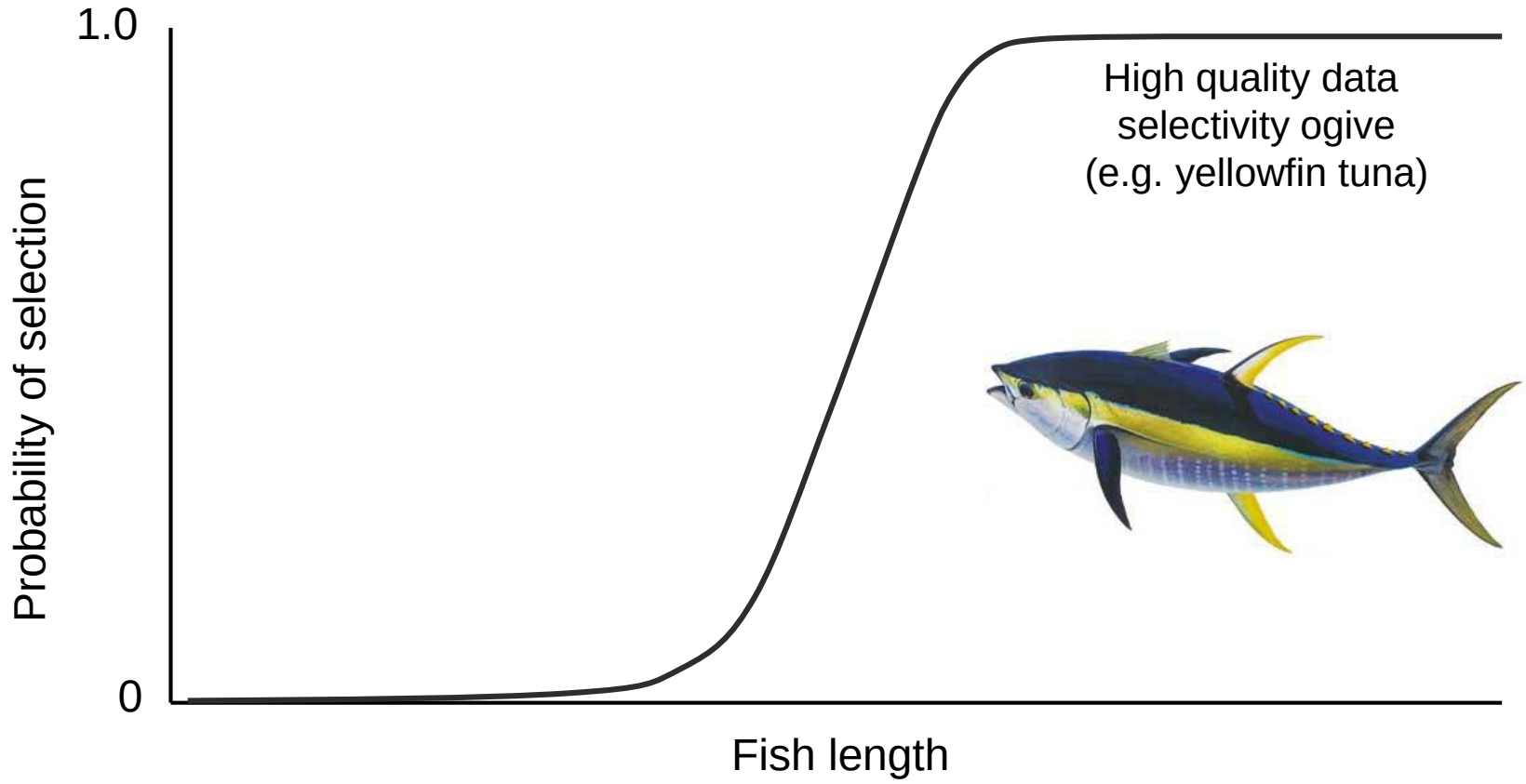
Encounterability

- Despite high fishery overlap, fish may not encounter the gear
- Proportion of vertical distribution overlap
  - Gear studies
  - Electronic tagging studies
  - Time-depth recorder studies
  - Expert opinion
- e.g. longline depth 0-300m
- Yellowfin tuna 0-300m (1.0)
- Escolar 100-1000m (0.2)
- Precautionary value is 1.0



Contact selectivity

- Susceptibility parameters flexible depending on data availability



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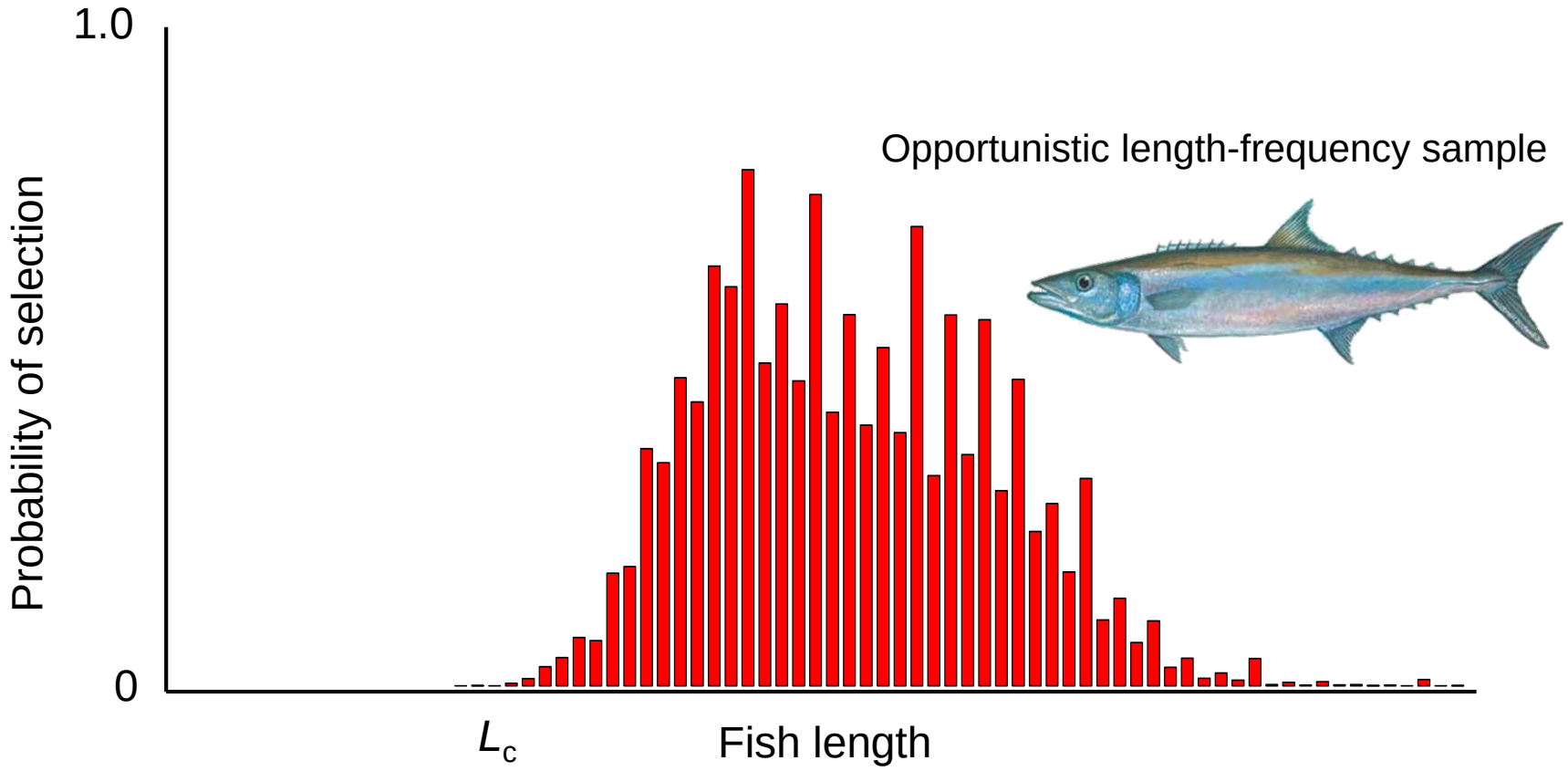

