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Preliminary Ecological Risk Assessment for the Purse-Seine Fishery in the Eastern Pacific Ocean

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Long-term ecological sustainability is a requirement of ecosystem-based fisheries management. Fishing directly impacts the populations of not only target species, but also the species incidentally caught as bycatch. The vulnerability to overfishing of many of the stocks incidentally caught in the tuna fisheries of the eastern Pacific Ocean (EPO) is unknown, and biological and fisheries data are severely limited for most of those stocks. Many fisheries managers and scientists are turning to risk assessments to evaluate vulnerability to fishing. Vulnerability is defined here as the potential for the productivity of a stock to be diminished by direct and indirect fishing pressure. The IATTC staff is evaluating established methods for determining the vulnerability of data-poor, non-target species caught by the purse-seine fishery in the EPO. A version of productivity and susceptibility analysis (PSA) (Patrick *et al.* 2010), used to evaluate other fisheries in recent years, considers a stock's vulnerability as a combination of its productivity and its susceptibility to the fishery. Stock productivity is the capacity of a stock to recover if it is depleted, and is a function of the species' life history traits. Stock susceptibility is the degree to which a fishery can negatively impact a stock, *i.e.* the propensity of a species to be captured by, and incur mortality from, a fishery. Productivity and susceptibility indices of a stock are typically determined by deriving a score ranging from 1 (low) to 3 (high) for a standardized set of attributes related to each index. The individual attribute scores are then averaged for each factor and graphically displayed on an x-y scatter plot. When scoring the attributes, the data quality associated with each attribute score is assessed, and the attributes are weighted by the data-quality score. Stocks that received a low productivity score (p) and high susceptibility score (s) are considered to be at a high risk of becoming depleted, while stocks with a high productivity score and low susceptibility score are considered to be at low risk. Vulnerability scores (v) are calculated from the p and s scores as the Euclidean distance from the origin of the x-y scatter plot and the datum point:

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

To examine the utility of productivity and susceptibility indices to assess vulnerability of incidentally-caught fishes, mammals, and turtles to overfishing in the EPO, a preliminary evaluation of three purse-seine "fisheries" (sets on dolphins, unassociated tunas, and floating objects) in the EPO was made. The PSA was focused on 33 species (Table 1) that comprised the majority of the biomass removed by purse-seine vessels of carrying capacity greater than 363 metric tons during 2005-2011. Nine productivity and eight susceptibility attributes (Tables 2 and 3, respectively) were based on the PSA methodology of Patrick *et al.* (2010), and some were modified for more consistency with the tuna fisheries in the EPO.

Information corresponding to the productivity attributes for each species was compiled from a variety of published and unpublished literature sources and EPO fisheries data (*i.e.* not adopted from previous PSAs) to better approximate the distribution of life history characteristics observed in the species found in the EPO. Scoring thresholds for productivity attributes (Table 2) were derived by dividing the compiled data into 1/3 percentiles. Scoring criteria for the susceptibility attributes (Table 3) were taken from Patrick *et al.* (2010) and modified where appropriate to better fit the EPO fisheries. The scores for each index were then averaged, weighted by the data quality score. Scatter plots of averaged productivity and

susceptibility scores for subsets of the 33 species caught by three purse-seine fisheries are shown in Figure 1 by group (see Table 1 for group species composition). The scale of the x-axis in Figure 1 is reversed because species/stocks with a high productivity score and a low susceptibility score (*i.e.* at the origin of the plots) are considered to be the least vulnerable.

In general, some of the sharks and the giant manta ray scored the highest in overall vulnerability to overfishing (equation above). The shortfin mako shark, scalloped, great, and smooth hammerhead sharks, and bigeye and pelagic thresher sharks had vulnerability scores greater than 2.0 (*i.e.* points to the right side of the semi-circle from susceptibility 3.0 to productivity 1.0 in Figure J-4).

The IATTC staff will continue working to improve and refine the PSA analysis for the EPO during 2012.

References

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.

TABLE 1. Annual bycatch per set (in metric tons) averaged over 2005-2011 for purse-seine vessels with carrying capacity greater than 363 metric tons, by three set methods. "n/a" indicates the tuna species that were included in the analysis, but no values were given because tunas are not bycatches of these fisheries. Only species with a catch value (or n/a) were used in the PSA for the corresponding set type.

Species			Bycatch (mt) per set		
Group	Common name	Scientific name	DEL	NOA	OBJ
Tunas	Yellowfin tuna	*Thunnus albacares*	n/a	n/a	n/a
	Bigeye tuna	*Thunnus obesus*	--	n/a	n/a
	Skipjack tuna	*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*	2.6	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

1 Included due to numerical importance in bycatch (≥1 individual per set)
2 "Vulnerable" status, IUCN Red List of Threatened Species
3 "Endangered" status, IUCN Red List of Threatened Species
4 "Near threatened" status, IUCN Red List of Threatened Species

TABLE 2. Productivity attributes and scoring thresholds used in the IATTC Productivity and Susceptibility Analysis.

