Use of productivity and susceptibility indices to evaluate vulnerability in the purse-seine fishery of the eastern Pacific Ocean

Robert Olson, Leanne Duffy, Mark Maunder, Cleridy Lennert-Cody, Michael Hinton, Michael Scott, Alexandre Aires-da-Silva, Richard Deriso

Scientific Advisory Committee, 3rd Meeting

3ª Reunión del Comité Científico Asesor

Antigua Convention

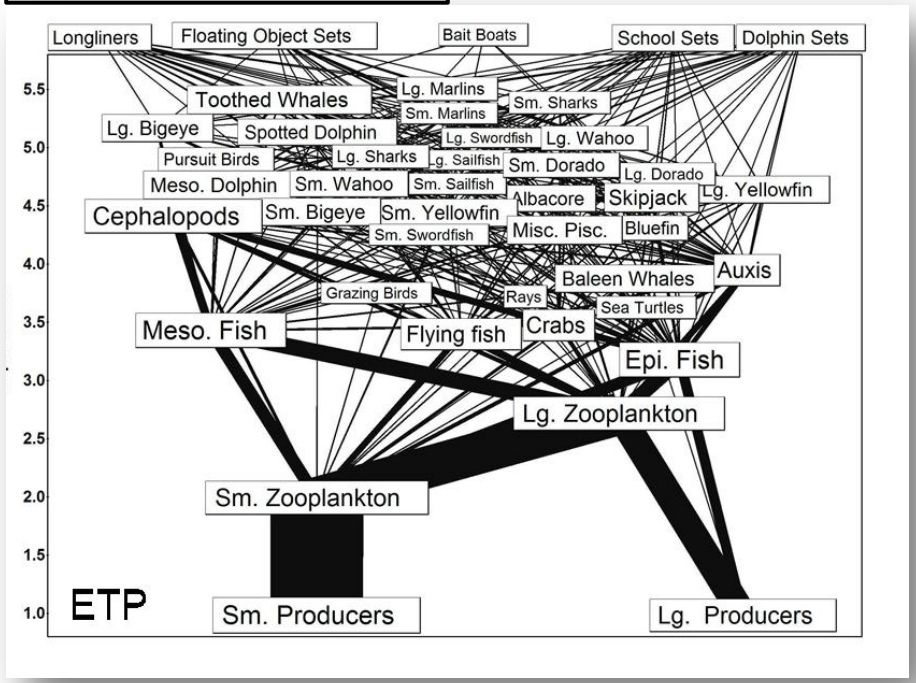
ARTICLE VII. FUNCTIONS OF THE COMMISSION

(f) 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;

(g) adopt appropriate measures to avoid, reduce and minimize waste, discards, catch by lost or discarded gear, catch of non-target species (both fish and non-fish species) and impacts on associated or dependent species, in particular endangered species;

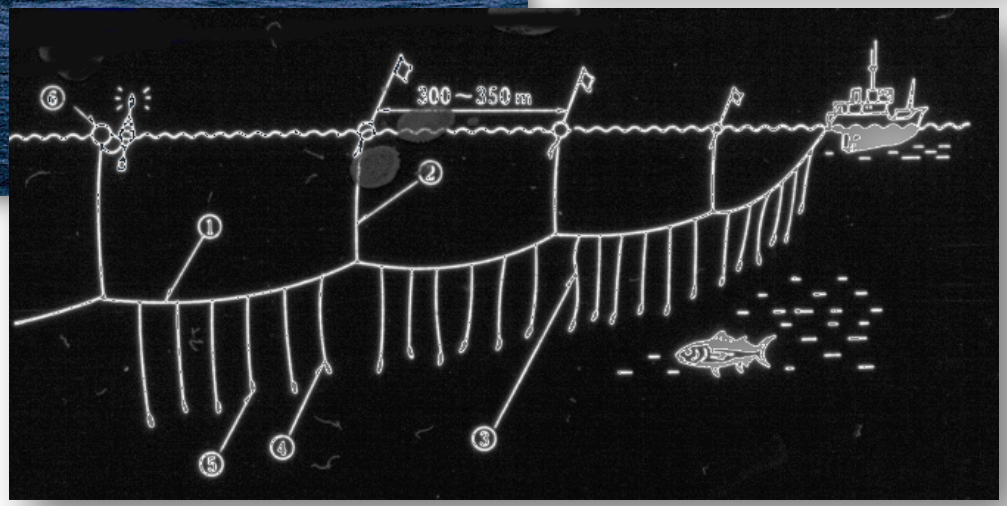
Direct associations

Indirect associations



EPO purse-seine fishery

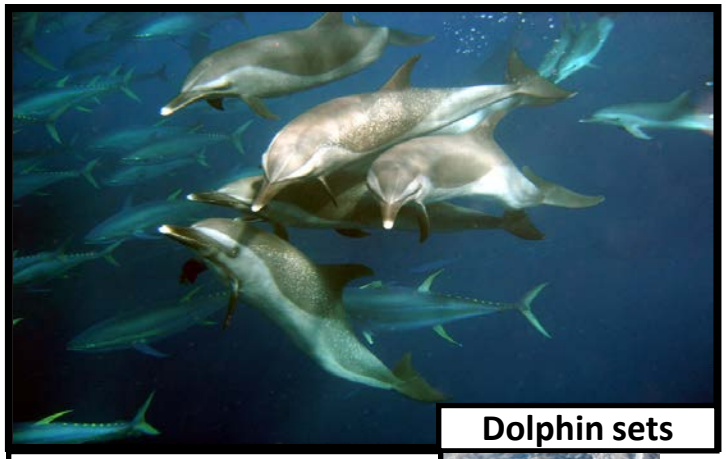
Pole and line



Longline

High seas and coastal

Tuna aggregation behavior determines PS fishing mode



Dolphin sets

- Sets on tuna-dolphin aggregation
- Target: large yellowfin tuna
- Bycatch: low amounts: dolphins, sharks

