QUASI-QUANTITATIVE RISK ASSESSMENT APPROACH TO FACILITATE PRIORITIZATION IN IMPLIMENTING ECOSYSTEM-BASED APPROACH TO FISHERIES MANAGEMENT

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SUMMARY

The paper explored a way to identify the priority species for management through a rank-based risk assessment approach. First, an indicator of overlaps with tunas and tuna fishing was established, and then, apply to all fish species to identify a set of Species Group that could interfere with ICCAT tunas fishing, i.e. a pseudo-community for evaluating potential management importance in EBFM. The priority species in order to minimize the potential impact of ICCAT tuna fisheries were examined as an example based on and three criteria: significance of ICCAT tuna fisheries, stock status, and availability evidence of bycatch. The exercise succeeded to identify relatively small number of priority species despite an extreme simplicity of methodology used. Although the evaluation against the existing management scheme could not be conducted due to time constraints, the approach explored seemed to be promising as potential tool to facilitate argument in setting EBFM priorities.

RÉSUMÉ

Le présent document explore la façon d'identifier les espèces prioritaires pour la gestion par le biais d'une approche d'évaluation des risques basée sur le classement. Tout d'abord, un indicateur de chevauchement avec les thonidés et la pêche thonière a été établi, puis, appliqué à toutes les espèces de poissons pour identifier un ensemble de groupes d'espèces qui pourraient interférer avec la pêche thonière de l'ICCAT, c'est-à-dire une pseudo-communauté pour évaluer l'importance potentielle de la gestion dans l'EBFM. Les espèces prioritaires ont été examinées afin de minimiser l'impact potentiel des pêcheries de thonidés de l'ICCAT à titre d'exemple sur la base de trois critères : l'importance des pêcheries de thonidés de l'ICCAT, l'état des stocks et les preuves de disponibilité des prises accessoires. L'exercice a permis d'identifier un nombre relativement faible d'espèces prioritaires malgré l'extrême simplicité de la méthodologie utilisée. Bien que l'évaluation par rapport au schéma de gestion actuel n'ait pas pu être réalisée en raison de contraintes de temps, l'approche explorée semble être prometteuse en tant qu'outil potentiel pour faciliter l'établissement des priorités EBFM.

RESUMEN

El documento explora una forma de identificar las especies prioritarias para la ordenación mediante un enfoque de evaluación de riesgo basado en una clasificación. En primer lugar, se estableció un indicador del solapamiento con los túnidos y la pesca de túnidos y, posteriormente, se aplicó a todas las especies de peces para identificar un Grupo de especies que podría interferir con la pesca de túnidos de ICCAT, es decir una pseudo-comunidad para evaluar la posible importancia de ordenación en el EBFM. Se examinaron las especies prioritarias con el fin de minimizar el posible impacto de las pesquerías de ICCAT como un ejemplo basado en tres criterios, la importancia de las pesquerías de túnidos de ICCAT, el estado del stock y las evidencias disponibles de captura fortuita. El ejercicio tuvo éxito para identificar un relativamente pequeño número de especies prioritarias a pesar de la extrema simplicidad de la metodología utilizada. Aunque la evaluación respecto al actual régimen de ordenación no pudo realizarse debido a limitaciones de tiempo, el enfoque explorado parecía prometedor como herramienta potencial para facilitar las razones para el establecimiento de prioridades para el EBFM.

KEYWORDS

habitat, EBFM, priority setting, risk analysis

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The 2020 SCRS agreed to establish the mechanisms of communicating with managers seek for their working-level feedback in developing EBFM components. This is the second time for the SC-ECO trying to establish a good communication with the COM seeking guidance on its management priority and principles in developing and implementing the ecosystem-based approach to the ICCAT fishery management (EBFM). At the previous attempt, although the progress on an EBFM plan was presented in the 2018 Dialogue with Science and Manager Meeting, the responses were extremely scarce and no follow-up actions were taken. Given the current strong pressure toward more holistic and sustainable management in line with the Sustainable Development Goals (SDGs), showing a concrete and achievable work plan toward implementing EBFM together with its goals would be of critical importance, which must be done urgently. Then, we cannot fail this second opportunity.

