Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



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

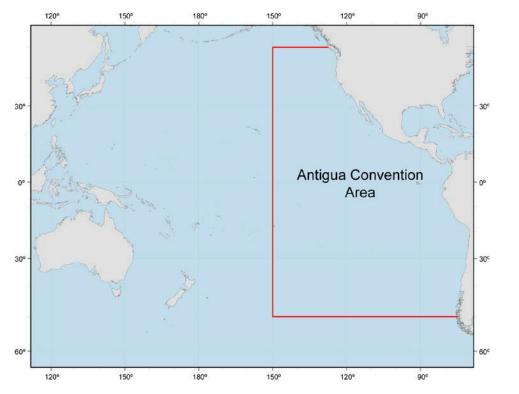
Outline

- 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 km² 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)"

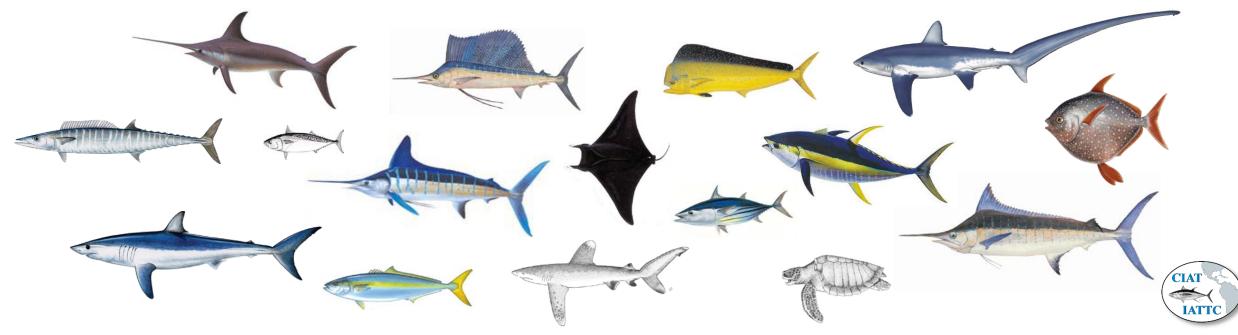
Article IV. "Where the status of target stocks or <u>non-target or associated or dependent species</u> is of concern, the members of the Commission shall subject such stocks and species to enhanced monitoring in order to review their status and the efficacy of conservation and management measures."

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



Ecological sustainability

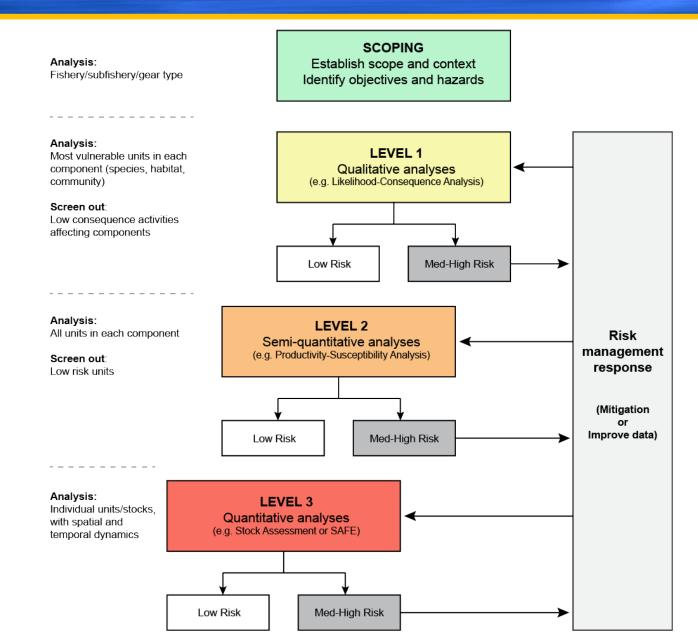
- But many species interactions across EPO fisheries
- Many caught incidentally "bycatch" & "byproduct"
- Some caught infrequently, many have little value, poor reporting or recorded in broad taxonomic groups (e.g. "sharks").
- Lack basic biological and ecological data for traditional assessment



- 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)

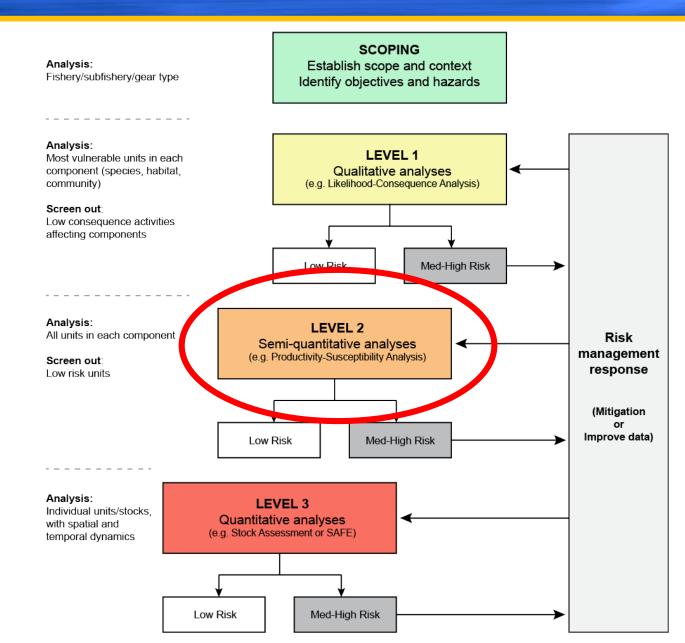


ERAEF Framework





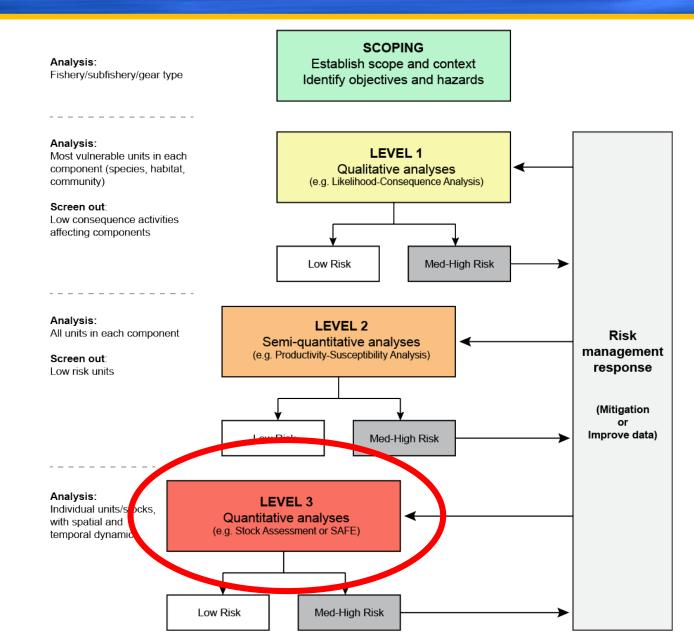
ERAEF Framework



- 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



- 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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- 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



- "Vulnerability" potential for the productivity of a stock to be diminished by direct and indirect fishing pressure.
- 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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- Productivity capacity to recover if stock is depleted, function of life history attributes (e.g. longevity, maturity) – 5 attributes



