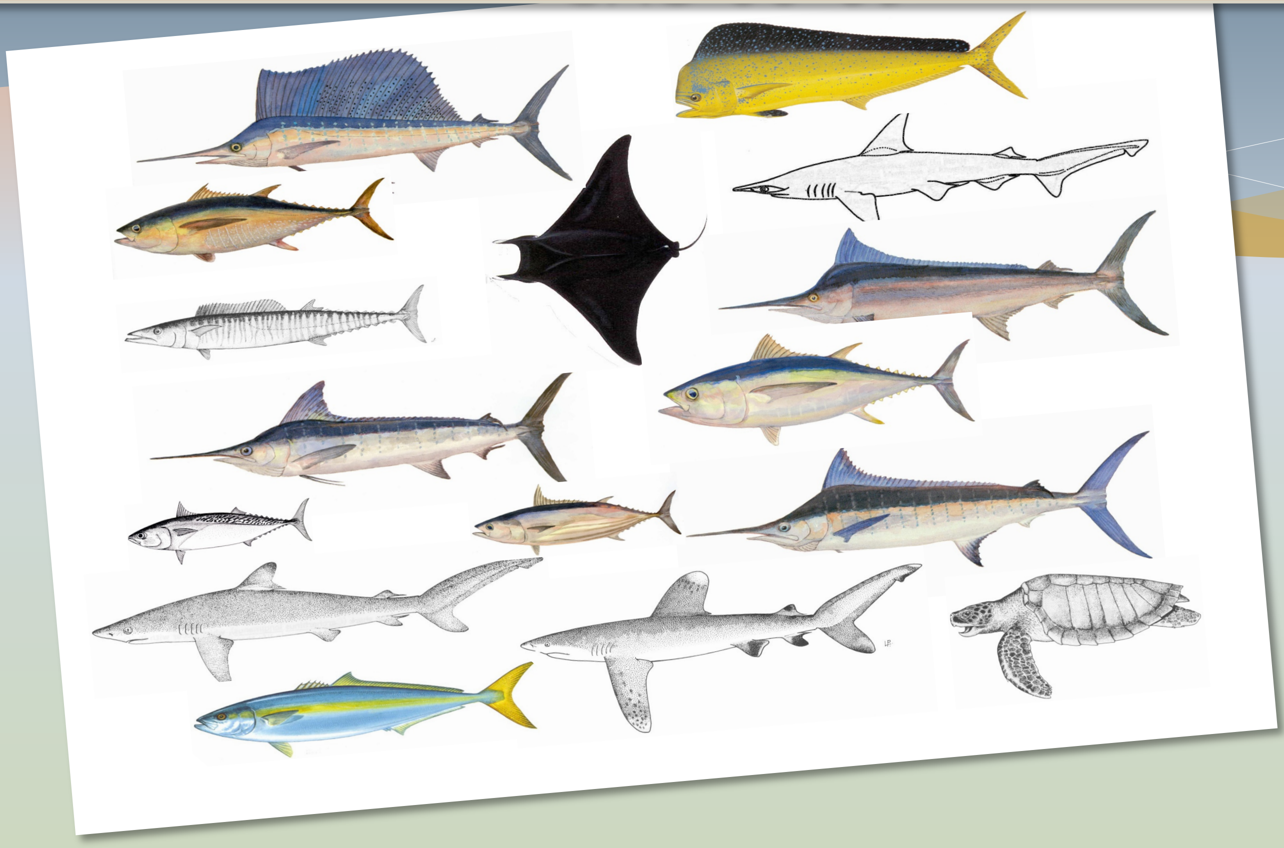
Ecosystem considerations in the eastern Pacific Ocean
SAC-06-09



Leanne Duffy and Robert Olson

6th Meeting of the Scientific Advisory Committee

6ª Reunión del Comité Científico Asesor

CIAT
IATTC

Summary: update of ecosystem considerations SAC-06-09

Trophic interactions

- Silky shark foraging ecology in the tropical EPO

Aggregate indicators

- Mean trophic level of organisms taken by the purse-seine and pole-and-line fisheries in the EPO

Ecological risk assessment (ERA)

- Modifications made to the Productivity and Susceptibility Assessment (PSA) during 2014 – proof of concept
- Future work on the ERA

Food-web structure and function

- Ecological research at the IATTC largely focused on the structure and function of the pelagic food web in the EPO

- Effects of tuna fisheries on ecosystem
  - Direct effects: e.g. bycatches of non-target species (some sensitive)
  - Indirect effects: e.g. predator-prey connections and competition via the food web

- Anticipating changes induced by fishing requires understanding of food web structure and function

- Diet studies are necessary for investigating pathways of energy flow in exploited ecosystems

- Knowledge of trophic position and linkages is essential for informing ecosystem models

- Knowledge of <u>pelagic</u> food webs is still rudimentary, in many aspects

Trophic interactions

- Novel classification tree methodology developed for analyzing complex diet data

  Kuhnert PM, Duffy LM, Young JW, Olson RJ (2012) Predicting fish diet composition using a bagged classification tree approach: a case study using yellowfin tuna (*Thunnus albacares*). Marine Biology 159: 87-100 doi 10.1007/s00227-011-1792-6

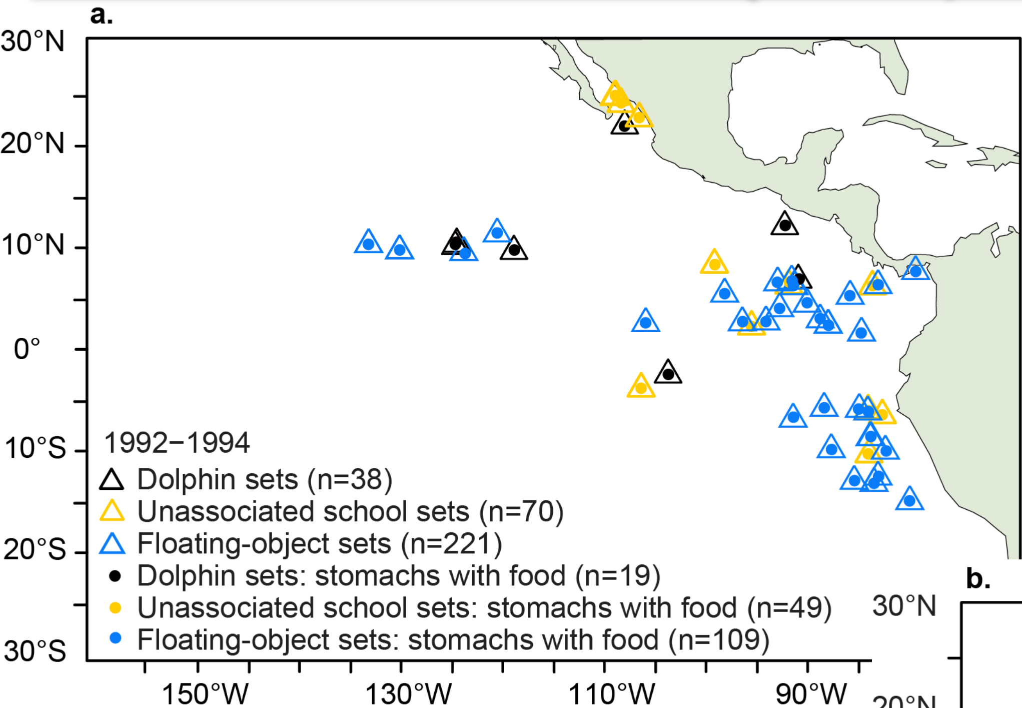
  Olson RJ, Duffy LM, Kuhnert PM, Galván-Magaña F, Bocanegra-Castillo N, Alatorre-Ramírez V (2014) Decadal diet shift in yellowfin tuna *Thunnus albacares* suggests broad-scale food web changes in the eastern tropical Pacific Ocean. Marine Ecology Progress Series 497: 157-178 doi 10.3354/meps10609