There might be several reasons of scarce feedbacks from the Commission. First of all, the SC-ECO work plan, established based on the 2015-2020 SCRS Science Strategic Plan, intends to develop Ecosystem Considerations Report (or Ecosystem Synthesis Report) and Ecosystem Risk Assessment with the input and participation from the Commission. Difficulty is nobody has clear understandings of what it is and how to be linked to actual management actions. Furthermore, while the plan was more suited to the area-based management institutions, e.g. national government whose responsibility includes conservation and managements of environments, the ICCAT's responsibility is limited to the management of tuna and tuna-like fishes and such other species of fishes exploited in tuna fishing in the Convention area as are not under investigation by another international fishery organizations. In reality, all the management actions are taken through control on tuna fishing operations. It is not easy to imagine a certain procedures to control "ecosystem" by modifying tuna fishing operations.

FAO Guidelines indicated four steps of implementing the ecosystem approach to fisheries, i.e. i) definition of broad objectives, ii) identification and prioritization of the issues to be addressed, iii) development of effective management system and measures, iv) formalizing management plan with appropriate monitoring of performance and communications. Somehow, we seemed to have jumped on the last step without having well-established shared view on the first three steps. It would be essential to establish clear and common understandings on the broad objectives and areas of priority of the ICCAT EBFM, and for that purpose, the most important thing is to visualize the questions in a way easily understandable for everyone, with an objective mechanism to identify priority areas.

Australian approach to achieve their Ecologically Sustainable Development (ESD) (Fletcher, 2005, 2015) interestingly followed the above-mentioned steps, almost literally, through risk-management process. For individual fisheries, the issues are identified, then for each issue, a potential consequences/ impacts (negligible, minor, moderate, severe, major, catastrophic) associated and corresponding likelihood (likely, occasional, possible, unlikely, rare, remote). Identification of issues, evaluation of impacts and likelihood is done through workshops participated by all main stakeholders. Multiple of impacts and likelihood is considered as risk value for a given issue. Risk is evaluated against for categories, i.e. target species, by-product and other non-retained species, non-retained protected species, and ecosystem, habitat, based on pre-defined guidelines. According to the risks evaluated, existing management activities will be either maintained, adjusted, or enhanced with additional management activities.

The whole process is well organized but quite simple and easy to understand. Separation of evaluation guideline/ judgment criteria from actual identifications of issues, and evaluation of impacts and likelihood would facilitate to reach agreement and keep consistency. Though it is expected to take substantial amount of time and efforts in order to establish similar system suitable for the ICCAT, even built upon the Australian experience, this document explored a way to identify a caveat of species who may interfere with tunas, tuna like species and tuna fishing operations, through evaluating potential overlaps of habitats, vertical and geographical distributions, and historical knowledge on their interactions with tunas and tuna fisheries, using pre-defined criteria. Then their potential importance was examined in the context of fishery management, again also based on the pre-defined principles. This allows prioritizing species once a certain set of management principle and priority would be set.

The approach seems to be quite flexible and the results of application are expected to largely depend on how management priorities would be set. The document shows the results reflecting the author's personal view, but only for the purpose of showing a process of the approach. In fact, this experimental application was only partially completed and is expected to carry quite many errors, inappropriate assignments, and inconsistency etc. Therefore, the results should not be taken as any meaningful indications in the context of fishery management.

Development of habitat overlap index with tunas and tuna fishing:

Milieu, climate zone, depth range, geographical distribution of all marine species, including those in brackish waters, were extracted from the FishBase data base[2], together with biology description, if available, IUCN Red List Status referred. The first three items are categorized and sometimes conflict with the information provided in the biology section. No evaluation was made on accuracy of extracted information, nor revision of extracted information after the most recent update on February 2021. This may cause that some of IUCN Red List Status may be out of dated.

For five categories, i.e. salinity preference, depth range, behavior type, habitat, and other ecological/ environmental characteristics, five ranks, unlikely (0), less likely (1), difficult to judge or no data (2), more likely (3), and highly expected (4), were assigned based on the information extracted. In general, salinity preference, depth range and behaviors were directly linked to the milieu, climate zone and depth range of FishBase. In principle, rank (2) is considered to represent the neutral situation including no data, then placing positive values only for those indicating clear preference to the area preferred by the target species, and negative values for those characteristics less likely for the target species to interfere. Whenever uncertain in assigning rank(s), conflicting information and/or coexisting multiple situations, etc., rank (2) is assigned. If no information available, the cells were kept as empty, i.e. no contribution to overall judgment, and returned to rank (2) when lack of any no additional information in the end.