• Precise or 'borrowed' parameter values reduced to a 1-3 score



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

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



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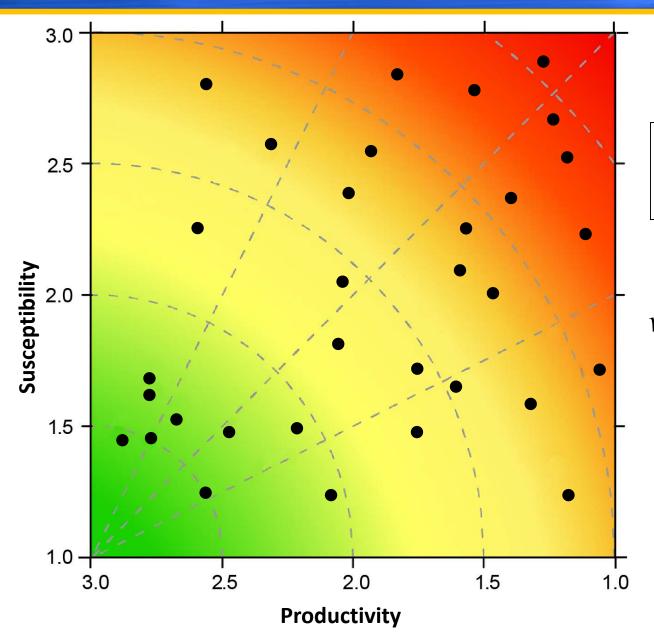


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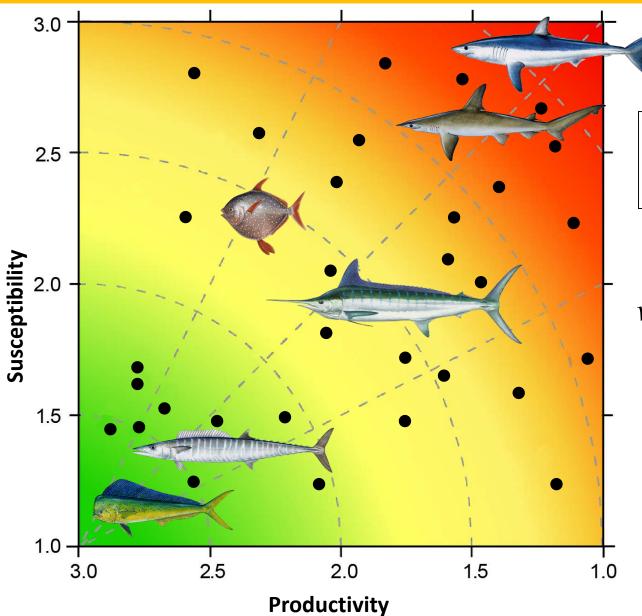
• Scores for all attributes averaged to provide a vulnerability score (v)





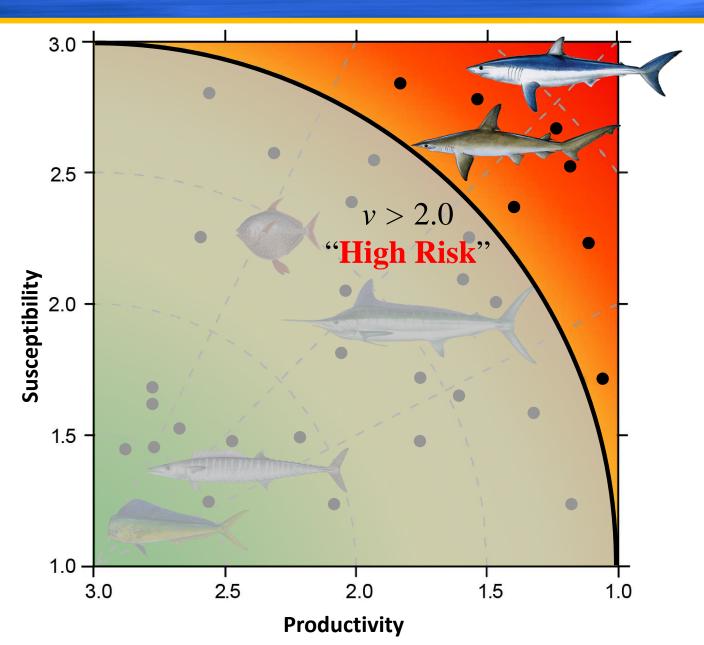
Vulnerability (*v*) is measured as Euclidean distance from plot origin

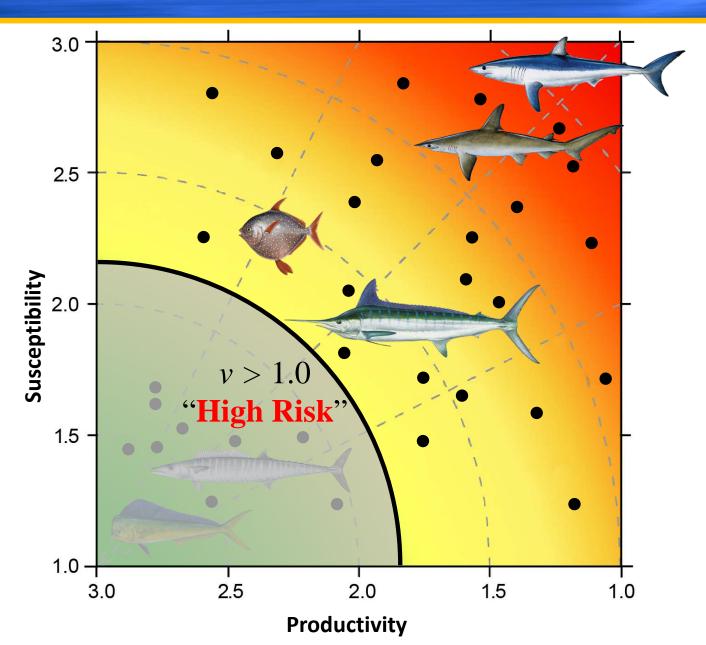
$$v = \sqrt{(p-3)^2 + (s-1)^2}$$



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

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





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)	Х
Maximum age (t _m)	Х
Maximum size (L _{max})	Х
Length-at-infinity (L∞)	
von Bertalanffy growth coefficient (K)	Х
Natural mortality (M)	Х
Fecundity	Х
Breeding strategy	Х
Recruitment pattern	Х
Age at maturity (t_m)	Х
Length-at-maturity (L_m or L_{50})	
Mean trophic level	Х

Susceptibility attribute

Areal overlap	Х
Geographic concentration	Х
Fishing season duration	
Vertical overlap (i.e. encounterability)	Х
Seasonal availability	Х
Schooling, aggregation, and behavioral responses	Х
Morphological characteristics affecting capture	Х
Gear selectivity	
Desirability or value of the fishery	Х
Management strategy	Х
Fishing rate relative to <i>M</i> (equivalent to <i>F</i> -based RPs)	Х
Biomass of spawners (SSB) or other proxies (equivalent to	Х
spawning biomass-based RPs)	
Survival after capture and release	Х
Impact of fisheries on essential fish habitat	Х