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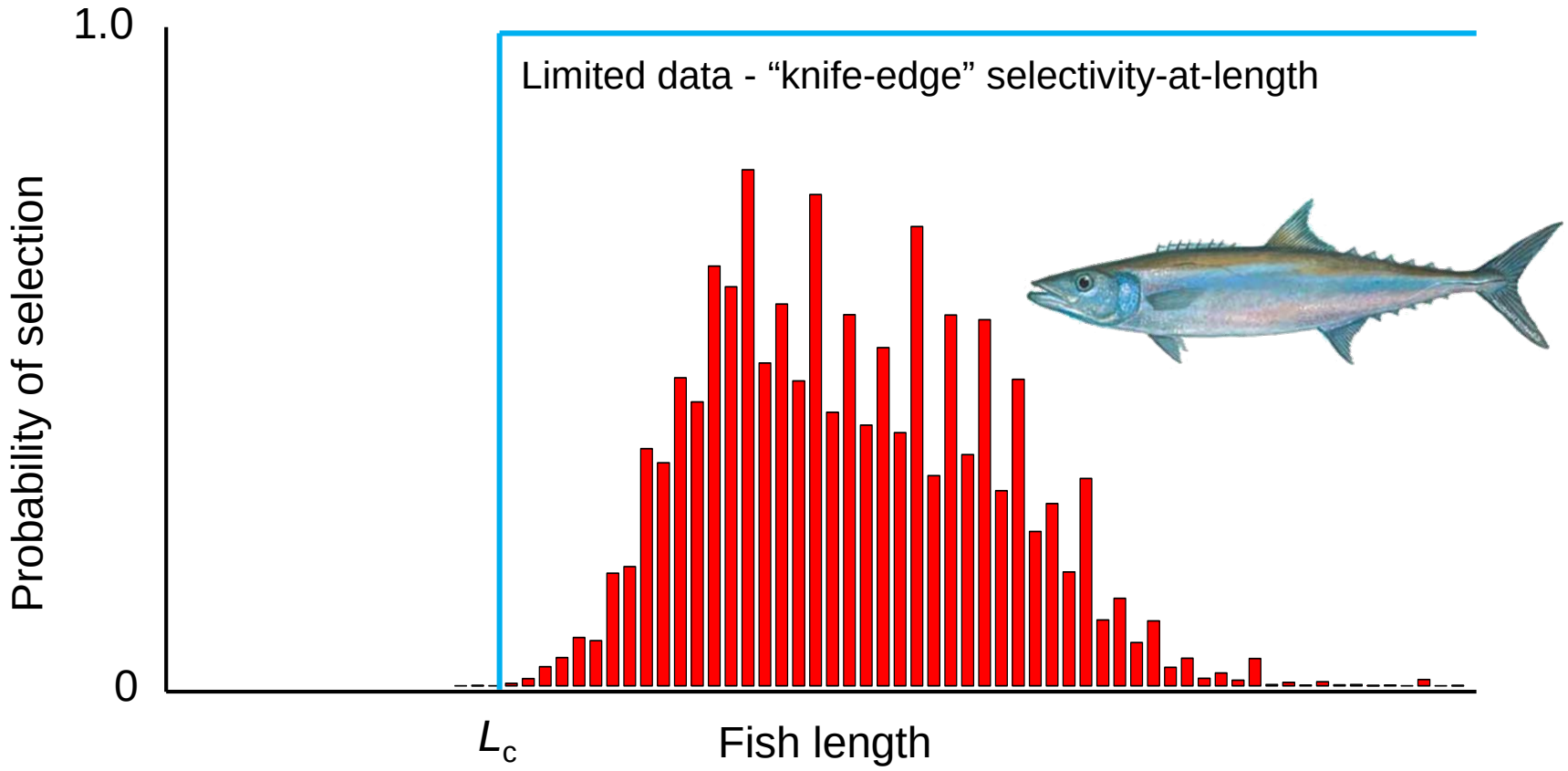
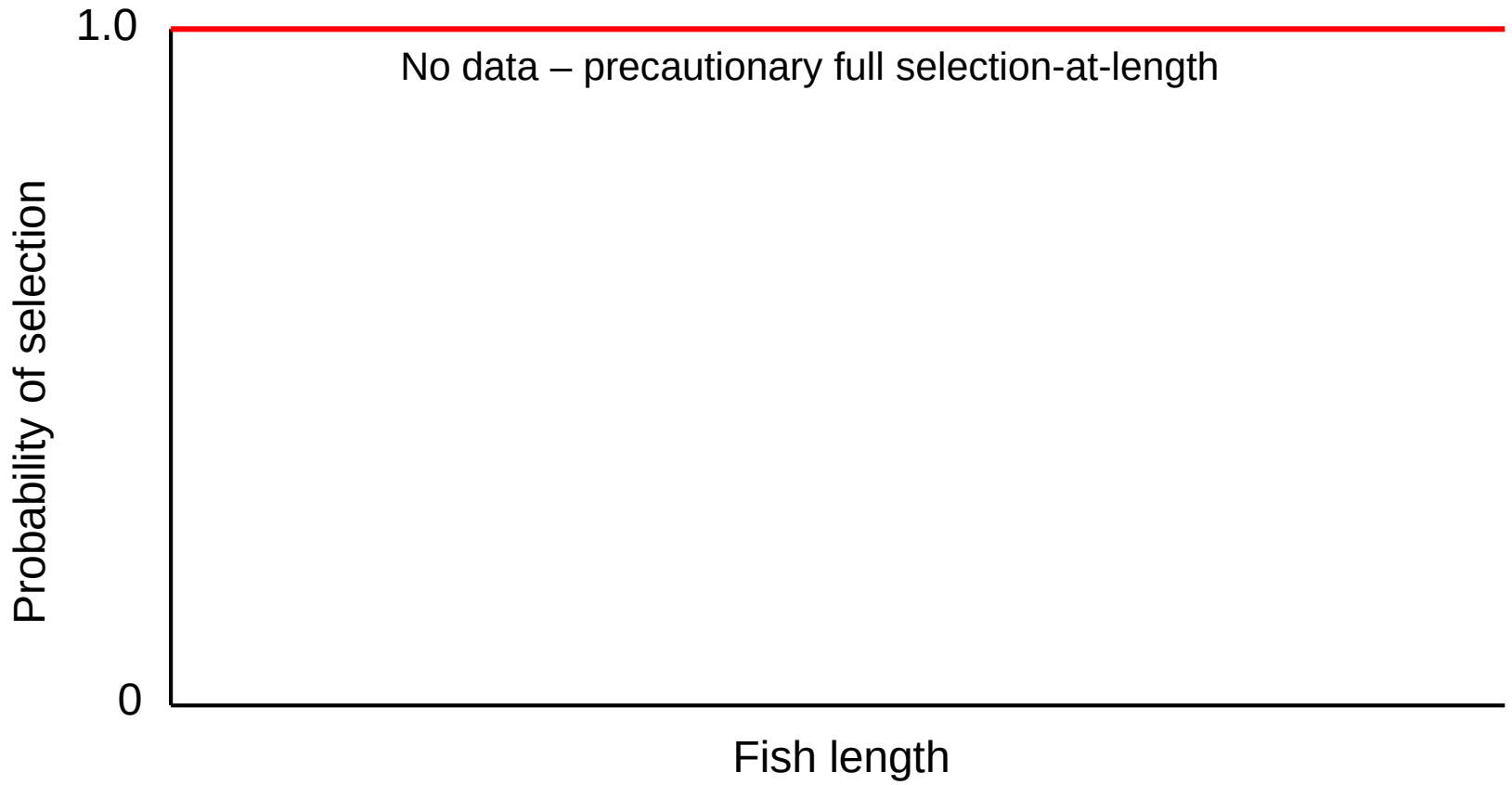


Contact selectivity

- Susceptibility parameters flexible depending on data availability
- Precautionary value of 1.0 where no data is available



Estimating fishing mortality (*F*)

- Total proportion of the population (*S*) caught by each fishery is summed and converted to become a proxy for *F*

$$F = -\ln\left[1 - \sum_{x=1} q_x E_x \left(\frac{\sum_{j=1}^{n} S_{xj}}{n}\right)\right]$$

- Catchability (*q*) and effort (*E*) are assumed to be 1 where no data
  - Implies 1 unit of effort catch all fish in a grid where selectivity parameters = 1

Productivity – per-recruit models

- *F* is compared to reference points from simple per-recruit models
- Length-based yield per-recruit model (Chen and Gordon 1997)

$$\frac{Y}{R} = \sum_{j=1}^{n} \frac{W_j b_j F}{b_j F + M} \left[1 - e^{-(b_j F + M)\Delta T_j}\right] e^{-\sum_{k=1}^{j-1}(b_k F + M)\Delta T_k}$$

  - Fishing mortality reference points F_{MSY} and precautionary $F_{0.1}$ and $F_{40\%}$

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  - Fishing mortality reference points $\boldsymbol{F_{MSY}}$ and precautionary $\boldsymbol{F_{0.1}}$ and $\boldsymbol{F_{40\%}}$

- Corresponding spawning stock biomass-per recruit (SSB):

