



Ecosystem considerations in the eastern Pacific Ocean

Stable isotope ecology
A complement to stomach contents analysis because all...
...is a measure of relative trophic...

Figure 7
Amino acid compound-specific isotope analysis (AA-CIA) of yellowfin tuna reveals a south-north isotopic gradient at the base of the food web in the eastern Pacific Ocean.

Figure 1
Excerpt from Article VII of the IATTC Antigua Convention highlighting recommendations and measures for dependent and associated species in the same ecosystem that are affected by fishing.

Food-web research

Trophic ecology of predator communities
Extensive stomach sampling efforts have been conducted primarily during four periods: 1965-1967¹, 1969-1972², 1990-1994³, and 2003-2005⁴. Tunas were sampled during the first two periods, while the predator community (entire purse-seine catch/bycatch) was sampled during the latter two periods (Figure 2).

Tuna-dolphin trophic interactions
Stomach sampling of yellowfin tuna and spotted and spinner dolphins caught together revealed these multi-species associations are not likely due to diet overlap. Dolphins fed largely at night on mesopelagic prey and had empty stomachs in the afternoon, while yellowfin tuna fed on epipelagic prey during primary daylight hours (Figure 3).

Other food-web components

Apex predation on tropical tunas
Tunas are commonly considered apex predators, but tropical tunas, even as adults, are subject to predation by large-body predators. Diet data for much of the apex-predator guild in the EPO over some 30 years revealed that yellowfin and skipjack some 30 years revealed that yellowfin and skipjack... and batfishes in...

Figure 2
Summarized diet data for predator captured by purse seine in the eastern Pacific Ocean during 1965-1994.

Figure 3
Feeding periodicity, in terms of stomach fullness and degree of prey selectivity, of tuna and two species of dolphins caught by purse seine with commercial fish trawls during four periods. The x-axis represents the time of day, and the y-axis represents the percentage of stomachs full. The shaded area represents the 95% confidence interval. The dotted line represents the 95% confidence interval for the skipjack and yellowfin.

Figure 4
Frequency (number) of skipjack and yellowfin tunas by body size, assessed by white-stripe spot rank, for the light gray bars, and skipjack tunas by body size, assessed by white-stripe spot rank, for the dark gray bars. The shaded area represents the 95% confidence interval.

Figure 5
Fishery productivity and sustainability for the world's largest fishery in the eastern Pacific Ocean.

Figure 6
Comparative diversity index for various trophic levels in the eastern Pacific Ocean, showing a decrease in diversity from the base of the food web to the top.

Figure 7
Ecological risk assessment: Long-term ecological sustainability is a requirement of ecosystem-based fisheries management. The vulnerability to overfishing of many of the stocks incidentally caught in the EPO tuna fisheries is unknown, and biological and fisheries data are severely limited for most of those stocks. A vision of productivity and sustainability analysis (PSA), used to evaluate other fisheries, considers a stock's vulnerability as a combination of its productivity and its susceptibility to the fishery. A preliminary evaluation of three purse-seine "fisheries" (skipjack, floating object sein, and mammal stocks) in the EPO was made to assess vulnerability of fish, turtle, and mammal stocks to overfishing, in terms of overall vulnerability (i.e. Euclidean distance from the origin of Figure 5 to the data points), some of the sharks, and the giant moray ray scored the highest (Figure 5).

Figure 8
Ecosystem modeling: Ecosystem-based fisheries management is facilitated through the development of ecosystem-based fisheries management models that represent ecological interactions among species and their environment in open-ocean ecosystems.

Figure 9
Diagram showing the structure of an ecosystem model, including various trophic levels and their interactions.

Leanne Duffy and Robert Olson

5th Meeting of the Scientific Advisory Committee
5^a Reunión del Comité Científico Asesor

IATTC Fishery Status Report - SAC-05-13

INTER-AMERICAN TROPICAL TUNA COMMISSION COMISIÓN INTERAMERICANA DEL ATÚN TROPICAL

Fishery Status Report—Informe de la Situación de la Pesquería

TUNAS AND BILLFISHES IN THE EASTERN PACIFIC OCEAN
LOS ATUNES Y PECES PICUDOS EN EL OCEANO PACÍFICO ORIENTAL



INTER-AMERICAN TROPICAL TUNA COMMISSION
SCIENTIFIC ADVISORY COMMITTEE

FIFTH MEETING

La Jolla, California (USA)
12-16 May 2014

DOCUMENT SAC-05-13

ECOSYSTEM CONSIDERATIONS

1. Introduction	1
2. Impact of catches	2
3. Other fauna	6
4. Trophic interactions	9
5. Physical environment	10
6. Aggregate indicators	12
7. Ecological risk assessment	13
8. Ecosystem modeling	15
9. Actions by the IATTC and the AIDCP addressing ecosystem considerations	16
10. Future developments	18

- Call attention to the “Ecosystem Considerations” section of Fishery Status Report
- Review concepts, recent data, and research
 - International calls for “Ecosystem-based Management”
 - Biological and physical marine environment
 - Human activity in the marine environment
 - Focus on the ecosystem as a whole
 - Direct effects of fisheries on species – sustainability
 - Indirect effects of fisheries act through the food web – sustainability
 - Physical environment – inter-annual and long-term variability

Ecosystem Research in the Eastern Tropical Pacific Ocean

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The Inter-American Tropical Tuna Commission (IATTC) is charged with management of the tropical tuna and billfish stocks in the eastern Pacific Ocean (EPO), while taking into account other components of the ecosystem that are 1) affected by fishing or 2) dependent upon or associated with the target fish stocks (Figure 1). Fisheries effects on ecosystems encompass both direct effects (e.g. catch of non-target species) and indirect effects (i.e. interactions via the food web).

Investigating fisheries effects on ecosystems requires accurate representations of pelagic food webs in ecosystem models. Defining trophic connections is a prerequisite for gaining insight into the role of predators and commercial fisheries in influencing food web structure and ecosystem dynamics. IATTC's ecosystem research program is largely focused on understanding the pelagic food web in the EPO.

- ARTICLE VII FUNCTIONS OF THE COMMISSION
- adopt, as necessary, conservation and management measures and recommendations for species belonging to the same ecosystem and that are affected by fishing (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);
 - 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;

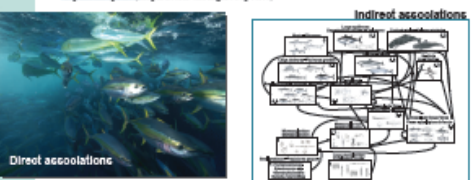


Figure 1 Excerpt from Article VII of the IATTC Antigua Convention highlighting recommendations and measures for dependent and associated species in the same ecosystem that are affected by fishing.

Food-web research

Trophic ecology of predator communities

Extensive stomach sampling efforts have been conducted primarily during four periods: 1955-1960¹, 1969-1972², 1992-1994³, and 2003-2005⁴. Tunas were sampled during the first two periods, while the predator community (entire purse-seine catch/bycatch) was sampled during the latter two periods (Figure 2).

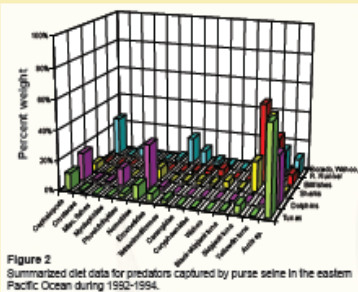
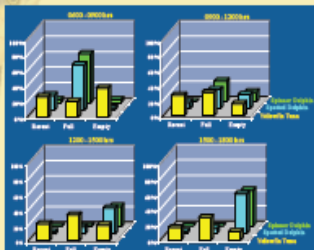


Figure 2 Summarized diet data for predators captured by purse seine in the eastern Pacific Ocean during 1952-1994.

Tuna-dolphin trophic interactions

Stomach sampling of yellowfin tuna and spotted and spinner dolphins caught together revealed these multi-species associations are not likely due to diet overlap. Dolphins fed largely at night on mesopelagic prey and had empty stomachs in the afternoon, while yellowfin tuna fed on epipelagic prey during primarily daylight hours (Figure 3).

Other food-web components

Apex predation on tropical tunas.

Tunas are commonly considered apex predators, but tropical tunas, even as adults, are subject to predation by large-body predators. Diet data for much of the apex-predator guild in the EPO over some 50 years revealed that yellowfin and skipjack tunas are consumed by sharks and billfishes in quantities and at sizes that can make a considerable contribution to the reproductive output of the populations⁵ (Figure 4).

Dolphinfish. Food habits and consumption rates of these abundant, ubiquitous predators have been characterized over a large portion of the EPO⁶.