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



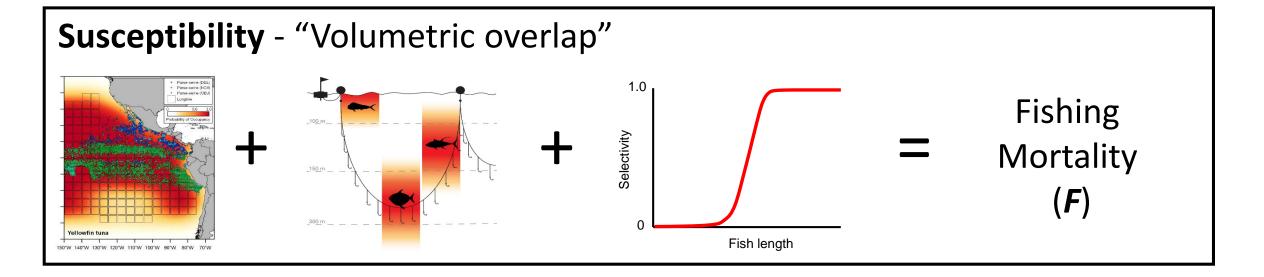
Need for improved ERA methods

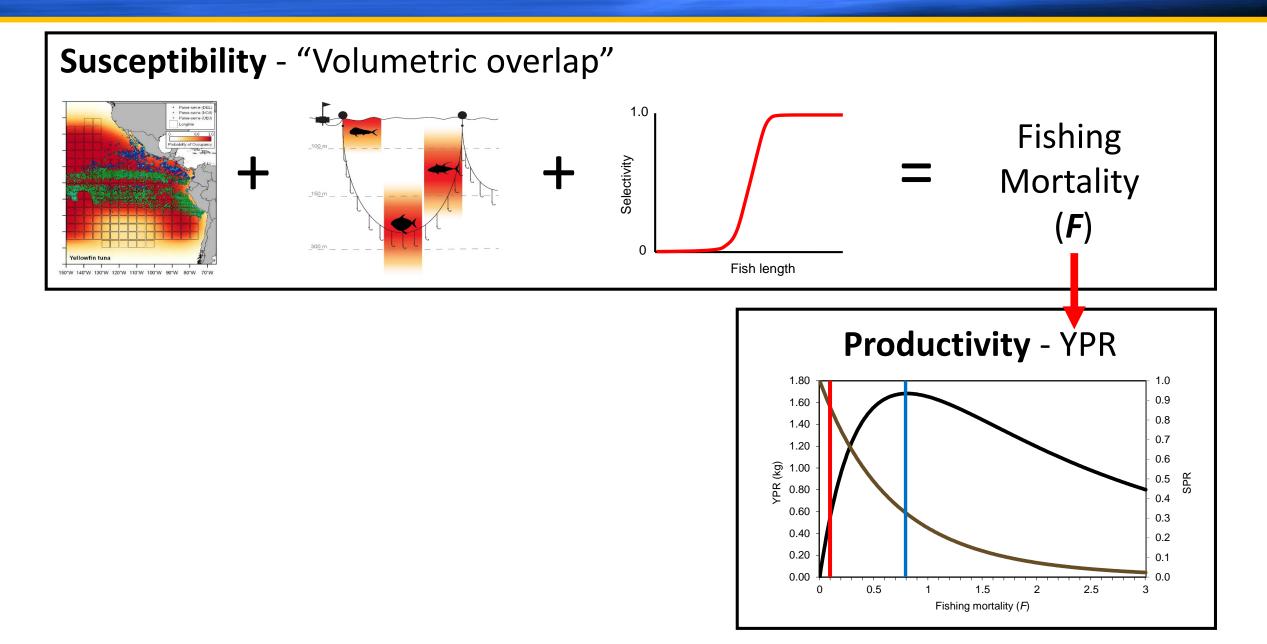
- Managers need a quantitative method to more reliably identify vulnerable species
- Rapid, inexpensive, and repeatable, especially in data-limited settings
- Spatially explicit for moving fishing effort, specify existing closures, but also to explore 'what if' scenarios as mitigation measures.

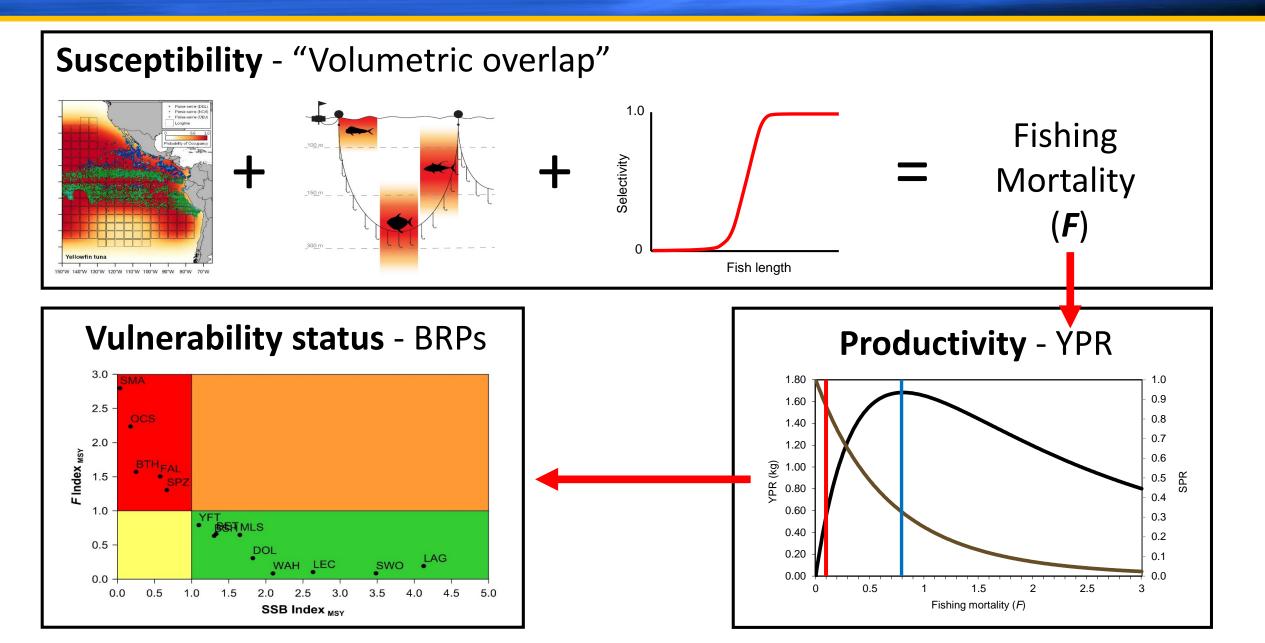


- <u>E</u>cological <u>A</u>ssessment of the <u>S</u>ustainable <u>I</u>mpacts by <u>Fish</u>eries (EASI-Fish)
- Similar PSA "Productivity" and "Susceptibility" components
- Susceptibility component estimates the proportion of the population that is potentially impacted by fishery *x*.
 - Exploitation 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









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)

