



Mitigating impacts of fishing on pelagic ecosystems: towards ecosystem-based management of tuna fisheries

Book of Abstracts

15-18 October 2012 Montpellier - France



**Mitigating impacts of fishing
on pelagic ecosystems:
towards ecosystem-based management
of tuna fisheries**

15-18 October 2012
Aquarium Mare Nostrum, Montpellier, France

Monday, October 15, 2012

TIME	EVENT
8:00 am - 9:30 am	Registration and welcoming breakfast (Lagoon)
9:30 am - 10:05 am	Opening (Auditorium)
10:05 am - 10:50 am	Keynote: Is it good or bad to fish with FADs? (Auditorium) - <i>Kim Holland, Victor Restrepo, Gala Moreno, Laurent Dagorn</i>
10:50 am - 12:30 pm	Session 1: BIODIVERSITY & BYCATCH (Auditorium)
10:50 - 11:10	› Large fish predators diversity highlighted by tuna fisheries data in the Indian Ocean - <i>Frédéric Ménard, UMR EME</i>
11:10 - 11:30	› Pelagic elasmobranch diversity and abundance in the Western Indian Ocean: an analysis of long-term trends from research and fisheries longline data - <i>Evgeny Romanov, CAP RUN / ARDA</i>
11:30 - 11:50	› Using fisheries data to identify pelagic predator hotspots in the North Atlantic - <i>Niall Mcginty</i>
11:50 - 12:10	› Characterization of interactions between marine mammals, whale sharks and tropical tuna purse seine fishery in the Indian and Atlantic Oceans - <i>Anna Capietto, University Montpellier 2, IRD</i>
12:10 - 12:30	› Bycatch recorded by the Mexican tuna purse-seine fleet in the eastern Pacific ocean - <i>Sofia Ortega-Garcia, INSTITUTO POLITECNICO NACIONAL-CENTRO INTERDISCIPLINARIO DE CIENCIAS MARINAS</i>
12:30 pm - 1:45 pm	Lunch (Ocean)
1:45 pm - 2:25 pm	Session 1: BIODIVERSITY & BYCATCH (Auditorium)
13:45 - 14:05	› Patterns of turtle bycatch in tuna fisheries off southern Brazil: towards EBFM of pelagic fisheries in the southwest Atlantic ocean - <i>Melissa Marcon, Graduate Program on Oceanography, Oceanographic Institute, University of São Paulo, Brazil - Maria de los Angeles Gasalla, Fisheries Ecosystems Laboratory (LabPesq), Department of Biological Oceanography, Oceanographic Institute, University of São Paulo, Brazil. mgasalla@usp.br - Bruno Giffoni, Fundação Pró-TAMAR, Ubatuba, São Paulo, Brazil</i>
14:05 - 14:25	› Pilot study of an electronic monitoring system on a tropical tuna purse seine vessel in the Atlantic Ocean - <i>Jon Ruiz, AZTI</i>
2:25 pm - 3:25 pm	Session 2: FISH ASSOCIATED WITH FADS: BIOLOGY & BEHAVIOR (Auditorium)
14:25 - 14:45	› Schooling behavior of juvenile yellowfin tuna around a FAD in the Philippines - <i>Yasushi Mitsunaga, Department of Fisheries, Kinki University</i>
14:45 - 15:05	› Lipid class composition and energy allocation during reproduction of yellowfin tuna in the western Indian ocean: comparison between FADs and free-swimming schools - <i>Iker Zudaire, AZTI Tecnalia - Hilario Murua, AZTI Tecnalia</i>
15:05 - 15:25	› Skipjack reproductive capacity in relation to energy reserves: is there an influence of the school type? - <i>Maitane Grande, AZTI Tecnalia - Hilario Murua, AZTI Tecnalia</i>
3:25 pm - 3:50 pm	Coffee break
3:50 pm - 5:50 pm	Session 2: FISH ASSOCIATED WITH FADS: BIOLOGY & BEHAVIOR (Auditorium)
15:50 - 16:10	› Temporal patterns of yellowfin and skipjack tuna associated with anchored and drifting FADs - <i>Marc Soria, Institut de Recherche pour le Développement</i>
16:10 - 16:30	› Residence times and vertical behaviour of tunas around drifting fish aggregating devices (DFADs) in the Indian Ocean - <i>Rodney Govinden, Seychelles Fishing Authority</i>
16:30 - 16:50	› Evolution of radio buoys technology for FAD, past, present and future. - <i>Francisco Pino, technology</i>
16:50 - 17:10	› Using fishers' echosounder buoys for scientific studies - <i>Jon Lopez, AZTI</i>
17:10 - 17:30	› The behavioural ecology of two major bycatch species of the tuna purse-seine fishery: the oceanic triggerfish and the rainbow runner - <i>Fabien Forget, Institut de Recherche pour le Développement, South African Institute of Aquatic Biodiversity, Rhodes University</i>
17:30 - 17:50	› Behavior of fish aggregations assessed using fishers' echosounder buoys - <i>Jon Lopez, AZTI</i>

