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A first approach to the management of the incidental catch of the eastern Pacific Mexican tuna fleet

Una primera aproximación para el manejo de la captura incidental de la flota atunera mexicana del Pacífico Oriental

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ABSTRACT

The information registered by the Mexican Tuna Management and Dolphin Protection Program (PNAAPD) observers on board the Mexican tuna vessels was used to make a basic statistical analysis of the incidental catch of the Mexican eastern Pacific fleet, and to evaluate different aspects of the spatial and seasonal closure strategy. Twenty spatial and seasonal units were identified and hierarchically classified by set-type into four categories (explosive, avoidable, preventive and acceptable) based on two criteria: the incidental catch per set and the number of sets. Incidental catch reduction curves were created. Finally, an example of incidental catch reduction was performed for the mahi-mahi (dolphin-fish) *Coryphaena hippurus* and *C. equiselis*, considering the reduction percentage of incidental catch and main objective species catch (yellowfin tuna, *Thunnus albacares*), and the number of spatial and seasonal units closed. Log-sets are the type of sets that contribute with the greatest amount of incidental catch, except for billfishes. Of the five analyzed areas, those located off the coasts of Mexico can be considered as those with lower risk for most of the species incidentally caught throughout the year. The direct strategy for most of the management objectives is to eliminate or reduce the number of log-sets for the Mexican tuna fleet, throughout the whole zone or in specific units, resulting in a significant incidental catch reduction and a minimal effect on the yellowfin catch. The choice among five alternatives, none better than the others, establishing the units to be closed and the order to do so to reduce the incidental catch, rests in the decision-makers, and is a function of their preferences in respect to the different criteria used to evaluate the alternatives.

Key words: Incidental catch, bycatch, hot spots, management strategies, spatial and seasonal closures.

RESUMEN

Se utilizó la información recopilada por los observadores del PNAAPD (Programa Nacional de Aprovechamiento del Atún y de Protección de Delfines) a bordo de las embarcaciones atuneras mexicanas para realizar un análisis estadístico básico de la captura incidental de la flota mexicana del Pacífico Oriental, así como para evaluar diferentes aspectos de la estrategia de veda espacial y/o temporal. Se identificaron y clasificaron jerárquicamente veinte estratos espacio-temporales por tipo de lance en cuatro categorías (explosivos, evitables, preventivos y aceptables) basándose en dos criterios: la captura incidental por lance y el número de lances. Se crearon curvas de eliminación de captura incidental. Finalmente se realizó un ejemplo de disminución de la captura incidental del dorado *(Coryphaena hippurus* y *C. equiselis)* considerando el porcentaje de reducción de la captura incidental y de la captura de la especie objetivo principal (atún aleta amarilla *Thunnus albacares*) y el número de estratos espacio-temporales vedados. Los lances sobre palos son los que contribuyen con la mayor cantidad de la captura incidental exceptuando a los picudos. De las cinco áreas analizadas, las localizadas frente a las costas mexicanas se pueden considerar como las de menor riesgo en cuanto a la mayoría de las especies capturadas incidentalmente durante todo el año. La estrategia directa para la mayoría de los objetivos de manejo es la eliminación o reducción en el número de lances sobre palos por la flota atunera mexicana, en toda la región o en estratos específicos, lo que causaría una disminución significativa en la captura incidental y un efecto mínimo en la captura del aleta amarilla. La elección entre cinco opciones, ninguna mejor que otra, que establecen cuales y el orden en que los estratos deben vedarse para reducir la captura incidental, descansa en los encargados de la toma de decisiones y está en función de las preferencias de éstos con respecto a los diferentes criterios utilizados para evaluarlas.

Palabras Claves: Captura incidental, focos rojos, estrategias de manejo, vedas espacio-temporales.

INTRODUCTION

The present worldwide incidental catches and discard levels are overwhelming. Although incidental catch and discards have been linked to fisheries since their beginnings, their magnitude has notably increased.

The definitions used by Caddy and Griffiths (1996) are used for the purpose of this study, in which the incidental catch is the part of the gross catch that is taken incidentally in respect to the species the effort is directed to regardless of the treatment, and the discard catch is the part of the gross catch not used in any way but returned back to the sea as whole fish or whole organism. These definitions are the product of a working group. That group reached the conclusion that many concepts and terms were used in fisheries management, meaning different things to different people.

Around 27 million tons are estimated to be discarded every year worldwide, with an estimated range of 17.9 to 39.5 million tons (Alverson *et al.*, 1994), and these estimates are considered conservative values. In particular, the eastern Pacific Ocean (EPO) purse-seine tuna fishery is catalogued within the 10 fisheries with fewer organisms discarded and incidentally caught per number of organisms loaded (Alverson *et al.*, 1994).

The incidental catch and discard levels of the EPO yellowfin tuna (YFT, *Thunnus albacares*) and skipjack *(Katsuwonus pelamis)* purse-seine fishery by the international fleet have been widely described (Hall, 1996; Hall, 1998; Anonymous, 2000) and are monitored by the staff of the Inter-American Tropical Tuna Commission (IATTC) and from the Mexican National Program for Tuna Management and Dolphin Protection (PNAAPD). The dolphin mortality that caused great mobilization of environmental groups and motivated the tuna embargo against Mexico and other countries by the United States, has reached levels considered as statistically zero and insignificant to the population (Hall, 1998). However, there is an amount of non-objective species catch (incidental catch) such as sharks, billfishes, mahi-mahi and many other species in the tuna fishery by the EPO international fleet. The ecological effects of this incidental catch are not known yet. The incidental catch is specially caught on sets referred to as log-sets, widely used by the international fleet and seldom by the Mexican fleet.

Tunas are caught in the EPO by different fisheries. In general terms, long-lines catch tunas in depths greater than 60 m., and purse-seines and bait-boats catch organisms near the surface and down to a depth of 50 m. There are three types of fishing maneuvers or sets made with purse-seines: sets on marine mammals (dolphin-sets), sets on free swimming schools (school-sets) and sets on floating objects (log-sets), focused on different associations of tuna schools. Practically all the purse-seine vessels can make the three types of sets. These procedures have also been widely described by Hall (1998) and Anonymous (2000).

It has been established that sets on marine mammals represent the best exploitation strategy for tuna, minimizing juvenile tuna discards and incidental catch (Joseph, 1994; Hall, 1998). Sets on floating objects represent, on the contrary, a strategy that jeopardizes the sustainability of the fishery and causes high juvenile tuna discards and also high incidental catches. Sets on schools represent a middle point between the other two types of sets.