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



Susceptibility

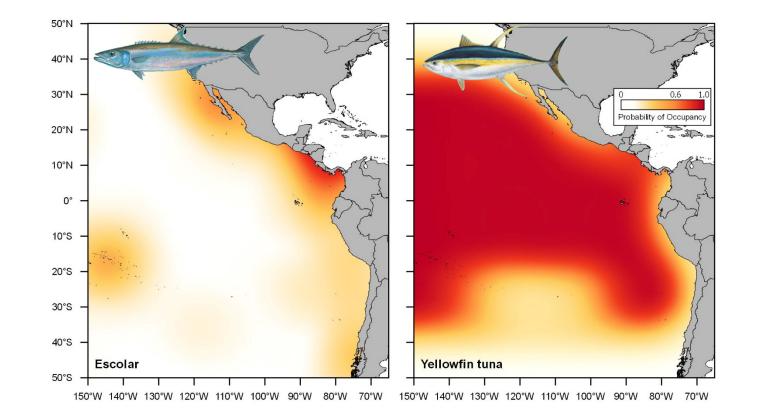
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Areal overlap

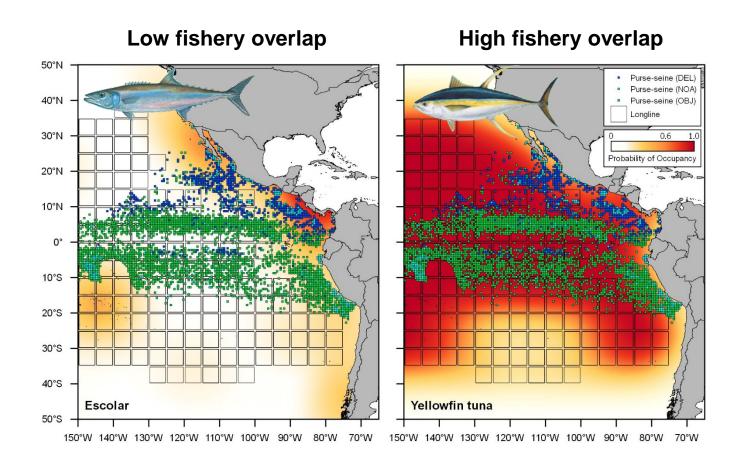
• Species habitat modeled using environmental envelope model





Areal overlap

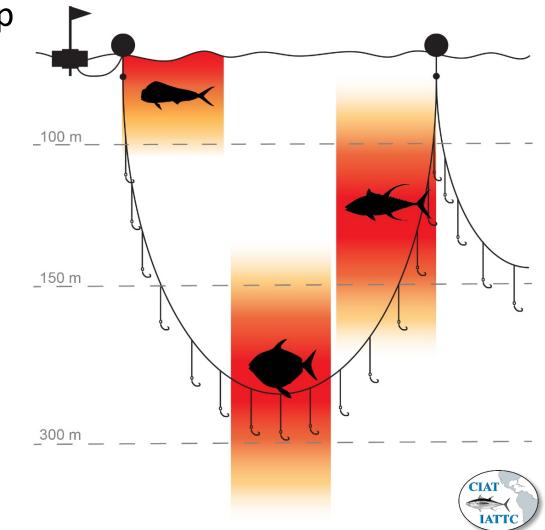
- Species habitat modeled using environmental envelope model
- Areal overlap no. grids occupied (G) that are fished (G_x)
- Target species overlap high (0.76 for LL), bycatch lower (0.48)