Floating- object sets

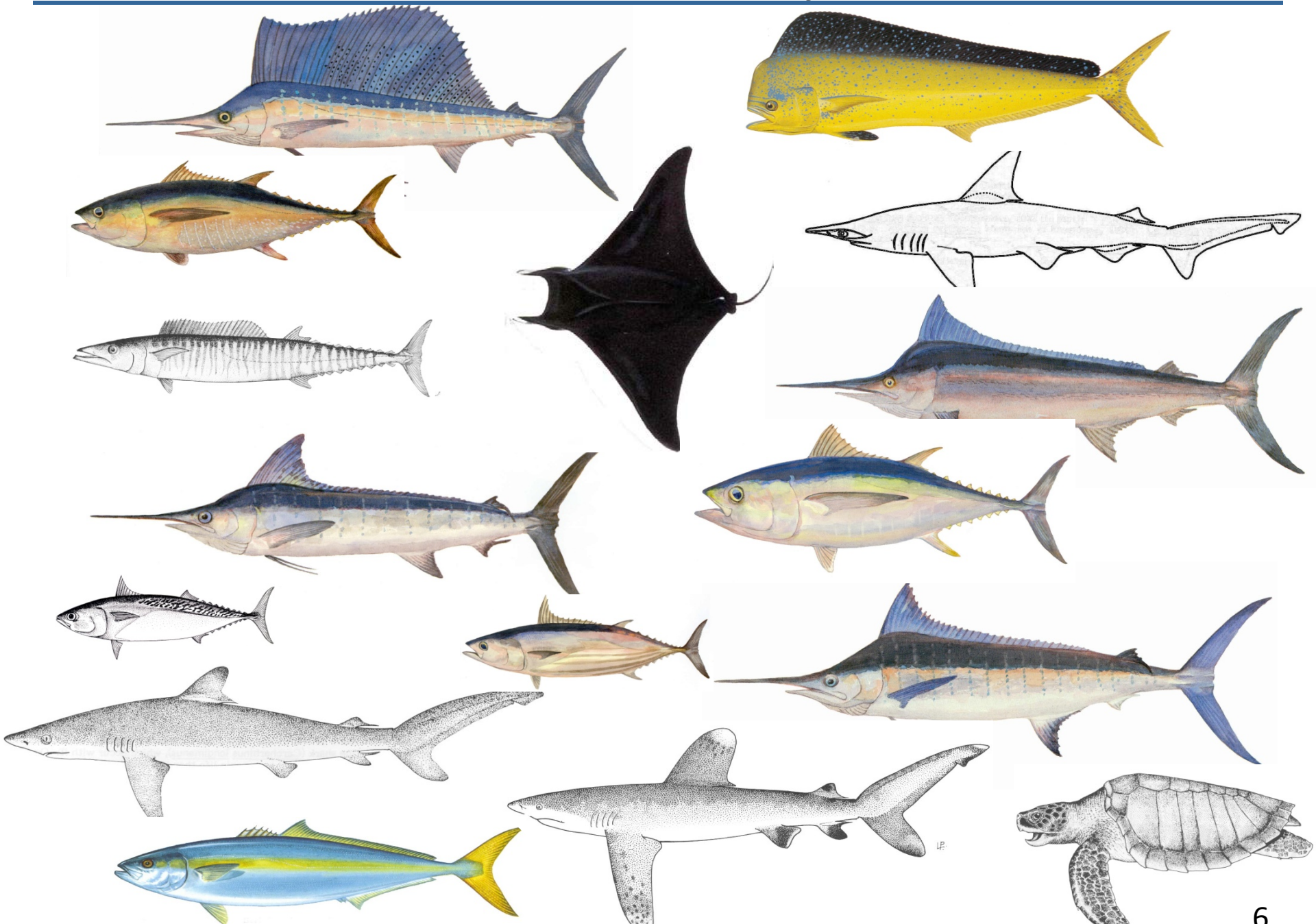
- Sets on tunas aggregating at floating objects
- Target: skipjack, small yellowfin tuna
- Bycatch: large amounts: misc fishes, sharks, billfishes

Unassociated sets

- Sets on unassociated, schooling tunas
- Target: small yellowfin tuna, skipjack
- Bycatch: medium amounts: misc fishes, sharks, billfishes

Pelagic carcharhinid sharks in PS bycatch

Tuna catch and bycatch



Resolutions to reduce incidence of bycatch of non-target species

INTER-AMERICAN TROPICAL TUNA COMMISSION

74TH MEETING

PUSAN (KOREA)
26-30 JUNE 2006

RESOLUTION C-04-05 (REV 2)

CONSOLIDATED RESOLUTION ON BYCATCH

The Inter-American Tropical Tuna Commission (IATTC):

Recalling and reaffirming the Resolutions on Bycatch adopted at the 66th, 68th, and 69th Meetings of the Commission in June 2000, 2001, and 2002, respectively;

Recognizing the value of consolidating the operative parts of these resolutions into one comprehensive resolution on bycatch;

Believing that any additional measures on bycatch should also be incorporated into this single resolution;

Has agreed as follows:

Vulnerability of non-target species

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. PSA: 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.