The YFT fishery in the EPO is of great importance to Mexico. The catches of the last years (1994-2001) have been over the 125-thousand-ton level, reaching just over 150 thousand tons in 1997. This fishery represents one of the main ones nationally, both for catch volume as for generated income. The tuna caught provides an important source of cheap animal-based protein to the Mexican population, which translates itself into a greater social wellbeing (SEPESCA, 1987). Finally, the tuna fishery also contributes to defend national sovereignty (Enríquez-Andrade, 1988; Székely, 1983) since tuna fishing is one of the few activities that can be found throughout the Mexican Economic Exclusive Zone (EEZ).

The first necessary step to reduce the incidental catch and discards in worldwide fisheries, and specifically within Mexico, is to have a basic qualitative and quantitative analysis. However, following the new natural resource management paradigms like the "Precautionary Principle", it is not enough to register the information and wait to have a long-enough historical record to be able to establish confident and safe management strategies. One must act as fast as possible, based on the best scientific evidence available and using the common sense, with the conviction that it is always better to make mistakes on the safe side, than on the risky side.

The objectives of this study are (1) to make a basic statistical analysis of the incidental catch (billfishes, sharks and other fishes) of the EPO Mexican tuna fleet from the data of the PNAAPD observers; (2) to present possible management objectives and some pertinent considerations; and (3) to evaluate different aspects of the spatial and seasonal closure strategy.

MATERIALS AND METHODS

The information used came from the PNAAPD observer database, recorded on board the Mexican tuna vessels. The databases used were: the Floating Object Record (FOR) from January 1992 to June 1997 for log-sets, and the Marine Fauna and Sightings Record (MFSR) from July 1997 (when it started to be used) to December 1998 for the three types of sets. The FOR is used to register the fauna associated to a floating object, encircled by the net, but not necessarily brought on board. This format does not consider the treatment or destiny of the organisms caught. The MFSR is used to register all the organisms sighted from the deck and those caught, as well as the type of treatment of the organisms loaded. This treatment can be: 1) kept on board for human consumption; 2) discarded to the sea, dead or alive; and 3) finning of sharks and rays, discarding the rest of their bodies.

Since 1992 the PNAAPD and the IATTC have a 100% observer coverage of the fishing trips of the Mexican vessels with more than 363 tons of carrying capacity according to the Official Mexican Norm NOM 001-PESC-1993. The PNAAPD has contributed with observer coverage of the fishing trips averaging 50%.

The database has 29 species or groups of species registered. The incidental or accidental catch of marine mammals, marine turtles or whale sharks *(Rhiniodon typus)* was not considered, and neither was the incidental catch of the group of invertebrates and the group of small bait fishes.

It was arbitrarily decided to use the number of organisms incidentally caught in the analysis, and the tonnage of the main target species catch. The tonnage of the incidental catch was not used because, in general terms and for most of the species, it is an estimate with a higher degree of error than the estimate of number of organisms. The records can have information of the incidental catch in both number of organisms or amount (kg or tons) caught, so a few conversions were necessary. Length-weight relations were used for data expressed in tons or kg and with weight or length information for the following species: mahi-mahi *Coryphaena hippurus* (Rose & Hassler, 1969); yellowtail *Seriola lalandi* (Lee *et al.*, 1991); blue marlin Makaira mazara, black marlin *Makaira indica*, striped marlin *Tetrapturus audax*, swordfish *Xiphias gladius*, and sailfish *Istiophorus platypterus* (Skillman & Yong, 1974); wahoo *Acanthocybium solandri* (Iversen & Yoshida, 1957); rainbow runner *Elagatis bipinnulatus* (Iwasaki, 1991); hammerhead shark *Sphyrna* spp. and silky shark *Carcharhinus falciformis* (Branstetter, 1987a); blacktip shark *Carcharhinus limbatus* and whitetip shark *Carcharhinus longimanus* (Branstetter, 1987b).

For data expressed in kg or tons but without information of length or weight of the organisms, average weights were used according to the species. Average weights were also used for unidentified organisms, for those without length-weight relationships, and for those organisms rarely caught. The species or group of species for which average weights were used are: trigger fish Family Balistidae; mantaray *Mobula* spp. and ray; unidentified marlin and billfish; shortbill marlin *Tetrapturus angustirostris*; other shark, unidentified shark and brown shark; other big fish, other small fish and unidentified fish; sun fish *Mola mola*; blue shark *Prionace glauca*; mako shark *Isurus* spp.; and common thresher shark *Alopias vulpinus*.

There could be a mistake in the positive identification of two types of sharks, the blacktip and the silky sharks. However, the observers' identification is respected in this study.

For general classification purposes, clusters of species with certain economic importance were created. The Big Fish cluster was formed with mahi-mahi, wahoo, yellowtail, sun fish, rainbow runner, other big fish, and unidentified fish. The Billfish cluster was formed with blue marlin, black marlin, striped marlin, shortbill marlin, swordfish, sailfish, unidentified marlin, and unidentified billfish. Finally, the Sharks and Rays cluster was formed with blue shark, hammerhead shark, mako shark, blacktip shark, whitetip shark, silky shark, thresher shark, brown shark, mantaray, ray, other shark and unidentified shark.

For practical reasons, the study was divided in two sections: I) the statistical description of the information, and II) the possible fishery policy strategies based on the management objectives.

I. Basic statistical description of the incidental catch

To have an overview of the problem, a summary of the incidental catch database was made, per type of set, treatment, and species or group of species. The information was analyzed and the different types of sets were compared, in general terms, in respect to the incidental catch of certain species or groups, and treatment.

Five areas and four quarters (January-March, April-June, July-September and October-December) were used for the spatial and seasonal analysis.

The identification of spatial strata with high concentrations of rates or levels of incidental catch, called "hot spots", is of great importance to structure incidental catch reduction plans (Gauvin *et al.*, 1995; Hall, 1996). Due to this, a hierarchical classification of spatial and seasonal strata per type of sets was made in order to identify these "hot spots". Only certain species or groups with high incidental catch levels, or considered particularly susceptible or important, were considered: trigger fish, mahi-mahi, yellowtail, blue marlin, black marlin, striped marlin, wahoo, hammerhead shark, whitetip shark and blacktip shark.

The incidental catch can be calculated by the following mathematical equation:

$$TIC = \Sigma S_i * \frac{IC_i}{S_i}$$

where TIC is Total Incidental Catch, IC is Incidental Catch, S is the number of sets, and i is the specie or group of species. If the magnitudes of both elements are high, the product (total incidental catch) will be high. If the magnitudes of both elements are low, the product will be low. If the magnitude of one is low and of the other one is high, then the product can be intermediate.