In order to establish rank criteria to determine an extent of potential overlaps with tuna and tuna fishing, first the biological and ecological characteristics of main target species were examined. Here, the main target was defined as nine Major tuna species, (Skipjack tuna, Atlantic bluefin tuna, Albacore, Yellowfin tuna, Bigeye tuna, Atlantic sailfish, Blue marlin, Atlantic white marlin, Longbill spearfish, and Swordfish) and three Major shark species (Shortfin mako, Porbeagle, and Blue shark) of the ICCAT. Ecological characteristics of ICCAT Major tuna and shark species is in **Table 1** and those including all tunas and sharks species with the ICCAT codes are available in **Appendix 1.**

Main characteristics commonly noted from included:

- Behavior-type as pelagic-oceanic;
- Occurrence in oceanic water;
- Epipelagic including surface water in depth range, though maximum depth vary by species;
- Highly Migratory species in Annex I of the 1982 Convention on the Law of the Sea

Based on this, Behavior type as “pelagic-oceanic”, occurrence in oceanic waters, epipelagic were set as the first criteria indicating the highest potential of overlap, i.e. rank (4). Considering a variation in capacity entering into coastal waters among target species, occurrence in coastal waters, estuaries, shallow waters, brackish habitats were not considered as negative in defining ranks. Indication in offshore and/or oceanic occurrence as well as pelagic other than those assigned in rank (4) was given rank (3).

Quick examination of those criteria with the other tunas and shark species with the ICCAT codes seemed to be more or less reasonable. Then, the criteria were examined against the list of species bycaught with tunas fishing operations, but except those in Appendix 1. The list of bycaught species were extracted from the ICCAT By-Catch Database (Version 12 July 2010), together with number of references by gear types. The references on bycatch at species level in the last 10 years publication of the Collective Volumes of ICCAT Scientific Papers were also added, which ended in total 100 species with 319 references, consisting comparative references in longline and purse seine bycatch and much less for the other gears.

The summary result is shown in **Table 2** (full tables in **Appendix 2**). It indicated that about 60 % of bycatch species examined were considered to be more likely to have overlap with tuna and tuna fishing according to the criteria mentioned above, while close to 10 % of bycatch occurred, even their ecological characteristics considered as less likely to overlap with tunas and tuna fishing. Detection of potential overlap was worse for purse seine bycatch and other gears that often operating in rather shallow areas. After reviewing the available information, it was decided to include another category for judgment, i.e. association, with rank (4) for direct associations with tunas and sharks, and rank (3) for association with floating objects, vessels and floating Sargassum. This improved the detection of potential overlap in particular for those taken by purse seine.

[2] https://www.fishbase.se/search.php

This set of rank criteria becomes a basis for further experiment, though has been modified several time in the process of applying to a variety of species, in order to accommodate a range of unexpected situation, by including additional negative criteria to eliminate a certain species from potential overlap. The current version of criteria currently in use is shown in **Table 3**. Cells will be assigned rank value, only when it is certain, otherwise they are kept as empty. The lowest between the assigned values and 2 (i.e. neutral) will become a combined index of overlap, except the positive value in associate that will override the combined index since providing more direct evidence of potential overlap.

Multiple references in salinity categories, e.g. "Marine; freshwater; brackish", may indicate at least two different situations: i.e. either occurring three different salinity conditions according to the growth etc., or having a tolerance against broader range of salinity while main habitat remaining, for example, in freshwater. Categorical values of "reef-associated" and "benthopelagic" also cause ambiguity in judging their extent of tendency toward pelagic. Technical judgment was used to adjust in both cases to assign values, if necessary. In similar way, the term of "bathy" was ignored since indicating different water depth depending on species group.

Filtering species of potential overlap with tunas and tuna fishing:

Rank criteria was applied all marine fish species to identify the group of species that would have higher potential of overlap/ interfere with tunas and tuna fishing. The purpose is to establish a quasi-community of species that may have an opportunity to receive impacts by tuna fishing, and therefore can be subject to the consideration in ICCAT EBFM.