Vulnerability of non-target species

The tool should be:

1. adaptable to factors in epipelagic ecosystem of EPO
2. flexible to different fisheries in the EPO
3. Applicable for data-poor species/stocks, different levels of data availability and reliability
4. History of use in other fisheries

Productivity and susceptibility procedure

Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing

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Paul Spencer[2]
Jason Link[3]
Jason Cope[4]
John Field[5]
Donald Kobayashi[6]
Peter Lawson[7]
Todd Gedamke[8]
Enric Cortés[9]
Olav Ormseth[2]
Keith Bigelow[6]
William Overholtz[3]

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.

History of PSA use in other fisheries

PSA originally developed to classify differences in bycatch sustainability in Australian prawn fishery (Stobutzki et al. 2001). Use in other fisheries (Milton 2001; Hobday et al. 2011; and others)

- Hobday, A.J., A.D.M. Smith, I.C. Stobutzki, C. Bulman, R. Daley, J.M. Dambacher, R.A. Deng, J. Dowdney, M. Fuller, D. Furlani, S.P. Griffiths, D. Johnson, R. Kenyon, I.A. Knuckey, S.D. Ling, R. Pitcher, K.J. Sainsbury, M. Sporcic, T. Smith, C. Turnbull, T.I. Walker, S.E. Wayte, H. Webb, A. Williams, B.S. Wise, and S. Zhou. 2011. Ecological risk assessment for the effects of fishing. Fish. Res. 108 (2–3): 372-384.
- Milton, D.A. 2001. Assessing the susceptibility to fishing of populations of rare trawl bycatch: sea snakes caught by Australia's northern prawn fishery. Biological Conservation, 101 (3): 281-290.
- Stobutzki, I.C., M. Miller, and D. Brewer. 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. Environmental Conservation, 28: 167-181.

Elements of IATTC's preliminary PSA

1) Portion of fishery to evaluate: purse-seine floating-object sets, dolphin sets, unassociated sets, vessels > 363 t.
2) Species complexes to evaluate: target species, species comprising greatest bycatches per set, sensitive species (sharks, turtle, dolphins).
3) Attributes pertinent to P and S: from Patrick et al. 2010 (modified, added).
4) Gathered attribute data for each species: published and unpublished sources, EPO fisheries data.
5) Determine scoring bins for P and S attribute data (low, moderate, high: Scores 1, 2, 3)
6) Compute weighted average P and S scores
7) Plot P and S scores on XY scatter plot
8) Vulnerability = distance from origin of plot to P-S point

Productivity indicators

1. Population growth rate (*r*)
2. Maximum age
3. Maximum size
4. von Bertalanffy growth coefficient (k)
5. Natural mortality
6. Fecundity
7. Breeding strategy (Winemiller's (1989) index of parental investment)
8. Recruitment pattern
9. Age at maturity
10. Mean trophic level

Patrick, W.S., P. Spencer, O. Ormseth, J. Cope, J. Field, D. Kobayashi, T. Gedamke, E. Cortés, K. Bigelow, W. Overholtz, J. Link, and P. Lawson. 2009. Use of productivity and susceptibility indices to determine stock vulnerability, with example applications to six U.S. fisheries. NOAA Technical Memorandum NMFS-F/SPO-101: 1-90.

Susceptibility indicators

Catchability:

1. Areal overlap with fishery
2. Geographic concentration (*i.e.*, patchiness)
3. Vertical overlap with fishery

Combined spatial measures (See SAC-01-INF-A)

4. Seasonal migrations
5. Schooling/Aggregation or other behavioral responses
6. Morphology affecting capture
7. Desirability/value of fishery (% retention)

Management:

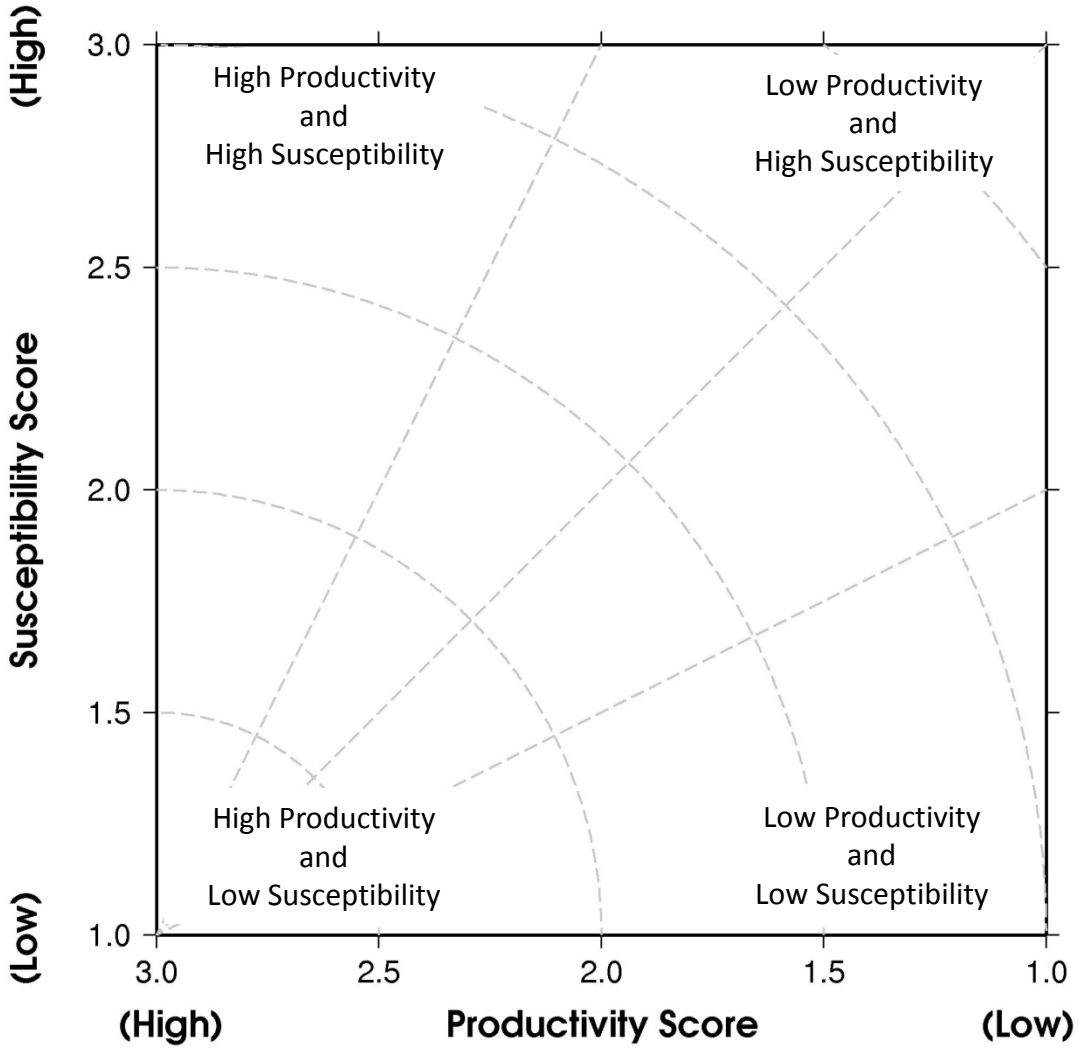
8. *Management Strategy (redefined, see Table 3)*
9. *F/M*
10. *Biomass of spawners*
11. *Survival after capture and release*
12. *Fishery impact on habitat*

New:

13. *Temporal catch trends (increasing, no change, decreasing)*

Patrick, W.S., P. Spencer, O. Ormseth, J. Cope, J. Field, D. Kobayashi, T. Gedamke, E. Cortés, K. Bigelow, W. Overholtz, J. Link, and P. Lawson. 2009. Use of productivity and susceptibility indices to determine stock vulnerability, with example applications to six U.S. fisheries. NOAA Technical Memorandum NMFS-F/SPO-101: 1-90.