Considering the above, both elements were used as criteria for the hierarchical classification. Four sets were made: 1) high S and high IC / S; 2) low S and high IC / S; 3) high S and low IC / S; and 4) low S and low IC / S. These four categories were called: 1) "hot spots", "red spots" or potentially explosive strata (referred to from now on as explosive) due to the high amount of organisms incidentally caught; 2) "orange spots" or avoidable strata, since the number of sets is relatively low and it is possible to avoid that area without any great problem, but there is an unknown phenomenon causing the high IC / S; 3) "yellow spots" or preventive strata, because although the incidental catch per set is low, the number of sets is high; and finally 4) "green spots" or acceptable strata, due to the combination of low number of sets and low incidental catch per set. The categories simulate a risk traffic light in terms of incidental catch. The potential risk difference between avoidable and preventive strata is subjective, since the potential risk of both can be the same or even in inverse order. However, this order was arbitrarily established for practical purposes.

To separate between "high" and "low" number of sets, an arbitrary criterion was chosen based on an explorative analysis using the mean, the median and the frequency histogram of the number of sets per strata. A similar procedure was used for IC / S.

Finally, incidental catch reduction curves were generated (Hall, 1996) for the previously chosen species, with three different strata selection criteria: a) hierarchical classification order, that is, by eliminating the explosive strata first, then the avoidable ones, followed by preventive and acceptable ones, considering within the same category the subcriterion of decreasing order of the total number of organisms incidentally caught; b) decreasing order of the total number of organisms incidentally caught, without considering the hierarchical classification; and c) decreasing order of the IC / total YFT catch rate, without considering the hierarchical classification.

II. Possible fishery policy strategies based on the management objectives

Some of the possible incidental catch management objectives were identified and listed, and the following two hypothetical simulation scenarios were structured:

a) To completely eliminate all log-sets without replacing any set. The tonnage of YFT caught by the Mexican tuna fleet with observers from the PNAAPD was obtained, from 1992 to 1998. The YFT catch that would have been caught had there been no log-sets was estimated, and the difference was calculated as a percentage in respect to the total observed. The incidental catch per cluster of species was also estimated from July 1997 to December 1998, and also the one that would have been caught had there been no log-sets. The incidental catch was also separated by treatment, with the purpose of estimating the discards that would have been avoided.

b) To completely eliminate all log-sets, replacing them with school-sets or dolphin-sets. The same source of information as the former scenario was used. The YFT catch that would have been caught had there been no log-sets was estimated, considering the replacement of those sets according to the following modes: 1) complete replacement with school-sets; 2) complete replacement with dolphin-sets; and 3) a 50–50% replacement with both types of sets. The number and type of sets to be replaced, and the corresponding catch per set, were considered to estimate the YFT catch. A similar methodology was used for incidental catch, but now considering the cluster of species and data from July 1997 to December 1998.

Finally, an example of a management objective was made: A gradual 80%-decrease of the incidental catch of mahi-mahi in a five-year period, considering the effect on YFT catch. Five options were structured, based on the spatial and seasonal strata, the hierarchical classification and the incidental catch reduction curves. Since most mahi-mahi are incidentally caught on log-sets, only this type of set was considered for the example.

The first three options were directly related to the mahi-mahi incidental catch reduction curves. The elimination order of the strata was made strictly following the corresponding elimination curves. That is, in the first option the strata were eliminated according to the hierarchical classification; in the second option, they were according to the total number of organisms incidentally caught; and, in the third option, they were according to the CI / total YFT catch rate.

For the fourth option the strata eliminated belonged to areas three, four and five, and for the last option strata from area three were eliminated first, followed by strata from area four and then area five. The criterion for selecting these areas was their distance to the Mexican EEZ. For the fourth option, the order of these three areas was strictly numerical; while for the fifth option the order represents the elimination of those areas outside Mexican jurisdiction first, and at last those closest to Mexican coasts. The criterion to eliminate quarters within the same area was strict chronological order.

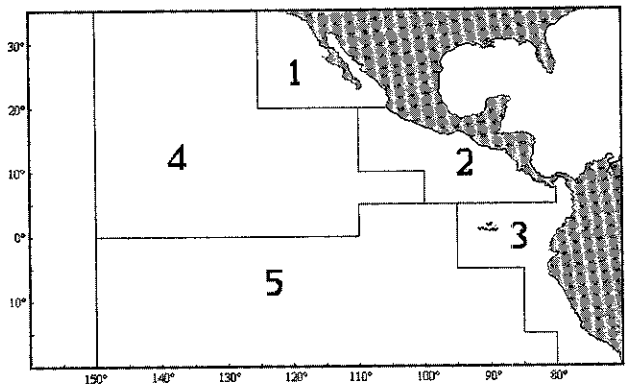

Figure 1. Areas established in the Pacific Ocean for the spatial and seasonal analysis.

The amount of strata eliminated per year for the five options was taken according to the arbitrary criterion of homogeneous elimination percentage. That is, if an 80% incidental catch reduction is desired in five years, an average 16%-reduction per year is necessary to reach the final objective.

RESULTS

Figure 1 shows the arbitrarily established areas in the EPO.

The Mexican tuna fleet makes, in general terms, a great proportion of dolphin-sets in respect to the total number of sets. In contrast, the fleet makes very few log-sets. Table 1 shows that the Mexican tuna fleet makes school-sets mainly in area one, followed by area four. Dolphin-sets are made mostly in area four, followed by areas one and two. Area four is where most of the log-sets are made, although the general trend is more homogeneous.

I. Basic statistical description of the incidental catch

Table 2 shows the estimates of the organisms incidentally caught per species or group of species, type of set, and treatment. For school-sets the amount is slightly less than 25 thousand organisms (all treatments included) in 1,770 total

Table 1. Number of sets in the 1992-1998 sample per spatial and seasonal strata and per type of set.

Area	School sets						Dolphin sets						Log sets					
Quarter	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
1	348	14	6	219	0	397	122	203	12	319	34	690	21	68	90	21	41	241
2	254	30	1	16	0	301	79	156	0	427	8	670	28	8	0	105	4	145
3	331	16	6	65	1	419	95	122	44	189	7	457	75	4	22	131	35	267
4	491	29	13	108	12	653	445	360	68	525	42	1,440	23	36	41	79	78	257
Total	1,424	89	26	218	13	1,770	741	841	124	1,460	91	3,257	147	116	153	336	158	910

Table 2. Estimates of the number of organisms incidentally caught per type of set. Data from the sample. Treatment 1 = retained on board, 2 = discarded, 3 = finning, Uk = Unknown.

