INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

1ST MEETING

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DOCUMENT SAC-01-INF-A

SUSCEPTIBILITY MEASURES DERIVED FROM FISHERIES OBSERVER DATA

1. INTRODUCTION

The extent to which a fishery will affect a species depends on the characteristics of its spatial distribution within the fishery area. Absent fishery-independent survey data, two spatial measures of susceptibility were derived from IATTC fisheries observer data from the eastern Pacific Ocean (EPO). The first measure ("$P_{0.05}$") is intended to quantify the relative spatial concentration of a species within the area of operation of the fishery. The second measure ("SO") is intended to quantify the relative spatial overlap of the fishery area and the species' distribution.

2. DATA

Bycatch data are from the IATTC observer data base for floating-object sets in 2009 within the EPO. Bycatch is defined as follows: for turtles it is the count of dead plus live animals that were involved in the set; for sharks it is the count of dead animals plus the number of animals released alive from the vessel's deck; for billfish and other fishes it is the number of dead animals. All data are from large vessels (>363 t fish-carrying capacity). The IATTC observer bycatch data base for 2009 was not complete at the time this analysis was conducted. The list of species considered in this analysis is based on criteria described in Document SAC-01-15

2.1. Measures of spatial interaction

2.1.1. Concentration

The measure of relative spatial concentration with respect to the fishery ($P_{0.05}$) is based on a modified version of Swain and Sinclair's (1994) fishery-independent measure of "geographic concentration." $P_{0.05}$ is the proportion of the area of the fishery occupied by ~95% of the stock. In order to compute $P_{0.05}$, the bycatch per set value (*bps*) that corresponds to the 0.05 percentile of the cumulative distribution of *bps* must be computed. The cumulative frequency of *bps*, $F(c)$, is defined as follows:

$$F(c) = \frac{\sum_{sets} bps \cdot 1\,(if\ bps\ value\ \leq c)}{\sum_{sets} bps}$$

The curve $F(c)$ is used to determine the value of c, $c_{0.05}$, at which $F(c) = 0.05$. Based on the value of $c_{0.05}$, the proportion of the fishery area occupied by the stock, $P_{0.05}$, is computed from the proportion of sets in each 1-degree square area that had a *bps* value less than or equal to $c_{0.05}$:

$$P_{0.05} = \frac{H - \sum_{h=1}^{H} \frac{1}{n_h} \sum_{i=1}^{n_h} 1\,(if\ bps\ value\ of\ set\ i\ in\ 1\ deg.sq.h\ \leq c_{0.05})}{H}$$

where H = total number of 1° areas with at least one floating-object set and n_h = number of floating-object sets in 1° area h.

Because bycatch is in whole animals, $c_{0.05}$ actually corresponds to the number of whole animals per set that is closest to $F(c) = 0.05$ or 1 animal, whichever is greater. For species rarely present in the bycatch, particularly animals that are typically solitary, $c_{0.05}$ must be taken to be 1 animal, and $F(1)$ will be much greater than 0.05. For these species $P_{0.05}$ may not be comparable to that of more abundant species. In addition, species that are rarely taken as bycatch will be associated with low values of $P_{0.05}$ because the areas where bycatch occurs are small relative to the overall area of the fishery, regardless of whether the bycatch is truly concentrated. Therefore, low values of $P_{0.05}$ correspond to species that are either relatively rare in the bycatch and/or species that are more common in the bycatch but are caught only in specific areas.

2.1.2. Overlap

The extent to which the area of the fishery with the greatest *bps* overlaps the areas of greatest fishing intensity is computed by weighting the total number of sets in each 5° area by the average bycatch per set in that 5° area. This measure puts the greatest weight on those 5° areas with both high bycatch rates and high levels of fishing activity (numbers of sets). The measure of spatial overlap, SO, is defined as follows:

$$\left[\frac{\sum_{5\ deg.sqs.}\left(\frac{sum\ of\ bycatch}{\#\ sets}\right)\times Total\ \#\ sets}{\sum_{5\ deg.sqs.}\left(\frac{sum\ of\ bycatch}{\#\ sets}\right)}\right]\times\frac{1}{\sum_{5\ deg\ sqs.} Total\ \#\ sets}$$

where Total # sets = all sets of large vessels of the international purse-seine fleet and # sets = number of sets in the observer bycatch data base.

3. RESULTS AND FUTURE WORK

The values of $P_{0.05}$ and *SO* for each species are shown in Figure 1 and Table 1. Three groups of species can be identified from Figure 1. The first group is made up of those species associated with low values of $P_{0.05}$ and *SO*, *i.e*. species whose bycatch is relatively rare and/or concentrated within the fishery area but for which the regions of highest bycatch rates are not associated with the greatest numbers of sets (or sets on large aggregations of these species are avoided). The second group is made up of species associated with low values of $P_{0.05}$ but high values of *SO*, *i.e*. species with relatively rare and/or concentrated bycatch which falls within the areas of greatest numbers of sets. The third group is made up of species associated with high $P_{0.05}$ and *SO*, *i.e*. species whose bycatch is not relatively concentrated or rare but that also have high bycatch rates in the areas with a greater numbers of sets.