Total 10,283 species in 62 orders/suborders (for Perciformes) were examined for their overlap index. Then they are filtered based on two criteria, i) whether the average of overlap indices was above 2 or ii) absence and presence of species of its overlap index as 4, highly expected, by taxonomic groups, i.e. Order and Families. The former reflects the general characteristics of the taxonomic groups, while the latter is to identify specific species that may indicate strong overlap tendency with tunas. (Class 1: overlap index =<2, no species with overlap index as 4, Class 2: overlap index =<2, but including species with overlap index as 4, Class 3: overlap index >2, no species with overlap index as 4, Class 4: overlap index >2, and including species with overlap index as 4). The taxonomic groups containing either reported ICCAT bycatch or species identified in stomach contents (Jock et al., 2010) were also included regardless the above-mentioned criteria. The result of filtering process was summarized in **Table 4**.

It should be noted that the rank assignment has not yet been completed due to time constraint. Although those taxa with any reported bycatch and stomach contents were processed with priority, one taxon with one bycatch record was overlooked by mistake and left behind, i.e. Labroidei. The other taxa not yet processed included part of Percoidei, part of Trachinoidei, Blennioidei, Callionymoidei, Gobioidei, Pleuronectiformes and Gobiesociformes. Summary of ecological characteristics of fish species in order/ suborder level was shown in **Appendix 3** and **Figure 1**.

With the intention to make the final list to be more inclusive than exclusive, it was decided to conduct filtering in higher taxonomic level, not at the species level. This would help to reduce Type II errors, by picking up such species showing the similar ecological and environmental characteristics with the other species in the group but assigned lower rank values. As a result, this filtering process did not provide too much help in reducing the number of species to be considered.

From the same reason, several taxonomic groups, neighboring with those accepted group and considered to be similar in ecological characteristics, were retrieved again after the more or less mechanical filtering.

At the end, the further filtering according to geographical distribution was applied. Geographical distribution was also ranked in three categories (i.e. 2 to 4), according to the extent of areas with reported occurrence in the Atlantic, from trans-Atlantic, to endemic or limited to a small area. Rank (1) is assigned for the occurrence in either Red Sea and off South Africa, to accommodate potential invasion from the Indian Ocean. No invasion from the Pacific Ocean was incorporated. Rank (0) is for the land area, as well as Polar and Antarctic region higher than 60 degrees in both sides.

The final list contained bit over 2,000 species. Although this list is still incomplete, it will serve adequately for the purpose of experimental analysis in identifying priority species using the similar quasi-quantitative approach.

Identification of priority species for fishery management:

Recognizing it would be more preferable to follow the similar approach as Fletcher (2005, 2015) described, the exercise here utilize much more simplified approach of defining the priority based on factors identified as important when implementing the fishery management. Again 3-5 ranks will be assigned for each factor identified, then combined them into one index.

Main issue tackled here is the potential impacts of catch taken by the ICCAT tuna fishing and three components, protected species, bycatch species and prey species. While the species listed as CR and EN in IUCN Red List were extracted for the protected species category, the whole species list was used for the latter two.

The factors selected and background rationales were as follows:

- Significance of ICCAT fishery: no need for explanation. This was defined based on a proportion of ICCAT catch to the Atlantic and Mediterranean catch reported to FAO.
- Stock status: Again, no rationales needed. Rank was defined based on the IUCN Red List, only for the convenience due to its comprehensiveness.
- Extent of evidence: no rationale needed. Rank was defined based on number of references for bycatch and prey, respectively, for bycatch and prey species categories. Rank on protected species category was determined based on status in CITES and other conservation instruments, including the Bonn Convention and Bern Convention, though only the information available at FishBase was used and not checked with original information. Here, the existence of management at RFMOs and level of commercial catch were also used, as indicator to judge an extent of seriousness in stock depletion.
- Distribution range: Since ICCAT is an international management organization, the species with a limited geographical distribution, and/or only occasional occurrence are considered less important. The rank for Atlantic distribution is used as it is.

The criteria in defining ranks are in **Table 5**. Combined index was calculated as multiple of all rank value divided by 2 to the power of number of factors used, to standardize to the situation where all ranks are neutral, i.e. 2. Species index higher than 1 is considered to indicate significance according to the factors selected. Indices with and without including factor of distribution range are examined for all 3 categories. Tables utilized in this calculation will be provided as Appendix in Excel format.