Treatment	School sets n=1,770			Dolphin sets n=3,257			Log sets n=910			
Species or group	1	2	3	1	2	3	1	2	3	Uk
Trigger fish		151						12,993		291,046
Mahi-mahi	2,479	1		157			6,786	3,399		72,877
Yellowtail	303	15,160			77		412	22,134		138,176
Blue marlin	34			33	1		24			59
Black marlin	69	2		33			27	1		99
Mantaray	3	1,193		14	60	2		2		24
Striped marlin	38			37			5			53
Marlin	42	2		13	1		8	1		29
Shortbill marlin	1						5			2
Other shark	32		2	31			3,445	4		1,175
Other big fish	2,358	1,090		2	2			120		423
Other small fish	55	502			12		7	1,442		134,977
Unidentified fish								133		17,417
Swordfish	5			13			1			5
Wahoo	329	2		16			4,322	166		20,117
Unidentified billfish					1			3		6
Sun fish	8	1		5						
Sailfish	124	4		230	3					27
Ray	5	67	15		6	21				16
Rainbow runner								500		5,454
Blue shark	1	2	1	2	1	1			5	1
Brown shark	2			7			115			1
Hammerhead shark	183		8	7		1			2	102
Mako shark				1						
Unidentified shark	10	2		7			15	82		1,805
Whitetip shark	37			276			622		2	1,333
Blacktip shark	204		2	515		29	2,927	1,019	6,659	9,213
Silky shark	3			38			10			111
Common thresher shark	39	9		14	2					
Total	6,364	18,188	28	1,451	166	54	18,731	41,999	6,668	694,548

sets. This type of set caught 25 of the 29 species or group of species, and there are no records of unidentified fish, unidentified billfish, rainbow runner or mako shark. The big amount of yellowtail caught is highlighted, followed by that of other big fish, mahi-mahi and mantaray. The most frequently caught sharks and billfishes are the blacktip shark, hammerhead shark, sailfish and black marlin, respectively. It is also important to note the scarce incidental catch of wahoo. The treatment greatly depends on the species: all trigger fish and low-valued species were discarded, while greater-sized species were, in general terms, kept on board. Only a few organisms were finned.

For dolphin-sets, an incidental catch of just over 1,500 organisms is estimated (all treatments) in 3,257 sets. There are no records of trigger fish, unidentified fish, rainbow runner or shortbill marlin. The relatively high amount of blacktip shark, whitetip shark, sailfish and mahi-mahi incidentally caught is highlighted. In general terms, organisms of all the other species were incidentally caught although few of each one. All yellowtail and other small fish were discarded, and so were most of the mantaray and other big fish. Most rays and very few blacktip sharks were finned. The rest of the organisms incidentally caught were kept on board.

The estimate for log-sets is over 760 thousand organisms incidentally caught (all treatments) in 910 sets, of which just over 600 thousand are trigger fish, yellowtail and other small fish. The absence of sun fish, mako shark and thresher shark is highlighted, and so is the incidental catch of tens of thousands of mahi-mahi, wahoo and blacktip shark. There is a great amount of organisms incidentally caught with unknown treatment since they were caught between 1992 and June 1997. In general terms, all trigger fish, other big and small fish are discarded in log-sets, as well as many unidentified fish and rainbow runner. Most mahi-mahi, other sharks, wahoo, whitetip shark and almost al billfishes are kept on board. Of the total blacktip sharks caught, approximately 50% were finned, and another important percentage of them were discarded.

Considering the total amount of organisms caught, six trends are observed, in respect to the three types of sets (LANPALO = log-sets, LANMAM = dolphin-sets, and LANATUN = school-sets). These trends are significant for those species or groups of species caught in high or intermediate numbers, except when incidental catch is minimal. The trends are:

Trend 1: LANPALO > LANATUN ≥ LANMAM (14 groups out of 29), for trigger fish, mahi-mahi, yellowtail, blue marlin, black marlin, striped marlin, shortbill marlin, other shark, other small fish, unidentified fish, wahoo, rainbow runner, blue shark and unidentified shark. This trend is much more enhanced when incidental catch per set is considered.

Trend 2: LANPALO > LANMAM > LANATUN (5 groups out of 29) for unidentified billfish, brown shark, whitetip shark, blacktip shark and silky shark. The trend stays the same when incidental catch per set is considered.

Trend 3: LANATUN > LANMAM > LANPALO (4 groups out of 29) for mantaray, sun fish, ray and thresher shark. The trend reverses for mantarays and rays in respect to LANMAM and LANPALO when incidental catch per set is considered.

Trend 4: LANMAM ≥ LANATUN > LANPALO (1 group out of 29) just for sailfish. The incidental catches per set for LANMAM and LANATUN are very similar, but both are greater then that of LANPALO.

Trend 5: LANMAM > LANPALO > LANATUN (1 group out of 29) just for swordfish. However, the incidental catch per set is greater for LANPALO than for LANMAM; and both these are greater than that of LANATUN.

Trend 6: LANATUN > LANPALO > LANMAM (3 groups out of 29) for unidentified marlin, other big fish and hammerhead shark. The trend reverses for unidentified marlins and hammerhead sharks in respect to LANATUN and LANPALO when incidental catch per set is considered.

The mako shark incidentally caught in a dolphin-set was not classified in any trend, as it is an exceptional case.

Most of the organisms of the selected species for the hierarchical classification were incidentally caught on log-sets, except for hammerhead shark. Due to this, only log-sets were considered for the hierarchical classification, and school-sets were for hammerhead sharks.

The arbitrary criterion to separate between "high" and "low" number of sets was considered to be 50 log-sets per strata, based on the median (36), the mean (48) and a visual inspection of the frequency histogram of the number of log-sets per spatial and seasonal strata.

Table 3 shows the criteria used to separate between "high" and "low" incidental catch per set for the previously selected species. The criteria are the incidental catches per log-set, and also per school-set for hammerhead shark. The magnitude of the criteria is different for each species, according to their own characteristics. The percentage of organisms belonging to each category is also shown. It is important to note that no explosive strata were found for black marlin, nor acceptable strata for striped marlin.

The hierarchical classification and the incidental catches per log-set are presented in table 4. To illustrate the type of information provided in table 4, three species are described: mahi-mahi, wahoo and blacktip shark.

Area one has the lowest potential risk for mahi-mahi, since three strata out of four are acceptable. Areas three and four have the highest potential risk. In area three there is one explosive stratum and two avoidable ones, while area four has one explosive stratum, one avoidable and two preventive ones. On the other hand, the only two explosive strata for mahi-mahi are found in the first and third quarters, as well as four out of

Table 3. Criteria used to classify the incidental catch per set (IC/S) on log sets per spatial and seasonal strata for some selected species, and percentage of organisms incidentally caught that belong to each category. Data for hammerhead sharks is presented for log sets and school sets.