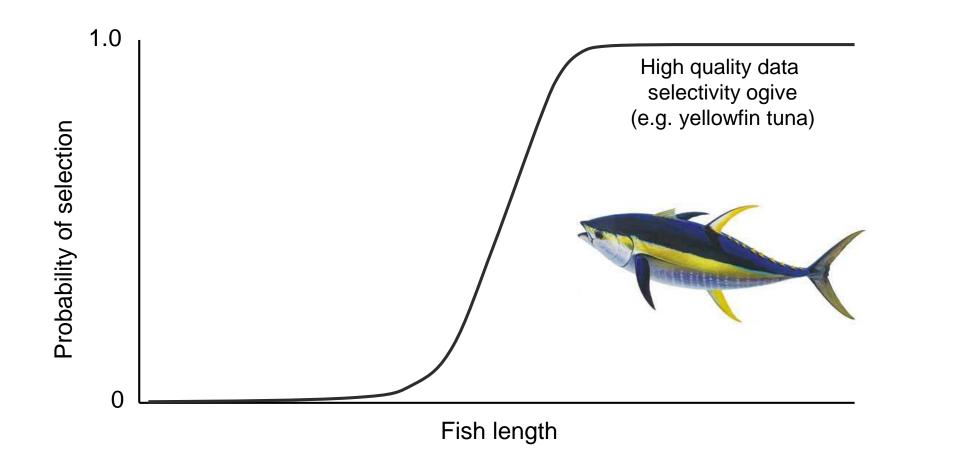


Encounterability

- 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

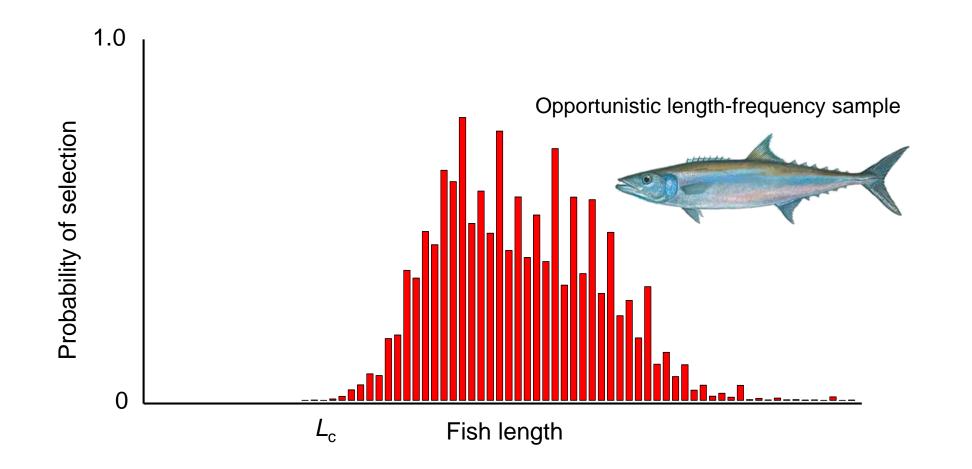


• Susceptibility parameters flexible depending on data availability



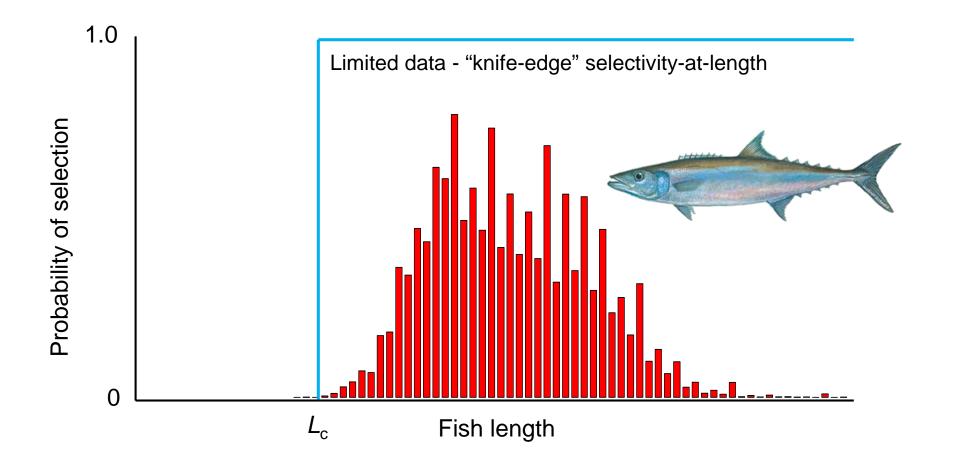


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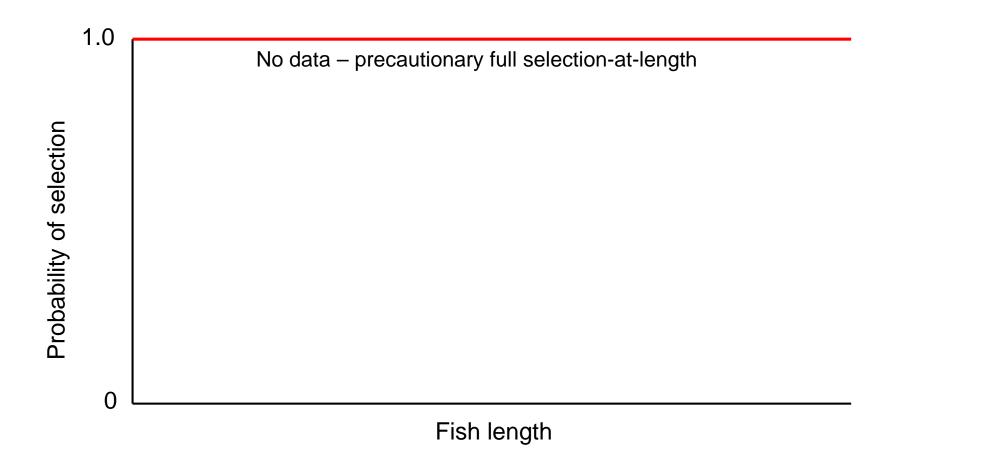


• Susceptibility parameters flexible depending on data availability





- 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*

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

- 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)

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

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



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- Fishing mortality reference points F_{MSY} and precautionary F_{0.1} and 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 SSB_{MSY} and precautionary SSB_{0.1} and SSB_{40%}
- Parameter uncertainty 10,000 Monte Carlo runs

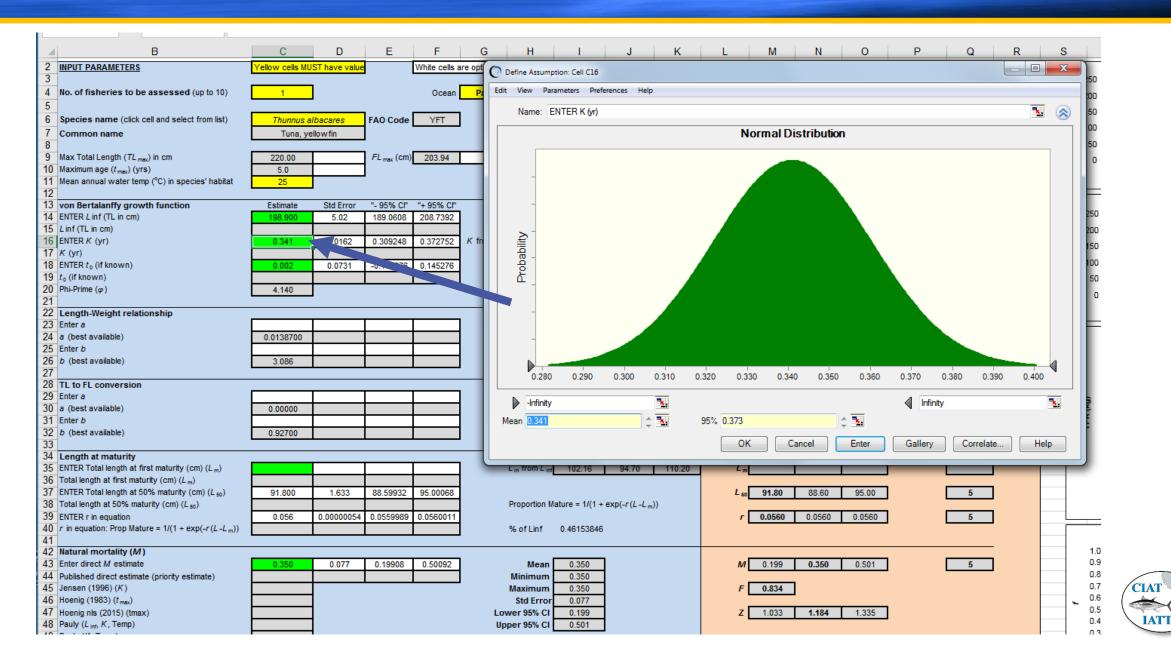


User-friendly interface

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

File Home Insert Draw Page	Layout Formulas Data Review View Developer Q Tell me what you want to do		Q. Share
C6 ▼ : × √ fx Ca	archarhinus falciformis		v
B 2 INPUT PARAMETERS	C D E F G H I J K Yellow cells MUST have value White cells are optional data override	L M N O P Q R	S T U V W X Y Z AA
3 4 No. of fisheries to be assessed (up to 10) 6 Species name (click cell and select from list) 7 Common name 8 Max Total Length (7L mm) in cm 10 Maximum age (mm) (yrs) 11 Mean annual water temp (°C) in species' habitat	1 Ocean Pacific, Eastern Carcharhinus falciformis O Code FAL Species type (1-fish; 2-elasmobranch) 2 Thumnus obesus Thumnus orientalis Factoria Statum orientalis Statum orientalis Katsuwonus pelanis Factoria Minimum depth (m) 0 Statum orientalis Kajakia uda una orientalis Maximum recorded depth (m) 100 Statum orientalis	Clear Inputs Prepare CB No. Iterations Compile Input Data and Results 7L _{max} (cm) 4 4 6 0 5 7L _{max} (cm) 550.00 Interval FL _{max} (cm) 464.08 Interval Min (m) 0 5 4 Min (m) 100 5 Max (m) 165 5	600 500 500 500 500 500 500 500
12 3 von Bertalanffy growth function 14 ENTER L inf (TL in cm) 15 L inf (TL in cm) 16 ENTER K (yr) 17 K (yr) 18 ENTER t ₀ (if known) 19 t ₀ (if known) 20 Ph-Prime (p) 21	Landburger Sector * 95% Cr * 95% Cr Estimate * 95% Cr 216.40 3.00 210.52 222.28 Linf from Lmax Linf from Lmax 0.143 0.030 0.089 0.207 K from L inf & Phi Prime -1.760 0.020 -1.799 -1.721 L:= L int (1 - exp(-K(t - t_0)))	Estimate Low 95% CIJpper 95% CI L = 216.40 210.52 222.28 5 K 0.148 0.089 0.207 5 t ₀ -1.760 -1.799 -1.721 5 Phi-Prime 3.950 Winf (kg) 1303.16 5	Length (TL)-st-Age
22 Length-Weight relationship 23 Enter a 24 a (best available) 25 Enter b 26 b (best available) 27	0.0273000 W = a TL^b (TL in cm) 2.860 Pred W (kg) Enter TL	a 0.027300 5	0 5 10 15 20 25 30 Length (cm) 9.000 8.000 7.000
28 TL to FL conversion 29 Enter ø 30 ø (best available) 31 Enter b 32 b (best available) 33 d (best available)	2.08000 FL (in cm) = a + b TL 1.32000 Pred FL Estimate "- 95% CF" *+ 95% CF"	a 2.0600 1 1	6.000 5.000 G 4.000 3.000 2.000
$\begin{array}{c} 34 \text{Length at maturity} \\ 35 \text{ENTER Total length at first maturity (cm) (L_m)} \\ 36 \text{Total length at first maturity (cm) (L_m)} \\ 37 \text{ENTER Total length at 50% maturity (cm) (L_{sc})} \\ 38 \text{ENTER Total length at 50% maturity (cm) (L_{sc})} \\ 39 \text{ENTER the requation} \\ 40 \text{in equation: Prop Mature = 1/(1 + exp(-r(L-L_m)))} \\ \end{array}$	Estimate 95% CT +95% CT Lm from Lm 110.64 102.20 119.80 147.50 1.50 144.560 150.440 Proportion Mature = 1/(1 + exp(-r(L-L_m))) 0.1380 0.0100 0.118 0.158 % of Linf 0.68160813	L = L = r 0.1380 0.1184 0.1576 5	1.000 0.000 0 0.5 1 1.5 2 2.5 3 Fishing mortality (P)
41 2 Natural mortality (M) 43 Enter direct M estimate 44 Published direct estimate (priority estimate) 45 47 Hoenig (1980) (K) 48 Pauly (C ten, K, Temp) 49 49 Pauly (K, Temp) 50 51 52 53 54 54 54 55 56 7 57 58 54 54 55 56 57 58 59 54 55 56 57 58 59 50 54 55 56 57 58 59 59 50	Mean 0.160 0.180 Minimum 0.160 0.222 Maximum 0.160 0.172 Std Error 0.58 0.257 Lower 95% CI 0.114 0.262 Upper 95% CI 0.206 0.312 0.173 0.206	M 0.114 0.160 0.206 2 F 0.879 Z 0.993 1.039 1.085	