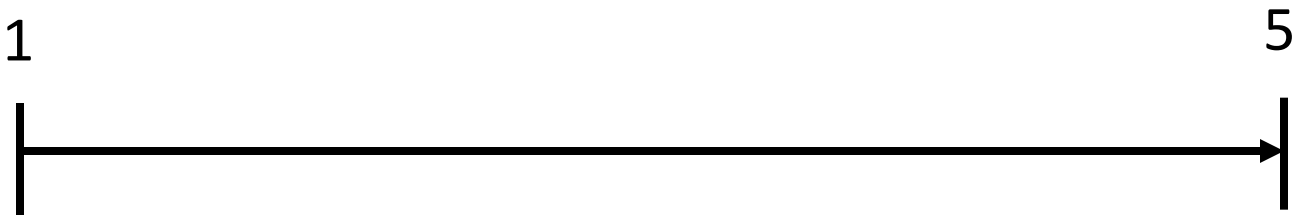
PSA scatter plot



Vulnerability is measured as Euclidian distance from plot origin

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

PSA data quality index



Recent data for stock and area of interest

No data. Not included in PSA, but included in data quality index score

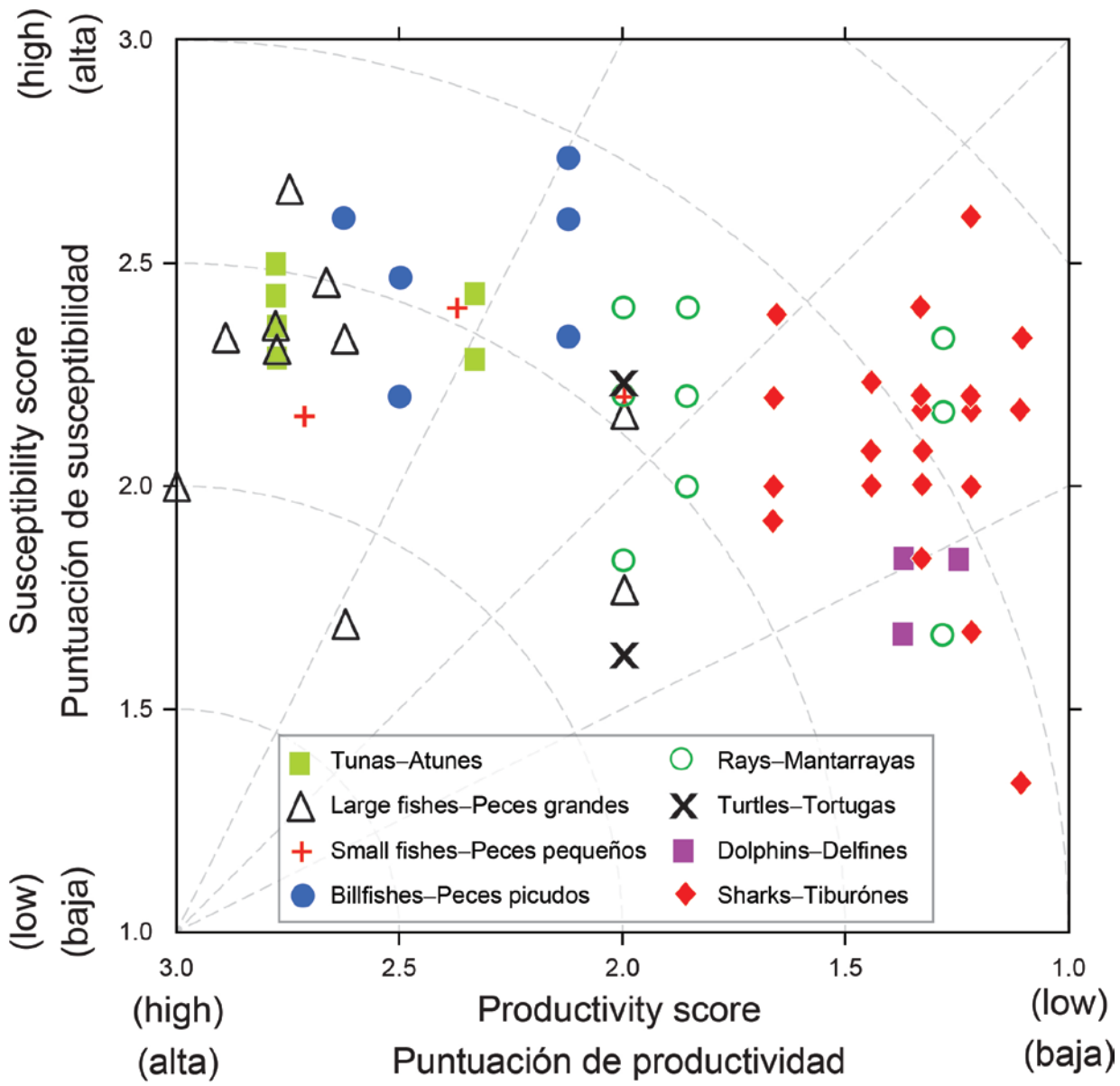
"Previous applications have generally ignored overall uncertainty, and assumed the lowest level of productivity (or highest susceptibility) for attributes with missing data. This could lead to inaccurate characterizations of risk."