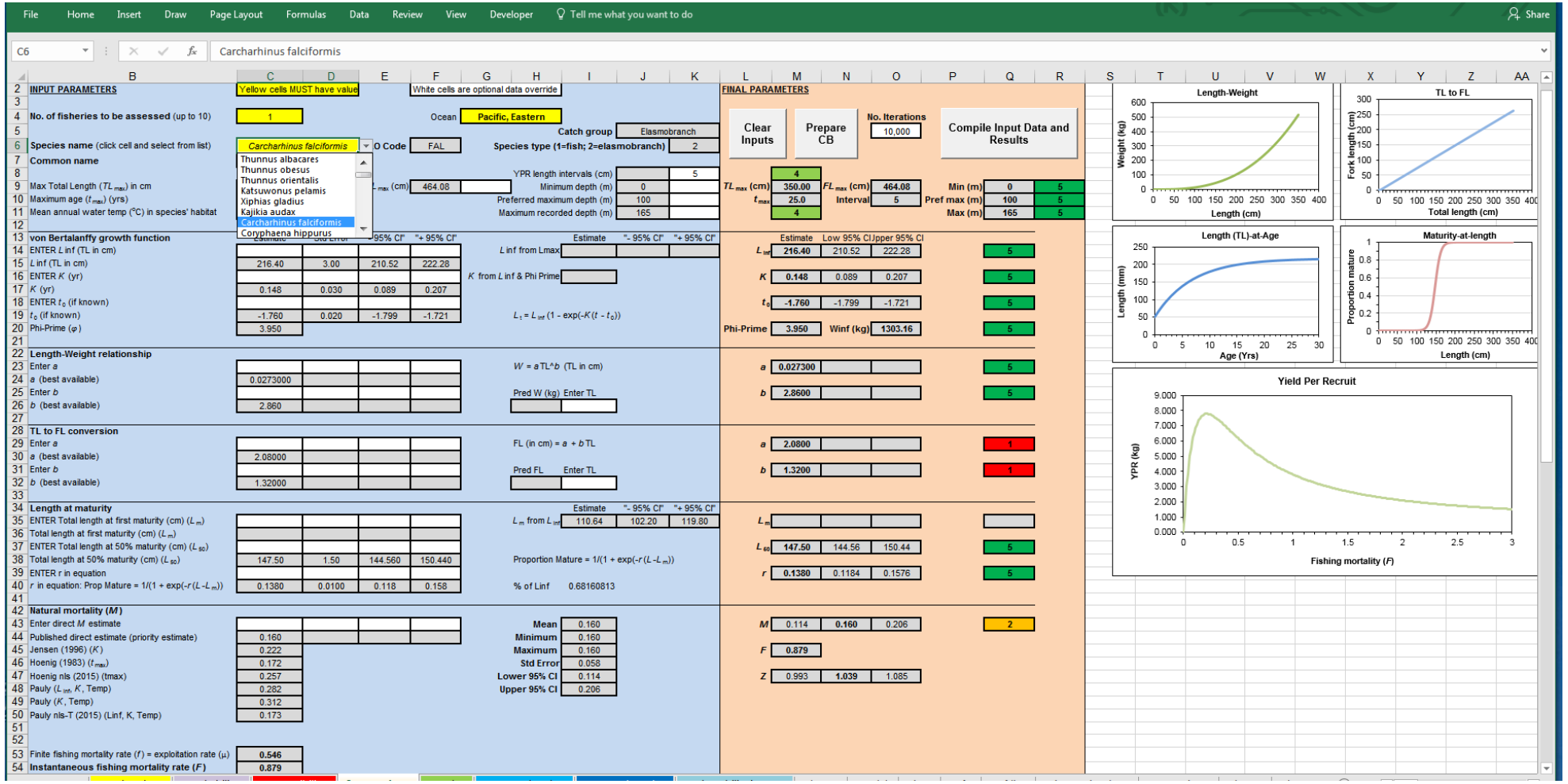
$$\frac{SSB}{R} = \sum_{j=1}^{n} W_j m_j \prod_{x=r}^{j-1} e^{-(b_j F + M)}$$

  - Biomass-based reference points $\boldsymbol{SSB_{MSY}}$ and precautionary $\boldsymbol{SSB_{0.1}}$ and $\boldsymbol{SSB_{40\%}}$

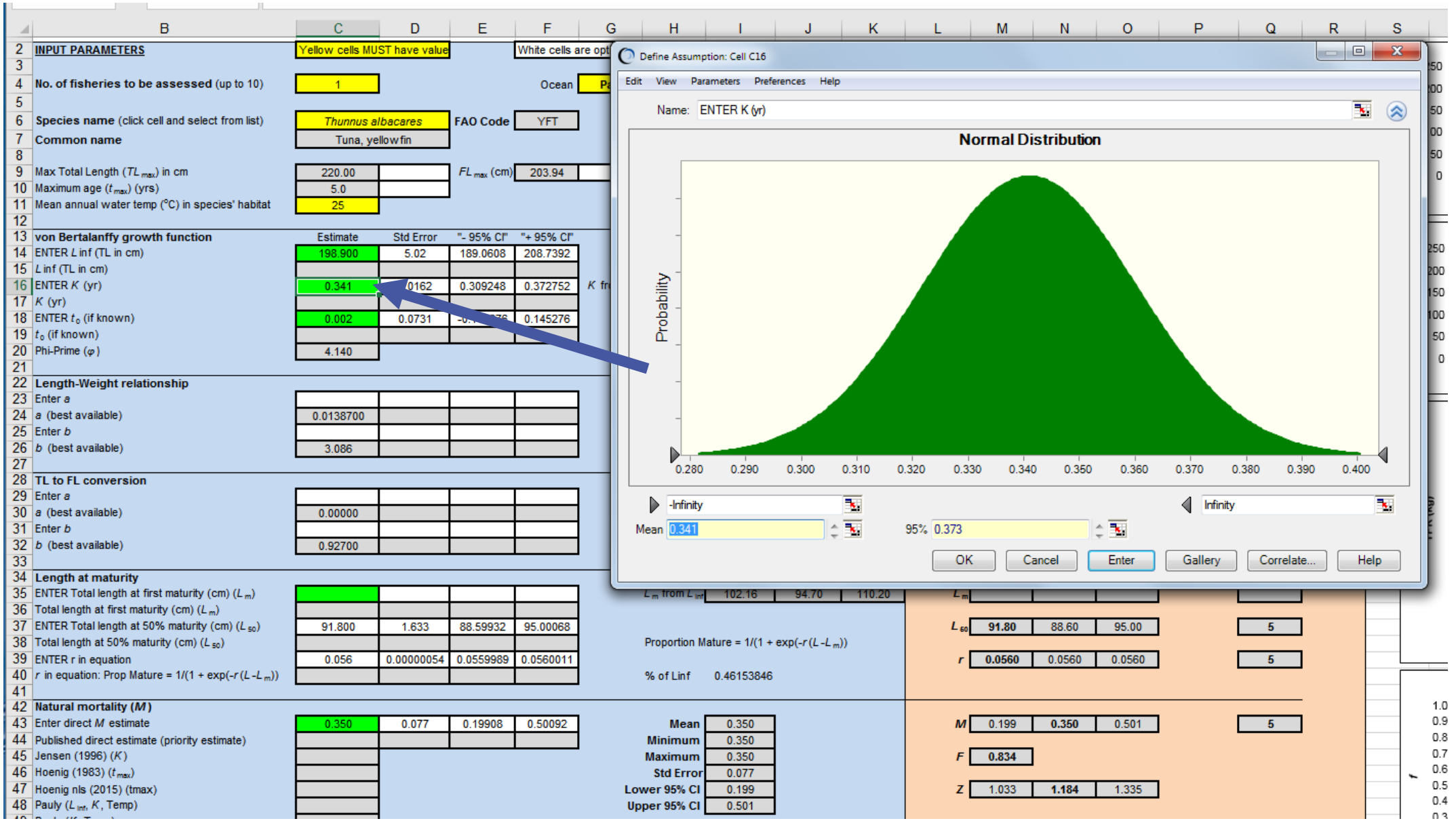
- Parameter uncertainty 10,000 Monte Carlo runs

User-friendly interface

- Created in Microsoft Excel, but possible to create an *R* package
- Add-ins for Monte Carlo simulations to incorporate parameter uncertainty