- Predation habits of silky sharks

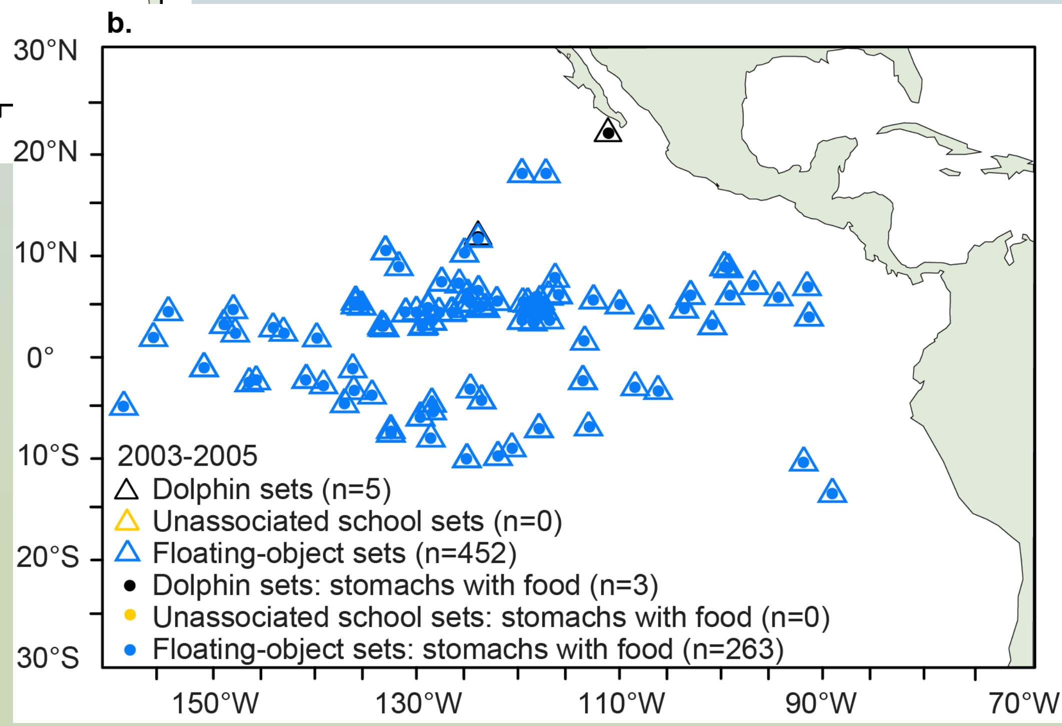
  Duffy L, Olson R, Lennert-Cody C, Galván-Magaña F, Bocanegra-Castillo N, Kuhnert P (2015) Foraging ecology of silky sharks, *Carcharhinus falciformis*, captured by the tuna purse-seine fishery in the eastern Pacific Ocean. Marine Biology 162: 571-593 doi 10.1007/s00227-014-2606-4

- Two sets of diet data separated by a decade
  - 1992-1994
  - 2003-2005

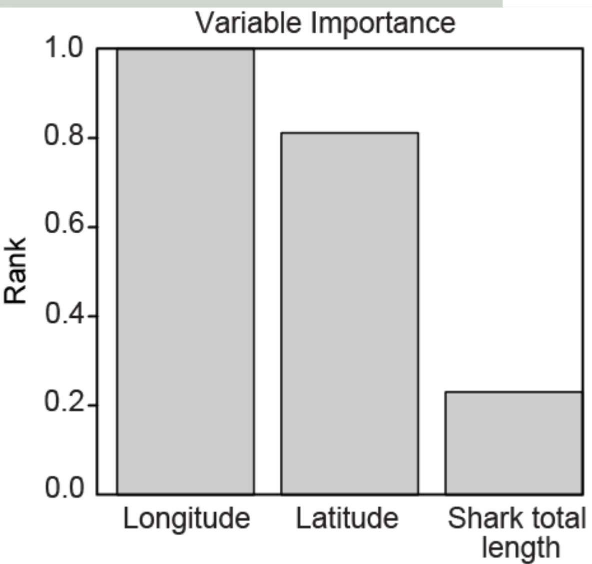
Trophic interactions: set locations, silky shark diet study (1990s, 2000s)

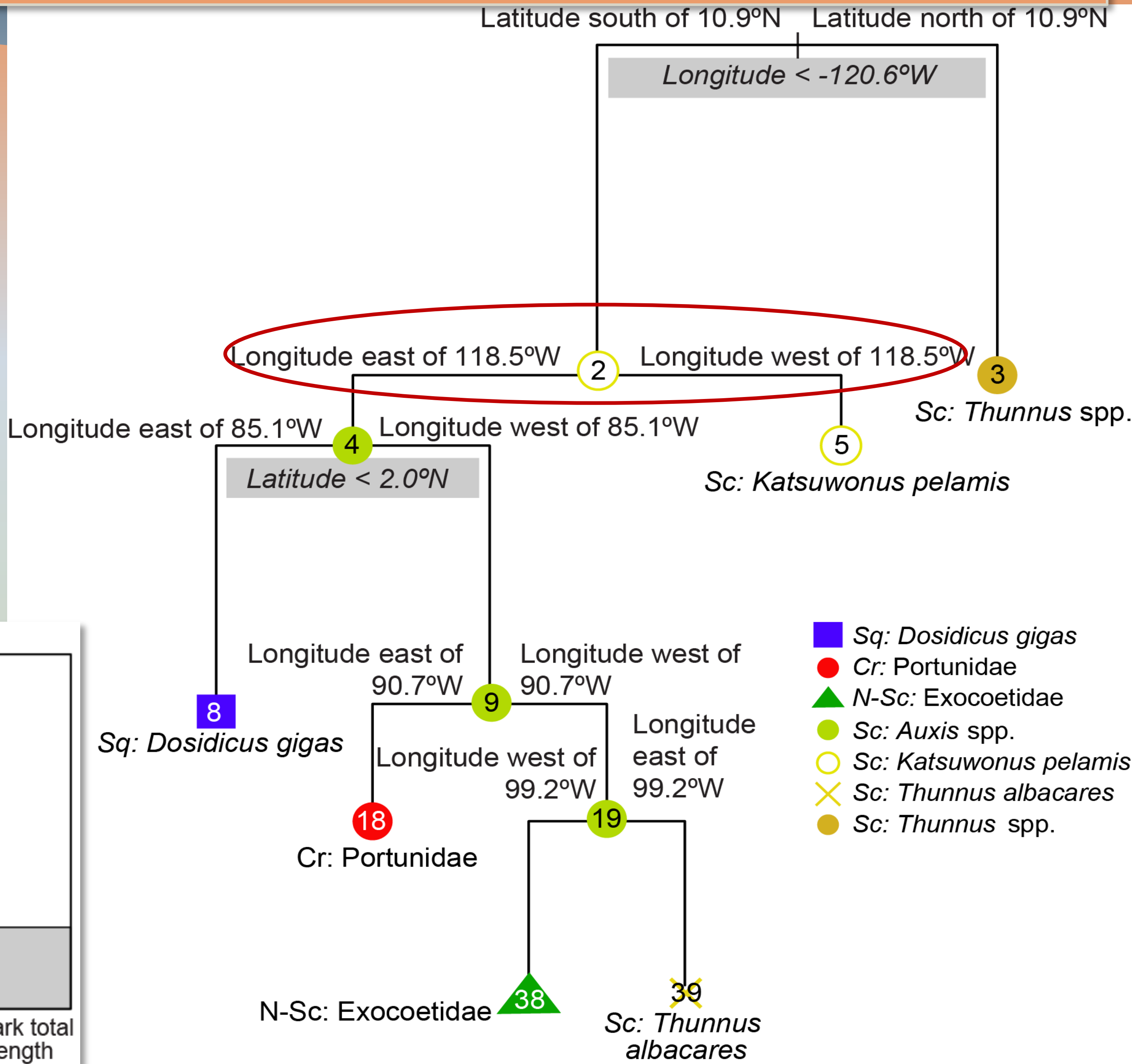


786 silky sharks sampled from 144 PS sets on 70 observed trips spanning 4 years. (289 stomachs from sharks captured as bycatch in sets on floating objects used in analysis)



Trophic interactions: classification tree analysis (silky sharks)