	Criteria	% of organisms per category			
	IC/S	Explosive	Avoidable	Preventive	Acceptable
Triggerfish	300	41.5	44.8	13.1	0.7
Mahi-mahi	100	30.0	35.6	27.5	6.9
Yellowtail	165	48.3	42.5	7.3	1.9
Blue marlin	0.1	59.0	12.0	20.5	8.4
Black marlin	0.2	0.0	33.9	55.1	11.0
Striped marlin	0.06	39.7	37.9	22.4	0.0
Wahoo	40	18.9	50.2	22.6	8.4
Hammerhead shark (log sets)	0.1	64.4	11.5	16.3	7.7
Hammerhead shark (school sets)	0.05	87.5	2.6	9.4	0.5
Whitetip shark	1	84.5	10.5	3.0	2.2
Blacktip shark	20	80.0	5.5	8.4	6.2

Table 4. Incidental catch per log set for each spatial and seasonal strata, from 1992 to 1998, for the previously selected species. The hierarchical classification is: explosive (***), avoidable (**), preventive (*), acceptable (no code). Data for hammerhead sharks is presented for log sets and school sets.

Area/ Quarter	1	2	3	4	5	Total
Trigger fish						
1	0.05	154.69 *	6.67 *	377.08 **	0.00	78.97
2	0.00	0.00		1195.38 ***	152.45	869.82
3	6.05 *	16.67	13.64	117.20 *	3263.04 **	488.31
4	6.52	378.89 **	20.85	112.37 *	48.06 *	106.11
Total	4.11	208.78	11.47	469.23	750.41	332.75
Mahi-mahi						
1	18.10	47.67 *	130.98 ***	264.81 **	62.08	97.58
2	50.87	12.13		70.10 *	50.86	62.66
3	51.62 *	125.00 **	177.16 **	100.47 ***	433.20 **	139.86
4	2.39	27.48	107.91 **	34.17 *	63.47 *	51.04
Total	44.09	41.62	131.44	85.66	144.69	91.28
Yellowtail						
1	0.00	29.46 *	0.19 *	9.62	0.10	9.24
2	4.43	1.00		276.77 ***	56.70	202.90
3	19.27 *	0.00	100.10	62.82 *	1950.21 **	300.13
4	0.00	8.40	0.82	614.93 ***	0.33 *	190.43
Total	10.68	19.95	14.72	256.17	433.64	176.62
Blue marlin						
1	0.00	0.16 ***	0.03 *	0.05	0.00	0.06
2	0.00	0.00		0.21 ***	0.00	0.15
3	0.01 *	0.00	0.09	0.08 *	0.06	0.06
4	0.09	0.14 **	0.12 **	0.20 ***	0.04 *	0.12
Total	0.02	0.14	0.07	0.15	0.03	0.09
Black marlin						
1	0.00	0.15 *	0.09 *	0.05	0.02	0.08
2	0.00	0.38 **		0.14 *	0.00	0.12
3	0.05 *	0.00	0.86 **	0.14 *	0.34 **	0.20
4	0.40 **	0.14	0.17	0.13 *	0.06 *	0.14
Total	0.09	0.16	0.22	0.13	0.11	0.14
Striped marlin						
1	0.52 **	0.03 *	0.03 *	0.00	0.00	0.07
2	0.00	0.00		0.05 *	0.00	0.03
3	0.03 *	0.00	0.00	0.10 ***	0.17 **	0.08
4	0.00	0.00	0.12 **	0.01 *	0.13 ***	0.06
Total	0.09	0.02	0.05	0.06	0.10	0.06
Wahoo						
1	1.67	1.50*	5.79 *	5.81	16.88	6.11
2	12.86	0.00		44.23 ***	209.10 **	40.28
3	6.30 *	25.00	27.27	17.26 *	166.25 **	34.65
4	113.46 **	4.06	75.33 **	7.87 *	20.19 *	31.29
Total	23.65	3.00	27.52	22.76	56.47	27.04
Hammerhead shark (log-sets)						
1	0.05	0.02 *	0.12 ***	0.33 **	0.00	0.08
2	0.07	0.00		0.02 *	0.00	0.03
3	0.24 ***	0.00	0.23 **	0.09 *	0.00	0.13
4	0.09	0.06	0.02	0.03 *	0.49 ***	0.18
Total	0.16	0.03	0.11	0.07	0.24	0.11
Hammerhead shark (school-sets)						
1	0.03 *	0.00	0.00	0.03	0.00	0.03
2	0.09 ***	0.00	0.00	0.00	0.00	0.08
3	0.02 *	0.00	0.17 **	0.00	0.00	0.02
4	0.24 ***	0.14 **	0.00	0.22 ***	0.00	0.23
Total	0.11	0.05	0.04	0.12	0.00	0.11
Whitetip shark						
1	0.00	0.47 *	0.30 *	9.77 **	0.12	1.12
2	0.11	0.00		8.20 ***	0.00	5.96
3	1.72 ***	0.00	0.50	2.60 ***	0.29	1.84
4	0.00	0.22	0.15	2.69 ***	1.37 ***	1.30
Total	0.90	0.35	0.29	4.82	0.77	2.15
Blacktip shark						
1	0.33	11.65 *	4.70 *	38.24 **	2.42	8.81
2	1.75	1.13		91.06 ***	69.79 **	68.27
3	3.31 *	1.50	6.00	34.74 ***	8.81	19.64
4	0.48	10.41	5.56	22.07 ***	2.49 *	9.93
Total	2.14	10.19	5.12	49.58	5.57	21.78

five avoidable strata. Specifically, area three first quarter, and area four third quarter are the two explosive strata.

The area with the lowest risk for wahoo is number two, with only one preventive stratum. Areas four and five have the highest potential risk for wahoo. Area four has the only explosive stratum for wahoo and two preventive ones; and area five has two avoidable strata and one preventive. The second quarter is when the only explosive stratum for wahoo is found, and the quarter with less risk is the first one. Specifically, area four second quarter is the explosive stratum.

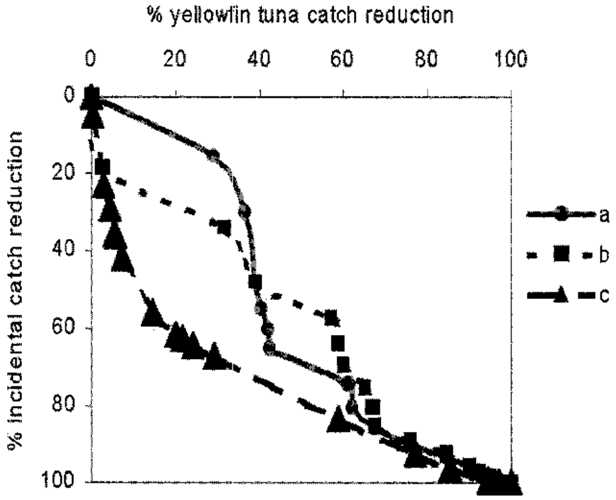

Figure 2. Incidental catch reduction curves: mahi-mahi on log sets. The horizontal axis represents the reduction percentage of YFT catch, and the vertical axis represents the reduction percentage of incidental catch.