Incorporating parameter uncertainty



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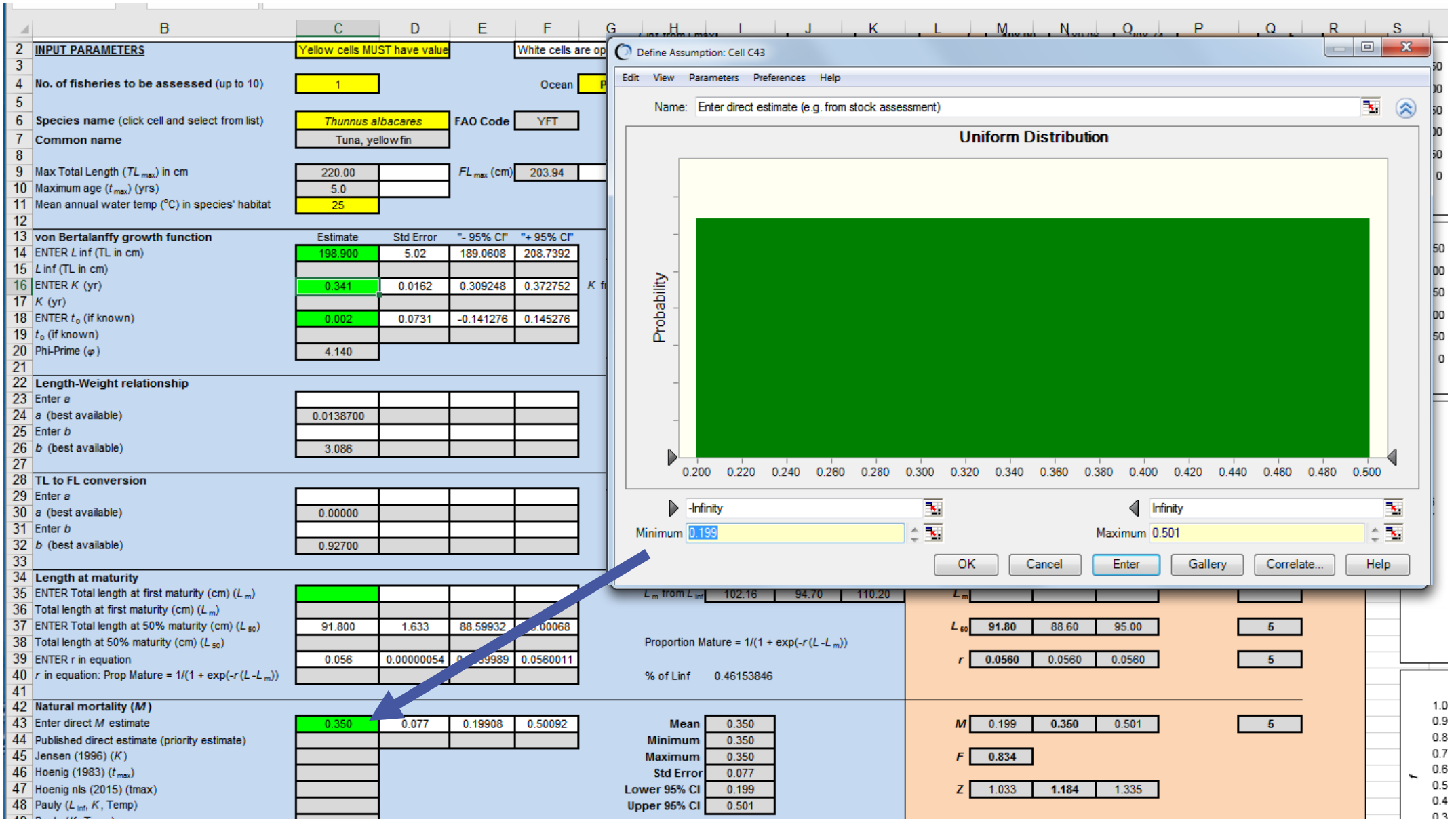
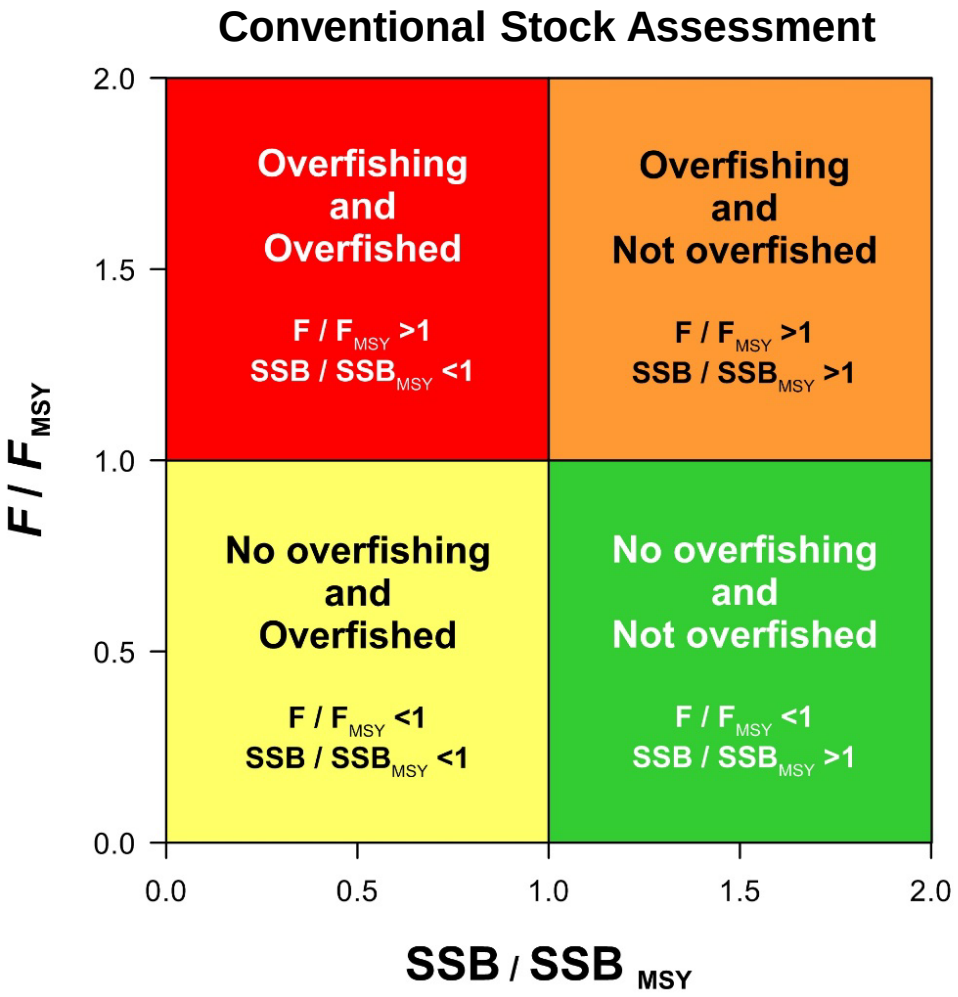


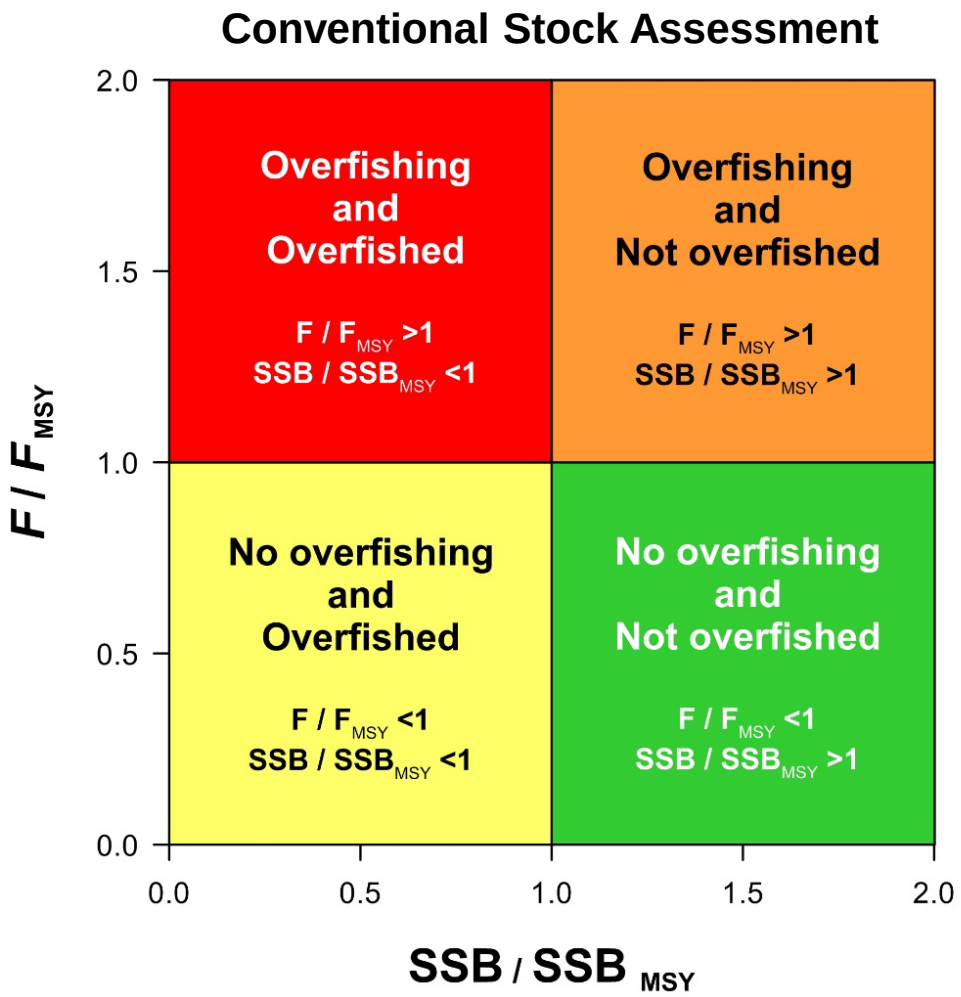
Defining vulnerability status

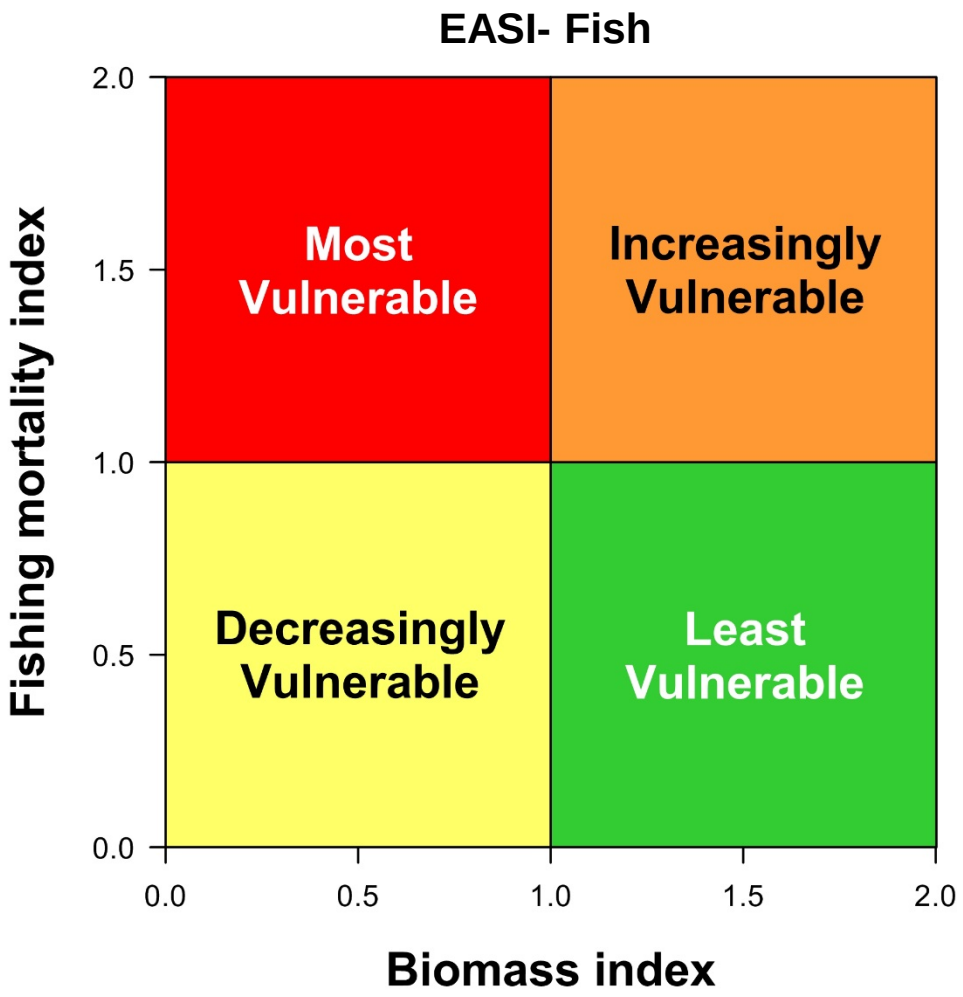
- In stock assessment BRPs define stock status (e.g. F/F_{MSY})