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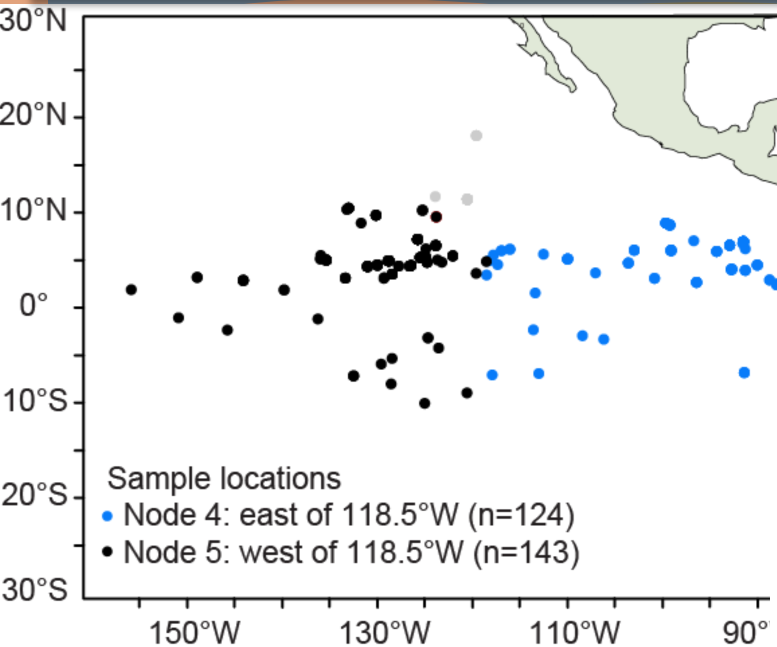
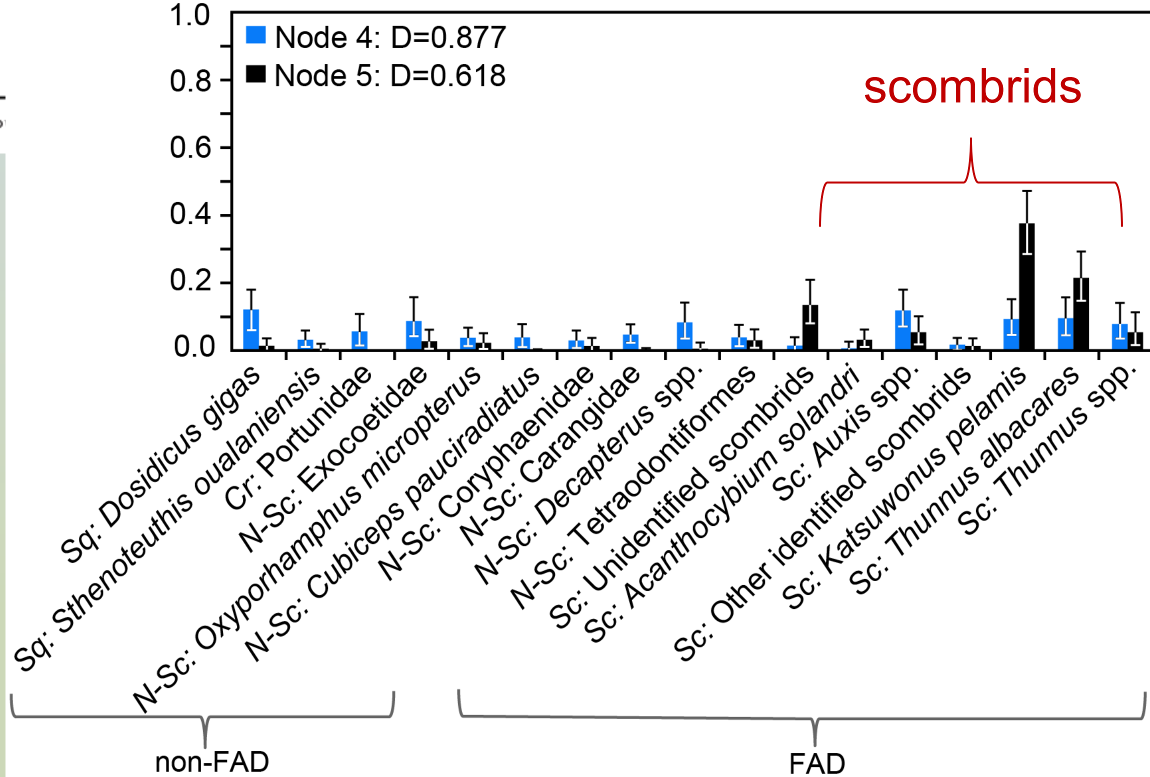
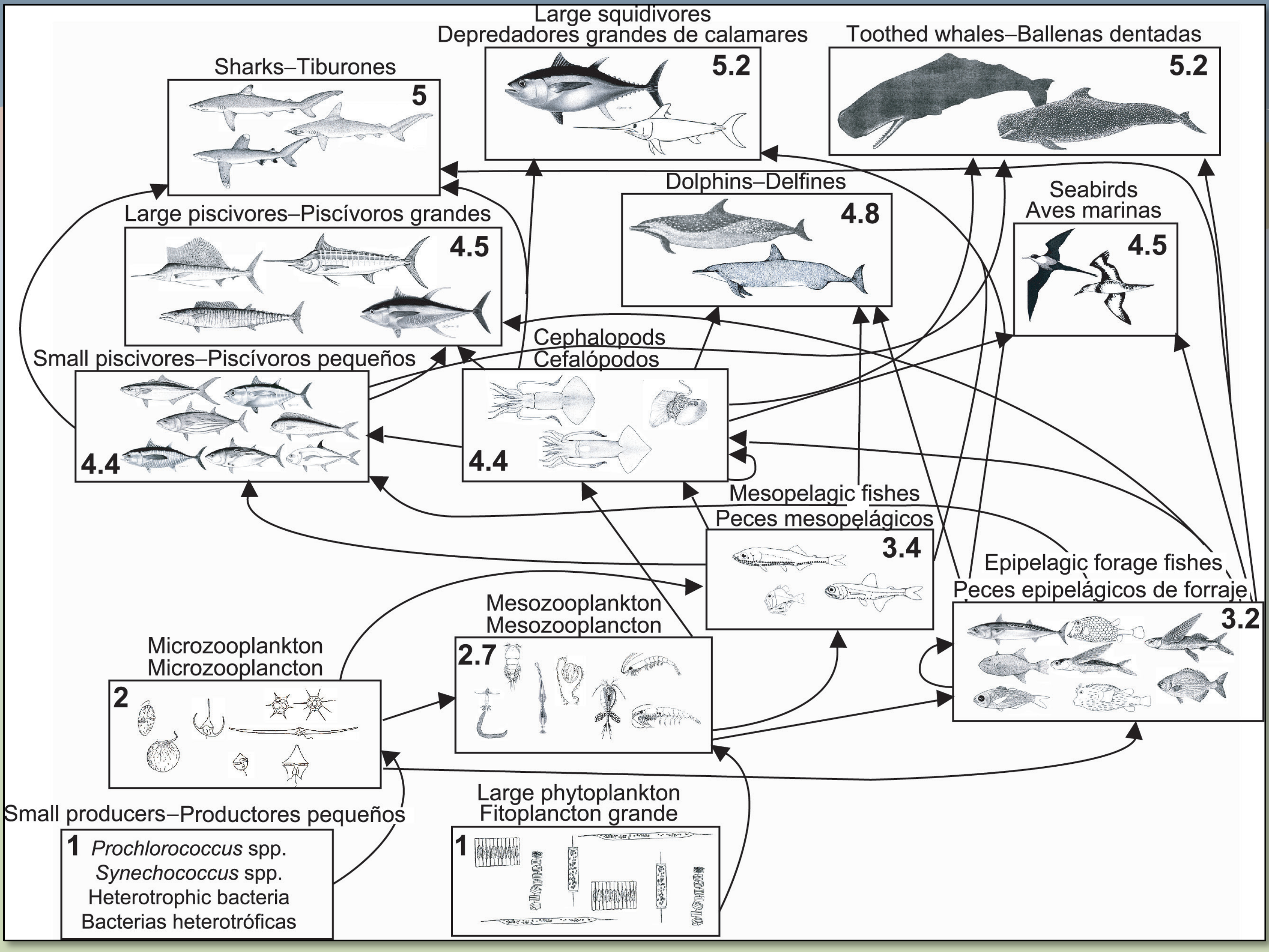