These preliminary results suggest that most species are rarely caught /spatially concentrated and occur about equally in areas most intensively fished and areas not commonly fished (or that sets on floating objects in which the species dominate the object-associated community are not commonly made). Future work will expand the data used to other years (and update the analysis for 2009), investigate combining data from different fisheries, and consider other measures from the general ecological literature that may be more appropriate for rare and/or solitary species (*e.g*. occupancy modeling; Royle and Kéry 2007).

REFERENCES

Royle, J. A., and Kéry, M. 2007. A Bayesian state-space formulation of dynamic occupancy models. Ecology 88: 1813–1823.

Swain, D.P. and Sinclair, A.F. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Canadian Journal of Fisheries and Aquatic Sciences 51: 1046-1054.

Species labels used in Figure 1 – Etiquetas de especies usadas en la Figura 1			
Code	**Scientific name**	**English common name**	**Spanish common name**
Codigo	**Nombre científico**	**Nombre común inglés**	**Nombre común español**
BLM	*Makaira indica*	Black marlin	Marlín negro
BUM	*Makaira nigricans*	Blue marlin	Marlín azul
CNT	*Canthidermis maculatus*	Oceanic triggerfish	Pez ballesta oceánico
CXS	*Caranx sexfasciatus*	Bigeye trevally	Jurel voraz
DOL	*Coryphaena hippurus*	Common dolphinfish	Dorado
FAL	*Carcharhinus falciformis*	Silky shark	Tiburón jaquetón (sedoso)
LKV	*Lepidochelys olivacea*	Olive ridley turtle	Tortuga golfina
MLS	*Tetrapturus audax*	Striped marlin	Marlín rayado
MOX	*Mola mola*	Ocean sunfish	Pez luna
OCS	*Carcharhinus longimanus*	Oceanic whitetip shark	Tiburón oceánico (punta blanca)
RRU	*Elagatis bipinnulata*	Rainbow runner	Salmón
SFA	*Istiophorus platypterus*	Indo-Pacific sailfish	Pez vela del Indo-Pacífico
SPL	*Sphyrna lewini*	Scalloped hammerhead shark	Cornuda común
SPZ	*Sphyrna zygaena*	Smooth hammerhead shark	Cornuda cruz
WAH	*Acanthocybium solandri*	Wahoo	Peto
YTC	*Seriola lalandi*	Yellowtail amberjack	Medregal rabo amarillo