Defining vulnerability status

- Similar reference points can define <u>relative vulnerability</u>





EASI-Fish vs PSA parameters

	PSA
Productivity attribute	
Intrinsic rate of population increase (r)	X
Maximum age (t_m)	X
Maximum size (L_{max})	X
Length-at-infinity (L_∞)	
von Bertalanffy growth coefficient (K)	X
Natural mortality (M)	X
Fecundity	X
Breeding strategy	X
Recruitment pattern	X
Age at maturity (t_m)	X
Length-at-maturity (L_m or L_{50})	
Mean trophic level	X
Susceptibility attribute	
Areal overlap	X
Geographic concentration	X
Fishing season duration	
Vertical overlap (i.e. encounterability)	X
Seasonal availability	X
Schooling, aggregation, and behavioral responses	X
Morphological characteristics affecting capture	X
Gear selectivity	
Desirability or value of the fishery	X
Management strategy	X
Fishing rate relative to M (equivalent to F-based RPs)	X
Biomass of spawners (SSB) or other proxies (equivalent to spawning biomass-based RPs)	X
Survival after capture and release	X
Impact of fisheries on essential fish habitat	X

EASI-Fish vs PSA parameters

	PSA	EASI-Fish
Productivity attribute		
Intrinsic rate of population increase (r)	X	
Maximum age (t_m)	X	X
Maximum size (L_{max})	X	X
Length-at-infinity (L_∞)		X
von Bertalanffy growth coefficient (K)	X	X
Natural mortality (M)	X	X
Fecundity	X	
Breeding strategy	X	
Recruitment pattern	X	
Age at maturity (t_m)	X	
Length-at-maturity (L_m or L_{50})		X
Mean trophic level	X	
Susceptibility attribute		
Areal overlap	X	X
Geographic concentration	X	
Fishing season duration		X
Vertical overlap (i.e. encounterability)	X	X
Seasonal availability	X	X
Schooling, aggregation, and behavioral responses	X	
Morphological characteristics affecting capture	X	
Gear selectivity		X
Desirability or value of the fishery	X	
Management strategy	X	
Fishing rate relative to M (equivalent to F-based RPs)	X	X
Biomass of spawners (SSB) or other proxies (equivalent to spawning biomass-based RPs)	X	X
Survival after capture and release	X	X
Impact of fisheries on essential fish habitat	X	

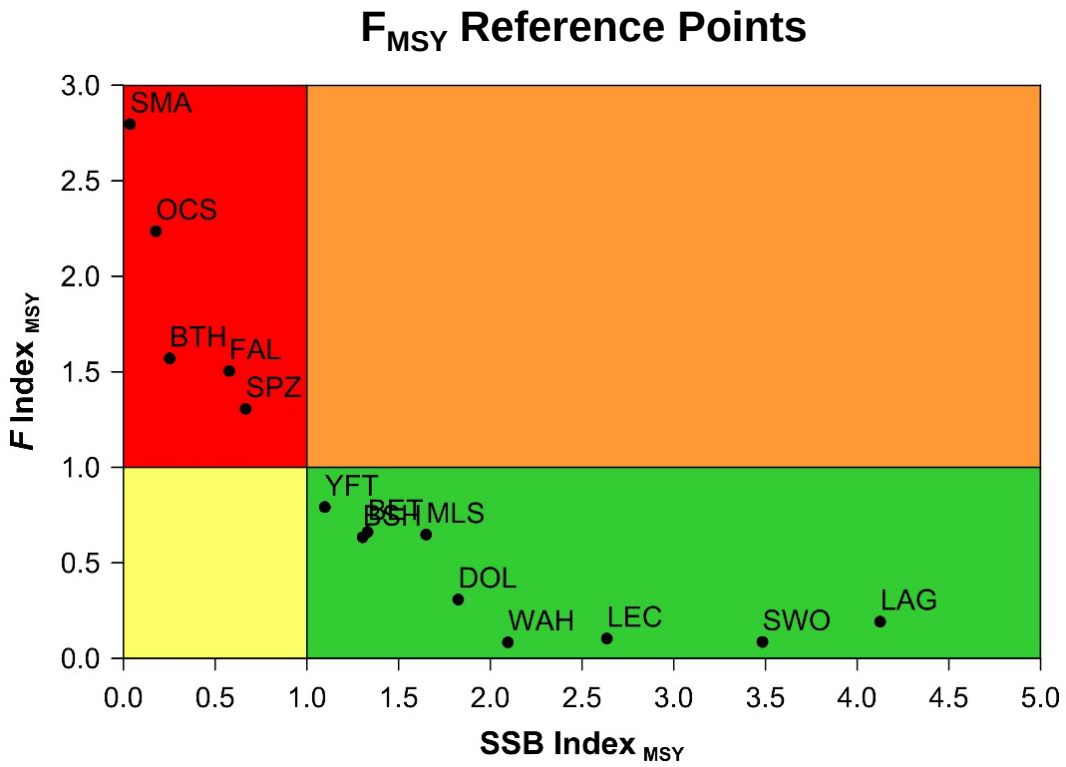
- PSA – 22 parameters
- EASI-Fish – 14 parameters

EPO ‘proof of concept’ assessment

- Four fisheries included in a ‘proof of concept’ assessment for 2016
  - Large scale tuna ‘industrial’ longline fishery
  - Purse-seine (NOA, DEL, OBJ)
- 14 representative species
  - 4 target species “data-rich”
  - 6 sharks “data-poor”
  - 2 non-target epipelagic fish (dorado, wahoo)
  - 2 non-target mesopelagic fish (escolar, opah)