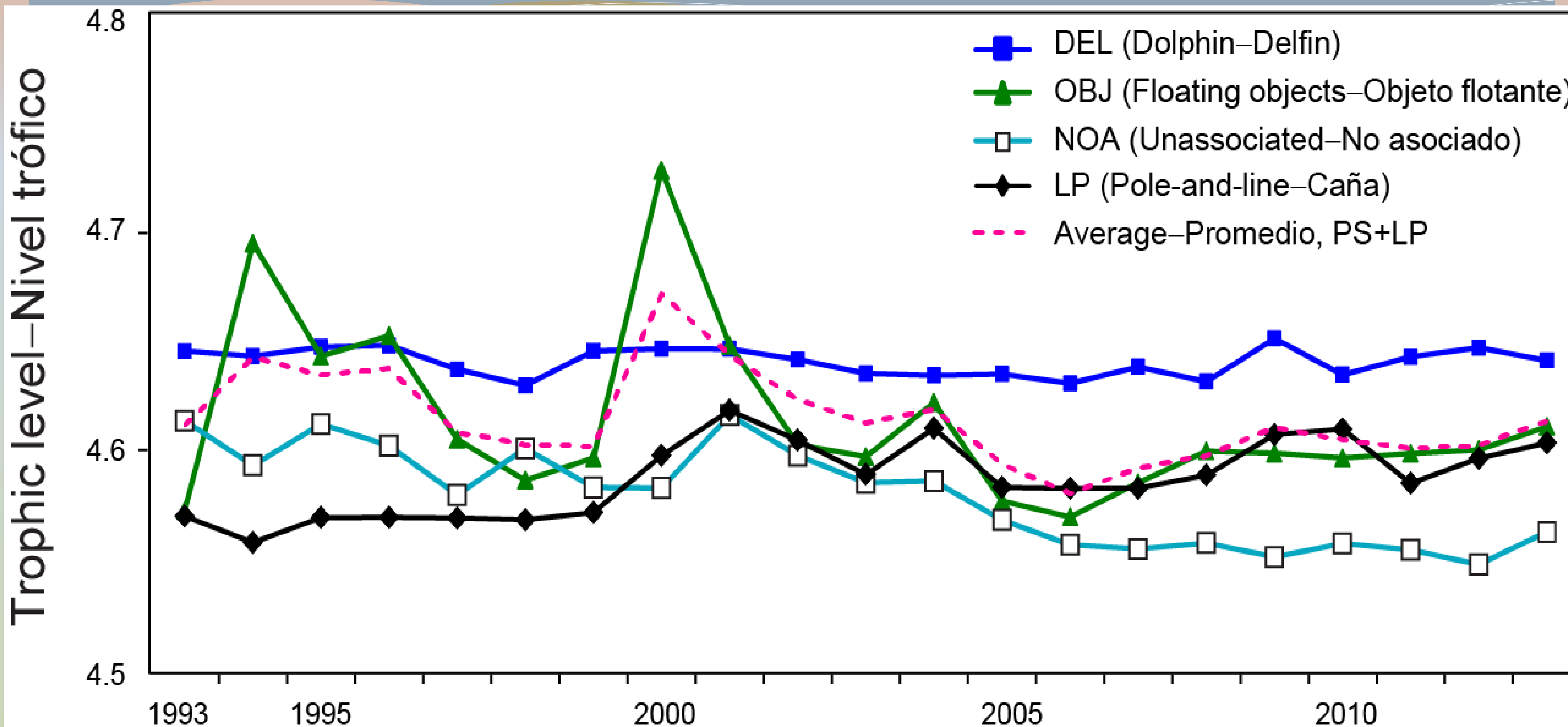


Aggregate indicators: trophic levels and a simplified food-web diagram in the EPO



Aggregate indicators: yearly mean trophic level of the catches

Mean trophic level – useful metric of ecosystem change and sustainability



Ecological Risk Assessment: vulnerability of non-target species


Use of Productivity and Susceptibility Indices to Evaluate Vulnerability in the Purse-Seine Fishery of the Eastern Pacific Ocean

Robert J. Olson[1], Leanne M. Duffy, Mark N. Maunder, Cleridy E. Lennert-Cody, Michael G. Hinton, Michael Scott, Alexandre Aires-da-Silva, Richard Deriso

The Fishery

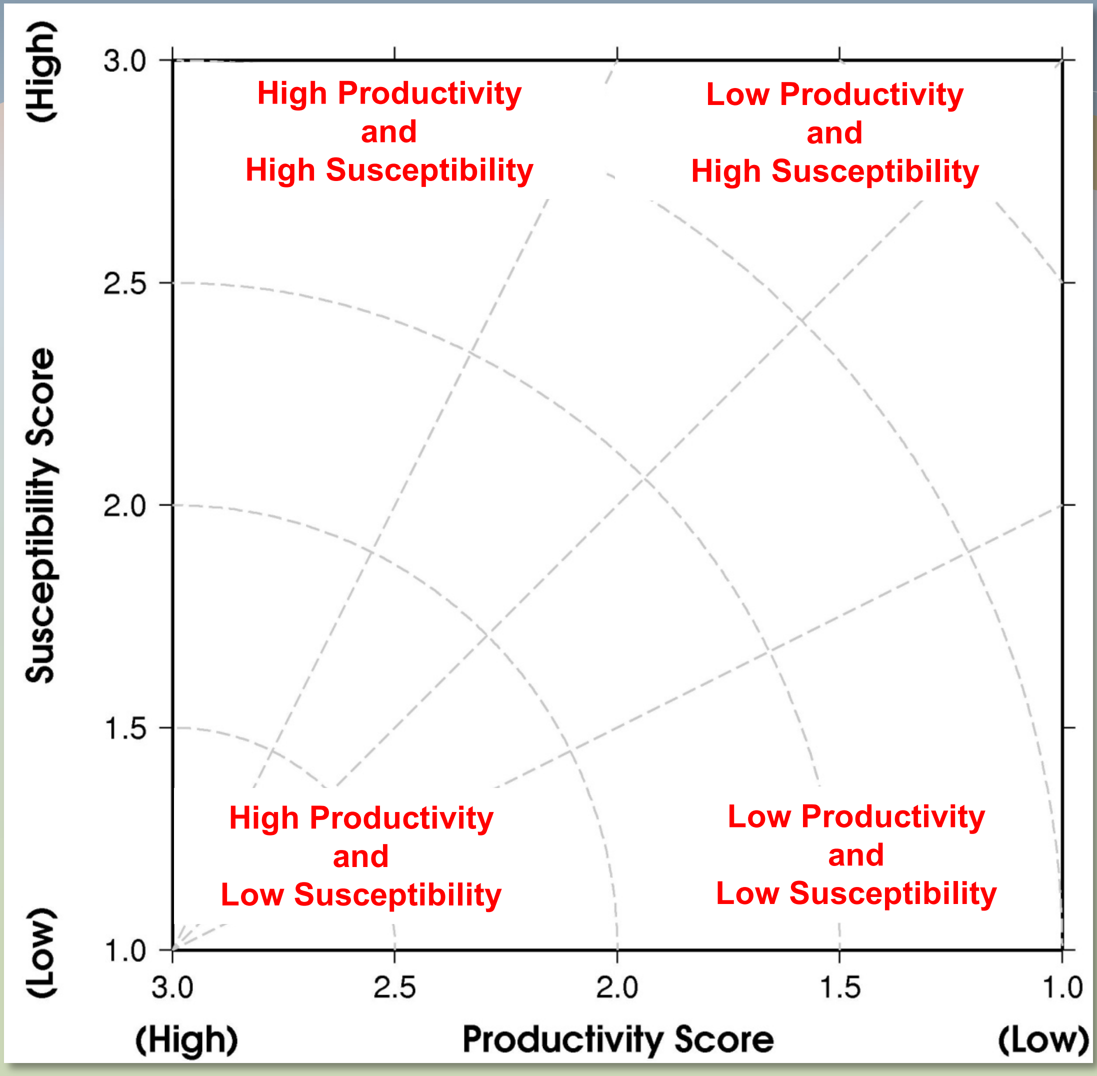
Purse-seine sets in the EPO are carried out by three different methods, related to different aggregation behaviors of the tuna. In "dolphin sets" the net is deployed around the tuna-dolphin aggregation (primarily yellowfin tuna *Thunnus albacares* and spotted dolphin *Stenella attenuata*) after a chase by speedboats.

Goal – Develop a tool for determining vulnerability of a species/stock to a fishery

- **Vulnerability**: potential for the productivity of a stock to be diminished by direct and indirect fishing pressure. <u>PSA</u>: vulnerability is combination of a stock's productivity and its susceptibility to the fishery.
- **Productivity** – capacity to recover if stock is depleted (function of life history characteristics)
- **Susceptibility** – degree to which a fishery can negatively impact a stock (propensity of species to be captured by and incur mortality from a fishery). Can differ by fishery.

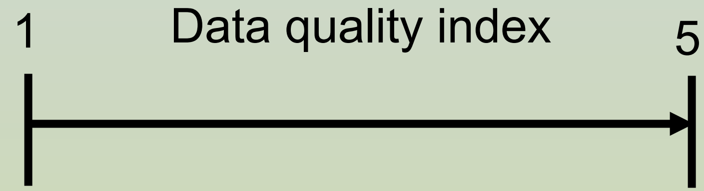
Patrick, W.S., P. Spencer, J. Link, J. Cope, J. Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Cortés, O. Ormseth, K. Bigelow, and W. Overholtz. 2010. Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. Fish. Bull. U.S. 108: 305-322.