Multitrophic fishes. Prey preference, diet partitioning, feeding chronology, and feeding selectivity of three species of this important group of mesopelagic fishes have been described⁷.

Novel method of diet data analysis

A classification tree modeling framework for investigating complex feeding relationships has been developed. The non-parametric method is both exploratory and predictive, and uses a bootstrap approach to provide standard errors of predicted prey proportions, variable importance measures to highlight important covariates, and partial dependence plots to explore the relationships between explanatory variables and predicted prey composition⁸ (Figure 5).

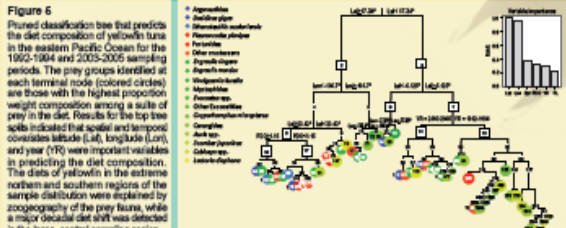


Figure 5 Plurid classification tree that predicts the diet composition of yellowfin tuna in the eastern Pacific Ocean for the 1992-1994 and 2003-2005 sampling periods. The prey groups identified at each terminal node (colored circles) are those with the highest proportion weight composition among a suite of prey in the diet. Results for the top five prey items (indicated by colored circles) are those with the highest proportion weight composition among a suite of prey in the diet. Results for the top five prey items (indicated by colored circles) are those with the highest proportion weight composition among a suite of prey in the diet.

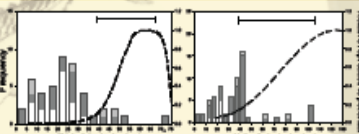


Figure 4 Frequency (number) of skipjack and yellowfin tunas, by body size, consumed by sharks (dark gray bars), martins (light gray bars), and large-bodied tunas (white bars) in the eastern tropical Pacific Ocean. The dashed black lines represent estimates of the relative reproductive potential of individual skipjack and yellowfin tunas across size classes. The solid black lines denote the body sizes that comprise 50% of tuna catches.

Stable isotope ecology

Stable carbon and nitrogen isotope analysis is a useful complement to stomach-content analysis because all components of the assimilated diet are integrated into an animal's tissues, providing a measure of relative trophic position (Figure 6). The spatial distribution of stable isotope values of yellowfin tuna in relation to those of copepods in the EPO showed an increasing trophic position of the tuna from inshore to offshore, a characteristic of the food web never detected in diet data⁹.

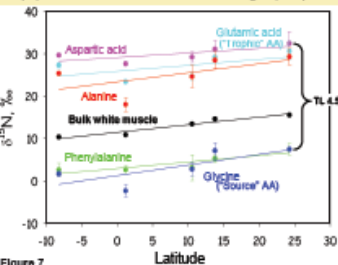


Figure 7 Amino acid compound-specific isotope analysis (AA-CSIA) of yellowfin tuna reveals a south-north isotopic gradient at the base of the food web in the eastern Pacific Ocean.

Additional insight is provided by compound-specific isotope analysis of amino acids (AA-CSIA). In samples of consumer tissues, "source" amino acids (e.g. phenylalanine, glycine) retain the isotopic values at the base of the food web, and "trophic" amino acids (e.g. glutamic acid) become enriched in ¹⁵N by about 7‰ relative to the baseline (Figure 7). Trophic position can be derived from samples of consumer tissues alone (i.e. not necessary to sample the food-web base).

Christina A. Patuode • IATTC Graphic Design/Layout

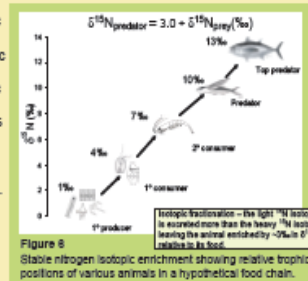


Figure 8 Stable nitrogen isotopic enrichment showing relative trophic positions of various animals in a hypothetical food chain.

Aggregate indicators

Ecological metrics of removals by purse-seine fishing

Ecosystem-based fisheries management requires an understanding of the ecological effects of removing animals by fishing. The degree to which fisheries affect ecosystems depends on the biomass, composition, life history, and ecological role of the different species captured. Animals caught by three methods of purse-seine fishing in the EPO were compared on the basis of biomass, number of individuals, trophic level, replacement time, and diversity. Differences in removals among the three methods were much smaller than previously described on the basis of discarded bycatch alone¹⁰ (Figure 8).

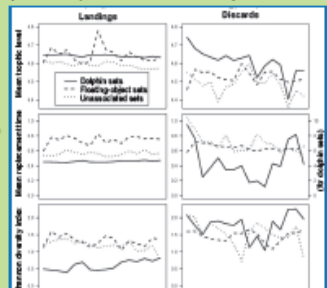


Figure 8 Comparison of mean trophic level, mean replacement time, and the Shannon diversity index for animals caught by three purse-seine fishing methods: sets on dolphins, sets in association with floating objects, and sets on unassociated tuna schools.

Ecological risk assessment

Long-term ecological sustainability is a requirement of ecosystem-based fisheries management. The vulnerability to overfishing of many of the stocks incidentally caught in the EPO tuna fisheries is unknown, and biological and fisheries data are severely limited for most of those stocks. A version of productivity and susceptibility analysis (PSA), used to evaluate other fisheries, considers a stock's vulnerability as a combination of its productivity and its susceptibility to the fishery. A preliminary evaluation of three purse-seine fisheries (dolphin sets, floating object sets, unassociated sets) in the EPO was made to assess vulnerability of fish, turtle, and mammal stocks to overfishing. In terms of overall vulnerability (i.e. Euclidean distance from the origin of Figure 9 to the data points), some of the sharks and the giant manta ray scored the highest¹¹ (Figure 9).

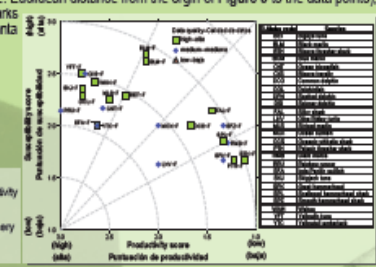


Figure 9 Preliminary productivity and susceptibility analysis for the floating-object fishery in the eastern Pacific Ocean.

Ecosystem modeling

Ecosystem-based fisheries management is facilitated through the development of multi-species ecosystem models that represent ecological interactions among species or guilds. Our understanding of the complex maze of connections in open-ocean ecosystems is at an early stage, and, consequently, the current ecosystem models are most useful as descriptive devices and for exploring hypothetical indirect effects of fishing based on best estimates of trophic links and energy pathways. The IATTC staff developed a model of the pelagic ecosystem in the tropical EPO¹² to represent 1993-1997. A sensitivity analysis indicated that changes in the parameters for two components at middle trophic levels, cephalopods and *Auax* spp., exerted the greatest influence on the ecosystem (Figure 10).

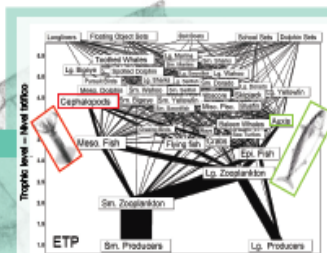


Figure 10 Ecosystem model for the eastern Pacific Ocean showing trophic levels for various animals captured by the different fisheries. A sensitivity analysis, indicated that cephalopods and *Auax* spp. exerted the greatest influence on the system.

Conclusions

Trophic structure represented in food webs is thought to be the central organizing concept in ecology. Anticipating changes induced by fishing requires improved understanding of food web structure and function. Knowledge of pelagic food webs in all oceans is rudimentary in many aspects. Greater understanding of the trophodynamics of pelagic food webs is needed, specifically the relative strength of the trophic links and the pathways of biomass flow.