Incorporating parameter uncertainty

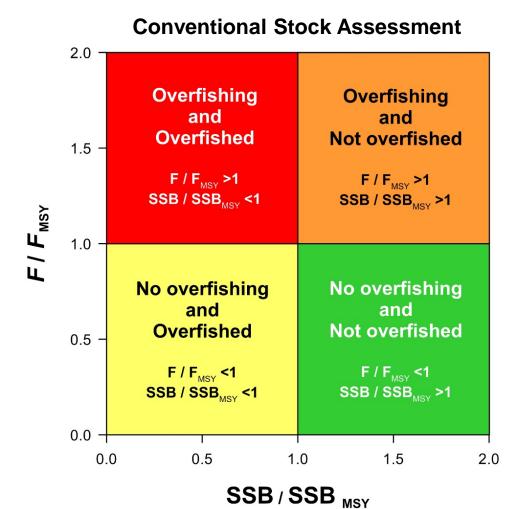


Incorporating parameter uncertainty

⊿ B	C D	E F	G H I J K	L M. N. N.	P Q R S
2 INPUT PARAMETERS	Yellow cells MUST have value	White cells are op	Define Assumption: Cell C43		
4 No. of fisheries to be assessed (up to 10)	1	Ocean F	Edit View Parameters Preferences Help		
5 6 Species name (click cell and select from list)	Thunnus albacares		Name: Enter direct estimate (e.g. from stock as	ssessment)	N (8)
7 Common name	Tuna, yellow fin	FAO Code YFT		Uniform Distribution	
8 9 Max Total Length (<i>TL</i> max) in cm	220.00	FL max (cm) 203.94	-		
10 Maximum age (t _{max}) (yrs)	5.0	200.04			
11 Mean annual water temp (°C) in species' habitat	25				
13 von Bertalanffy growth function	Estimate Std Error	"- 95% Cl" "+ 95% Cl"	1 -		
14 ENTER L inf (TL in cm) 15 L inf (TL in cm)	198.900 5.02	189.0608 208.7392			
16 ENTER K (yr)	0.341 0.0162	0.309248 0.372752 K f	Probability		
17 K (yr)			a - a - a - a - a - a - a - a - a - a -		
18 ENTER t _o (if known) 19 t _o (if known)	0.002 0.0731	-0.141276 0.145276			
20 Phi-Prime (φ)	4.140				
21					
22 Length-Weight relationship 23 Enter a					
24 a (best available)	0.0138700				
25 Enter b					
26 b (best available) 27	3.086				
28 TL to FL conversion			0.200 0.220 0.240 0.260 0.280	0.300 0.320 0.340 0.360 0.380 0.400 0.4	420 0.440 0.460 0.480 0.500
29 Enter a					
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 30 a (best available) 31 Enter b 32 b (best available) 33 34 Length at maturity 35 ENTER Total length at first maturity (cm) (L_m) 36 Total length at first maturity (cm) (L_{so}) 37 ENTER Total length at 50% maturity (cm) (L_{so}) 39 ENTER r in equation 40 r in equation: Prop Mature = 1/(1 + exp(-r(L-L_m))) 41 42 Natural mortality (M) 43 Enter direct M estimate 	0.92700 91.800 1.633 0.056 0.00000054		Minimum 0.199 L _m from L _{inf} 102.16 94.70 110.20 Proportion Mature = 1/(1 + exp(-r (L - L _m)) % of Linf 0.46153846 Mean 0.350		Gallery Correlate Help
31 Enter b 32 b (best available) 33 Length at maturity 34 Length at maturity 35 ENTER Total length at first maturity (cm) (Lm) 36 Total length at first maturity (cm) (Lm) 37 ENTER Total length at 50% maturity (cm) (Lso) 38 Total length at 50% maturity (cm) (Lso) 39 ENTER r in equation 40 r in equation: Prop Mature = 1/(1 + exp(-r (L-Lm))) 41 Enter direct M estimate 42 Natural mortality (M) 43 Enter direct M estimate 44 Published direct estimate (priority estimate)	0.92700 91.800 1.633 0.056 0.0000054	0.0560011	Minimum 0.199 L _m from L _{ind} 102.16 94.70 110.20 Proportion Mature = 1/(1 + exp(-r (L - L _m)) % of Linf 0.46153846 Mean 0.350 Minimum 0.350	Maximum 0.501 OK Cancel Enter Leo 91.80 88.60 95.00 r 0.0560 0.0560 M 0.199 0.350 0.501	Gallery Correlate Help
31 Enter b 32 b (best available) 33 Image: Constraint of the straight of the s	0.92700 91.800 1.633 0.056 0.0000054	0.0560011	Minimum 0.199 L _m from L _{inf} 102.16 94.70 110.20 Proportion Mature = 1/(1 + exp(-r (L-L _m)) % of Linf 0.46153846 Mean 0.350 Minimum 0.350 Maximum 0.350	↓ Maximum 0.501 OK Cancel Lm Lm Leo 91.80 88.60 95.00 r 0.0560 0.0560 0.0560	Gallery Correlate Help
 31 Enter b 32 b (best available) 33 34 Length at maturity 35 ENTER Total length at first maturity (cm) (L_m) 36 Total length at first maturity (cm) (L_{so}) 37 ENTER Total length at 50% maturity (cm) (L_{so}) 38 Total length at 50% maturity (cm) (L_{so}) 39 ENTER r in equation 40 r in equation: Prop Mature = 1/(1 + exp(-r(L-L_m))) 41 42 Natural mortality (M) 43 Enter direct M estimate 44 Published direct estimate (priority estimate) 	0.92700 91.800 1.633 0.056 0.0000054	0.0560011	Minimum 0.199 L _m from L _{ind} 102.16 94.70 110.20 Proportion Mature = 1/(1 + exp(-r (L - L _m)) % of Linf 0.46153846 Mean 0.350 Minimum 0.350	Maximum 0.501 OK Cancel Enter Leo 91.80 88.60 95.00 r 0.0560 0.0560 M 0.199 0.350 0.501	Gallery Correlate Help