Ecological Risk Assessment:
Productivity and Susceptibility Assessment (PSA) scatter plot



Vulnerability (v) is measured as Euclidian distance from plot origin

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



Recent data for stock & area of interest

No data, not included in PSA but included in data quality index score

Ecological Risk Assessment: Proof of concept modifications to the EPO PSA for the purse-seine fishery

- Established 2-step procedure to identify and exclude rare species
    1. If biomass was never > 0.05% in any year (2005-2013), species was excluded
    2. If proportion catch was < 5% in any set type, the set type for that species was excluded

Precautionary approach - include IUCN red listed species even if they are rare in the bycatch

- Combined, for each species, the susceptibility values corresponding to each fishery to produce one overall susceptibility value for each species

- The use of bycatch and catch information in the formulation of susceptibility was modified (created 2 alternate susceptibilities)
    1. Current catch information used as an alternate susceptibility
    2. Long-term catch trend information used as an alternate susceptibility

Ecological Risk Assessment: productivity attributes

TABLE J-1 Productivity attributes and scoring thresholds used in the IATTC PSA

	Ranking – Clasificación		
Productivity attribute **Atributo de productividad**	**Low –** **Bajo (1)**	**Moderate –** **Moderado (2)**	**High –** **Alto (3)**
Intrinsic rate of population growth (*r*) Tasa intrínseca de crecimiento de la población (*r*)	≤ 0.1	> 0.1, ≤ 1.3	>1.3
Maximum age (years) Edad máxima (años)	≥ 20	> 11, < 20	≤ 11
Maximum size (cm) Talla máxima (cm)	> 350	> 200, ≤ 350	≤ 200
von Bertalanffy growth coefficient (*k*) Coeficiente de crecimiento de von Bertalanffy (*k*)	< 0.095	0.095 – 0.21	> 0.21
Natural mortality (*M*) Mortalidad natural (*M*)	< 0.25	0.25 – 0.48	> 0.48
Fecundity (measured) Fecundidad (medida)	< 10	10 – 200,000	> 200,000
Breeding strategy Estrategia de reproducción	≥ 4	1 to-a 3	0
Age at maturity (years) Edad de madurez (años)	≥ 7.0	≥ 2.7, < 7.0	< 2.7
Mean trophic level Nivel trófico medio	> 5.1	4.5 – 5.1	< 4.5

Ecological Risk Assessment: modified susceptibility attributes

TABLE J-2. Susceptibility attributes and scoring thresholds used in the IATTC PSA.

Susceptibility attribute	Ranking		
	Low (1)	Moderate (2)	High (3)
Management strategy	Management and proactive accountability measures in place	Stocks specifically named in conservation resolutions; closely monitored	No management measures; stocks closely monitored
Areal overlap - geographical concentration index	Greatest bycatches outside areas with the most sets and stock not concentrated (or not rare)	Greatest bycatches outside areas with the most sets and stock concentrated (or rare), OR Greatest bycatches in areas with the most sets and stock not concentrated (or not rare)	Greatest bycatches in areas with the most sets and stock concentrated (or rare)
Vertical overlap with gear	< 25% of stock occurs at the depths fished	Between 25% and 50% of the stock occurs at the depths fished	> 50% of the stock occurs in the depths fished
Seasonal migrations	Seasonal migrations decrease overlap with the fishery	Seasonal migrations do not substantially affect the overlap with the fishery	Seasonal migrations increase overlap with the fishery
Schooling/Aggregation and other behavioral responses to gear	Behavioral responses decrease the catchability of the gear	Behavioral responses do not substantially affect the catchability of the gear	Behavioral responses increase the catchability of the gear
Potential survival after capture and release under current fishing practices	Probability of survival > 67%	33% < probability of survival ≤ 67%	Probability of survival < 33%
Desirability/value of catch (percent retention)	Stock is not highly valued or desired by the fishery (< 33%	Stock is moderately valued or desired by the fishery (33-66% retention)	Stock is highly valued or desired by the fishery (> 66% retention)

Patrick, W.S., P. Spencer, J. Link, J. Cope, J. Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Cortés, O. Ormseth, K. Bigelow, and W. Overholtz. 2010. Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. Fish. Bull. U.S. 108: 305-322.

Ecological Risk Assessment: EPO PSA preliminary proof of concept susceptibility calculation

Proof of concept goals:

- Create one overall susceptibility score for the purse-seine fishery

- Explore variations in the calculation of susceptibility

- Approach 1

$$s_j^1 = \sum_k s_{jk} p_k$$

where,

s_j^1 is the combined susceptibility for species *j*

s_{jk} is the susceptibility for species *j* in set type *k,* computed using only the attributes in Table J-2. s_{jk} ranges from 1 (lowest) to 3 (highest)

$p_k = \left(\frac{N_k}{\sum_k N_k}\right)$ and N_k is the total number of sets (class-6) of set type *k* in 2013

Ecological Risk Assessment: Preliminary species list, productivity, susceptibility and vulnerability scores

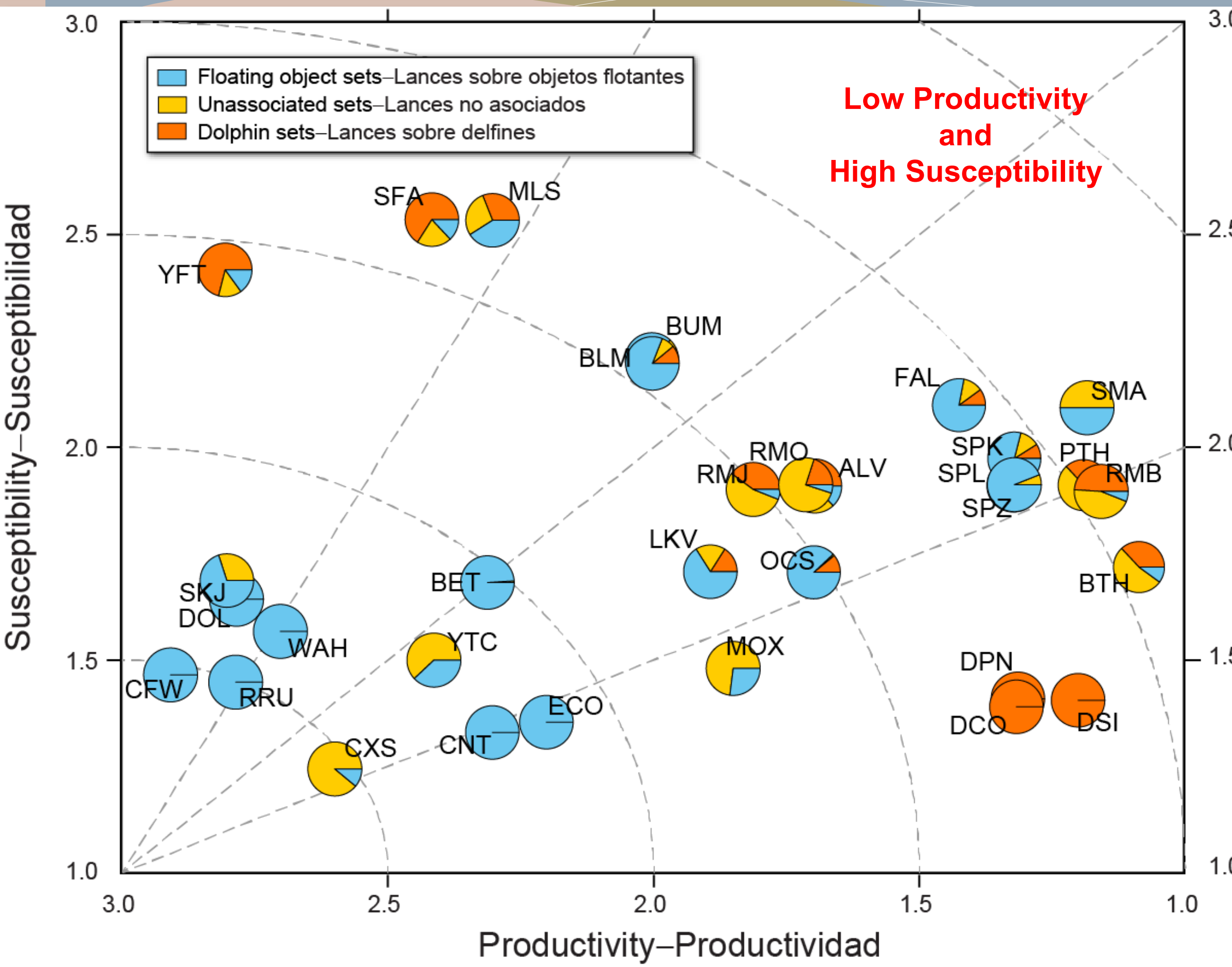
Approach 1 combined susceptibility: $s_j^1 = \sum_k s_{jk} p_k$