Several different ways of combining assigned ranks were examined but all showed quite good correlations. Inclusion of distribution range seems to place too much emphasis on the species with broad distribution. **Table 6** shows quick summary of the results, indicating surprisingly high occurrences of those species with ICCAT codes, which means that the majority of species with significant importance when considering the impacts of ICCAT fisheries were already incorporated into the ICCAT management system, in different level. Those species with the ICCAT codes but not being picked up as significant tended to indicate least concerned stock status.

As one additional exploration, the results when removing the catch significant factor were also included in **Table 6**, which shows relative importance of species only based on its stock status and references as either bycatch or as prey. The exercise filtered only small number of species as significant for prey, reflecting general lack and flatness of information, and became least representing the ICCAT species list. Tool is provided as supplement for this document for further examination of the results shown here as well we for free exploration of the tool.

Next step is supposed to make a similar quasi-quantitative assessment on the existing management schemes against those species identified as significance. Then, those showing substantial gaps between the extent of significance and the status of management should be the area required further efforts in improving management. However, there was no time to explore this phase during this document.

Preliminary findings:

Despite extremely simple mechanism, the approach succeeded to identify relatively small number of management important species, covering well those already under the management scheme of the ICCAT. The assignment of overlap index and filtering based on them seemed to have rather limited contribution. The most cumbersome and time-consuming part was an assemblage of necessary information. Now the primary database was established at least to the level enabling various explorations, it would be desirable as well as more effective and efficient if combined efforts with many different ideas would focus on developing solid and reliable rules for the second and third parts, i.e. identifying significant species for a certain issue according to the pre-established factors, and identifying gaps and priority area in the current management. This should be a combined effort among scientists, managers and other stakeholders.

In this exercise, species was used as a common unit and whenever the information is available only at higher taxonomic group, the same information was assigned to all member of that taxonomic group. This seemed to introduce strange flatness in the result. It would be better to keep the same level of details as original information carried and to find the way to handle data in mixed level of details simultaneously.

The ICCAT has already accommodated many of environmental and ecological concerns, in other words necessary components of EBFM, but always been subject to the criticism of not adequately holistic, critical components still missing, etc. The approach explored here, with further enhancement, could be an excellent tool to justify the ecological coverage, against a certain principles and priority rules to determine the management priority. The process would also facilitate the areas of weakness and gap in more objective way. Hopefully, this type of tool can assist better communication among concerned stakeholder and visualize the way to go in more clarity and concreteness.

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Table 1 Ecological characteristics of the target species for the ICCAT management, extracted from FishBase description

Common name		Scientific name	Distribution		Vertical range					
			Salinity	General habitat	In records		Usually			Link with landmass
Major tuna species										
Skipjack tuna	SKJ	Katsuwonus pelamis	Marine	pelagic-oceanic	0	260	0	?	school in surface waters	Offshore
Atlantic bluefin tuna	BFT	Thunnus thynnus	Marine; brackish	pelagic-oceanic	0	985	0	100		Oceanic but seasonally coming close to shore.
Albacore	ALB	Thunnus alalunga	Marine	pelagic-oceanic	0	600			epipelagic and mesopelagic; along thermal discontinuities	Oceanic
Yellowfin tuna	YFT	Thunnus albacares	Marine; brackish	pelagic-oceanic	1	250	1	100	Above and below the thermoclines	Oceanic, Open water, but rarely seen near reefs
Bigeye tuna	BET	Thunnus obesus	Marine	pelagic-oceanic	0	1500	0	500	school at the surface; Adults stay in deeper waters	
Atlantic sailfish	SAI	Istiophorus albicans	Marine	pelagic-oceanic	0	200			Usually found in the upper layers of warm water above the thermocline, but also capable of descending to rather deep water.	Often migrate into near-shore waters.
Blue marlin	BUM	Makaira nigricans	Marine	pelagic-oceanic	0	1000				Oceanic
Atlantic white marlin	WHM	Kajikia albida/ Tetrapturus albidus	Marine	pelagic-oceanic	0	150	0	100	deep (over 100 m) blue water; Usually above the thermocline.	
Longbill spearfish	SPF	Tetrapturus pfluegeri	Marine	pelagic						
Swordfish	SWO	Xiphias gladius	Marine	pelagic-oceanic	0	2878	0	550	Generally above the thermocline;	Oceanic but sometimes found in coastal waters
Major shark species										
Shortfin mako	SMA	Isurus oxyrinchus	Marine	pelagic-oceanic	1	500	0	150	epipelagic	Oceanic, but sometimes found close inshore.
Porbeagle	POR	Lamna nasus	Marine	pelagic-oceanic	0	1360	0	300		Occurs inshore to offshore fishing banks and occasionally to open ocean areas; Most abundant on continental offshore fishing banks
Blue shark	BSH	Prionace glauca	Marine, brackish	pelagic-oceanic			?	150	Epipelagic	Oceanic, but may be found close inshore where the continental shelf is narrow. Reported from estuaries, occasionally occurs in littoral areas;

Table 1 Ecological characteristics of the target species for the ICCAT management, extracted from FishBase description (cont.)