For blacktip shark, there are three areas with low potential risk: number one, two and three, with only one preventive stratum each. The highest risk is concentrated in area four, where the three explosive strata for this species are found, and half of the avoidable ones. All quarters have either explosive or avoidable strata. Area four second, third and fourth quarters are the explosive strata.

Only the incidental catch reduction curves for mahi-mahi are presented here as an example of the type of information these curves provide. Figure 2 shows that the three incidental catch reduction curves for mahi-mahi are different depending on the criterion used to select the elimination order of strata. Curve (a) shows that the elimination of the first stratum has a 15% mahi-mahi incidental catch reduction effect, but with the side effect of a 30% YFT catch reduction in log-sets. However, when all explosive and avoidable strata are eliminated (7 in total), a 65% reduction of the incidental catch is achieved with only a 42% YFT catch reduction in log-sets. This effect is represented as an almost vertical trend in the curve.

The pattern is different for curve (b), starting with the elimination of the first stratum (area five, third quarter), where a 20% reduction of the incidental catch is achieved with an almost negligible effect on the YFT catch in log-sets. An almost vertical segment of the curve is also shown when the incidental catch reduction goes from 60% to 85% with a side effect of only 10% YFT catch reduction in log-sets.

The criterion used for curve (c) produces a smooth concave curve, where the initial slope is such that a 56% reduction of the incidental catch is achieved with only a 15% YFT catch reduction in log-sets. However, at the end of the curve, each additional unit reduction of incidental catch has a higher YFT log-set trade-off.

Table 5. Total YFT catch (tons) and the estimate of the catch without log sets (no replacement) obtained by the Mexican tuna fleet from 1992 to 1998 with observers from the PNAAPD.

Year	Total observed	Without log-sets	% Diference
1992	74161	73294	-1.2
1993	50288	49491	-1.6
1994	46470	45564	-1.9
1995	54696	50463	-7.7
1996	62291	59532	-4.4
1997	73906	71060	-3.9
1998	56431	55047	-2.5
Total	418243	404451	-3.3

II. Possible fishery policy strategies based on the management objectives

One of the main aspects in fishery resource management, whether they are target or non-target species, is the explicit definition of objectives (FAO, 1977; Murawski, 1995; Hall, 1996). Management objectives can be biological, social or economical, monospecific or community-based, global or for certain areas or seasons, etc.

Seven incidental catch management objectives were identified:

1) To maintain the *status quo*.

2) Total elimination of the incidental catch.

3) To maintain an exploitation of the ecosystem. This objective can be sub-divided into (a) homogeneous exploitation (catch structure similar to that of the community), or (b) monospecific exploitation (similar to objective 2).

4) Immediate reduction of the incidental catch; as much as technically possible. This objective can be divided into (a)

Table 6. Estimated number of organisms incidentally caught per species cluster and the catch without log sets (no replacement). Data from the sample.

Cluster	Total observed 1992 a 1998	July 1997 to December 1998: Total observed all sets	Without Log-sets	% Difference
Billfishes	1041	761	686	-9.9
Bigfishes	314427	59962	21990	-63.3
Sharks and rays	33255	19474	4564	-76.6

Table 7. Estimated total YFT catch (tons) obtained by the Mexican fleet from 1992 to 1998 with observers form the PNAAPD, and the catch (tons and %) resulting from the replacement of log sets by different combinations of the other types of sets.

	Total observed	Replacement by School-sets		Dolphin-sets		50 % - 50 %	
Year		tons	%	tons	%	tons	%
1992	74161	74365	0.28	75118	1.29	74742	0.78
1993	50288	49932	-0.71	50038	-0.50	49985	-0.60
1994	46470	46684	0.46	47659	2.56	47171	1.51
1995	54696	53465	-2.25	56130	2.62	54797	0.18
1996	62291	60938	-2.17	61455	-1.34	61197	-1.76
1997	73906	73282	-0.84	75031	1.52	74156	0.34
1998	56431	56462	0.05	56962	0.94	56712	0.50
Total	418243	415128	-0.74	422392	0.99	418760	0.12

reduction without significantly affecting YFT catch, or (b) reduction without considering the effect on YFT catch.

5) Gradual reduction of the incidental catch; as much as technically possible. This objective can be divided into (a) reduction without significantly affecting YFT catch, or (b) reduction without considering the effect on YFT catch. It can have a pre-established yearly reduction quota, or it can have no restrictions at all.

6) Reduction of the portion of the incidental catch that is discarded.

7) Reduction of the incidental catch of certain species, based on whether they (a) are endangered; (b) are charismatic species (mahi-mahi, billfish, sun fish); (c) have low reproductive potential (sharks); (d) are species of commercial or sport-fishing interest (mahi-mahi, billfish, shark); (e) are species of lower trophic levels (bait fish, trigger fish); and/or (f) feature other characteristics.

Table 8. Estimated number of organisms incidentally caught per species cluster from July 1997 to December 1998, and the number of organisms incidentally caught (number and %) resulting from the replacement of log sets by different combinations of the other types of sets. Data from the sample.

	Total observed	Replacement by School-sets		Dolphin-sets		50 % - 50 %	
Cluster		#	%	#	%	#	%
Billfishes	761	716	-5.91	704	-7.49	710	-6.70
Big fishes	59962	24003	-59.97	22003	-63.31	23003	-61.64
Sharks and rays	19474	4733	-75.70	4703	-75.85	4718	-75.77
Total	198549	48548	-75.55	44888	-77.39	46718	-76.47

The objectives identified are not necessarily all the possibilities available or feasible, neither are they independent. That is, there may exist the objective to reduce the incidental catch of discarded species, particularly that of charismatic species, in a gradual scheme without considering the effect on YFT catch.

The results of the first simulation scenario (a) are shown in Table 5. The YFT catch of the Mexican tuna fleet with PNAAPD observers has been higher than 45 thousand tons per year, and log-sets have contributed an average of 3.3% of the total, with a maximum 7.7% in 1995. The table shows the catches that would have been obtained had there been no log-sets, and it is evident that the difference is not important.

However, the contribution of log-sets to the incidental catch is quite different (table 6), depending on the cluster of species. Had there been no log-sets, only 10% of the billfish incidental catch would have been avoided, contrasting with the 77% of shark incidentally caught and the 63% of big fish, without mentioning small fish.