Table J-3a Preliminary productivity and susceptibility scores used to compute the overall vulnerability

					s_{jk} scores by fishery					
GROUP	**Scientific name**	**Common name**	**3-alpha species code**	**IUCN***	**DEL**	**NOA**	**OBJ**	p	s_j^1	v_1
Tunas	*Thunnus albacares*	Yellowfin tuna	YFT	NT	2.38	2.38	2.38	2.78	2.38	1.40
	Thunnus obesus	Bigeye tuna	BET	VU	1.00	2.23	2.38	2.33	1.70	0.97
	Katsuwonus pelamis	Skipjack tuna	SKJ	LC	1.00	2.38	2.38	2.78	1.73	0.76
Billfishes	*Makaira nigricans*	Blue marlin	BUM	VU	2.23	2.23	2.69	2.00	2.39	1.71
	Istiompax indica	Black marlin	BLM	DD	2.23	2.23	2.69	2.00	2.39	1.71
	Kajikia audax	Striped marlin	MLS	NT	2.54	2.54	2.54	2.33	2.54	1.68
	Istiophorus platypterus	Indo-Pacific sailfish	SFA	LC	2.54	2.54	2.54	2.44	2.54	1.64
Dolphins	*Stenella longirostris*	Unidentified spinner dolphin	DSI	DD	1.77	1.00	1.00	1.22	1.36	1.82
	Stenella attenuata	Unidentified spotted dolphin	DPN	LC	1.77	1.00	1.00	1.33	1.36	1.71
	Delphinus delphis	Common dolphin	DCO	LC	1.62	1.00	1.00	1.33	1.29	1.70
Large fishes	*Coryphaena hippurus*	Common dolphinfish	DOL	LC	1.00	2.00	2.31	2.78	1.64	0.68
	Coryphaena equiselis	Pompano dolphinfish	CFW	LC	1.00	1.00	2.38	2.89	1.48	0.50
	Acanthocybium solandri	Wahoo	WAH	LC	1.00	1.00	2.62	2.67	1.57	0.66
	Elagatis bipinnulata	Rainbow runner	RRU	NA	1.00	1.00	2.31	2.78	1.46	0.51
	Mola mola	Ocean sunfish, Mola	MOX	NA	1.00	1.92	1.92	1.78	1.49	1.31
	Caranx sexfasciatus	Bigeye trevally	CXS	LC	1.00	2.38	1.00	2.56	1.25	0.51
	Seriola lalandi	Yellowtail amberjack	YTC	NA	1.00	2.08	1.85	2.44	1.49	0.75
Rays	*Manta birostris*	Giant manta	RMB	VU	1.92	2.08	1.77	1.22	1.90	1.99
	Mobula japanica	Spinetail manta	RMJ	NT	1.92	2.08	1.77	1.78	1.90	1.51
	Mobula thurstoni	Smoothtail manta	RMO	NT	1.92	2.08	1.77	1.67	1.90	1.60
Sharks	*Carcharhinus falciformis*	Silky shark	FAL	NT	2.08	2.08	2.15	1.44	2.10	1.91
	Carcharhinus longimanus	Oceanic whitetip shark	OCS	VU	1.69	1.00	2.08	1.67	1.70	1.50
	Sphyrna zygaena	Smooth hammerhead shark	SPZ	VU	1.77	1.92	2.08	1.33	1.91	1.90
	Sphyrna lewini	Scalloped hammerhead shark	SPL	EN	1.77	1.92	2.08	1.33	1.91	1.90
	Sphyrna mokarran	Great hammerhead shark	SPK	EN	2.08	1.77	1.92	1.33	1.97	1.93
	Alopias pelagicus	Pelagic thresher shark	PTH	VU	1.92	1.92	1.77	1.22	1.87	1.98
	Alopias superciliosus	Bigeye thresher shark	BTH	VU	1.77	2.08	1.46	1.11	1.72	2.02
	Alopias vulpinus	Common thresher shark	ALV	VU	1.92	1.92	1.77	1.67	1.87	1.59
	Isurus oxyrinchus	Short fin mako shark	SMA	VU	2.23	2.23	1.92	1.22	2.12	2.10
Small fishes	*Canthidermis maculatus*	Ocean triggerfish	CNT	NA	1.00	1.00	2.00	2.33	1.35	0.76
	Sectator ocyurus	Bluestriped chub	ECO	NA	1.00	1.00	2.08	2.22	1.38	0.87
Turtles	*Lepidochelys olivacea*	Olive ridley turtle	LKV	VU	1.62	2.23	1.62	1.89	1.73	1.33

Ecological Risk Assessment: EPO PSA Proof of concept Approach 1

Approach 1 combined susceptibility: $s_j^1 = \sum_k s_{jk} p_k$



Group	Species code	Common name
Tunas	YFT	Yellowfin tuna
	BET	Bigeye tuna
	SKJ	Skipjack tuna
Billfishes	BUM	Blue marlin
	BLM	Black marlin
	MLS	Striped marlin
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Dolphins	DSI	Spinner dolphin
	DPN	Spotted dolphin
	DCO	Common dolphin
Large fishes	DOL	Common dophinfish
	CFW	Pompano dolphinfish
	WAH	Wahoo
	RRU	Rainbow runner
	MOX	Ocean sunfish
	CXS	Bigeye Trevally
	YTC	Yellowtail amberjack
Rays	RMB	Giant manta ray
	RMJ	Spinetail manta
	RMO	Smoothtail manta
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	OCS	Ocean whitetip shark
	SPL	Scalloped hammerhead
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	SPK	Great hammerhead
	BTH	Bigeye thresher shark
	PTH	Pelagic thresher shark
	ALV	Common thresher shark
	SMA	Shortfin mako shark
Small fishes	CNT	Ocean triggerfish
	ECO	Bluestriped chub
Turtles	LKV	Olive Ridley turtle

Ecological Risk Assessment: EPO PSA
Preliminary proof of concept alternate susceptibility calculation

Proof of concept: Approach 2 bringing catch information into formulation of susceptibility

$$s_j^2 = \sum_k s_{jk}^* p_k$$

where

s_j^2 is the combined susceptibility for species *j*, adjusted for recent catch rates

s_{jk}^* is the average of s_{jk} and of the catch rate susceptibility : $s_{jk}^* = \frac{1}{2}\left(s_{jk} + s_{cps\_jk}\right)$

s_{jk} is as defined for s_j^1

s_{cps_jk} is the catch rate susceptibility and takes a value of 1, 2 or 3. For non-target species, catch-per set, in number of animals per set, is used to assign a value to s_{cps_jk}:

$$\begin{cases} 1 & \text{for} \quad \text{cps}_{jk} = 0 \\ 2 & \text{for } 0 < \text{cps}_{jk} < 1.0 \\ 3 & \text{for cps}_{jk} \geq 1.0 \end{cases}$$

If the species is a target tuna species, then the following values are assigned to s_{cps_jk}:

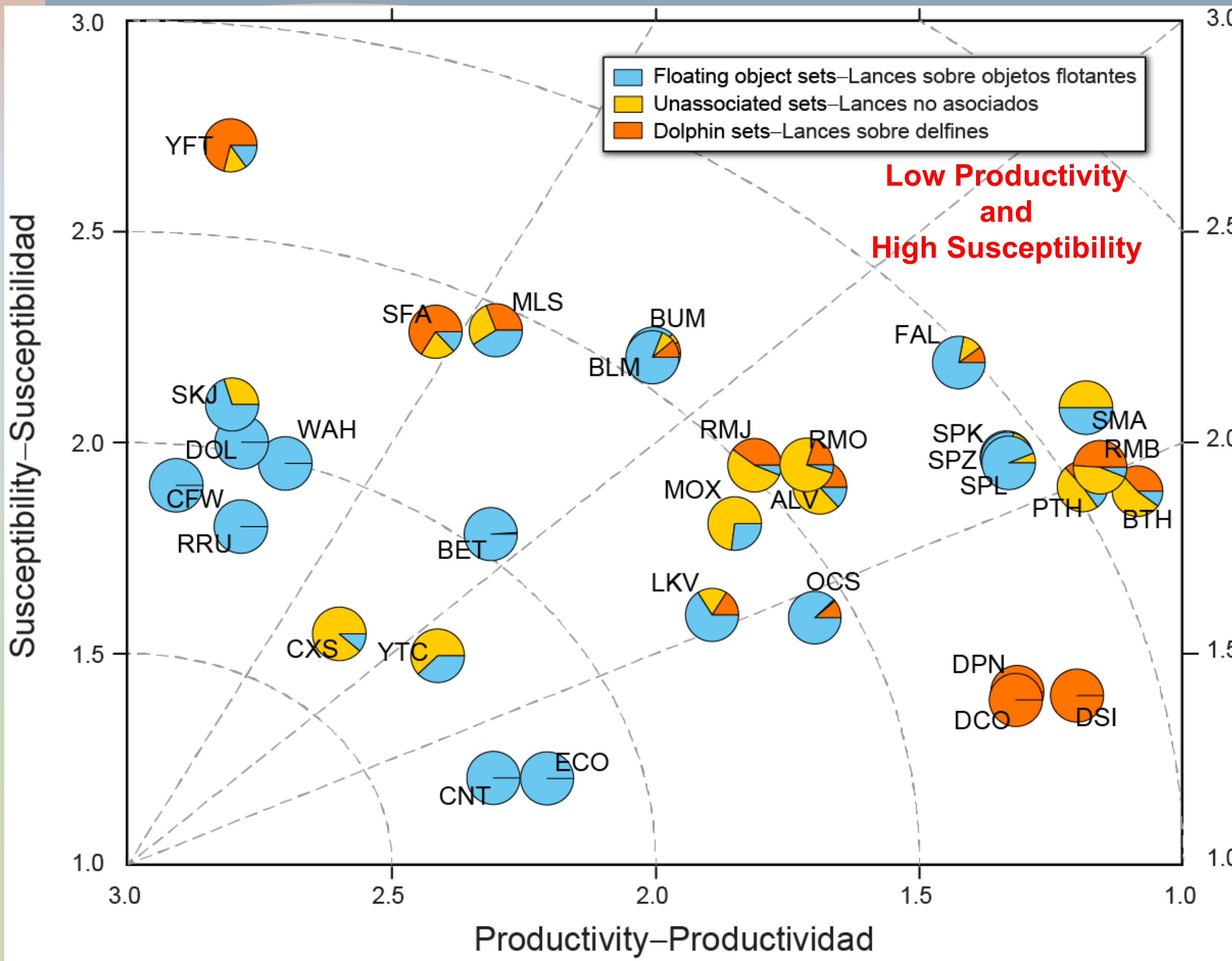
	Dolphin sets	Unassociated sets	Floating-object sets
Bigeye	1	2	3
Yellowfin	3	3	3
Skipjack	2	3	3

$cps_{\_jk}$ is the catch-per-set for species *j* in set type *k* (= class-6 catch (in numbers of animals) divided by number of class-6 sets), for the most recent year (2013).