Defining vulnerability status

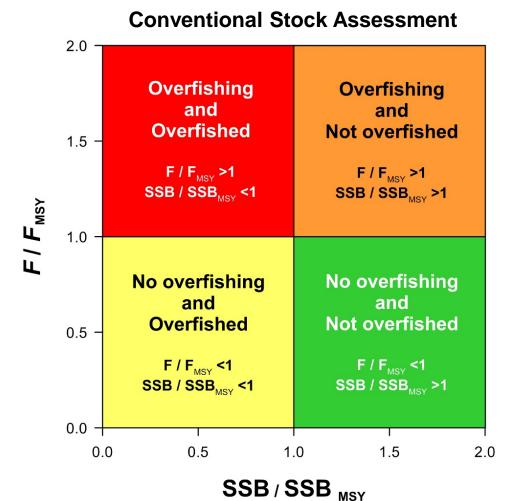
• In stock assessment BRPs define stock status (e.g. F/F_{MSY})

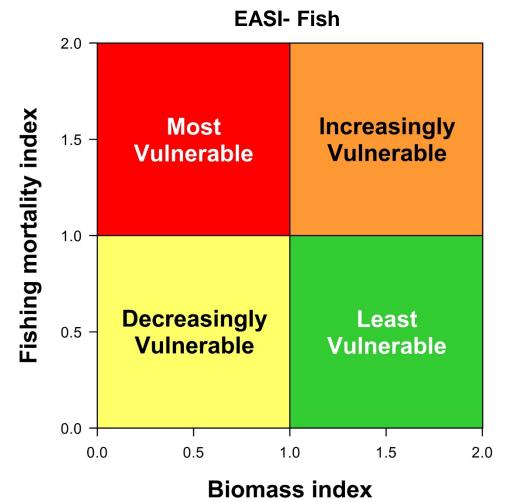


CIAT

Defining vulnerability status

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







EASI-Fish vs PSA parameters

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



EASI-Fish vs PSA parameters

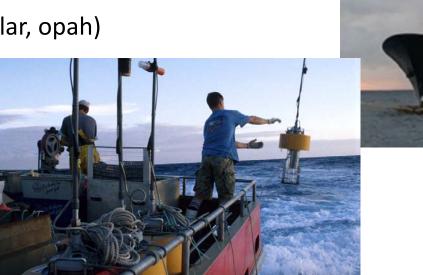
	PSA	EASI-Fish
Droductivity attribute		
Productivity attribute	V	
Intrinsic rate of population increase (r)	X	X
Maximum age (t _m)	X	X
Maximum size (L _{max})	Х	Х
Length-at-infinity (L_{∞})		Х
von Bertalanffy growth coefficient (K)	Х	Х
Natural mortality (<i>M</i>)	Х	Х
Fecundity	Х	
Breeding strategy	Х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

- 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)

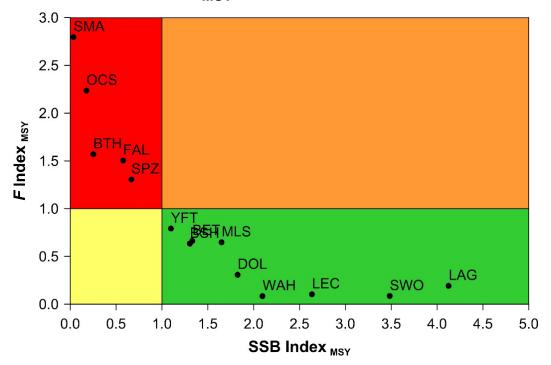






Results

- Sharks classified as "most vulnerable" SMA, OCS, BTH, FAL, SPZ
- Teleosts "least vulnerable"

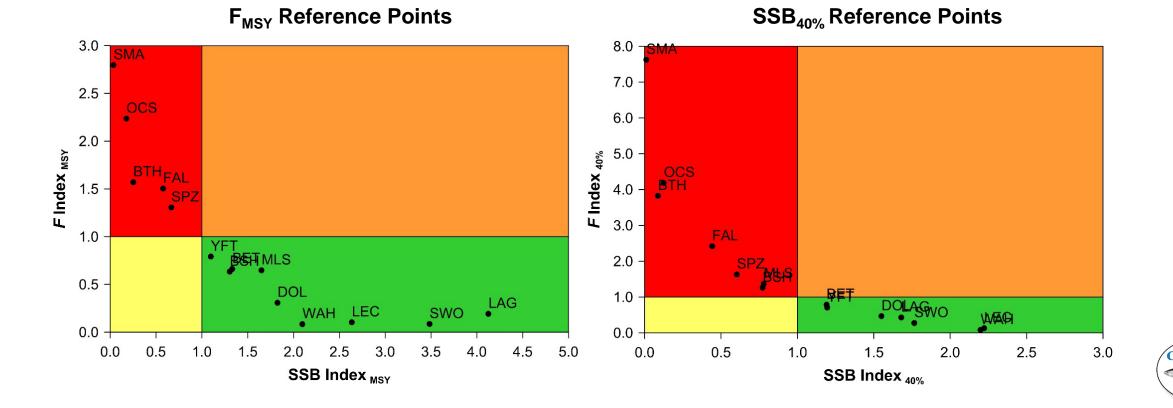






Results

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



AT'

Data reliability index

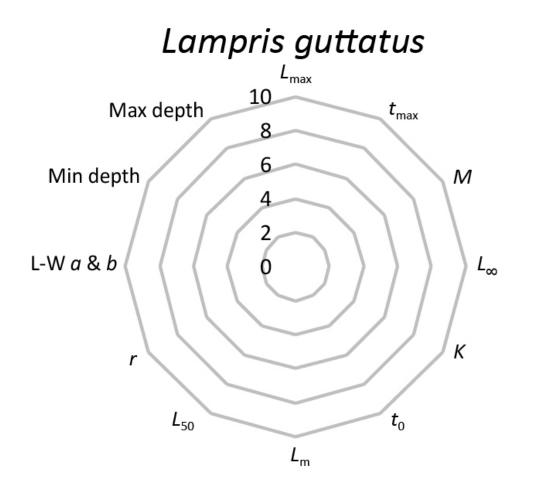
- Some species may only be "vulnerable" due to the quality of input data
- Developed a qualitative data reliability index
- Quality/precision of source study vs. relevance to species/area