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 pelagic food webs is still rudimentary, in many aspects

- Predation habits of yellowfin tuna: a wide-ranging generalist predator with high energy requirements (samplers of forage community)

Olson RJ, Duffy LM, Kuhnert PM, Galván-Magaña F, Bocanegra-Castillo N, Alatorre-Ramirez 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

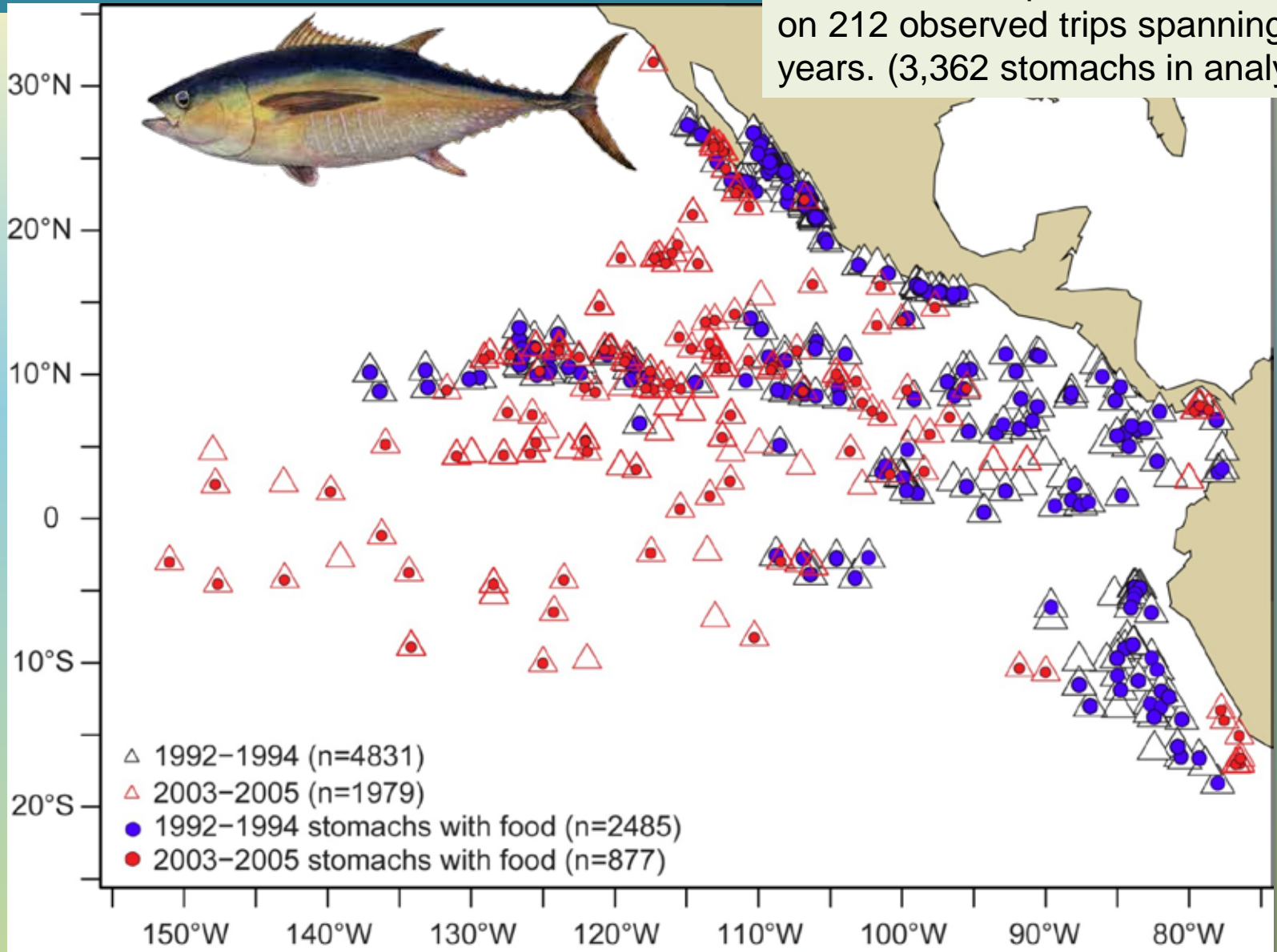
- Novel classification tree methodology developed for analyzing complex diet data

Kuhnert P, Duffy L, Young J, Olson R (2012) Predicting fish diet composition using a bagged classification tree approach: a case study using yellowfin tuna (*Thunnus albacares*). *Marine Biology*: 1-14

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

Trophic interactions: set locations, yellowfin tuna diet study (1990s, 2000s)

6,810 YFT sampled from 300 PS sets on 212 observed trips spanning 4 years. (3,362 stomachs in analysis)

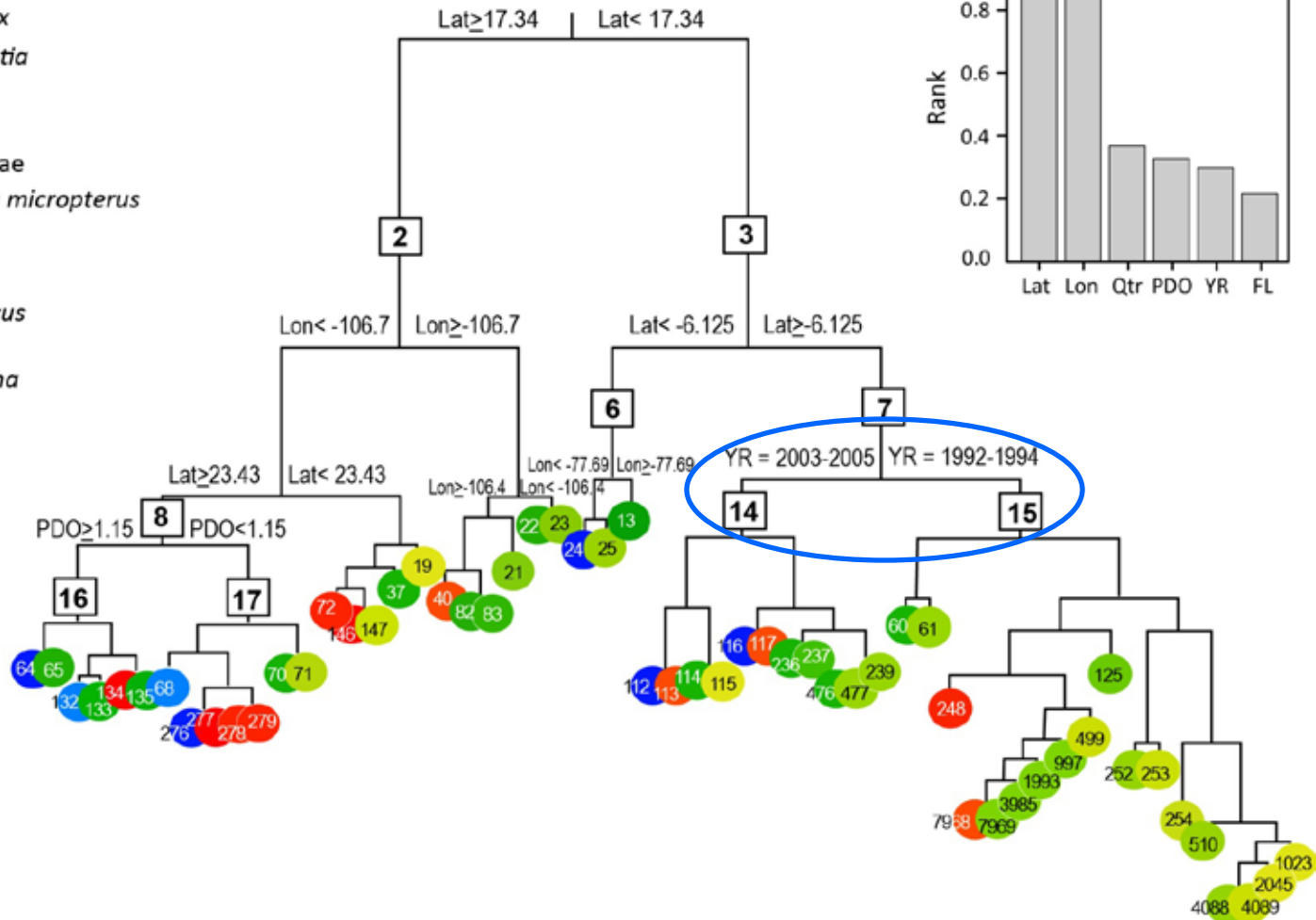


Trophic interactions: classification tree analysis (YFT)