Tuesday, October 16, 2012

TIME	EVENT
9:00 am - 9:45 am	Keynote: The Behavior of Pelagic Fishes and its Pertinence to Fisheries (Auditorium) - <i>Kim Holland</i>
9:45 am - 10:25 am	Session 2: FISH ASSOCIATED WITH FADS: BIOLOGY & BEHAVIOR (Auditorium)
09:45 - 10:05	› Behavioural plasticity displayed by tuna at fish aggregating devices (FADs) - <i>Marianne Robert, Laboratoire d Ecologie Sociale - Université Libre de Bruxelles, Institut de Recherche pour le Développement</i>
10:05 - 10:25	› Role of social interactions on dynamics of fish aggregations in a multi-site system of fish aggregating devices (FADs) - <i>Grégory Sempo, Unit of Social Ecology, Université Libre de Bruxelles</i>
10:25 am - 10:50 am	Coffee break (Ocean)
10:50 am - 11:30 am	Session 2: FISH ASSOCIATED WITH FADS: BIOLOGY & BEHAVIOR (Auditorium)

TIME	EVENT
10:50 - 11:10	› Establishing a reference point to assess the existence of an ecological trap for tropical tunas - <i>Marianne Robert, Institut de Recherche pour le Développement, Laboratoire d'Ecologie Sociale - Université Libre de Bruxelles</i>
11:10 - 11:30	› The role of FADs in the ecology of juvenile silky sharks - <i>John Filmlalter, Institut de Recherche pour le Développement, South African Institute for Aquatic Biodiversity, Department of Ichthyology and Fisheries Science</i>
11:30 am - 12:30 pm	Session 3: BIOLOGY & ECOLOGY OF PELAGIC SHARKS (Auditorium)
11:30 - 11:50	› Linear growth of two oceanic sharks, <i>Prionace glauca</i> (blue shark) and <i>Carcharhinus falciformis</i> (silky shark) in the south western Indian Ocean assessed by back-calculation from vertebrae age readings - <i>Niriniony Rabehagasoa, UMR EME - Evgeny Romanov, CAP RUN</i>
11:50 - 12:10	› Bomb radiocarbon dating of the Indian Ocean blue shark <i>Prionace glauca</i>: a preliminary test of ageing accuracy - <i>Evgeny Romanov, CAP RUN / ARDA</i>
12:10 - 12:30	› Fin to carcass weight ratios for the silky shark, <i>Carcharhinus falciformis</i>, in the south-western Indian Ocean - <i>Bernard Séret, Institut de Recherche pour le Développement</i>
12:30 pm - 1:45 pm	Lunch (Ocean)
1:45 pm - 3:25 pm	Session 3: BIOLOGY & ECOLOGY OF PELAGIC SHARKS (Auditorium)
13:45 - 14:05	› Can stable isotopes document trophic position, diet, and movement in pelagic sharks? Case studies in the Atlantic and Indian Oceans - <i>Frédéric Ménard, Institut de Recherche pour le Développement, UMR EME</i>
14:05 - 14:25	› Recent Developments in Pop-up Tag Technology in Support of Fisheries Research - <i>Melinda Holland, Wildlife Computers</i>
14:25 - 14:45	› Migratory movements and environmental preferences of south Atlantic blue sharks - <i>Felipe Carvalho, University of Florida</i>
14:45 - 15:05	› Spatial ecology and fisheries of juvenile blue shark (<i>Prionace glauca</i>) in the mid-North Atlantic - <i>Frederic Vandepierre, University of the Azores</i>
15:05 - 15:25	› Identification of nursery areas of the blue and the oceanic whitetip sharks in southwestern Atlantic Ocean - <i>Mariana Tolotti, Universidade Federal de Pernambuco, Laboratório de Ecologia Marinha</i>
3:25 pm - 3:50 pm	Coffee break (Ocean)
3:50 pm - 4:30 pm	Session 3: BIOLOGY & ECOLOGY OF PELAGIC SHARKS (Auditorium)
15:50 - 16:10	› Horizontal and vertical behavior of the oceanic whitetip shark in the western Atlantic ocean - <i>Mariana Tolotti, Institut de Recherche pour le Développement, Universidade Federal de Pernambuco, Laboratório de Ecologia Marinha</i>
16:10 - 16:30	› Horizontal movement behaviour of silky and oceanic whitetip sharks in the Indian Ocean. - <i>John Filmlalter, Institut de Recherche pour le Développement, South African Institute for Aquatic Biodiversity, Department of Ichthyology and Fisheries Science</i>
4:30 pm - 5:50 pm	Session 4: FISHERY IMPACTS (Auditorium)
16:30 - 16:50	› The respective role of vessels, skipper and environment in tuna catches - <i>Patrice Guillotreau, Université de Nantes</i>
16:50 - 17:10	› Ecological Risk Assessment for species incidentally caught by fisheries managed by the Indian Ocean Tuna Commission (IOTC) - <i>Hilario Murua, AZTI Tecnalia</i>
17:10 - 17:30	› How much do fish aggregating devices (FADs) modify the habitat of tropical tunas? - <i>Nicolas Bez, Institut de Recherche pour le Développement, UMR EME</i>
17:30 - 17:50	› On the fast track to managing FADs - <i>Susan Jackson, International Seafood Sustainability Foundation</i>