$p_k = \left(\frac{N_k}{\sum_k N_k}\right)$ and N_k is the total number of sets (class-6) of set type *k* in 2013

Ecological Risk Assessment: EPO PSA Proof of concept
PSA scatter plot for all species and all purse-seine fisheries

Approach 2 combined susceptibility: $s_j^2 = \sum_k s_{jk}^* p_k$ modifies s_j^1 to take into consideration current catch rates



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Small fishes	CNT	Ocean triggerfish
	ECO	Bluestriped chub
Turtles	LKV	Olive Ridley turtle

Proof of concept: Approach 3 bringing catch trend information into formulation of susceptibility

$$s_j^3 = \sum_k s_{jk}^{**} p_k$$

where

s_j^3 is the combined susceptibility for species *j*, adjusted for long-term trends

s_{jk}^{**} is the average of s_{jk} and the trend susceptibility: $s_{jk}^{**} = \frac{1}{2}\left(s_{jk} + s_{trend\_jk}\right)$;

s_{jk} is as defined for s_j^1

S_{trend_jk} is the trend susceptibility for species *j* in set type *k*, obtained as follows:

$$\begin{cases} 1.0 & \text{if species } j \text{ does not occur in set type } k \\ 1.5 & \text{if } trend_{jk} \text{ is not significant or is significant but increasing} \\ 3.0 & \text{if } trend_{jk} \text{ is significant and decreasing} \end{cases}$$

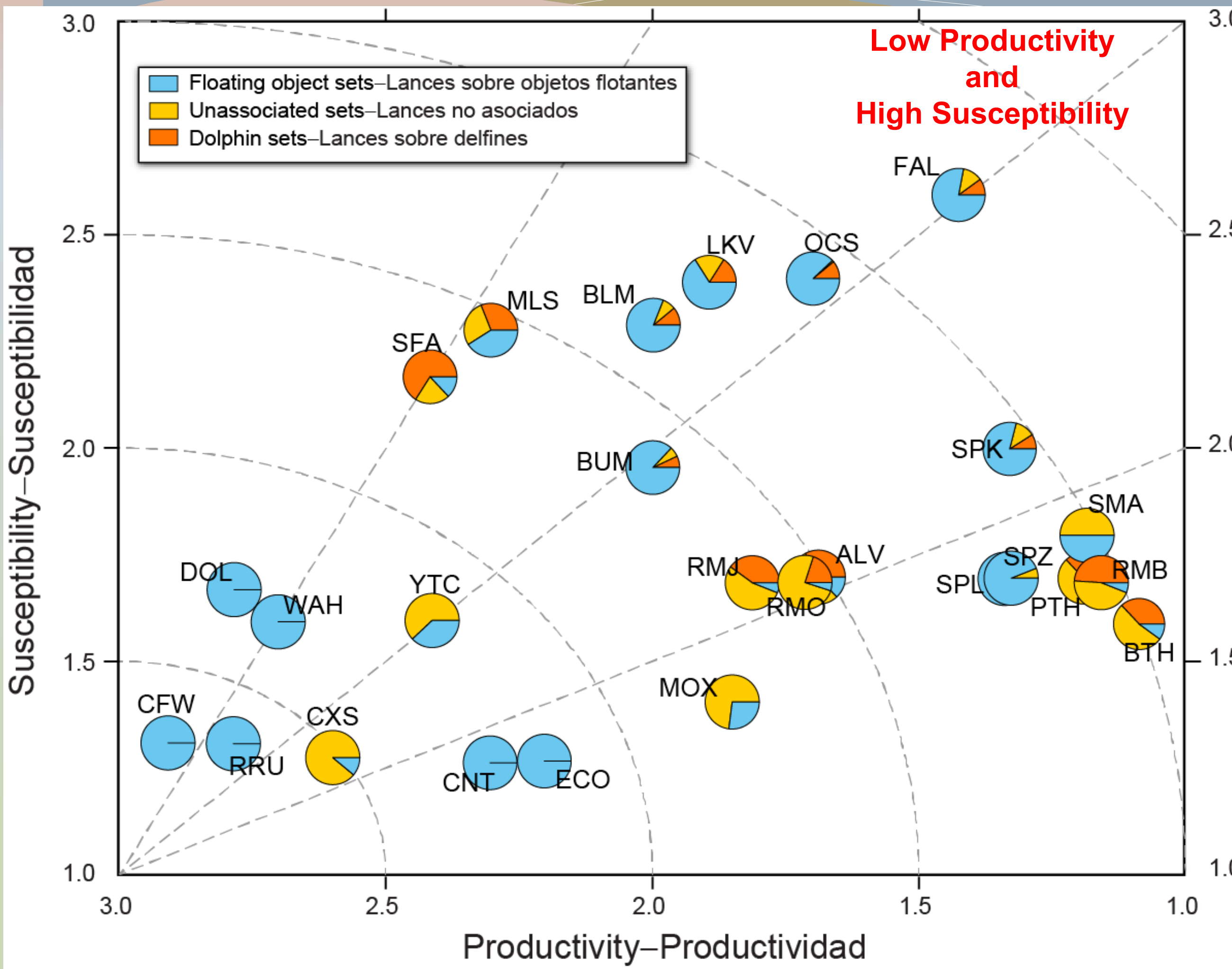
$trend_{jk}$ is the slope of the regression of $cps_{jk,y}$ and year *y*, from the start of the data collection (which may vary by species). A significant trend was any slope with a *p*-value < 0.05.

$cps_{,jk,y}$ is the catch-per-set of species *j* of set type *k* in year *y*

$p_k = \left(\frac{N_k}{\sum_k N_k}\right)$ and N_k is the total number of sets (class-6) of set type *k* in 2013

Ecological Risk Assessment: EPO PSA Proof of concept
PSA scatter plot for all species and all purse-seine fisheries

Approach 3 combined susceptibility: $s_j^3 = \sum_k s_{jk}^{**} p_k$
modifies s_j^1 to take into consideration long-term catch trends



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Turtles	LKV	Olive Ridley turtle

Ecological Risk Assessment: EPO PSA Proof of concept - some comments

Approach 1: s_j^1

Differences among set-type specific susceptibilities do not always agree with differences among bycatch rates that we see in the fishery data

The list of susceptibility attributes does not address long-term population change

Approach 2: s_j^2

Does not account for long-term population change (e.g. Oceanic whitetip sharks)

May be compromised by differences among species in abundance

Approach 3: s_j^3

CPUE trends may not reflect changes in abundance and/or may represent the integrated affects of multiple fisheries (e.g., longline and purse-seine).