Common name		Scientific name	Behaviors: Association	Behaviors: Preys		Other
Major tuna species						
Skipjack tuna	SKJ	Katsuwonus pelamis	birds, drifting objects, sharks, whales	fishes, crustaceans, cephalopods and mollusks; cannibalism is common	HMS	May show a characteristic behavior like jumping, feeding, foaming, etc.
Atlantic bluefin tuna	BFT	Thunnus thynnus	albacore, yellowfin, bigeye, skipjack etc	Visual predators preying on small schooling fishes (anchovies, sauries, hakes) or on squids and red crabs.	HMS	They school by size, sometimes together with albacore, yellowfin, bigeye, skipjack etc.
Albacore	ALB	Thunnus alalunga	Form mixed schools with skipjack tuna, yellowfin tuna and bluefin tuna, schools may be associated with floating objects, including sargassum weeds.	fishes, crustaceans and squids.	HMS	
Yellowfin tuna	YFT	Thunnus albacares	Larger fish frequently school with porpoises, also associated with floating debris and other objects.	fishes, crustaceans and squids.	HMS	Sensitive to low concentrations of oxygen and therefore is not usually caught below 250 m in the tropics
Bigeye tuna	BET	Thunnus obesus	schooling of mono-species groups or mixed with other tunas, may be associated with floating objects.	Variety of fishes, cephalopods and crustaceans	HMS	
Atlantic sailfish	SAI	Istiophorus albicans		small pelagic fishes but also takes bottom-dwelling organisms.	HMS	
Blue marlin	BUM	Makaira nigricans		mainly on fishes but also preys on octopods and squids.	HMS	Water color affects its occurrence, preference for blue water. Rarely gathers in schools and usually found as scattered single individuals.
Atlantic white marlin	WHM	Kajikia albida/ Tetrapturus albidus		fishes and squids.	HMS	Diistribution varies seasonally, reaching higher latitudes in both the northern and southern hemispheres only during the respective warm seasons.
Longbill spearfish	SPF	Tetrapturus pfluegeri			HMS	
Swordfish	SWO	Xiphias gladius		opportunistic feeders, fishes (Atlantic mackerel, barracudinas, silver hake, redfish, herring and lanternfishes; also on crustaceans and squids	HMS	
Major shark species						
Shortfin mako	SMA	Isurus oxyrinchus				Marked sexually segregated population structure
Porbeagle	POR	Lamna nasus				Trans-Atlantic migrations; One of the most cold-tolerant sharks; segregation by sex and size
Blue shark	BSH	Prionace glauca				May travel considerable distances

Table 2 Evaluation of rank criteria to define overlap with tuna and tuna-like species with species bycaught by tuna fishing operation, and results of adjustments

	No. species					No. references				
	LL	PS	GN	OH	Total	LL	PS	GN	OH	Total
Total	**35**	**49**	**8**	**8**	**100**	**159**	**141**	**9**	**10**	**319**
Classified as more likely (3 & 4)	23	26	5	2	56	138	75	6	3	222
	66 %	53 %	63 %	25 %	56%	87 %	53 %	67 %	30 %	70%
Classified as less likely (1)	3	3	2	1	9	2	12	1	0	15
	9%	6%	25 %	13 %	9%	1%	6%	11 %	0%	5%
When added "Associate criteria"										
Classified as more likely (3 & 4)	25	39	5	3	72	143	118	6	4	271
	71 %	80 %	63 %	38 %	72%	90 %	84 %	67 %	40 %	85%
Classified as less likely (1)	2	2	1	0	5	2	7	1	0	10
	6%	4%	13 %	0%	5%	1%	5%	11 %	0%	3%