Wednesday, October 17, 2012

TIME	EVENT
9:00 am - 9:45 am	Keynote: Balanced harvest? What is it and how does it relate to EAF? (Auditorium) - <i>Serge Garcia</i>
9:45 am - 10:25 am	Session 4: FISHERY IMPACTS (Auditorium)
09:45 - 10:05	› Using FADs to derive fishery independent indices for monitoring ecosystem impacts from industrial fishing - <i>Laurent Dagorn, IRD</i>
10:05 - 10:25	› Yellowfin tuna as an indicator of ecosystem state in the eastern tropical Pacific - <i>Summer L. Martin, Scripps Institution of Oceanography, University of California San Diego</i>
10:25 am - 10:50 am	Coffee break (Ocean)
10:50 am - 12:30 pm	Session 4: FISHERY IMPACTS (Auditorium)
10:50 - 11:10	› Ecological metrics of biomass removed by three methods of purse-seine fishing for tunas in the eastern tropical Pacific Ocean - <i>Tim Gerrodette, Southwest Fisheries Science Center, NMFS, NOAA</i>
11:10 - 11:30	› Ghost fishing of silky sharks by drifting FADs: highlighting the extent of the problem - <i>John Filmlalter, Institut de Recherche pour le Développement, South African Institute for Aquatic Biodiversity</i>
11:30 - 11:50	› Full Retention in tuna fisheries: Benefits, costs, and unintended consequences - <i>Valerie Chan, National Marine Fisheries Service, NOAA</i>
11:50 - 12:10	› Understanding fisheries credit systems: do they offer something new to existing management arrangements? - <i>Mariëlle van Riel, Environmental Policy group Wageningen University</i>