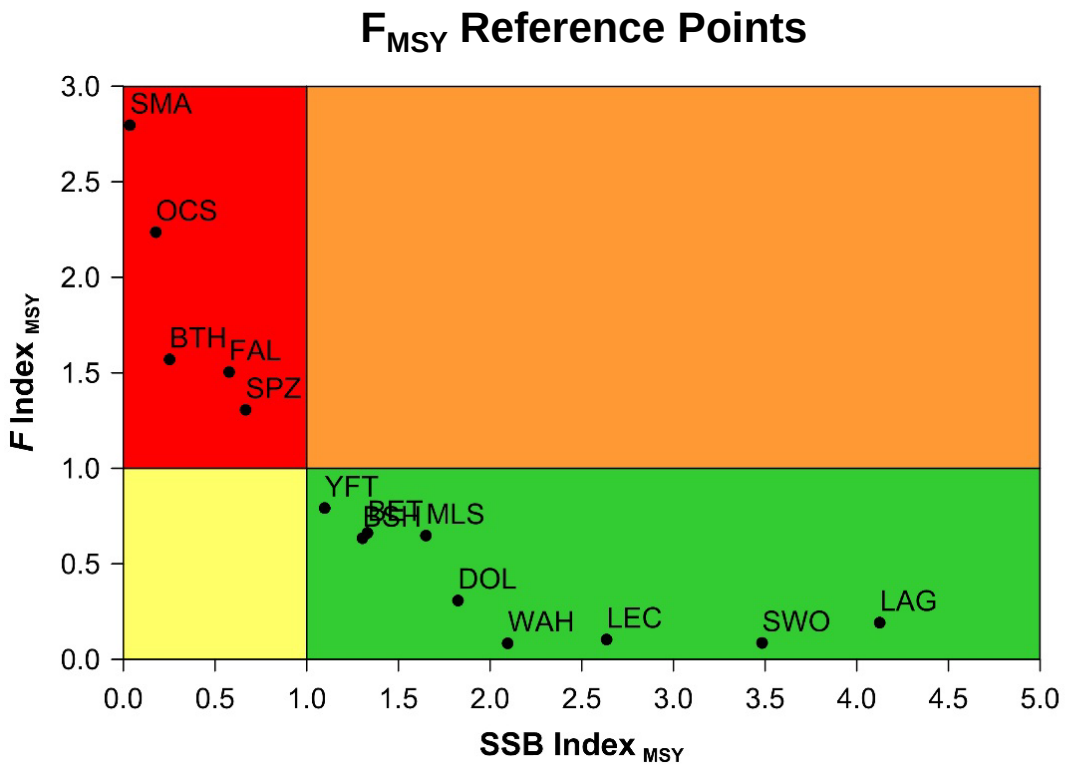
Results

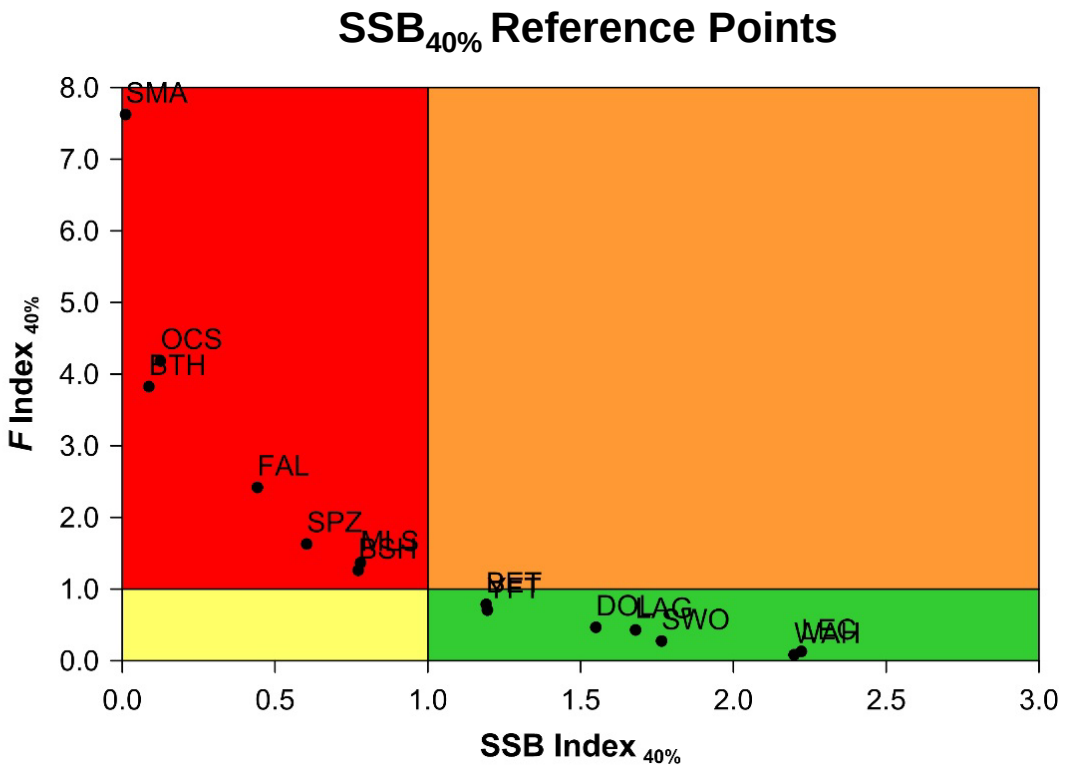
- Sharks classified as “most vulnerable” – SMA, OCS, BTH, FAL, SPZ
- Teleosts “least vulnerable”



Results

- Sharks classified as "most vulnerable" – SMA, OCS, BTH, FAL, SPZ
- Teleosts "least vulnerable"
- Precautionary BRP includes BSH and MLS as "most vulnerable"





Data reliability index

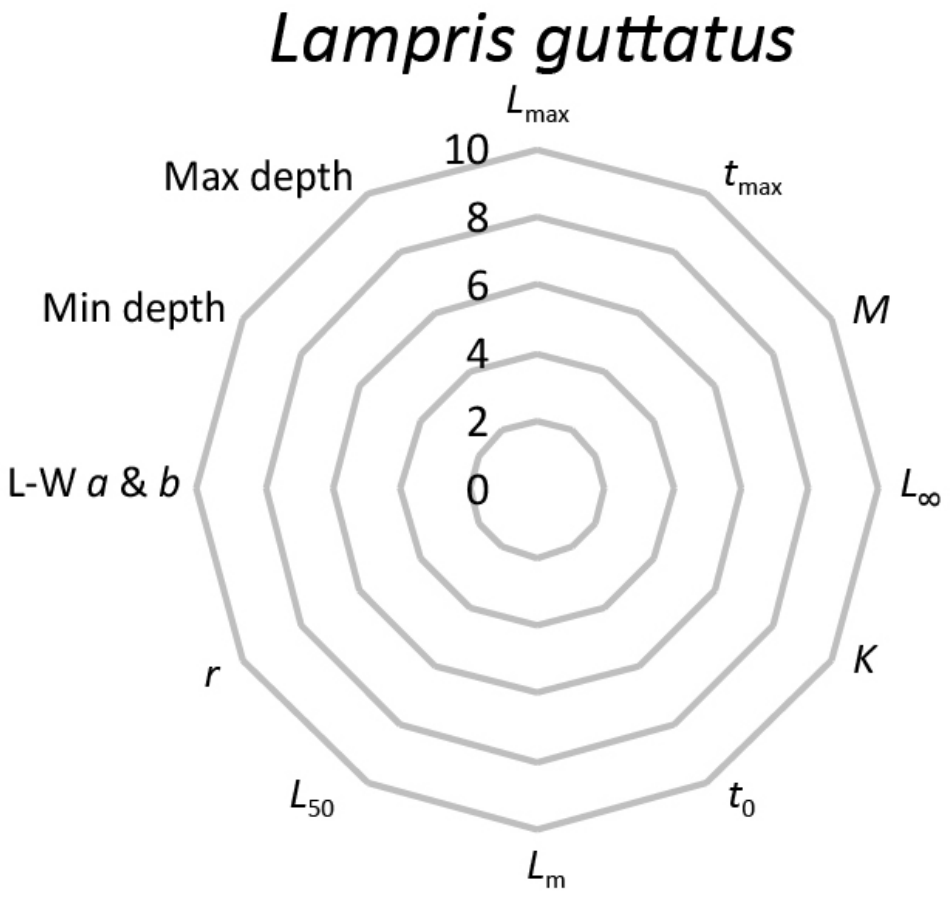
- Some species may only be “vulnerable” due to the quality of input data
- Developed a qualitative data reliability index
- Quality/precision of source study vs. relevance to species/area

Data source reliability and precision

Relevance of source to species and region		High reliability		Moderate reliability		Low reliability		No data
		High precision	Low precision	High precision	Low precision	High precision	Low precision	
Species-specific	EPO	10	9	8	7	6	5	0
	WCPO	9	8	7	6	5	4	0
	Other	8	7	6	5	4	3	0
Related species	EPO	7	6	5	4	3	2	0
	WCPO	6	5	4	3	2	1	0
	Other	5	4	3	2	1	1	0