Table 3 Criteria for assigning rank

	Salinity preference		Habitat
	Primary	Secondary	
Unlikely (0)	Freshwater	Brackish	
Less likely (1)	Brackish Marine; freshwater; brackish;	Marine; brackish	inter-tidal; sea-grass beds, mouth of rivers, mangrove, estuaries, littoral, weedy, tide pool, coral reef, jetty
Neutral, or no way to judge (2)	Marine; brackish Marine;		
More likely (3)	-	-	Offshore
Highly expected (4)	-	-	Oceanic

	Depth range		
	Min	Max	
Unlikely (0)	> 3000 m	-	
Less likely (1)	> 1500 m	-	
Neutral, or no way to judge (2)			
Only when Behavior type as pelagic			
More likely (3)	< 750m	-	mesopelagic
Highly expected (4)	< 200m	> 1500 m	

	Behavior type	
	Primary	Secondary
Unlikely (0)	-	-
Less likely (1)	-	-
Neutral, or no way to judge (2)	Demersal Reef-associated Benthopelagic	- - -
More likely (3)	Pelagic-neritic	Benthopelagic
Highly expected (4)	Pelagic-oceanic Pelagic	-

	Other characteristics	Associate
Unlikely (0)		Ice
Less likely (1)	cryptic, burrow in sand, secretive, cave	
Neutral, or no way to judge (2)		Jellyfishes
More likely (3)		Floating objects, turtles
Highly expected (4)		Tunas, sharks, billfishes

Table 4 Summary of filtering process of a list of species, based on overlap index, to be worked for identifying priority species for fishery management

Average overlap index # species with overlap index as 4	>2 Present	>2 Absent	=<2 Present	=<2 Absent
Order-level filtering:				
Orders with species in marine habitat	62 *10,283*	22 *3,640*	7 *87*	12 *5,749*	21 *807*
Orders with reported ICCAT bycatch	21 *5,952* *58%*	12 *2,137* *59%*	1 *33* *38%*	6 *3,731* *65%*	2 *51* *6%*
Orders reported as prey for tunas	16 *5,287* *51%*	11 *1,801* *49%*	0 *0* *0%*	5 *3,486* *61%*	0 *0* *0%*
Orders filtered	43 *8,276*	22 *3,640*	7 *87*	12 *4,498*	2 *51*
Family-level filtering:					
Families with species in marine habitat	294 *9,538*	85 *2,834*	53 *585*	20 *3,157*	136 *2,962*
Families with reported ICCAT bycatch	62 *3,082* *32%*	32 *897* *32%*	9 *200* *34%*	7 *1,591* *50%*	14 *394* *13%*
Families reported as prey for tunas	34 *1,757* *18%*	19 *917* *32%*	6 *162* *28%*	5 *479* *15%*	4 *199* *7%*
Families filtered	163 *5,704*	85 *2,834*	53 *585*	10 *1,860*	15 *425*
After final adjustment	189 *6,061*	71 *2,511*	45 *550*	12 *1,989*	61 *1,011*
Atlantic relevance	***2,103***	***1,147***	***149***	***565***	***242***

Table 5 Criteria to rank for identifying an extent of significance on selected factors.

	Less significant (1)	Neutral or no data (2)	Major significance (3)	Quite significant (4)
Significance of ICCAT fishery				
% ICCAT catch to FAO Atlantic catch	<10%	10-60%	60-90%	90% <
Stock status (IUCN Red List)	LC	NT, DD, na	VU	EN, CR
Extent of evidence				
Bycath: # reference	Not in the Family	None but Yes in the same Family	1-10	10 <
Prey: # reference	Not in the Family	None but Yes in the same Family	Yes	Multiple references
Protected	No RFMO management, significant catch	RFMO management	CITES II or equivalent	CITES I or equivalent
Distribution range (same as rank for Atlantic distribution)	1	2	3	4

Table 6 Quick summary of the results in applying ranks in selected factors

	Protected		Bycatch		Prey		Catch significance excluded	
Atl. Range	Y	N	Y	N	N	Y	Bycatch	Prey
TOTAL	33	33	2243	2243	2243	2243	2243	2243
Significant	16	10	158	104	35	84	98	16
Major tunas	2	2	10	9	8	10	8	3
Other tunas	1	1	20	12	5	19	8	1
Major sharks	1	1	3	3	1	3	3	0
Other sharks	8	6	47	28	15	31	39	0
Others	0	0	24	6	0	9	10	3
% w ICCAT codes	75%	100%	34%	37%	66%	57%	41%	25%
% in ICCAT Catch DB	75%	100%	66%	56%	83%	86%	69%	44%
% w ICCAT code but not filtered			31%	39%	51%	71%	49%	95%