EPO PSA Proof of concept - comparing approaches

Some shark species and the giant manta have the highest vulnerability scores

Comparing s_j^1 and s_j^2 :

Percent difference between s_j^1 and s_j^2 ranges from 1 – 8% for species with highest vulnerability scores

For many species, $s_j^2 > s_j^1$ with largest differences for some of the large fishes:

e.g. Pompano dolphinfish, Bigeye trevally, Wahoo

Comparing s_j^1 and s_j^3:

For many species, $s_j^1 > s_j^3$, with the largest differences for s_j^3 for:

Oceanic whitetip, Olive Ridley turtles, Silky sharks

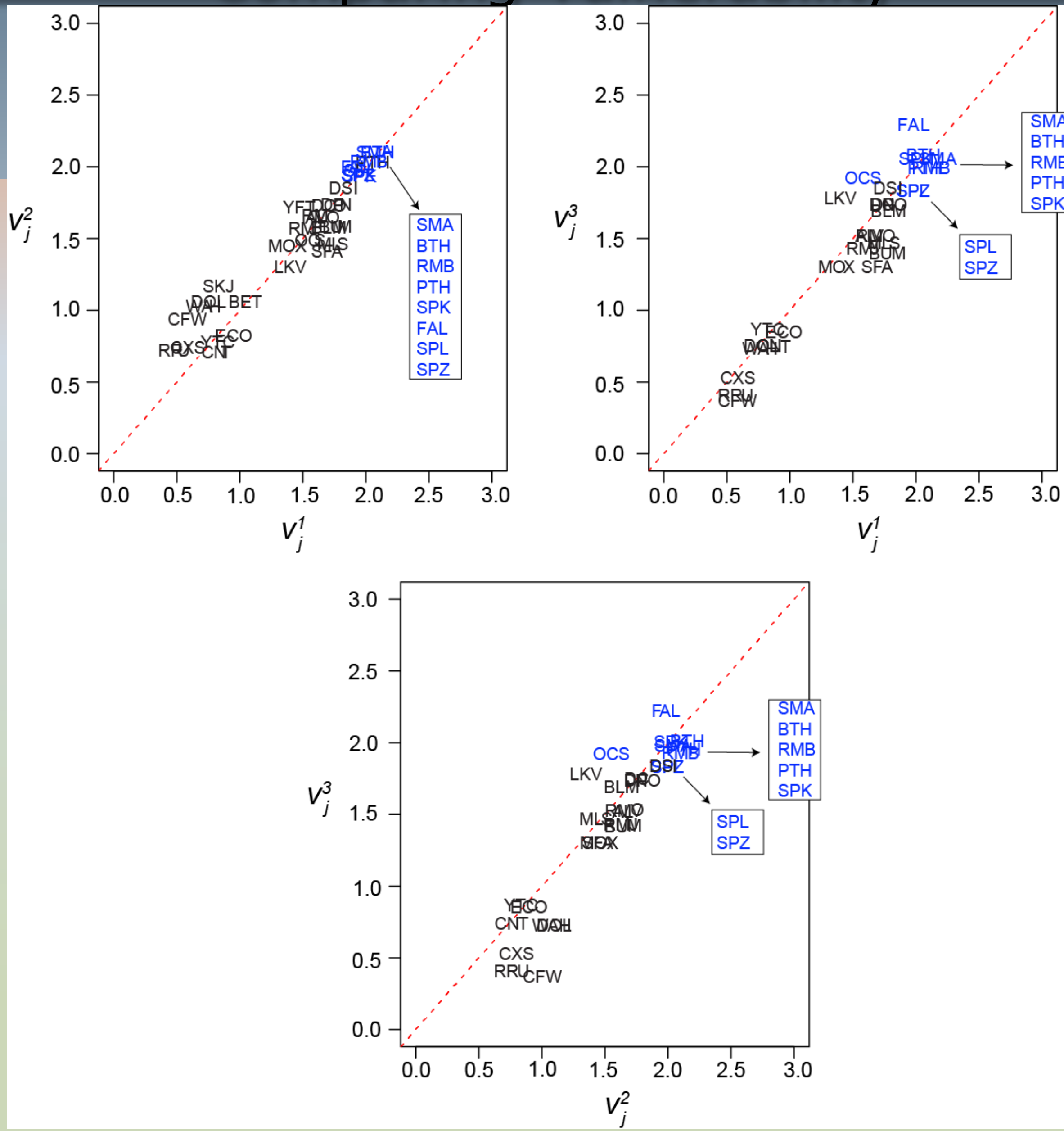
Comparing s_j^2 and s_j^3 :

For many species, $s_j^2 > s_j^3$, with the largest differences for s_j^3 for:

Oceanic whitetip, Olive Ridley turtles

Comment: When using catch data for susceptibility, it is difficult to isolate the affect of the one fishery: oceanic whitetip is associated with a high value of s_j^3 because current cps is quite low compared to historical levels – the affect of all fisheries operating in the EPO, not just purse-seine.

Ecological Risk Assessment: Comparing vulnerability



Ecological Risk Assessment: the EPO PSA – future improvements

- Further evaluate which method for calculating susceptibility is preferable and if more revisions should be made
- Thorough review of susceptibility attributes included in the analysis
- Full literature review in progress
- Carefully evaluate data on catch trends and decide if/how we can include information about depletion (e.g. Oceanic whitetip sharks)
- Explore variations on methods used by ICCAT

  - Arrizabalaga, H., P. de Bruyn, G.A. Diaz, H. Murua, P. Chavance, A.D. de Molina, D. Gaertner, J. Ariz, J. Ruiz, and L.T. Kell. 2011. Productivity and susceptibility analysis for species caught in Atlantic tuna fisheries. Aquatic Living Resources 24(01): 1-12.
  - Cortés, E., F. Arocha, L.R. Beerkircher, F. Carvalho, A. Domingo, M. Heupel, H. Holtzhausen, M.N. Santos, M. Ribera, and C. Simpfendorfer. 2010. Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. Aquat. Living Resour. 23: 25-34.

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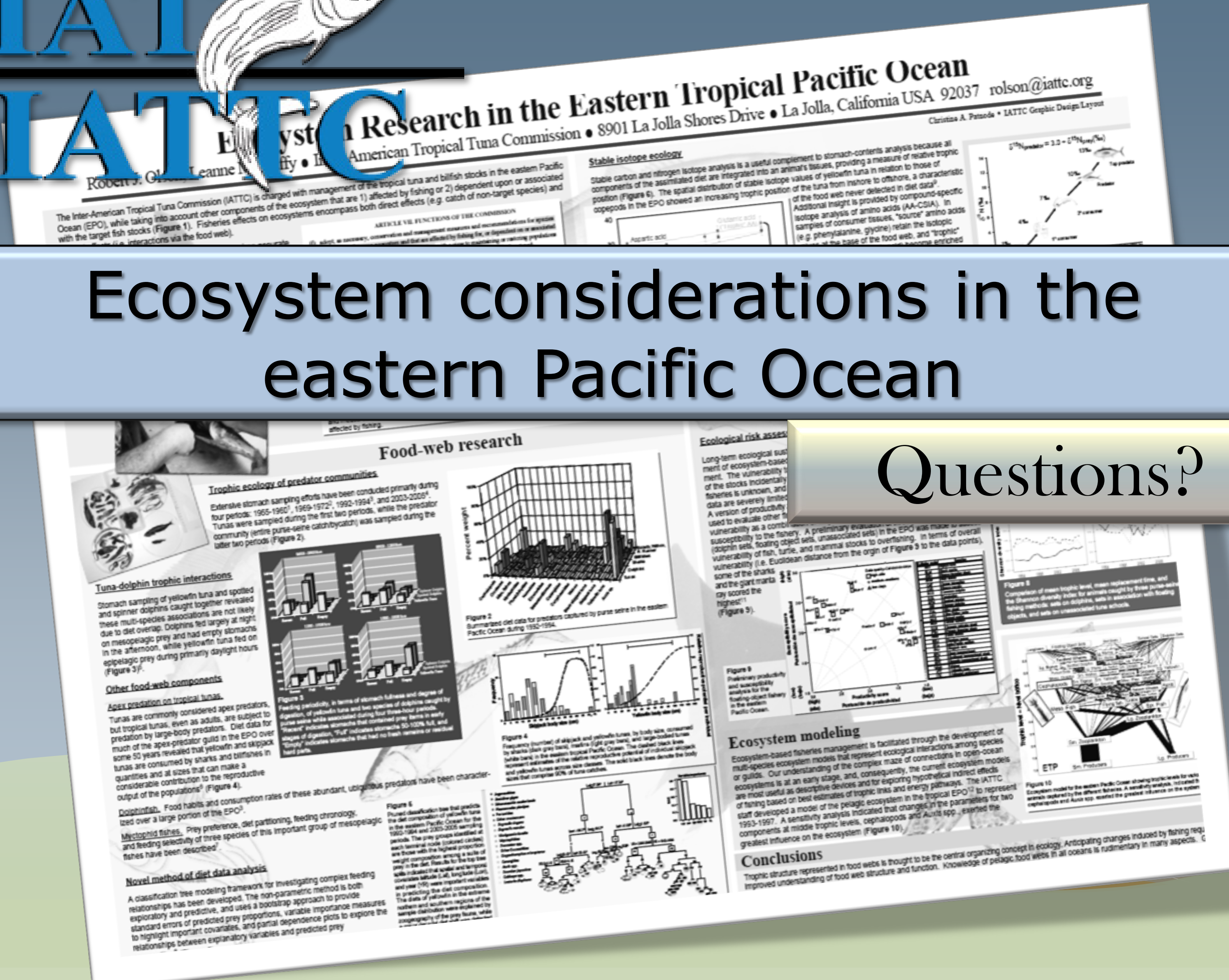

Ecosystem considerations in the eastern Pacific Ocean

Questions?