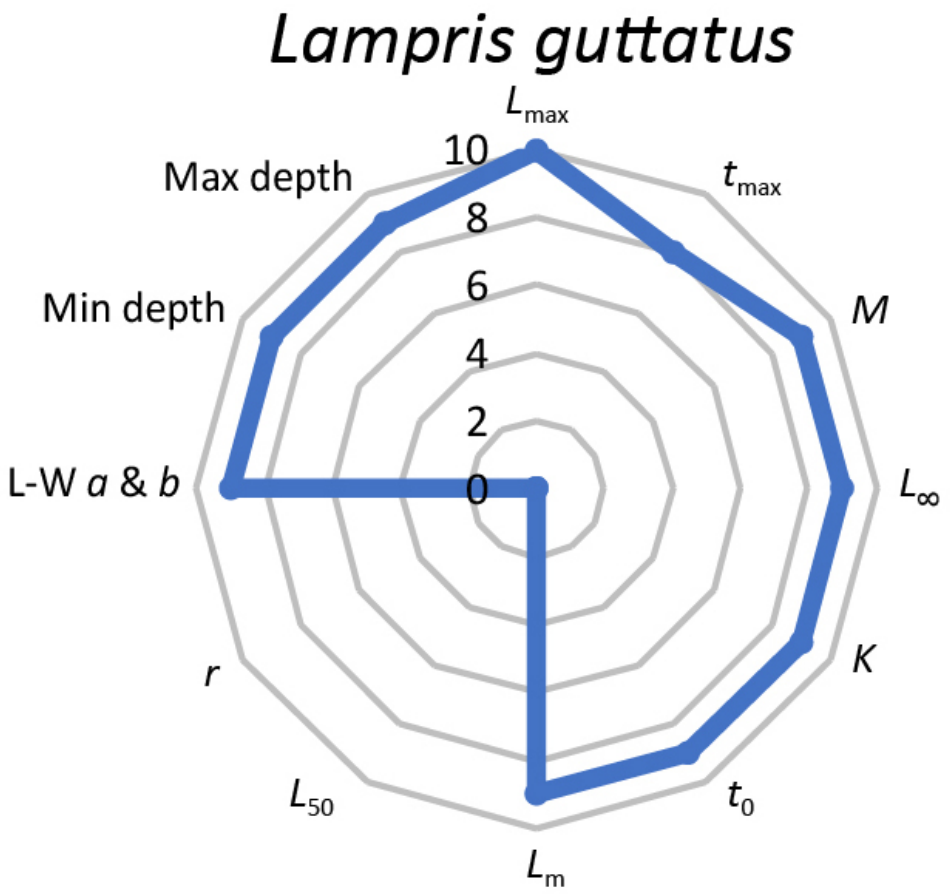
Data reliability – Radar plots

- Radar plot per species identifies data gaps

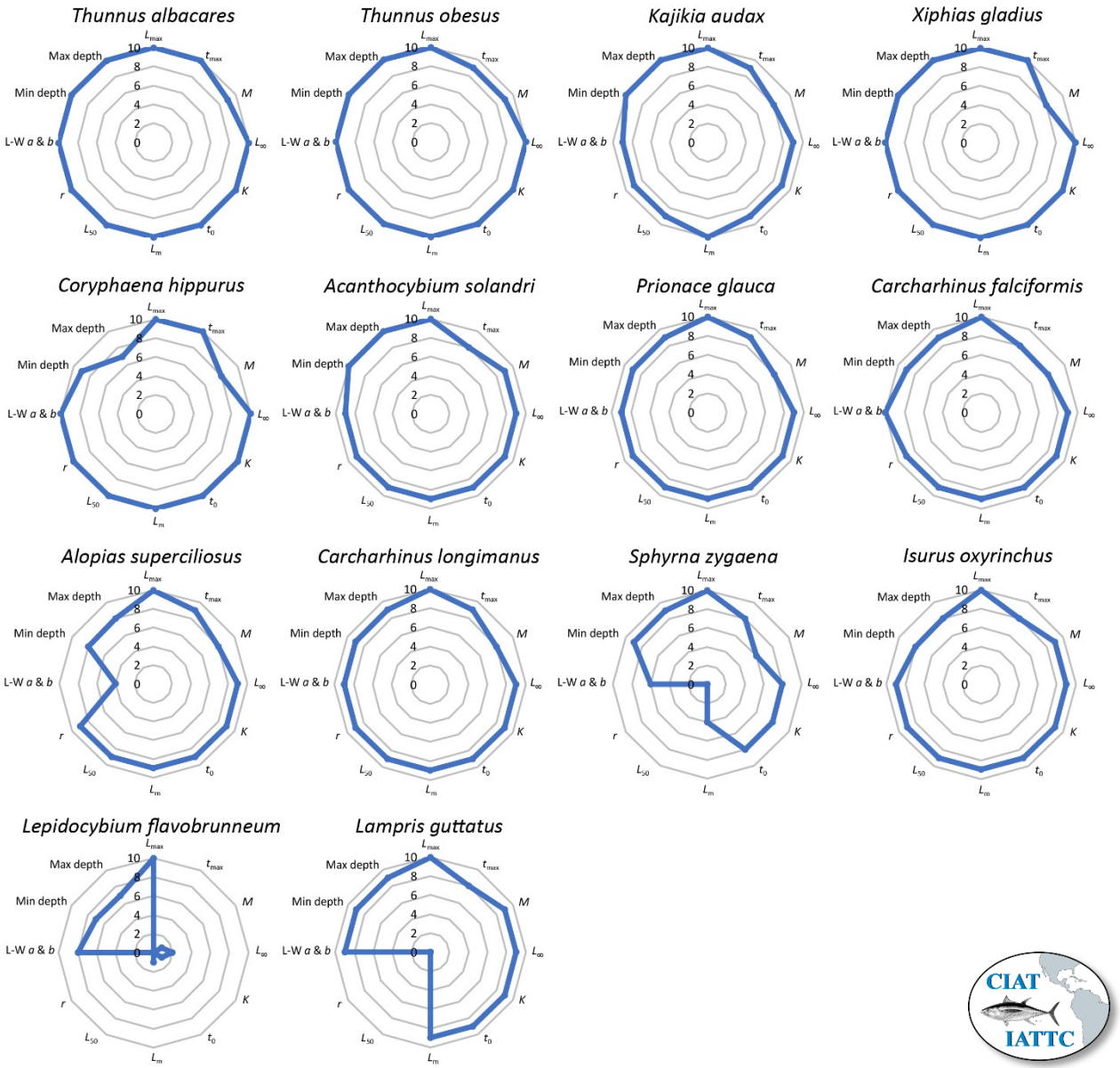


Data reliability – Radar plots

- Radar plot per species identifies data gaps

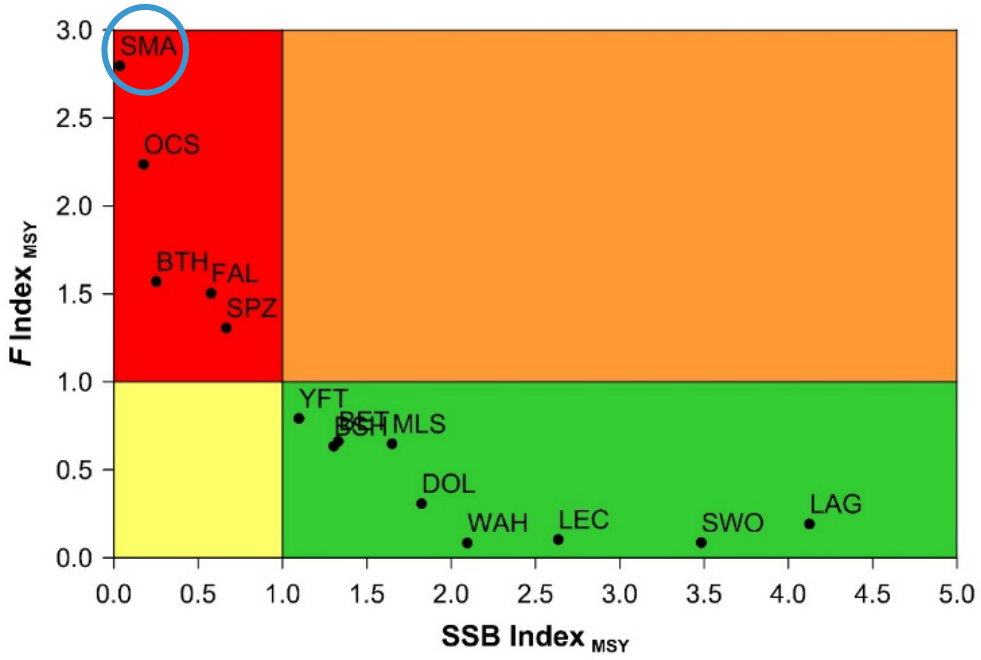


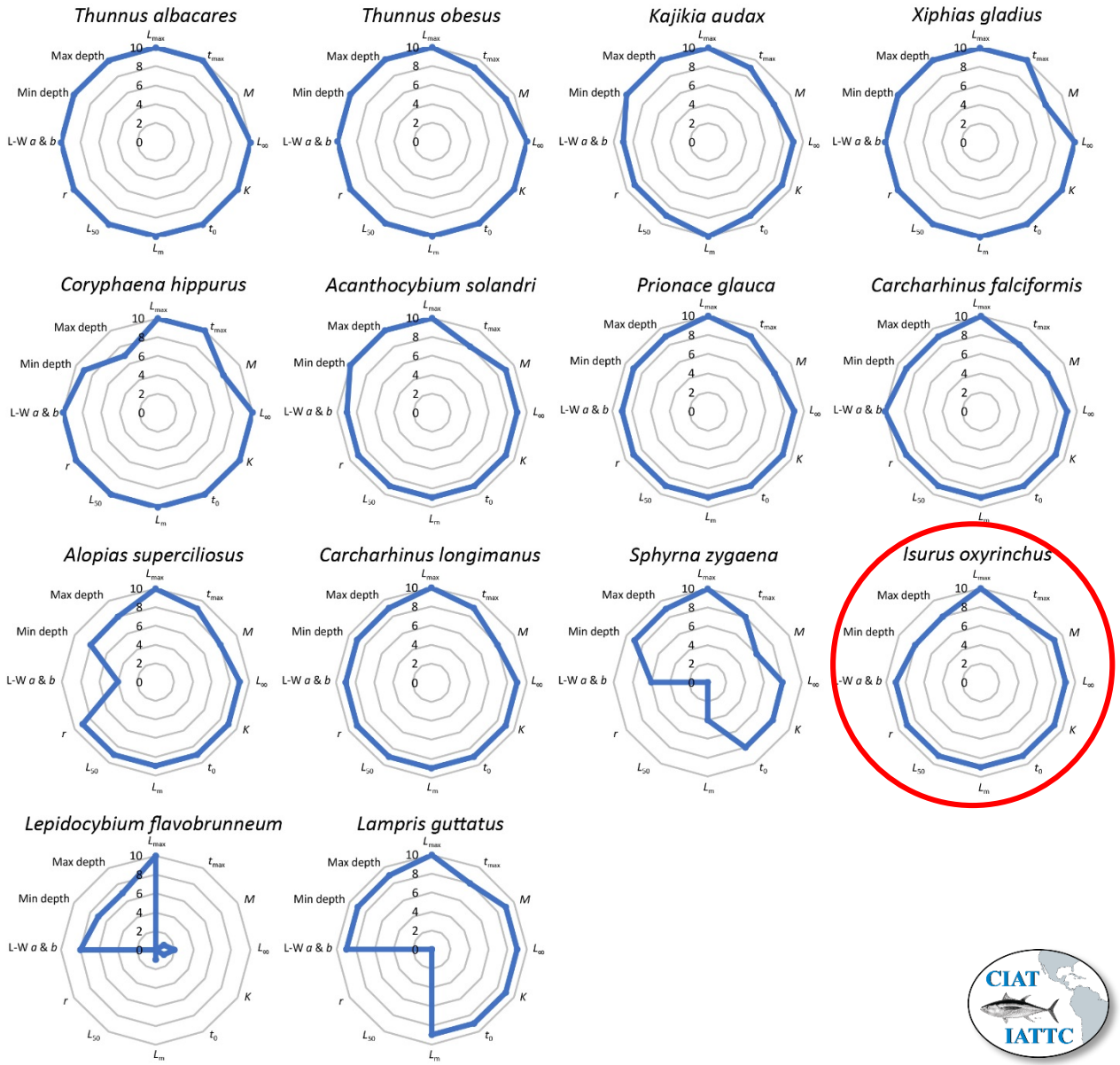
Data reliability – Radar plots



Data reliability – Radar plots

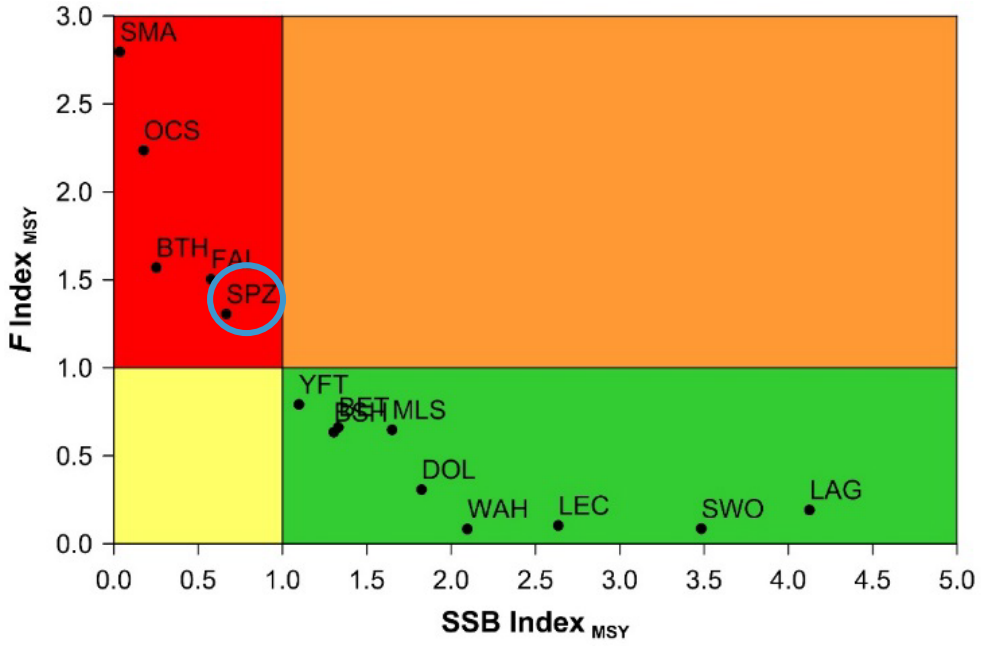
- Mako
  - Immediate attention

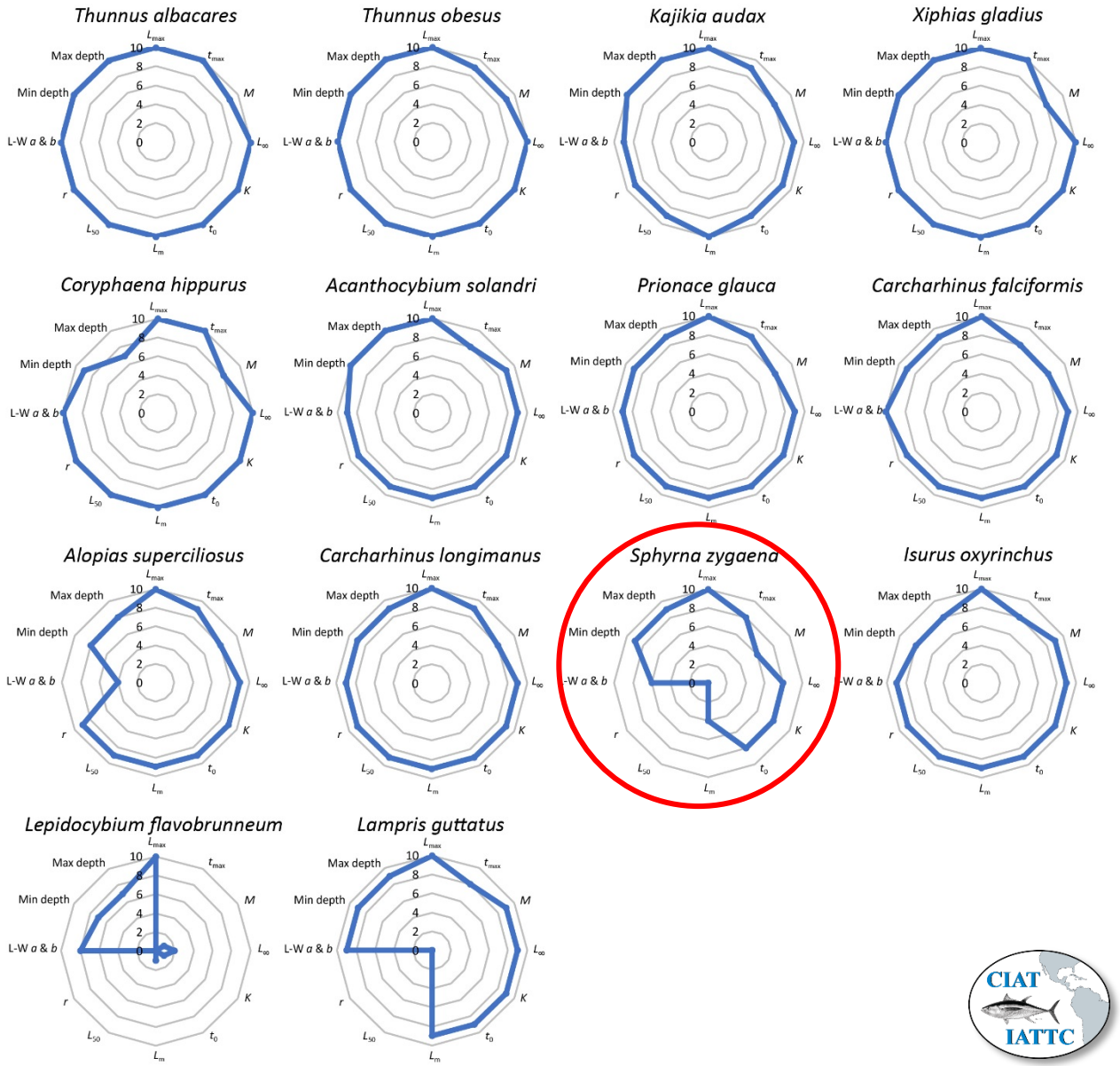




Data reliability – Radar plots

- Mako
  - Immediate attention
- Hammerhead
  - Data-deficient
  - False positive?





EASI-Fish vs PSA results

Group	FAO code	Common name	PSA
Tunas	YFT	Yellowfin tuna	High
	BET	Bigeye tuna	Med
	SKJ	Skipjack	Med
Billfishes	SWO	Swordfish	High
	MLS	Striped marlin	High
	BUM	Blue marlin	Med
Elasmobranchs	BTH	Bigeye thresher shark	High
	BSH	Blue shark	High
	SMA	Shortfin mako shark	High
	SPZ	Smooth hammerhead	High
	FAL	Silky shark	Med
	OCS	Oceanic whitetip shark	Med
Large fishes	WAH	Wahoo	High
	DOL	Common dolphinfish	Med
	LAG	Opah	Med
	LEC	Escolar	Med

- PSA
  - Longline fishery only (SAC-08)

EASI-Fish vs PSA results

Group	FAO code	Common name	PSA	EASI- Fish
Tunas	YFT	Yellowfin tuna	High	Low
	BET	Bigeye tuna	Med	Low
	SKJ	Skipjack	Med	Low
Billfishes	SWO	Swordfish	High	Low
	MLS	Striped marlin	High	Low
	BUM	Blue marlin	Med	Low
Elasmobranchs	BTH	Bigeye thresher shark	High	High
	BSH	Blue shark	High	High
	SMA	Shortfin mako shark	High	High
	SPZ	Smooth hammerhead	High	High
	FAL	Silky shark	Med	High
	OCS	Oceanic whitetip shark	Med	High
Large fishes	WAH	Wahoo	High	Low
	DOL	Common dolphinfish	Med	Low
	LAG	Opah	Med	Low
	LEC	Escolar	Med	Low

- PSA