TIME	EVENT
12:10 - 12:30	› How the MSC fisheries certification program assesses environmental issues of tuna fisheries and minimizes their impacts on the ecosystems - <i>Carlos Montero, Marine Stewardship Council</i>
12:30 pm - 1:30 pm	Lunch (Ocean)
1:30 pm - 2:15 pm	Keynote: Mitigating Problematic Bycatch & Broader Ecosystem-level Effects of Pelagic Tuna Fisheries (Auditorium) - <i>Eric Gilman</i>
2:15 pm - 3:35 pm	Session 5: TIME-AREA CLOSURES TO MITIGATE BYCATCH (Auditorium)
14:15 - 14:35	› Is spatial closure efficient for reducing silky shark bycatch by purse seiners? - <i>Monin Amandé, Institut de Recherche pour le Développement</i>
14:35 - 14:55	› Prediction of spatial distribution of the catches rates of sharks in southwest Atlantic - <i>Thierry Frédou, Universidade Federal Rural de Pernambuco - Flávia Lucena Frédou, Universidade Federal Rural de Pernambuco</i>
14:55 - 15:15	› Spatio-temporal distribution pattern of juvenile swordfish in the eastern Mediterranean - <i>George Tserpes, Hellenic Centre for Marine Research</i>
15:15 - 15:35	› Using multi-scale electronic tracking data to evaluate spatial protection measures for juvenile (undersized) bycatch of longline fisheries - <i>Pedro Afonso, IMAR</i>
3:35 pm - 4:00 pm	Coffee break (Ocean)
4:00 pm - 6:20 pm	Session 6: MITIGATION TECHNIQUES IN LONGLINE FISHERIES (Auditorium)
16:00 - 16:20	› Stress response and post-release survival of longline captures sharks - <i>Diego Bernal, University of Massachusetts - Greg Skomal, Massachusetts Division of Marine Fisheries</i>
16:20 - 16:40	› Bait innovation as a new challenge in pelagic longlining - <i>Pascal Bach, Institut de Recherche pour le Développement, UMR EME</i>
16:40 - 17:00	› Vertical behavior of juvenile swordfish revealed by electronic tags - <i>Constantin Koutsikopoulos, University of Patras</i>
17:00 - 17:20	› Effects of environmental parameters and fishing practices on long-line swordfish catches in the eastern Mediterranean - <i>George Tserpes, Hellenic Centre for Marine Research</i>
17:20 - 17:40	› Is the fishing time an appropriate bycatch mitigation measure in swordfish-targeting longline fisheries? - <i>Pascal Bach, Institut de Recherche pour le Développement, UMR EME</i>
17:40 - 18:00	› Spatio-temporal patterns of hooking contacts in pelagic longlining : Do they depend on the catch composition (target species versus bycatch)? - <i>Manuela Capello, Institut de Recherche pour le Développement</i>
18:00 - 18:20	› Evaluation of electropositive metal for reducing shark bycatch in a commercial pelagic longline fishery - <i>Tonya Wimmer, WWF-Canada</i>

Thursday, October 18, 2012

TIME	EVENT
9:00 am - 9:45 am	Keynote: Economic Incentives to Address Bycatch (Auditorium) - <i>Dale Squires</i>
9:45 am - 10:25 am	Session 7: MITIGATION TECHNIQUES IN PURSE SEINE FISHERIES (Auditorium)
09:45 - 10:05	› Economic challenges of the mitigation measures - <i>Arantza Murillas-Maza, AZTI Tecnalia - Patrice Guillotreau, Nantes University</i>
10:05 - 10:25	› Size selectivity of small-scale purse seine in the Philippines - <i>Ricardo Babaran, College of Fisheries and Ocean Sciences, University of the Philippines Visayas</i>
10:25 am - 10:50 am	Coffee break (Ocean)
10:50 am - 12:30 pm	Session 7: MITIGATION TECHNIQUES IN PURSE SEINE FISHERIES (Auditorium)
10:50 - 11:10	› ISSF Skippers Workshops: finding best practices in bycatch reduction with the collaboration of tuna purse seine fishers. - <i>Jefferson Murua, AZTI-Tecnalia</i>
11:10 - 11:30	› An alternative drifting FAD for reducing turtle and shark mortality in Atlantic Ocean - <i>Jose Franco, AZTI</i>
11:30 - 11:50	› Outcomes of the French program aiming at a widespread use of "non-entangling FADs" - <i>Michel Goujon, Orthongel</i>
11:50 - 12:10	› Targeting bigger schools can reduce ecosystem impacts of fisheries - <i>Laurent Dagorn, Institut de Recherche pour le Développement</i>
12:10 - 12:30	› Simultaneous behavior of bigeye, skipjack and yellowfin tunas associated with drifting fish-aggregating devices in the Equatorial eastern Pacific ocean - <i>Kurt Schaefer, Inter-American Tropical Tuna Commission</i>
12:30 pm - 1:45 pm	Lunch - Showing of movie on EU project MADE (Ocean)
1:45 pm - 3:25 pm	Session 7: MITIGATION TECHNIQUES IN PURSE SEINE FISHERIES (Auditorium)
13:45 - 14:05	› Can the fishing time at FADs be adjusted to reduce bycatch by purse seiners? - <i>Fabien Forget, Rhodes University, South African Institute of Aquatic Biodiversity, Institut de Recherche pour le Développement</i>
14:05 - 14:20	› Evaluating a purse-seine captain's ability to accurately predict species composition, sizes and quantities of tunas prior to setting around drifting fish aggregating devices - <i>Kurt Schaefer, Inter-American Tropical Tuna Commission</i>
14:25 - 14:45	› Mitigating bycatch of Bigeye on purse seine FAD operation using light stimuli - <i>Tatsuki Oshima, Marine Fisheries Research and Development Center</i>