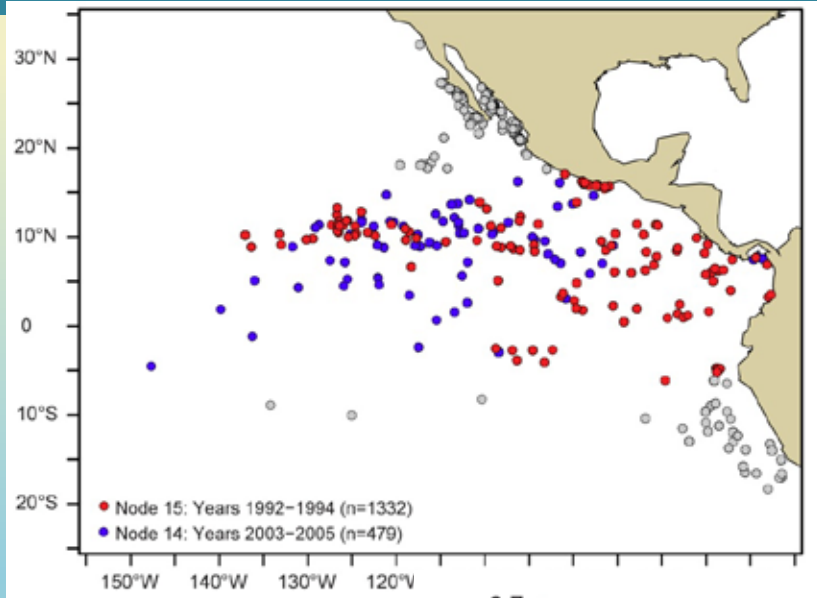
- Argonautidae
- *Dosidicus gigas*
- *Sthenoteuthis oualaniensis*
- *Pleuroncodes planipes*
- Portunidae
- Other crustaceans
- *Cetengraulis mysticetus*
- *Engraulis mordax*
- *Vinciguerria lucetia*
- Myctophidae
- *Exocoetus* spp.
- Other Exocoetidae
- *Oxyporhamphus micropterus*
- Carangidae
- *Auxis* spp.
- *Scomber japonicus*
- *Cubiceps* spp.
- *Lactoria diaphana*

1 SE tree.

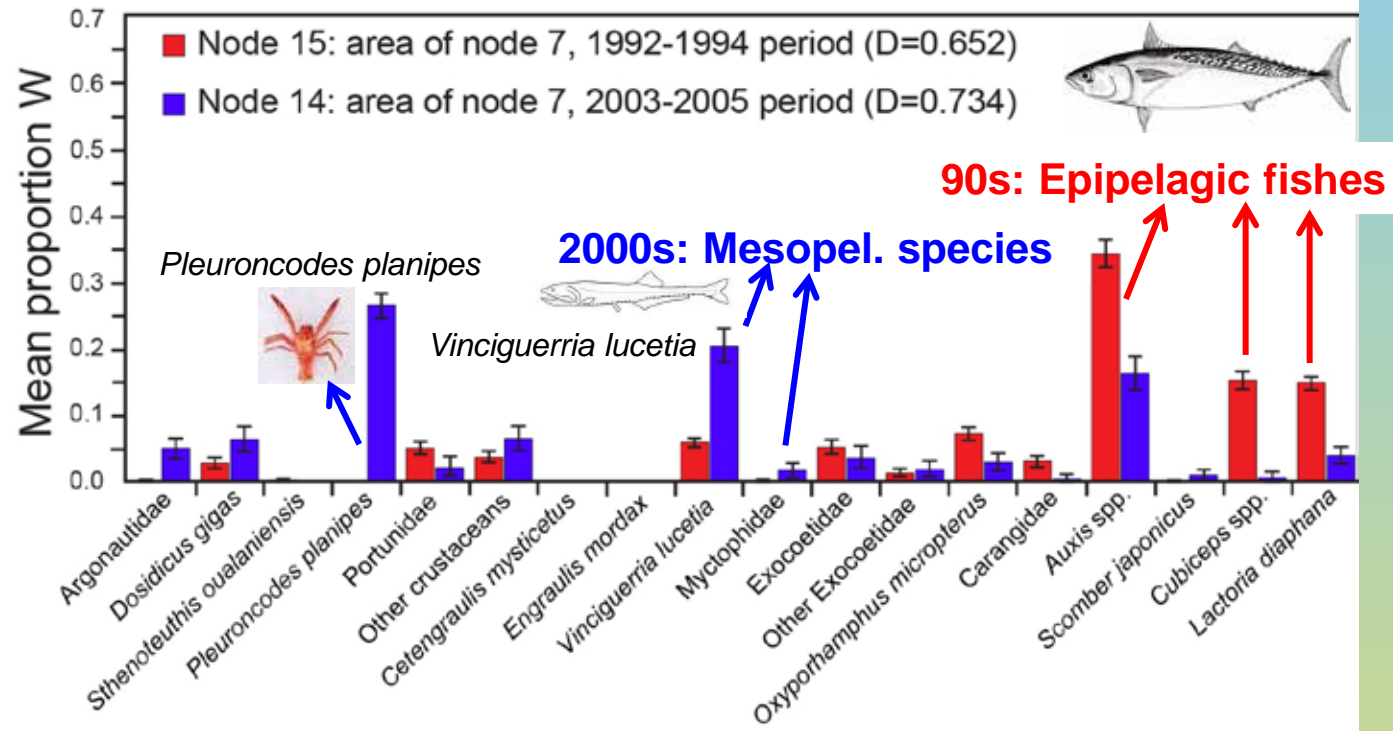
Cross-validated error rate low:
0.376, $R^2 = 62\%$



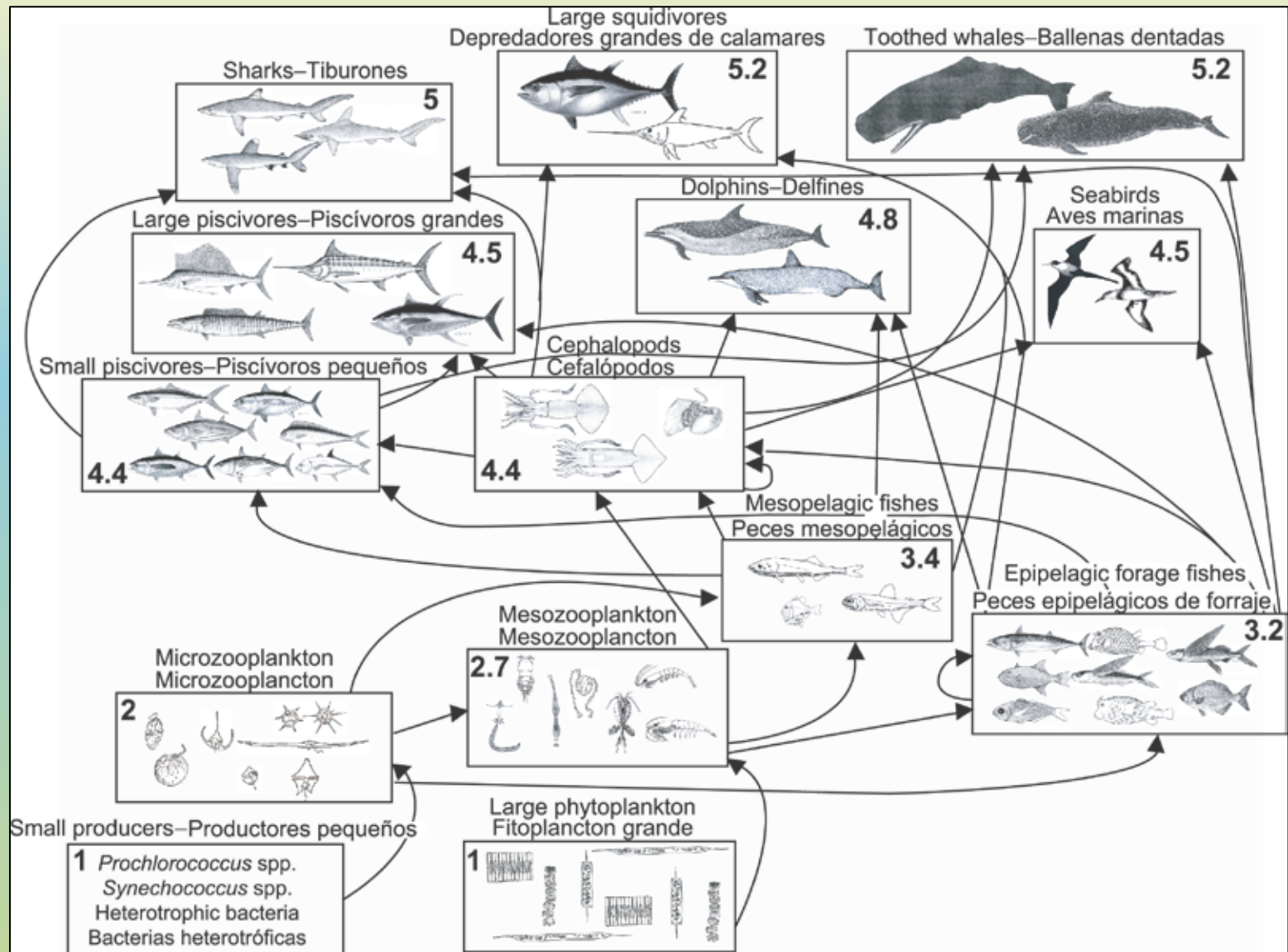
Trophic interactions: classification tree analysis (YFT) diet shift