Species for EPO PSA

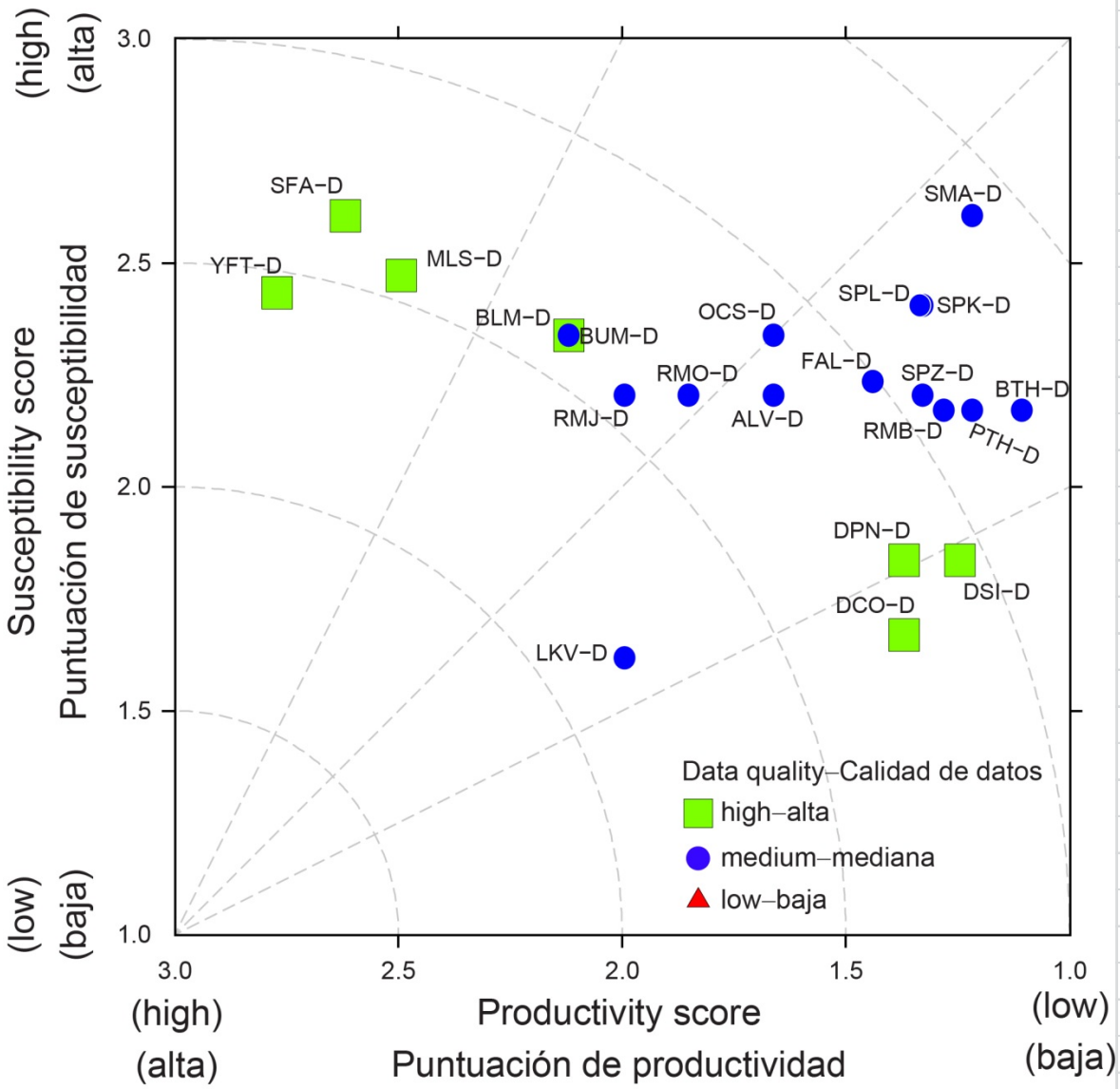
Species			Bycatch (mt) per set		
Group	Common Name	Scientific Name	Dolphin	Unassoc.	Floating-obj.
Tunas	Yellowfin tuna	*Thunnus albacares*	n/a	n/a	n/a
	Bigeye tuna	*Thunnus obesus*	--	n/a	n/a
	Skipjack	*Katsuwonus pelamis*	--	n/a	n/a
Billfishes	Black marlin	*Makaira indica*	1.0	1.1	10.7
	Blue marlin	*Makaira nigricans* [2]	1.1	1.8	23.3
	Striped marlin	*Kajikia audax*	1.1	1.6	2.3
	Indo-Pacific sailfish	*Istiophorus platypterus*	2.3	1.4	--
Dolphins	Spotted dolphin	*Stenella attenuata*	2.2	--	--
	Spinner dolphin	*Stenella longirostris*	2.3	--	--
	Common dolphin	*Delphinus delphis*	1.6	--	--
Large Fishes	Common dolphinfish	*Coryphaena hippurus*	--	3.2	169.6
	Pompano dolphinfish	*Coryphaena equiselis*	--	--	10.8
	Wahoo	*Acanthocybium solandri*	--	--	59.3
	Rainbow runner	*Elagatis bipinnulata*	--	--	9.5
	Bigeye trevally	*Caranx sexfasciatus*	--	4.2	--
	Yellowtail amberjack	*Seriola lalandi*	--	3.5	1.8
	Ocean sunfish	*Mola mola*	--	5.0	1.4
Rays	Giant manta	*Manta birostris* [2]	2.6	2.9	0.5
	Spinetail manta	*Mobula japanica* [4]	1.3	2.7	0.3
	Smoothtail manta	*Mobula thurstoni* [4]	0.3	1.4	0.1
Sharks	Silky shark	*Carcharhinus falciformis* [4]	4.1	9.1	55.8
	Oceanic whitetip shark	*Carcharhinus longimanus* [2]	<0.1	--	0.4
	Bigeye thresher shark	*Alopias superciliosus* [2]	0.3	0.6	0.1
	Pelagic thresher shark	*Alopias pelagicus* [2]	0.3	0.6	0.2
	Common thresher shark	*Alopias vulpinus* [2]	<0.1	0.2	<0.1
	Scalloped hammerhead shark	*Sphyrna lewini* [3]	0.1	0.7	2.3
	Great hammerhead	*Sphyrna mokarran* [3]	<0.1	<0.1	0.2
	Smooth hammerhead shark	*Sphyrna zygaena* [2]	0.1	0.3	4.5
	Short fin mako shark	*Isurus oxyrinchus* [2]	<0.1	0.3	0.2
Small Fishes	Ocean triggerfish	*Canthidermis maculatus*	--	--	7.7
	Bluestriped chub	*Sectator ocyurus*	--	--	2.0
	Scrawled filefish	*Aluterus scriptus* [1]	--	--	0.2
Turtles	Olive Ridley turtle	*Lepidochelys olivacea* [2]	<0.1	<0.1	<0.1

Biomass importance (>1 t/set)
1. Numerical importance
2. “Vulnerable” IUCN status
3. “Endangered” IUCN status
4. “Near threatened” IUCN status

IATTC PSA (all species and purse-seine fisheries)