TIME	EVENT
14:45 - 15:05	› Behavior of target and non-target species when encircled by tuna purse seine gear - Jeff Muir, Pelagic Fisheries research Program, University of Hawaii
15:05 - 15:25	› Preliminary results of bycatch mitigation techniques before and during setting in the tuna purse seine fishery - Fabien Forget, Rhodes University, South African Institute of Aquatic Biodiversity, Institut de Recherche pour le Développement
3:25 pm - 3:50 pm	Coffee break (Ocean)
3:50 pm - 5:50 pm	Session 7: MITIGATION TECHNIQUES IN PURSE SEINE FISHERIES (Auditorium)
15:50 - 16:10	› Part of the Solution: Industry's Role in Research & Science - Thierry Leguennec, TRIMARINE
16:10 - 16:30	› Selectively releasing sharks from Purse Seine gear: development and testing a release panel concept - David Itano, University of Hawaii at Manoa
16:30 - 16:50	› Post-release survival of silky sharks caught in tuna purse seine gear - Melanie Hutchinson
16:50 - 17:10	› Survival rate of silky sharks (<i>Carcharhinus falciformis</i>) caught incidentally onboard French tropical purse seiners. - Francois Poisson, Institut Francais de Recherche pour l'Exploitation de la Mer - John David Filmatter, Rhodes University, Institut de Recherche pour le Développement, South African Institute for Aquatic Biodiversity - Anne-lise Vernet, IRD - Michel Goujon, Orthongel - Laurent DAGORN, Institut de Recherche pour le Développement
17:10 - 17:30	› Post-release survival of sharks capture by purse seine in the eastern Pacific Ocean - William Eddy, University of Massachusetts - Diego Bernal, University of Massachusetts
17:30 - 17:50	› Good practices to reduce the mortality of sharks and rays caught incidentally by the tropical tuna purse seiners. - Francois Poisson, Institut Francais de Recherche pour l'Exploitation de la Mer
7:30 pm - 11:30 pm	Cocktail (Lagoon)

**Symposium on Mitigating Impacts of Fishing on Pelagic Ecosystems:
Towards Ecosystem-based Management of Tuna Fisheries
15-18 October 2012, Aquarium Mare Nostrum, Montpellier**

**KEYNOTE MONDAY, OCTOBER 15
10:05-10:50**



Dr Kim Holland

Hawaii Institute of Marine Biology - Joint Institute for Marine and Atmospheric Research, University of Hawaii



Dr Victor Restrepo

Chair of the ISSF Scientific Advisory Committee



Dr Laurent Dagorn

Institut de Recherche pour le Développement

Is it good or bad to fish with FADs?

Dr. Kim Holland is a Researcher at the Hawaii Institute of Marine Biology and Senior Research Fellow at the Joint Institute for Marine and Atmospheric Research, University of Hawaii. Dr. Holland has pioneered the use of electronic tagging in the study of the behavior of pelagic fishes such as tunas and marlins.

Dr. Restrepo currently serves as Chair of the ISSF Scientific Advisory Committee. Previously, he worked with the International Commission for the Conservation of Atlantic Tunas (ICCAT). He has also served as the Chief of the NOAA/NMFS Sustainable Fisheries Division in the southeast USA, where he acted as head scientist of the USA Delegation to ICCAT.

A French senior scientist working for the *Institut de Recherche pour le Développement* (France), Laurent Dagorn is currently the coordinator of the FP7 EU project MADE dealing with the mitigation of adverse ecological impacts of open ocean fisheries (tuna purse seiners and longliners) in the Indian ocean, Atlantic ocean and the Mediterranean Sea. He is a member of the Scientific Advisory Committee of the International Seafood Sustainability Foundation (ISSF), and chairs the ISSF Bycatch project committee.

Dr Holland, Restrepo and Dagorn will review the current state of scientific knowledge of fishing on FADs and current management strategies, to encourage objective discussion of the topic and highlight areas worthy of future research.