		High re	liability	Moderate	reliability	Low reliability		No data	
			High precision	Low precision	High precision	Low precision	High precision	Low precision	
egion	cific	EPO	10	9	8	7	6	5	0
of source to species and region	Species-specific	WCPO	9	8	7	6	5	4	0
to speci	Spec	Other	8	7	6	5	4	3	0
source 1	cies	EPO	7	6	5	4	3	2	0
ance of	Related species	WCPO	6	5	4	3	2	1	0
Releva	Relevance Related	Other	5	4	3	2	1	1	0

Data source reliability and precision

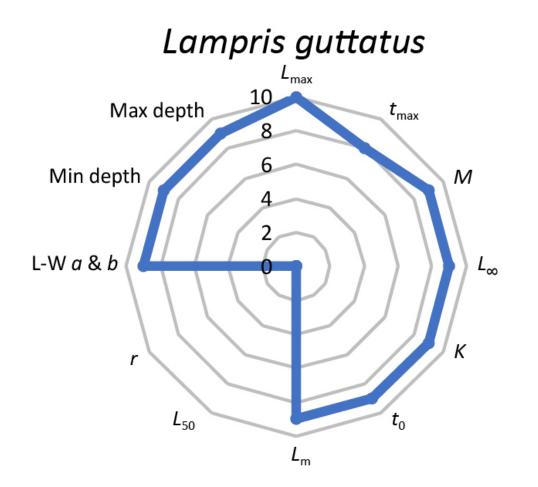


• Radar plot per species identifies data gaps

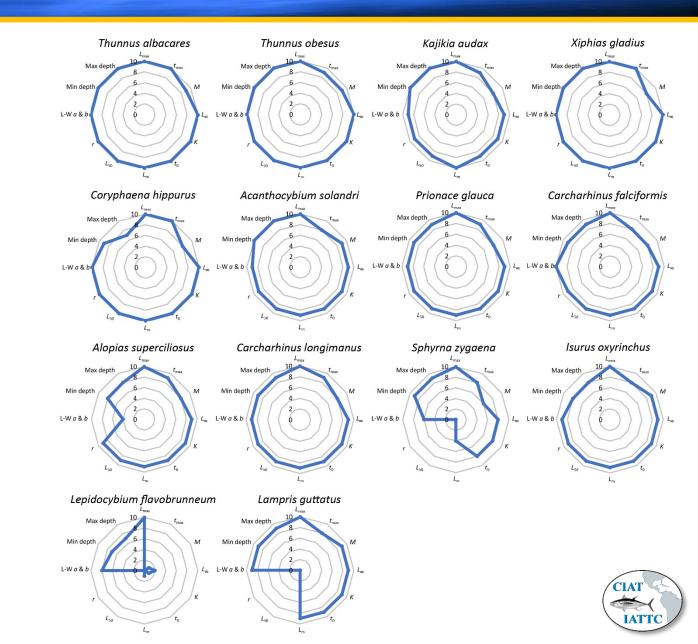




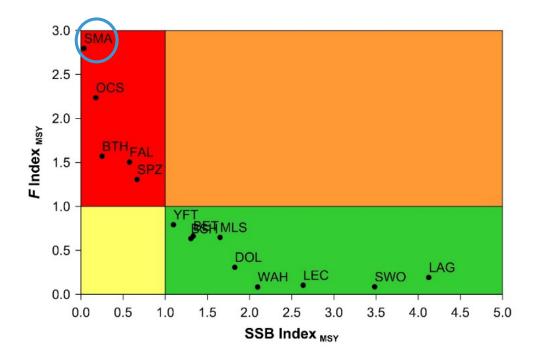
• Radar plot per species identifies data gaps

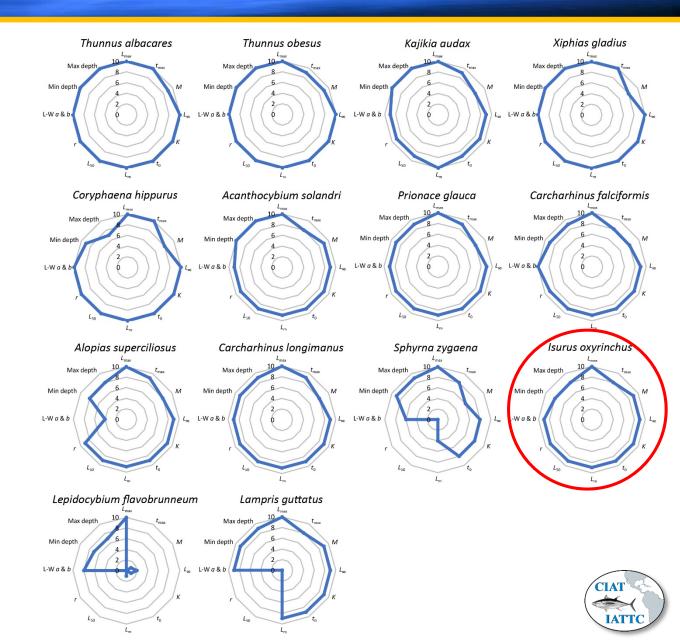




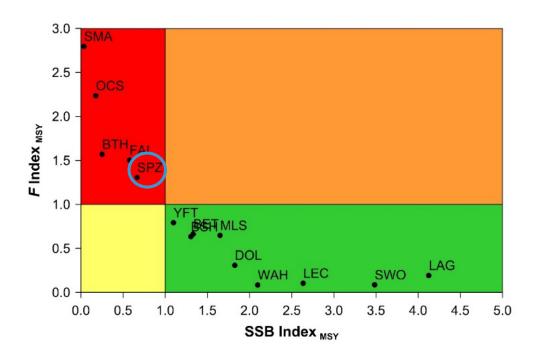


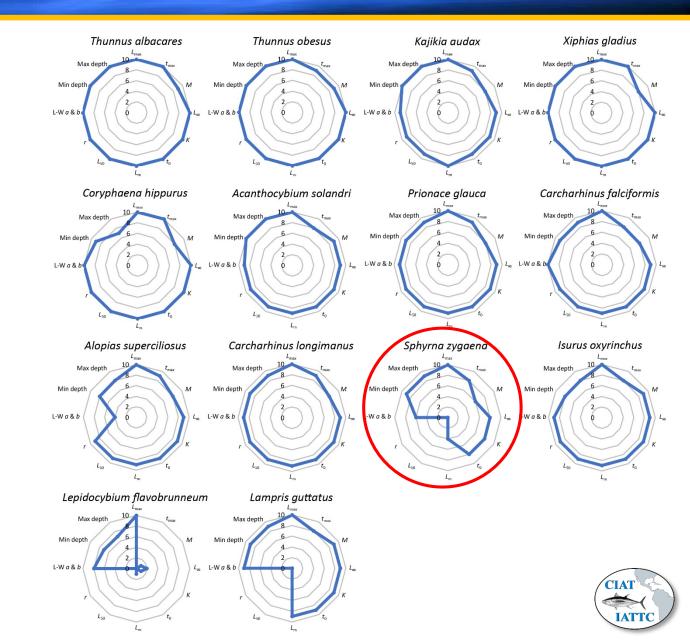
- Mako
 - Immediate attention





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





EASI-Fish vs PSA results

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