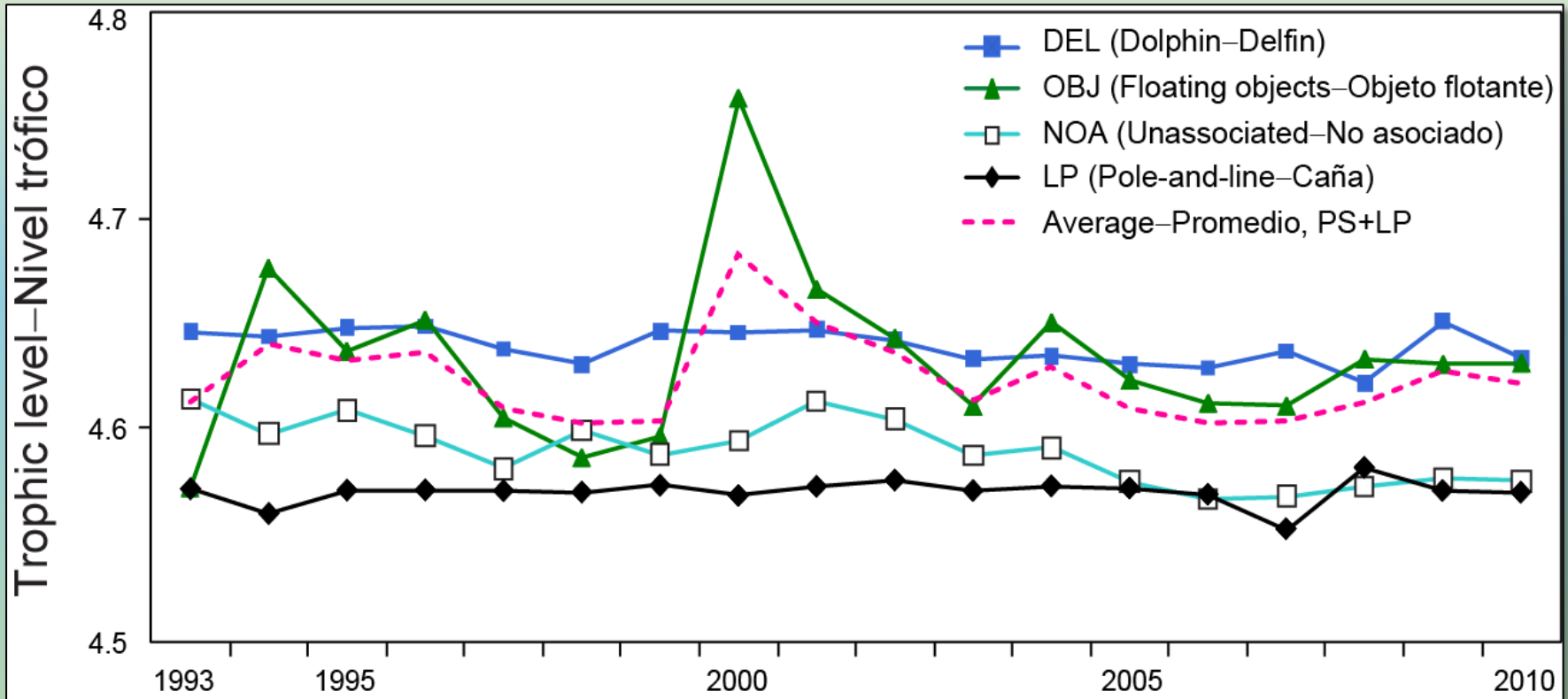
Simultaneously widespread reductions in:
 Biological production
 Phytoplankton community composition
 Expansion & intensification of OMZ



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



Aggregate indicators: yearly mean trophic level of the catches



Antigua Convention

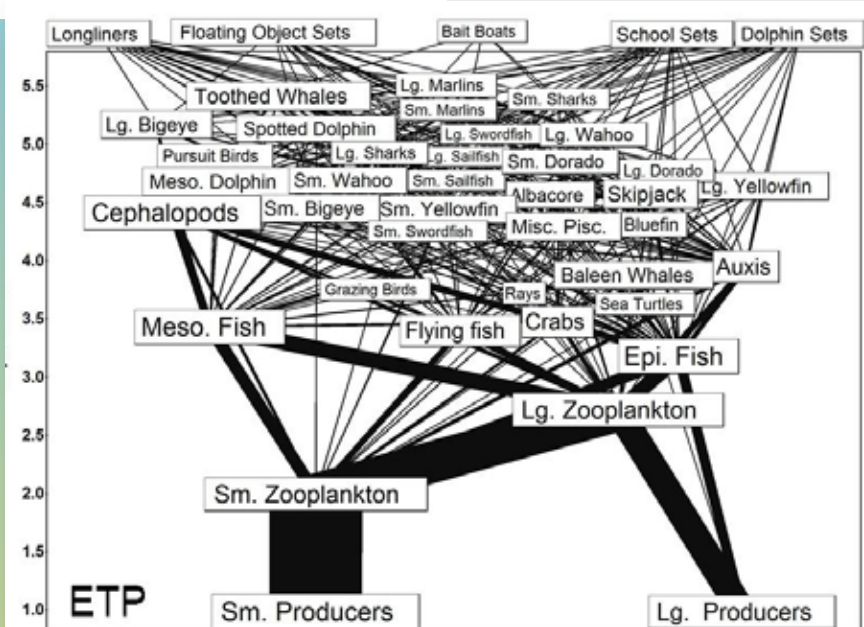
ARTICLE VII. FUNCTIONS OF THE COMMISSION

- (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



Resolutions to reduce incidence of bycatch of non-target species

USE OF PRODUCTIVITY AND SUSCEPTIBILITY INDICES TO EVALUATE VULNERABILITY IN THE
Purse-Seine Fishery of the Eastern Pacific Ocean
P. Lawson, F. Leggett-Cody, Michael G. Hinton, Michael Scott, Alexandre Aires-da-Silva, Richard Deriso
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La Jolla, California USA 92037

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;

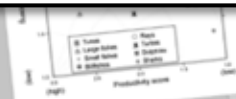
Recognizing the value of consolidating the operative parts of these resolutions into one comprehensive resolution on bycatch;

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

Has agreed as follows:

origin of the X-Y
point (Figure 1)

$$y = \sqrt{(p-3)^2 + (x-1)^2}$$



P. Lawson, F. Leggett-Cody, Michael G. Hinton, Michael Scott, Alexandre Aires-da-Silva, Richard Deriso, 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.

Preliminary Ecological Risk Assessment

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

Robert J. Olson¹, Leanne M. Duffy, Mark N. Maunder, Cleridy E. Lennert-Cody, Michael G. Hinton, Michael Scott, Alexandre Aires-da-Silva, Richard Deniso
 Inter-American Tropical Tuna Commission (IATTC) • 8604 La Jolla Shores Drive • La Jolla, California USA 92037 • rolson@iattc.org

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 eastern Pacific Ocean (EPO) tuna fisheries 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.



Productivity and Susceptibility Analysis

Productivity and susceptibility analysis (PSA) (e.g. Patrick et al. 2010) 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 are determined by deriving a score ranging from 1 (low) to 3 (high) for a standardized set of attributes related to each index for each stock in question. The individual attribute scores are then averaged for each index and graphically displayed on an x-y scatter plot (Figure 1). When scoring the attributes, the data quality associated with each attribute score is assessed, and the attributes 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) were calculated from the p and s scores as the Euclidean distance from the origin of the x-y scatter plot to each data point (Figure 1).

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

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. Tunas also aggregate near the surface in the vicinity of floating objects, most commonly fish aggregating devices (FADs). Purse-seine sets are also made on unassociated schools of tuna. Incidental catches are markedly different by fishing mode. Floating-object sets have the greatest bycatch.

Reducing the catch of non-target species is required by the IATTC convention, but such efforts should be prioritized according to the species most vulnerable to over-exploitation.



DEL - Dolphin sets



NOA - Unassociated sets

OBJ - Floating-object sets

PSA for EPO purse-seine fishery

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" (fishing modes) was made. The PSA was focused on 33 species (Table 1) that comprised the majority of the biomass removed by the purse-seine vessels with carrying capacity greater than 363 metric tons during 2005-2011. Information corresponding to nine 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 eight susceptibility attributes (Table 3) were taken from Patrick et al. (2010) and modified where appropriate to better suit the EPO fisheries.