  - Longline fishery only (SAC-08)
- EASI-Fish
  - Longline
  - 3 purse-seine fisheries
- Tunas - 3 false positives
- Billfishes - 3 false positives
- Sharks - 2 false negatives
- Large fish - 4 false positives

Conclusions

- Demonstrating ecological sustainability a significant challenge, but increasingly important for fisheries worldwide moving to EBFM
- EASI-Fish improves on previous ERA methods:
  - Quantitative assessment of cumulative fishing impacts
  - Spatially-explicit, so vulnerability assessed under spatial and temporal scenarios
  - Uses reference points and result display format (Kobe plot) familiar to managers
  - Requires less data than PSA
- EASI-Fish is precautionary and results in less false positives
  - Saves fisheries valuable resources by requiring fewer species to be monitored or managed
- EASI-Fish is not a stock assessment, it's a quantitative prioritization tool
  - Identifies species requiring immediate mitigation measures
  - Further data collection and research for future conventional stock assessment

Future work

- Methodology fine tuning:
  - Determine most appropriate method for species distribution basemaps (GAMs, Maxent)
  - Define BRPs for species groups (F_{MSY} for teleosts; $SPR_{40\%}$ for elasmobranchs?)
- First formal EPO assessment
  - 100+ species to be assessed across EPO tuna fisheries
  - 'Industrial' longline, class 6 purse-seine (OBJ, NOA, DEL) as a minimum (finish 2019-2020)
  - Class 1-5 purse-seine, artisanal fisheries important (esp. sharks), sport fisheries
  - Encourage collaboration of CPCs to supply data for these smaller fisheries
- EASI-Fish in development, so any comments or criticisms welcome

Questions?

Model validation