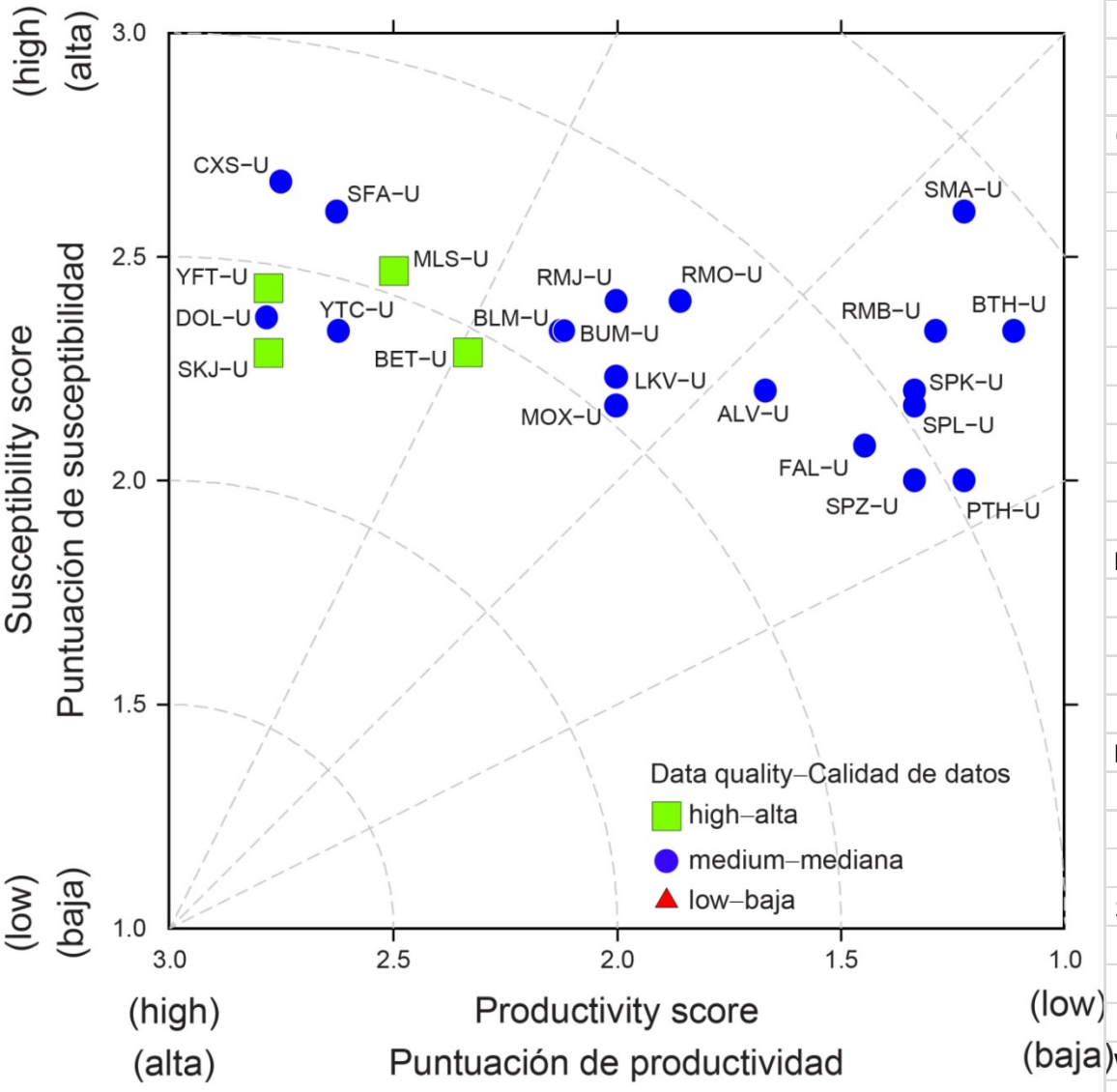


Dolphin sets



Code	Species	
ALN	Aluterus scriptus	Scrawled filefish
ALV	Alopias vulpinus	Common thresher shark
BET	Thunnus obesus	Bigeye tuna
BLM	Makaira indica	Black marlin
BTH	Alopias superciliosus	Bigeye thresher shark
BUM	Makaira nigricans	Blue marlin
CFW	Coryphaena equiselis	Pompano dolphinfish
CNT	Canthidermis maculatus	Ocean triggerfish
CXS	Caranx sexfasciatus	Bigeye trevally
DCO	Delphinus delphis	Common dolphin
DOL	Coryphaena hippurus	Common dolphinfish
DPN	Stenella attenuata	Spotted dolphin
DSI	Stenella longirostris	Spinner dolphin
ECO	Sectator ocyurus	Bluestriped chub
FAL	Carcharhinus falciformis	Silky shark
LKV	Lepidochelys olivacea	Olive Ridley turtle
MLS	Kajikia audax	Striped marlin
MOX	Mola mola	Ocean sunfish
OCS	Carcharhinus longimanus	Oceanic whitetip shark
PTH	Alopias pelagicus	Pelagic thresher shark
RMB	Manta birostris	Giant manta
RMJ	Mobula japanica	Spinetail manta
RMO	Mobula thurstoni	Smoothtail manta
RRU	Elagatis bipinnulata	Rainbow runner
SFA	Istiophorus platypterus	Indo-Pacific sailfish
SKJ	Katsuwonus pelamis	Skipjack
SMA	Isurus oxyrinchus	Short fin mako shark
SPK	Sphyrna mokarran	Great hammerhead
SPL	Sphyrna lewini	Scalloped hammerhead shark
SPZ	Sphyrna zygaena	Smooth hammerhead shark
WAH	Acanthocybium solandri	Wahoo
YFT	Thunnus albacares	Yellowfin tuna
YTC	Seriola lalandi	Yellowtail amberjack