A scatter plot of averaged productivity and susceptibility scores for 33 species caught by three purse-seine fisheries (on dolphins, unassociated species, and floating objects) are shown in Figure 2 by group (see Table 1 tunas, and floating objects). In general, some of the sharks and the giant manta ray scored the highest in overall vulnerability to overfishing. 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 2).

Table 2. Productivity attributes and thresholds

Productivity attribute	Low (1)	Midrange (2)	High (3)
Annual rate of population growth (r)	≤ 0.1	> 0.1 - ≤ 0.2	> 0.2
Western age length	≤ 50	> 50 - ≤ 70	> 70
Western age zero	≤ 300	> 300 - ≤ 350	> 350
Western age zero	≤ 0.500	> 0.500 - ≤ 0.7	> 0.7
Sex ratio	≤ 0.50	> 0.50 - ≤ 0.6	> 0.6
Female fecundity	≤ 10	> 10 - ≤ 50,000	> 50,000
Sexual maturity	≤ 2	> 2 - ≤ 3	> 3
Age at maturity length	≤ 0.7	> 0.7 - ≤ 1.0	> 1.0
Sex ratio trend	> 0.4	> 0.4 - ≤ 0.7	> 0.7

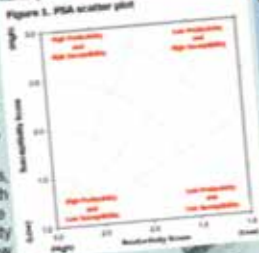
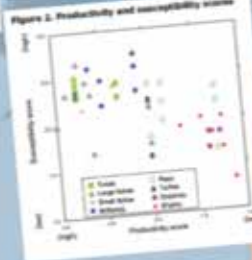


Table 3. Susceptibility attributes and thresholds

Susceptibility attribute	High (1)	Midrange (2)	Low (3)
Endemism	Endemic to the Eastern Pacific	Endemic to the Eastern Pacific and the Western Pacific	Endemic to the Eastern Pacific, Western Pacific, and the Indian Ocean
Geographic range	< 1000 km	1000 - 2000 km	> 2000 km
Habitat specificity	Specialized	Generalist	Generalist
Life history	Short-lived	Medium-lived	Long-lived
Life span	< 10 years	10 - 20 years	> 20 years
Migration	Non-migratory	Migratory	Migratory
Reproductive strategy	K-selected	r-selected	r-selected
Resilience	Low	Medium	High
Taxonomic group	Shark	Mammal	Fish



Literature Cited

Patrick, W.S., P. Spencer, J. Link, J. Cope, J. Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Opatás, 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: vulnerability of non-target species

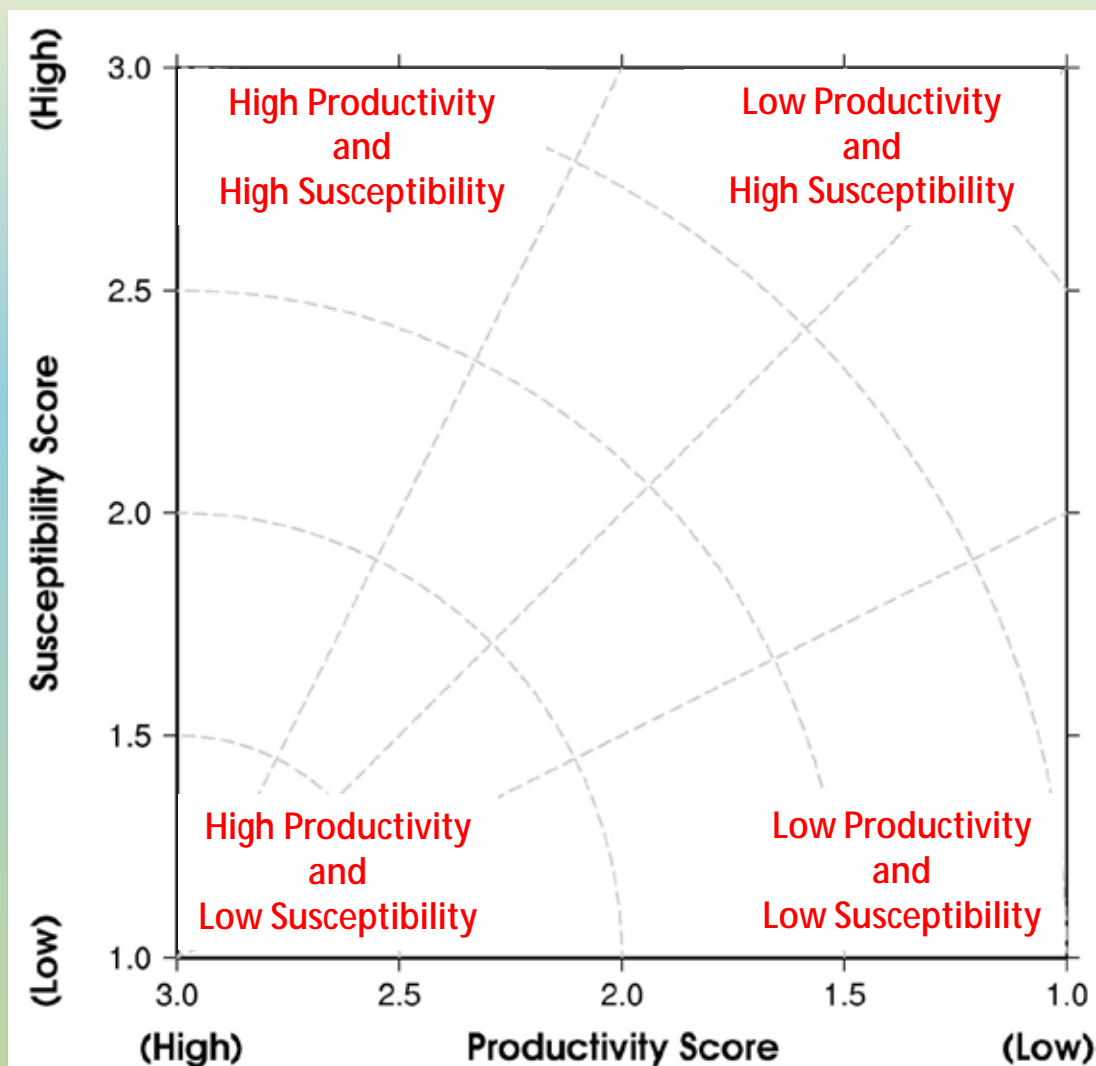
USE OF PRODUCTIVITY AND SUSCEPTIBILITY INDICES TO EVALUATE VULNERABILITY IN THE Purse-Seine Fishery of the Eastern Pacific Ocean

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

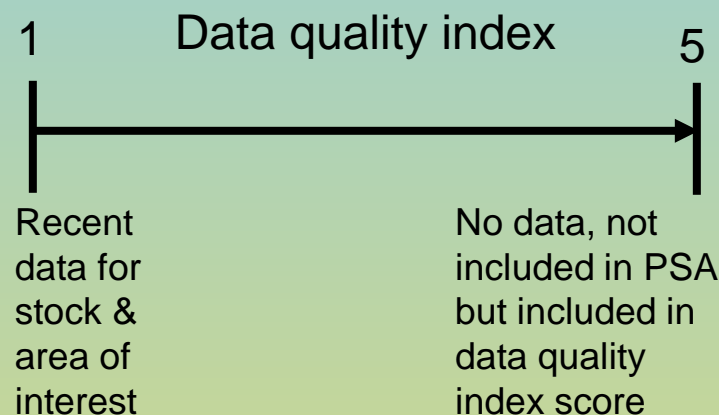
- **Vulnerability:** potential for the productivity of a stock to be diminished by direct and indirect fishing pressure. PSA: vulnerability is combination of a stock's productivity and its susceptibility to the fishery.
- **Productivity** – capacity to recover if stock is depleted (function of life history 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.

Ecological Risk Assessment: PSA scatter plot



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

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



Preliminary Ecological Risk Assessment: productivity attributes for EPO PSA

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

TABLA J-2. Atributos de productividad y umbrales de puntuación usados en el APS de la CIAT.

Productivity attribute Atributo de productividad	Ranking – Clasificación		
	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	$> 0.1, \leq 1.3$	> 1.3
Maximum age (years) Edad máxima (años)	≥ 20	$> 11, < 20$	≤ 11
Maximum size (cm) Talla máxima (cm)	> 350	$> 200, \leq 350$	≤ 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	$\geq 2.7, < 7.0$	< 2.7
Mean trophic level Nivel trófico medio	> 5.1	$4.5 - 5.1$	< 4.5

Preliminary Ecological Risk Assessment: susceptibility attributes for EPO PSA

TABLE J-3. 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 <u>and</u> stock not concentrated (or not rare)	Greatest bycatches outside areas with the most sets <u>and</u> stock concentrated (or rare), OR Greatest bycatches in areas with the most sets <u>and</u> stock not concentrated (or not rare)	Greatest bycatches in areas with the most sets <u>and</u> 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

Preliminary Ecological Risk Assessment: species for EPO PSA

TABLE J-1. Annual bycatch per set (in kilograms) 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 PSA 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.