	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

TABLE 3. Susceptibility attributes and scoring thresholds used in the IATTC Productivity and Susceptibility Analysis.

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% retention)	Stock is moderately valued or desired by the fishery (33-66% retention)	Stock is highly valued or desired by the fishery (> 66% retention)
Catch trends	Catch-per-set increased over time	No Catch-per-set trend over time	Catch-per-set decreased over time

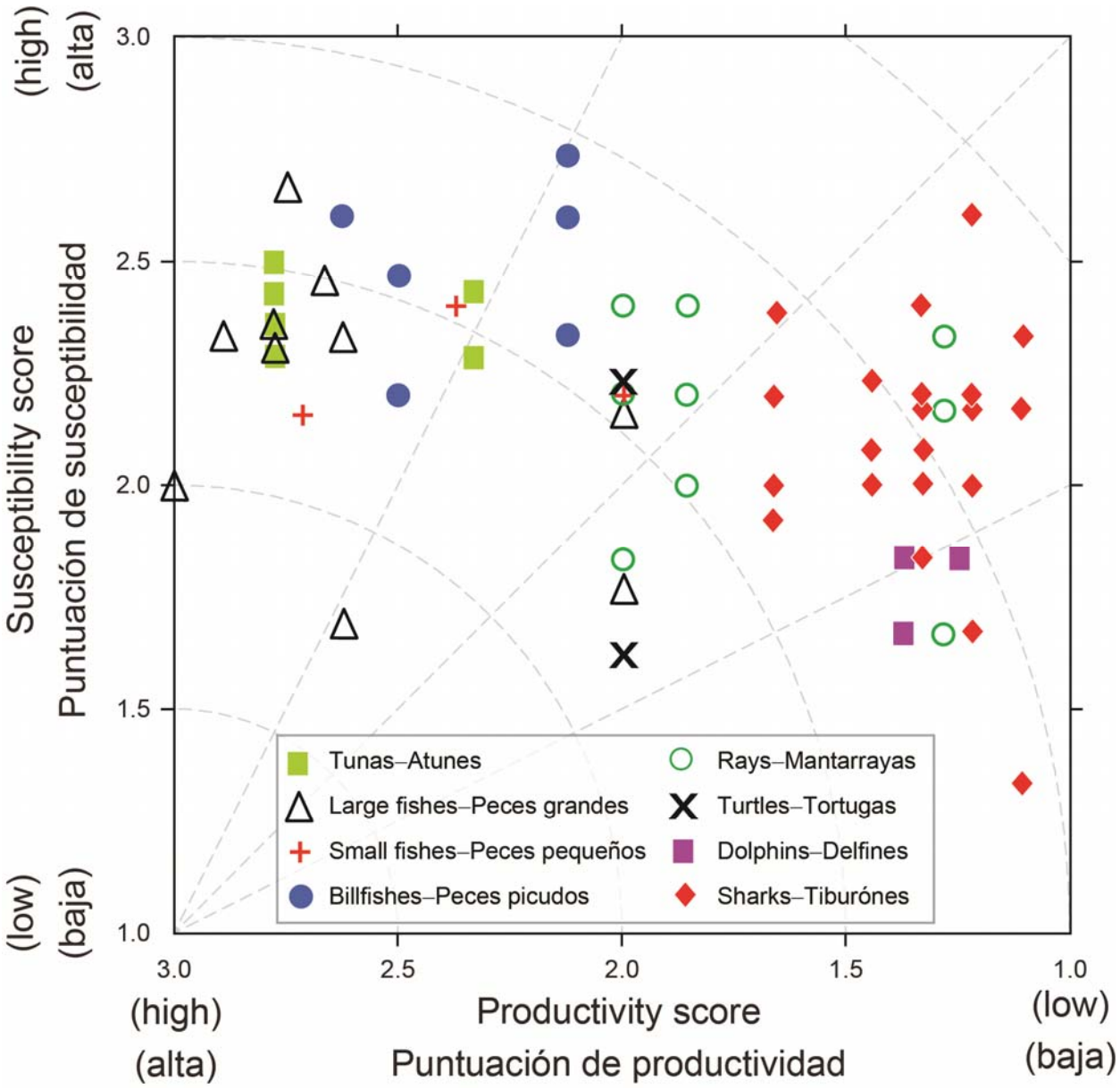

FIGURE 1. Productivity and susceptibility x-y plot for target and bycatch species caught by the purse-seine fishery of the eastern Pacific Ocean during 2005-2011. Group species composition is shown in Table 1.