Table 7 shows the results of the second simulation scenario (b). It can be seen that YFT catches in the simulation are practically the same as the observed catches. It is important to note that catch is not always greater if log-sets are replaced by dolphin-sets or school-sets, since catch per set varies depending on the type of set and year. The number of replaced sets are: 107, 35, 146, 284, 105, 214, 128 for 1992 to 1998, respectively, with a total of 1,019 log-sets replaced.

Table 8 shows that the incidental catch obtained with the simulation is significantly lower for big fish, sharks and rays than the observed ones, but not so for billfish. A total of 164 log-sets were replaced. The greatest reduction percentages were achieved with dolphin-set replacement.

The results of the five options for the mahi-mahi incidental catch management example are shown in table 9. All options achieved the planned 80% reduction of the incidental catch, and only the last two surpassed it by 6%. The first three options were named 1a, 1b and 1c since they were directly related to the incidental catch reduction curves (fig. 2), in such a way that option 1a relates to curve (a), and so on. The last two options were named 2a and 2b because they originated from the elimination of three complete areas based on their distance to the Mexican coasts and EEZ.

Options 1a, 1b and 1c mainly eliminate strata from areas three, four and five, without it being their objective. Option 1a reduces 62.2% of YFT log-set catch closing nine strata; option 1b reduces 66.9% of YFT log-set catch with eight strata closed; option 1c, 58.6% with 13 closed strata; and options 2a and 2b reduce 76.4% of YFT log-set catch with 11 closed strata.

Table 9. Order of the spatial and seasonal strata (area-quarter) that must be eliminated in each consecutive year, and the accumulated reduction percentage of mahi-mahi incidental catch reached, for each of the five options.

	Options									
	1a		1b		1c		2a		2b	
year	Strata	% reduction	Strata	% reduction	Strata reduction	% reduction	Strata	% reduction	Strata	% reduction
1	(4-3)	15.8	(5-3)	18.3	(3-3) (5-3)	22.9	(3-1) (3-3)	18.9	(3-1) (3-3)	18.9
2	(3-1)	30	(4-3)	34.1	(5-4) (4-1)	35.6	(3-4) (4-1)	30.9	(3-4) (5-1) (5-2) (5-3)	30.9
3	(5-3)	48.3	(3-1)	48.3	(2-3) (3-4) (3-1)	55.7	(4-2) (4-3)	55.6	(5-4)	55.6
4	(4-1) (3-4) (3-3)	65	(4-2) (4-1)	63.8	(5-2) (1-3) (2-4) (1-2)	64.4	(4-4) (5-1) (5-2)	62.2	(4-1) (4-2)	62.2
5	(2-3) (4-2) (5-4)	80.4	(5-4) (1-3) (3-4)	80.7	(5-1) (4-3)	83.3	(5-3) (5-4)	86.4	(4-3) (4-4)	86.4

Despite the fact that all options achieve a very similar reduction of the mahi-mahi incidental catch, the effect on YFT log-set catch is much broader, between 58 and 76%. It is also important to note the difference in the amount of strata closed (8-13), and yet all of them accomplish the main management objective, the reduction of the incidental catch of mahi-mahi. There is no option presenting the best levels for all the three criteria: the highest reduction percentage of the incidental catch, the lowest reduction percentage of YFT catch in log-sets and the lowest number of closed strata.

DISCUSSION

The estimate of number of organisms incidentally caught has at least two important error sources: (1) the estimate made by the observer on board the tuna vessels, both on the amount caught (kg or number of organisms) and the average weight or length of the organisms, and (2) the length – weight relationships and average weights used, with their inherent sources of error, or much worse, that they may belong to the same species but come from a different geographical area, or from a similar species. It is important to note that the observer has the explicit instruction not to interfere with the fishing maneuvers, and quite often has no direct access to the incidental catch.

Despite that, based on the Precautionary Principle, in those cases action should precede any plan to correct those mistakes, which may not be even significant in the management scheme for the reduction of the incidental catch. In any case, attention should be focused on the general trends and magnitudes of the incidental catch, rather than on exact amounts.

I. Basic statistical description of the incidental catch

The absence of unidentified groups on school and dolphin-set records may be due to the fact that incidental catch per set is not very high and, therefore, observers have more time, and is easier for them, to identify the organisms. On the contrary, the absence of certain species on log-sets may be due to the high incidental catch per set and, therefore, the observers had to include them in the unidentified or "other" groups for time or other practical reasons.

There are sharp differences in respect to the treatment of the incidental catch per type of set. On dolphin-sets, practically all the incidental catch is kept on board, while on log-sets and school-sets the only organisms kept (and even then sometimes) are those with some economic or nutritional importance. That is, additional to the low incidental catch per dolphin-set, almost all organisms caught are used for human consumption on board or to be sold later on. This situation contrasts with that of log-sets where, in addition to the high incidental catch per set, most organisms are discarded, especially those of low economic importance. This is a key element since there is a wide belief that discards represent an unacceptable waste of natural resources (Crowder & Murawski, 1998). It is important to remember that this study does not consider marine mammals, which cannot be kept on board by law.

When considering individual species, the statement that log-sets produce most of the incidental catch, followed by school-sets and by dolphin-sets, may not be necessarily true. The general trends show that only for half of the registered species that statement holds true. Certain important species or groups (economically, biologically or charismatically) show different trends. This is important since any management plan must consider if the incidental catch reduction is for all species or for a particular one and, therefore, action on the three types of sets may not be homogeneous but differential.

Despite the exceptions, log-sets do produce a high incidental catch. The elimination or ban of log-sets on explosive and avoidable strata would reduce significantly the amount of organisms incidentally caught. That is, it is not necessary to eliminate all log-sets to significantly reduce the incidental catch for particular species.

The identification of explosive and avoidable strata facilitates the process of structuring fishery policy strategies to reduce incidental catch. In this sense, Hall (1996) mentions five lines of defense to reduce incidental catch, and the first one is to increase the selectivity by choosing appropriate fishing gear, grounds and/or seasons. Explosive and avoidable strata can be the base to declare closures, especially for log-sets.

The incidental catch reduction curves precisely give the necessary support to establish the order of closure of these explosive and avoidable strata, with the additional advantage of providing an insight of their effect on the catch of the main target species. The number and order of strata to be closed depends on the management objectives and reduction quotas. In general terms, the most convenient way is to eliminate those strata that allow significant incidental catch reductions. The vertical portions of the curve should be sought after if no YFT catch reduction is wanted. Although the example shown is for mahi-mahi, the incidental catch reduction curves can be generated for any species or group of species.

II. Possible fishery policy strategies based on the management objectives

The seven incidental catch management objectives identified feature certain particular characteristics, as well as advantages and disadvantages.