Unassociated sets



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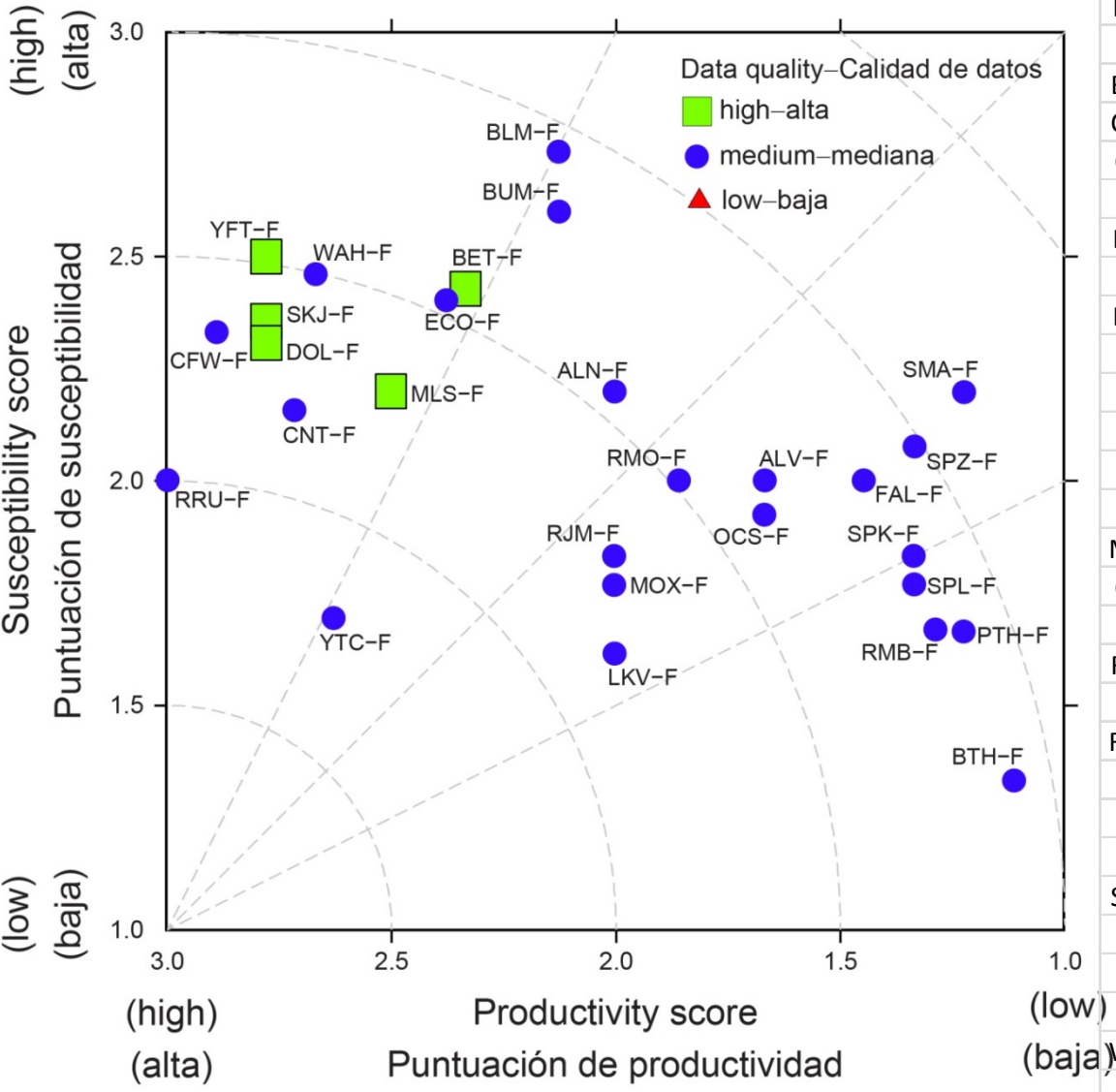
Floating-object sets



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Caveats (PSA method)

- PSA: a relative measure of risk among group of species examined.
- No indication from PSA if highest risk species are truly unsustainable & vice versa.
- Other newer methods ("SAFE" Zhou & Griffiths 2008; "ERAEF" Hobday et al. 2011) also use aspects of the PSA or need to estimate catchability.
- PSA provides comparison with other tuna fisheries (W Pacific, Atlantic)

PSA used by other organizations

Marine Stewardship Council
Fisheries Assessment Methodology
and
Guidance to Certification Bodies

Including Default Assessment Tree
and Risk-Based Framework

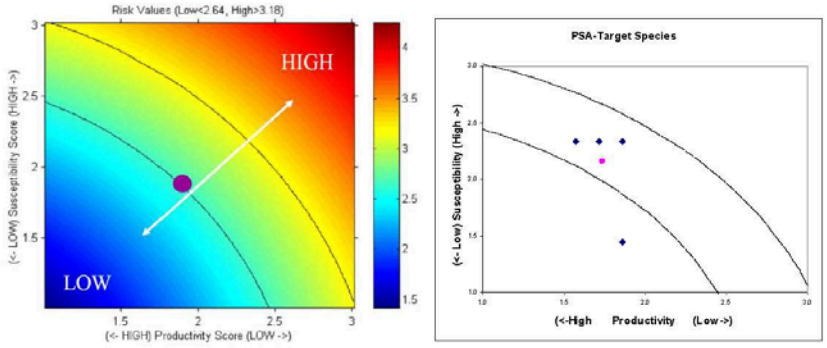

Figure A2. Examples of diagnostic charts for displaying PSA values for each species. **Left:** Low risk species have high productivity and low susceptibility, while high risk species have low productivity and high susceptibility. The curved lines divide the potential risk scores into thirds on the basis of the Euclidean distance from the origin (0,0). **Right**. Example PSA plot for a set of target species. Note the curved lines that divide the risk space into equal thirds, as described in the text

PSA Step 4: Convert PSA scores into MSC scores and feed back into default assessment tree

A3.3.31 Using the Excel worksheet PSA for MSC.xls, or the formula provided in Paragraph 4.4.2, convert the PSA scores resulting from this analysis into MSC scores. Follow guidance in Section 4.4 as well for scoring a PI using PSA results for multiple species.