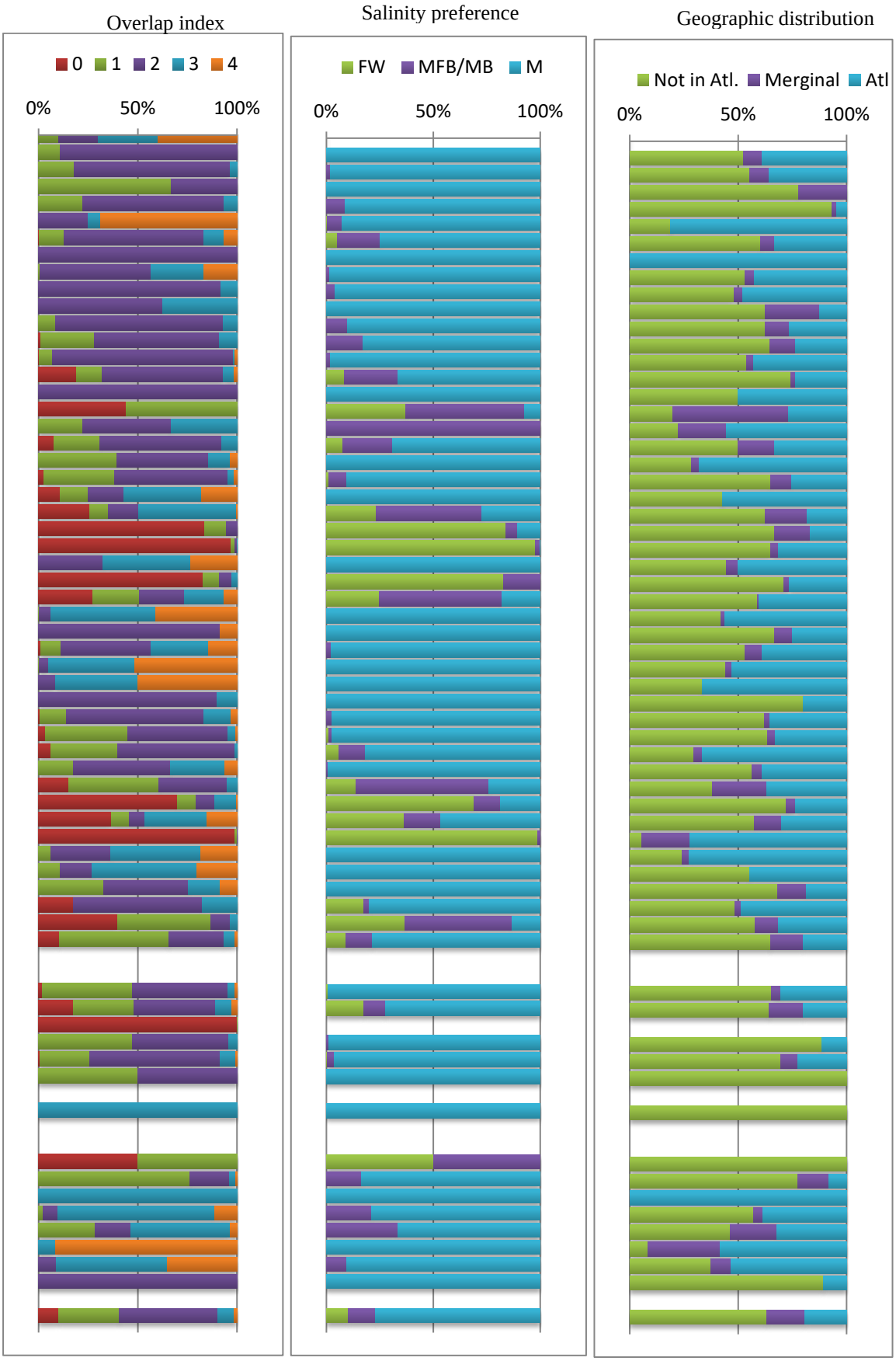

Figure 1 Characteristics of orders examined. Each bar corresponds to one family. Since the figures only aimed to show general pattern, the name of familites were not included.