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

¹ Included due to numerical importance in bycatch (≥1 individual per set)

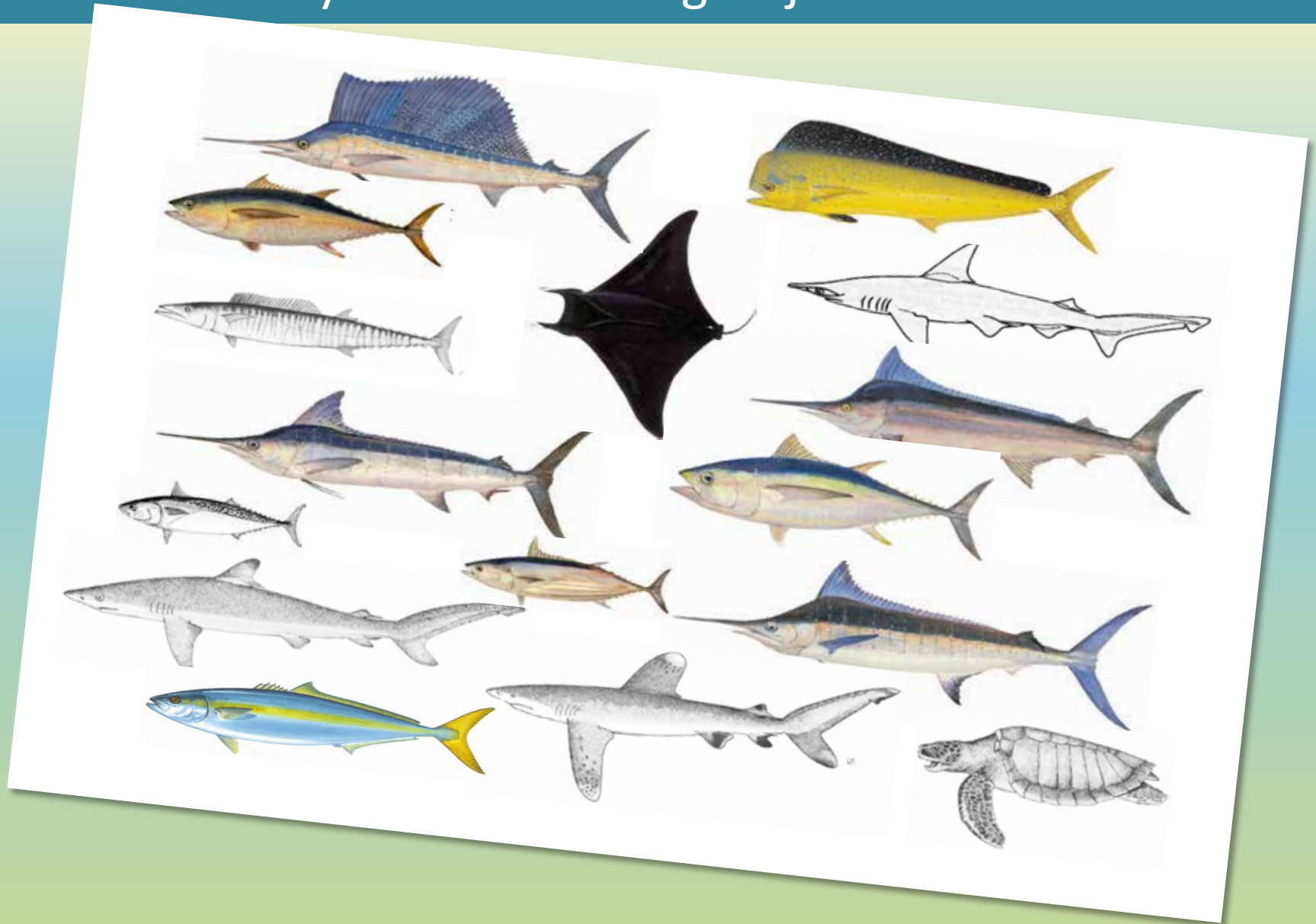
² "Vulnerable" status, IUCN Red List of Threatened Species

³ "Endangered" status, IUCN Red List of Threatened Species

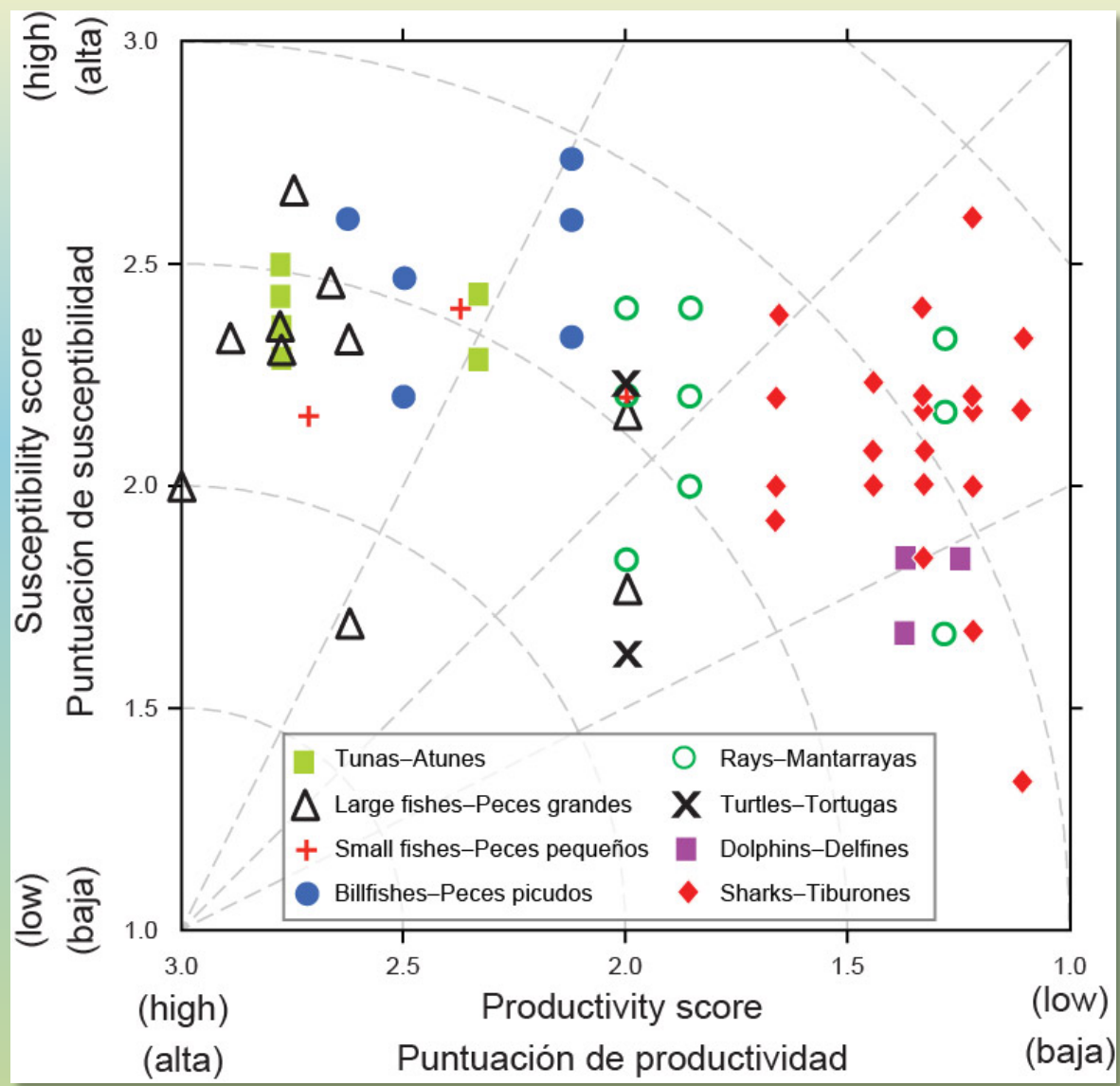
⁴ "Near threatened" status, IUCN Red List of Threatened Species