1) To maintain the status quo. This is the most "comfortable" objective, and implies the least effort. It does not necessarily mean that incidental catch is not an important issue, or that decision-makers are not concerned about the problem. The damages may not justify a corrective action, or the costs of modifying the fishing strategies may be greater than the potential benefits. Some advantages of this objective are: a) information continues being recorded; b) changes that may cause conflicts with fishermen communities are avoided; c) the additional income for some crew members from selling the kept incidental catch is still received. Some disadvantages are: a) many species are still incidentally caught, some in important quantities, some even with an unknown population level; b) there is a risk of significantly alter trophic communities; c) there is a conflict with worldwide trends on sustainable and responsible management objectives set by FAO and other international organizations and institutions.

2) Total elimination of the incidental catch. All sets with incidental catch records would have to be eliminated, including school and dolphin-sets. Log-sets are not a key component for the Mexican tuna fleet in terms of YFT catch, and their suppression would not represent big sacrifices. However, school-sets are important in coastal regions, and dolphin-sets contribute with most of the YFT Mexican catch. Some of its advantages are: a) the incidental catch problem stops completely; b) there is a compliance with worldwide trends and accepted international management objectives. Some disadvantages of this objective are: a) main target species are not caught, and therefore there is a loss of related benefits; b) changes create conflict with fishermen communities; c) the additional income for selling the incidental catch is lost; d) there is an additional administrative cost to enforce these measures.

3) To maintain an exploitation of the ecosystem – homogeneous or monospecific. If the decision is to catch a species composition similar or equivalent to that of the community in proportional amounts, then the option is similar to objective one *(status quo)*. Furthermore, the catch of non-target species would have to be increased to "balance" the intensive extraction of one of the components (the tuna) with the rest of the community components. Advantages and disadvantages are similar to those in objective one, with the additional "advantage" that the fishing effect would be homogeneously spread out through the pelagic ecosystem. The major disadvantage of this approach is that it would be clearly opposed to the new natural resource management paradigms. There are still no hard evidences to support that this type of exploitation would be less damaging or even beneficial to the ecosystem.

However, if the decision is to maintain a monospecific exploitation, then all incidental catch would have to be eliminated. The option to achieve this is similar to objective two, with the same advantages and disadvantages. It is important to mention that there is an ongoing controversy regarding which one of the two options is the most adequate (Joseph, 1994; Hall, 1996; Hall, 1998).

4) The immediate reduction of the incidental catch to a previously established level can be achieved both easily and quickly by banning log-sets in some particular strata. If the decision considers the restriction of not reducing the YFT catch, log-sets can be replaced by any other type of sets with less incidental catch rates. Some advantages of this objective are: a) incidental catch is reduced; b) YFT catch is not affected. Some disadvantages are: a) the impossibility to make log-sets in certain areas; b) the additional income is lost. However, if the decision is to reduce incidental catch without considering the effect on YFT catch, then set replacement is not necessary, with the additional disadvantage of a slight reduction of the YFT catch.

5) The gradual reduction of the incidental catch to a previously established level can be done quickly and easily by gradually banning log-sets in some particular strata. The order of elimination could be given by the identification of problematic strata (explosive, avoidable and preventive). The

advantages and disadvantages are similar to those of objective four, with an additional advantage: there is a time lag to assimilate changes.

6) Discard reduction. Discarded organisms may be regarded as a resource waste, but they may have an important ecological function (Hall, 1996). Different strategies may be used, like suppressing all log-sets, or compulsory retaining all organisms caught in all set types. Some advantages of this objective are: a) resource waste is reduced, specially since energy has already been spent to catch them; b) the additional income may not be reduced, on the contrary, it may even be increased. Some disadvantages of this are: a) the impossibility to make log-sets; b) conflict with fishermen communities for having to retain all non-target species.

7) Reduction of the incidental catch of particular species. Strategies depend directly on the type of set and spatial and seasonal strata in which the particular species is caught, and the level of reduction established. A clear example is the enormous amount of actions displayed to reduce dolphin mortality in which Mexico played an important role. To reduce the incidental catch of certain species, and only those species, a more detailed research would be needed, including perhaps fishing gear modification.

In respect to the hypothetical simulation scenarios, had there been no log-sets from 1992 to 1998, with no set replacement, YFT catch would have been reduced by only 3%. That is, the approximately 14 thousand tons of YFT not caught by the fleet with PNAAPD observers, are not significant compared to the 400 thousand tons of YFT caught with the other set types during that period. However, the significant incidental catch reduction of small fishes, big fishes, sharks and rays would have represented a net decrease of natural resource waste, since most of them are usually discarded. Nevertheless, the side effect of this decrease of resource waste would have been the reduced retention of valuable species such as mahi-mahi, wahoo and fins from sharks and rays. The effect on billfishes would have been minimal, since although most of them are kept on board and represent an additional income, the amount caught on log-sets is very low. In practical terms, it is impossible to determine if there is set replacement, since the total number of sets of each type is variable and changes from year to year.

Had the Mexican tuna fleet to continue making some log-sets due to political, strategic or economic reasons (for some vessels), there are some spatial and seasonal strata where their effects on incidental catch would be minimal.

There are two criteria to choose the best option in the management objective example: the reduction percentage of YFT catch in log-sets and the number of closed strata. If the first criterion is used, the best option is 1c, but if the second criterion is chosen, then the best option is 1b. At least among options 1a, 1b and 1c, the one compromising both criteria is option 1a (to eliminate strata according to the hierarchical classification). A third criterion can be the distance to Mexican coasts, and a good option would be to eliminate the least amount of strata inside the Mexican EEZ. However, options 2a and 2b eliminate far too many strata and have high reduction percentages of YFT catch in log-sets.

The election among the five options would rest on the decision-makers' hands. The decision could be based on their particular preferences regarding the three criteria used, or based on independent criteria such as political, social or cultural.

Log-sets are unnecessary for the Mexican tuna fleet in terms of total YFT catch, but their elimination would cause a significant incidental catch reduction. It is important to note that incidental catch represents just a marginal benefit for Mexico in the form of additional income for fishermen. However, it is also important to remember that Mexico only contributes a small percentage of the incidental catch of the EPO tuna fishery, and the reduction of the Mexican incidental catch would only help marginally to the overall reduction. That is why it would be interesting to make a similar analysis with information from the international fleet, something that would allow to define larger-scale incidental catch reduction strategies (all EPO and all stakeholders included), and therefore have more significant impacts.

Finally, the Mexican tuna fishery played an important role in the resolution of the dolphin mortality. It would be convenient that the Mexican tuna fishery now also encourages the change to solve the incidental catch problem according to the Precautionary Principle. That is, it would be highly beneficial for the Mexican tuna fishery to be a prototype of sustainable and responsible fishing. Mexico would be again a key promoter of changes in fishery matters.

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