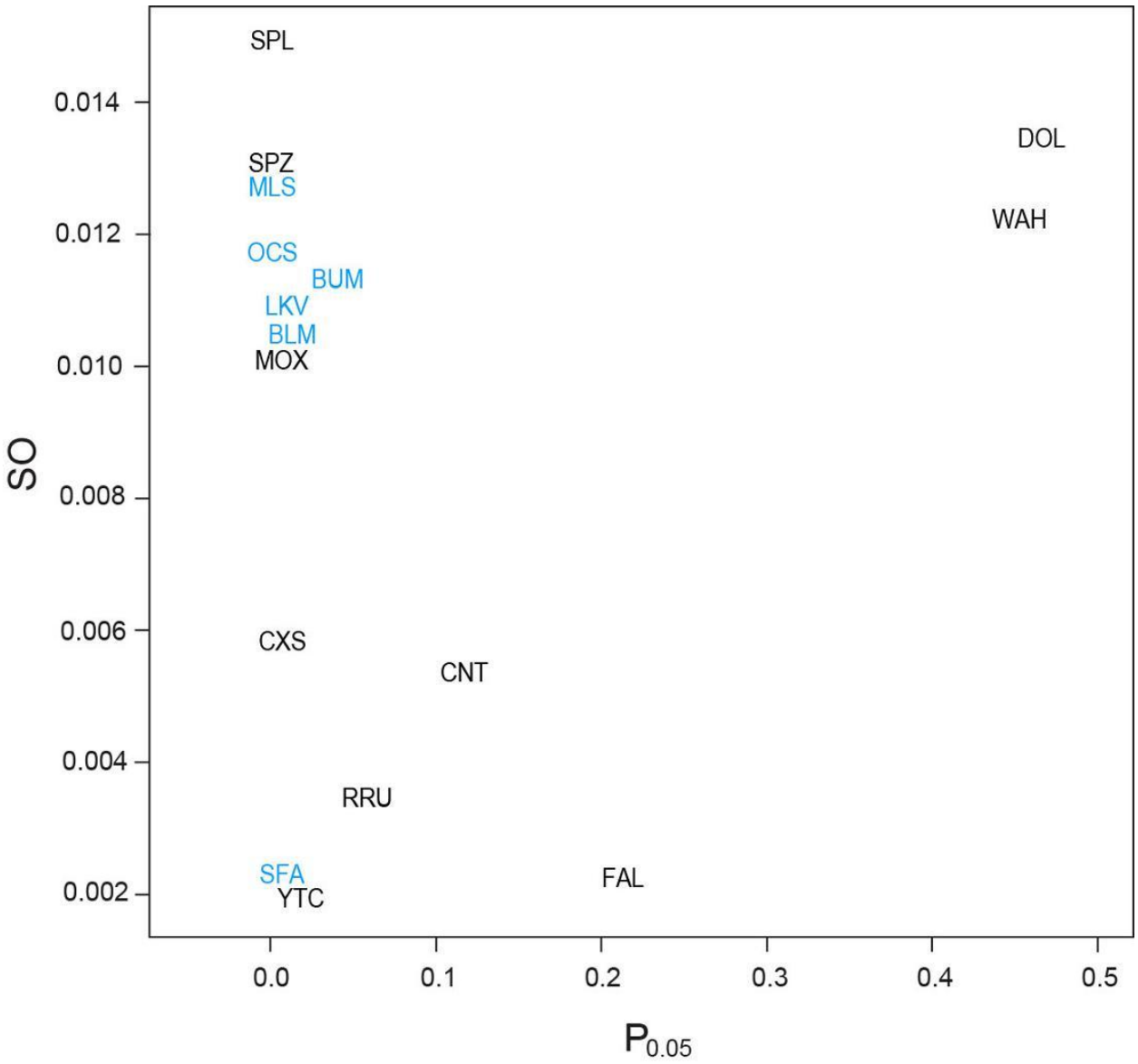

FIGURE 1. $P_{0.05}$ *versus SO* for the floating-object set data. Species names in color are those species for which $F(1) >> 0.05$ and hence the value of $P_{0.05}$ (x axis) computed for these species may not be comparable to that of other species. For those species with similar values, point labels have been shifted slightly to make all labels visible. Actual values of $P_{0.05}$ and *SO* are shown in Table 1. See previous page for species labels.

FIGURA 1. $P_{0.05}$ como función de *SO* en los datos de lances sobre objetos flotantes. Los nombres de especies en color son aquéllas especies para las cuales $F(1) >> 0.05$, y por lo tanto el valor de $P_{0.05}$ (eje x) computado para estas especies podría no ser comparable con aquél de otras especies. En el caso de especies con valores similares, se han movido ligeramente las etiquetas para que todas las etiquetas sean visibles. En la Tabla 1 se presentan los valores reales de $P_{0.05}$ y *SO*. Ver etiquetas de las especies en la página previa.

TABLE 1. Measures of spatial interaction for the purse-seine fishery on floating objects. " * " indicates those species for which *F(c)* at a *bps* of 1 animal per set was much greater than 0.05; these tend to be species for which a large percentage of sets have a *bps* = 0 and which are caught predominantly as solitary animals. The value of $P_{0.05}$ computed for these species (in shaded cells) may not be comparable to that of other species. " ----- " indicates that there were too few sets with bycatch of this species to compute these measures. *n*: number of animals in data set.

TABLA 1. Medidas de interacción espacial en la pesquería de cerco sobre objetos flotantes. " * " indica las especies para las cuales *F(c)* en un *bps* de 1 animal por lance fue mucho mayor que 0.05; estas suelen ser especies para las cuales un gran porcentaje de lances tienen un *bps* = 0 y que son capturadas predominantemente como animales solitarios. El valor de $P_{0.05}$ computado para estas especies (en casillas sombreadas) no es necesariamente comparable con aquél de otras especies. " ----- " indica que no hay suficientes lances con captura incidental de la especie para computar estos índices. *n*: número de animals en el conjunto de datos.

		n	$c_{0.05}$	$P_{0.05}$	SO
Indo-Pacific sailfish	Pez vela	34	1*	0.003	0.0022
Black marlin	Marlín negro	273	1*	0.013	0.0102
Blue marlin	Marlín azul	834	1*	0.036	0.0112
Striped marlin	Marlín rayado	120	1*	0.003	0.0129
Wahoo	Peto	18,2815	15	0.45	0.0122
Bigeye trevally	Jurel voraz	180	2	0.005	0.0059
Common dolphinfish	Dorado	303,747	20	0.46	0.0134
Rainbow runner	Salmón	49,781	12	0.053	0.0034
Ocean sunfish	Pez luna	355	2	0.002	0.0101
Yellowtail amberjack	Medregal rabo amarillo	1,225	5	0.012	0.0019
Giant manta ray	Mantarraya gigante	1	1*	----	----
Pelagic thresher shark	Zorro pelágico	7	1*	----	----
Bigeye thresher shark	Zorro én	7	1*	----	----
Scalloped hammerhead shark	Cornuda común	163	1	0.003	0.0147
Great hammerhead shark	Cornuda gigante	2	1*	-----	----
Smooth hammerhead shark	Cornuda cruz	169	1	0.003	0.0131
Oceanic triggerfish	Pez ballesta oceánico	42,504	11	0.118	0.0054
Olive ridley turtle	Tortuga golfina	275	1*	0.004	0.0112
Silky shark	Tiburón jaquetón (sedoso)	13,608	2	0.211	0.0023
Oceanic whitetip shark	Tiburón oceánico (punta blanca)	78	1*	0.002	0.0115