Preliminary Ecological Risk Assessment: species for EPO PSA

Tuna catch and bycatch in floating-object sets

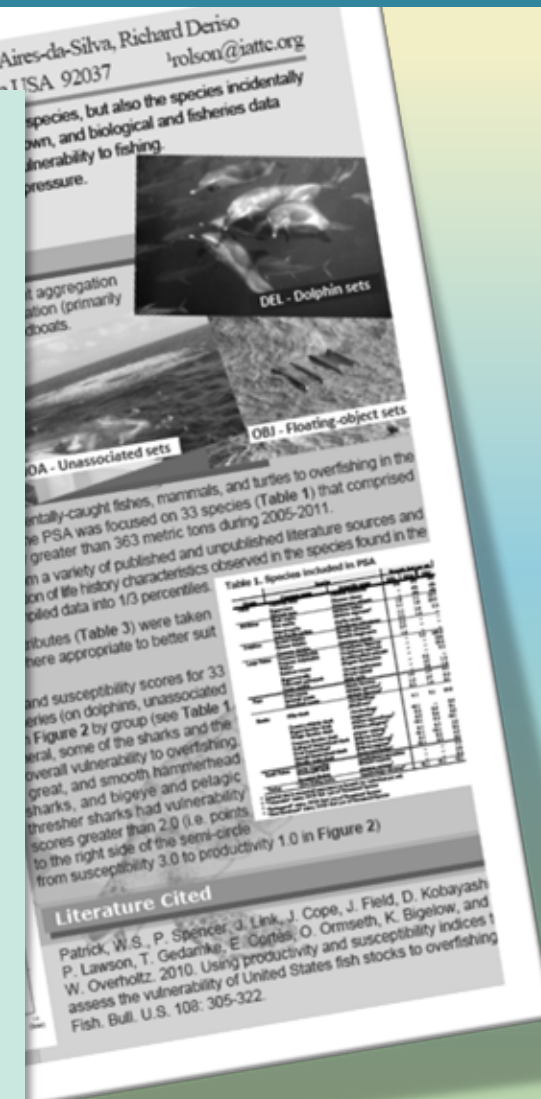


Preliminary Ecological Risk Assessment: PSA scatter plot for all species and all purse-seine fisheries



Ecological Risk Assessment: the PSA

- 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)



Ecological Risk Assessment: PSA used by other organizations

Marine Stewardship Council
Fisheries Assessment Methodology
and
Guidance to Certification Bodies

Including Default Assessment Tree
and Risk-Based Framework

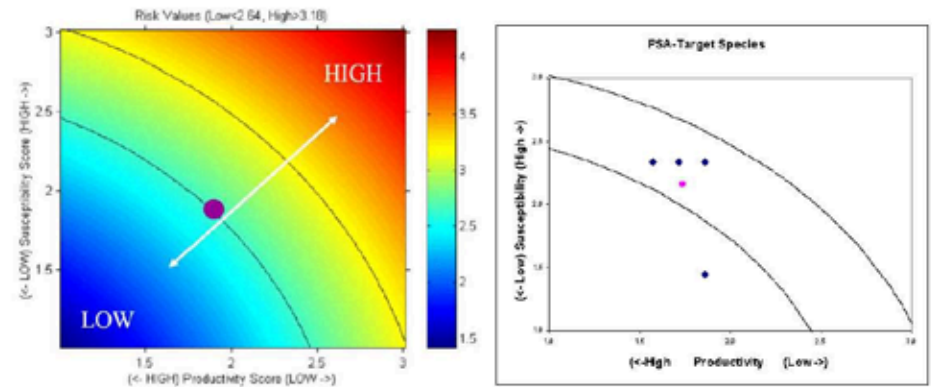


Figure A2. Examples of diagnostic charts for displaying PSA values for each species. **Left:** Low risk species have high productivity and low susceptibility, while high risk species have low productivity and high susceptibility. The curved lines divide the potential risk scores into thirds on the basis 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.



Ecosystem considerations in the eastern Pacific Ocean

Food-web research

Trophic ecology of predator communities
 Extensive stomach sampling efforts have been conducted primarily during four periods: 1965-1967, 1969-1972, 1990-1994, and 2003-2005. Tunas were sampled during the first two periods, while the predator community (entire purse-seine catch/bycatch) was sampled during the latter two periods (Figure 2).

Tuna-dolphin trophic interactions
 Stomach sampling of yellowfin tuna and spotted and spinner dolphins caught together revealed these multi-species associations are not likely due to diet overlap. Dolphins fed largely at night on mesopelagic prey and had empty stomachs in the afternoon, while yellowfin tuna fed on epipelagic prey during primary daylight hours (Figure 3).

Other food-web components
Apex predation on tropical tunas. Tunas are commonly considered apex predators, but tropical tunas, even as adults, are subject to predation by large-body predators. Diet data for much of the apex-predator guild in the EPO over some 30 years revealed that yellowfin and skipjack tunas are consumed by sharks and billfishes in quantities and at sizes that can make a considerable contribution to the reproductive output of the populations (Figure 4).

Dorsal fish. Food habits and consumption rates of these abundant, ubiquitous predators have been characterized over a large portion of the EPO.

Microplankton. Prey preference, diet partitioning, feeding chronology, and feeding selectivity of three species of this important group of mesopelagic fishes have been described.

Novel method of diet data analysis
 A classification tree modeling framework for investigating complex feeding relationships has been developed. The non-parametric method is both exploratory and predictive, and uses a bootstrap approach to provide standard errors of predicted prey proportions, variable importance measures to highlight important covariables, and partial dependence plots to explore the relationships between explanatory variables and predicted prey

Figure 1 Excerpt from Article VII of the IATTC Antigua Convention highlighting recommendations and measures for dependent and associated species in the same ecosystem that are affected by fishing.

Figure 2 Summarized diet data for predators captured by purse seine in the eastern Pacific Ocean during 1965-1994.

Figure 3 Feeding chronology, in terms of stomach fullness and degree of prey consumption, of yellowfin tuna and big eye tuna during four time periods. Yellowfin tuna were sampled during four time periods, while big eye tuna were sampled during only three periods. "Full" indicates 100% stomach fullness, "1/2" indicates 50% fullness, and "empty" indicates 0% fullness. The number of individuals that had no been retained or retained but were not analyzed are shown.

Figure 4 Prey classification tree that predicts the diet composition of yellowfin tuna in the eastern Pacific Ocean for the period 1965-2005. The tree groups identified at each terminal node (branches) are those with the highest proportion of weight composition among a suite of all prey items in the diet. Branches for the first two nodes in the diet composition tree are shown in the inset. The inset shows the diet composition of the yellowfin tuna in the diet composition tree. The inset shows the diet composition of the yellowfin tuna in the diet composition tree.

Figure 5 Fisheries productivity and selectivity for the leading target fishery in the EPO.

Figure 6 Ecological risk assessment. Long-term ecological sustainability is a requirement of ecosystem-based fisheries management. The vulnerability to overfishing of many of the stocks indifferently caught in the EPO tuna fisheries is unknown, and biological and fisheries data are severely limited for most of those stocks. A version of productivity and susceptibility analysis (PSA), used to evaluate other fisheries, considers a stock's vulnerability as a combination of its productivity and its susceptibility to the fishery. A preliminary evaluation of three purse-seine "fisheries" (skipjack, floating object sets, unassociated sets) in the EPO was made to assess vulnerability of fish, turtle, and mammal stocks to overfishing, in terms of overall vulnerability (i.e. Euclidean distance from the origin of Figure 5 to the data points), some of the sharks, and the giant manta ray scored the highest (Figure 6).

Figure 7 Antiga acid compound-specific isotope analysis (AA-CIA) of yellowfin tuna reveals a south-north isotopic gradient at the base of the food web in the eastern Pacific Ocean.

Figure 8 Comparison of mean bycatch levels, mean replacement time, and coefficient of variation (CV) for species caught by three purse-seine fishing methods (purse-seine, floating object sets, and unassociated sets) with respect to bycatch, replacement time, and mean unassociated bycatch.

Figure 9 Ecological metrics of removals by purse-seine fishing. Ecosystem-based fisheries management requires an understanding of the ecological effects removing animals by fishing. The degree to which fisheries affect ecosystems depends on biomass, composition, life history, and ecological role of the different species captured. Analyses were conducted for three methods of purse-seine fishing in the EPO were compared on the basis of biomass, number of individuals, trophic level, replacement time, and diversity. Differences in removals among the three methods were much smaller than previously described on the basis of discarded bycatch alone (Figure 8).

Figure 10 Conclusions. Trophic structure represented in food webs is thought to be the central organizing concept in ecology. Anticipating changes induced by fishing require improved understanding of food web structure and function. Knowledge of pelagic food webs in all oceans is rudimentary in many aspects. G

Questions?