**KEYNOTE TUESDAY, OCTOBER 16
9:00-9:45**



Dr Kim Holland

Hawaii Institute of Marine
Biology

Joint Institute for Marine
and Atmospheric
Research, University of
Hawaii

**The Behavior of Pelagic Fishes
and its Pertinence to Fisheries**

Dr. Kim Holland is a Researcher at the Hawaii Institute of Marine Biology and Senior Research Fellow at the Joint Institute for Marine and Atmospheric Research, University of Hawaii. Dr. Holland has pioneered the use of electronic tagging in the study of the behavior of pelagic fishes such as tunas and marlins. Much of his research has focused on the influence of fish aggregation devices (FADs) on the behavior and distribution of these commercially important species.

In this lecture he will explore how the biology and behavior of pelagic fishes influences the way in which they are harvested and how their behavior can be used to manage this resource in a sustainable fashion. He will discuss possible productive areas of future research.

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**KEYNOTE WEDNESDAY, OCTOBER 17
9:00-9:45**



Dr Serge M. Garcia

Chair-Fisheries Expert
Group of the IUCN
Commission on Ecosystem
Management
(IUCN/CEM/FEG)

**Balanced harvest? What is it and how
does it relate to EAF?**

A French Scientist, formerly in IRD as Research Director and in FAO as Director, Fisheries Management Division, Dr. S. M. Garcia holds a Doctorate in Sciences of the University of Marseille (France, 1976). He successively specialized in shrimp population dynamics, tropical fisheries management, and governance. He contributed to the development of the FAO Code of Conduct for responsible fisheries and championed the Precautionary Approach and the Ecosystem Approach to Fisheries. Now retired, he heads the IUCN/CEM/FEG that he contributed to establish with the view to bridge the governance systems of fisheries and biodiversity conservation.

**KEYNOTE WEDNESDAY, OCTOBER 17
13:45-14:30**



Dr Eric Gilman

Sustainable Fisheries
Partnership

Hawaii Pacific University
College of Natural
Sciences

Mitigating Problematic Bycatch & Broader Ecosystem-level Effects of Pelagic Tuna Fisheries

Dr. Eric Gilman is a Fisheries Scientist with the Sustainable Fisheries Partnership and Marine Research Scientist at Hawaii Pacific University College of Natural Sciences. Dr. Gilman's research focuses on gear technology methods to mitigate problematic bycatch, and on understanding broad ecosystem effects from marine capture fisheries.

In his presentation, Gilman will describe bycatch problems and broader ecosystem effects of longline and purse seine tuna fisheries, best practice effective and commercially viable mitigation methods, and progress by tuna regional fisheries management organizations in governing tuna fisheries' ecosystem effects. The presentation will conclude by identifying priorities for research and development, and to fill regional governance deficits.

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**KEYNOTE THURSDAY, OCTOBER 18
9:00-9:45**



Dr Dale Squires

National Marine Fisheries
Service, NOAA, U.S. Dept.
of Commerce

Economic Incentives to Address Bycatch

Dr. Dale Squires, an economist, is Senior Scientist with U.S. NOAA Fisheries in La Jolla, California, Adjunct Professor of Economics, University of California San Diego, on the Scientific Advisory Committee of the International Seafood Sustainability Foundation, and Handling Editor for the journal *Conservation Biology*.

He will emphasize social norms and economic incentives when addressing bycatch reduction, review innovative approaches to bycatch reduction (such as bycatch insurance schemes), and discuss compensatory mitigation (biodiversity offsets) and other potential conservation policies principally drawn from the terrestrial realm.

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Large fish predators diversity highlighted by tuna fisheries data in the Indian Ocean

Ménard Frédéric ¹, Simier Monique ¹, Lezama Nerea ², Amandè Monin ¹, Potier Michel ¹, Romanov Evgeny ³, Bach Pascal ¹, Murua Hilario ², Bez Nicolas ¹, Chavance Pierre ¹, Delgado De Molina Alicia ⁴, Merigot Bastien ⁵

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Data collected on board tuna fishing vessels can be used as a tool for documenting species diversity of the pelagic ecosystem in open oceans. In this work, we used scientific-observer records from both pelagic longline and purse seine fisheries in the tropical Indian Ocean to investigate diversity patterns of pelagic oceanic species assemblages. Each fishing gear or fishing strategies act as a filter and are complementary in investigating species diversity because of their respective selectivity (e.g., purse seine sets made around floating objects or on free swimming school, day or night fishing for pelagic longline), and their fishing areas or depth. We documented the entire catches of both targeted and bycatch species for each fisheries. Fishing operations were assigned to strata taking into account the main habitat features such as distance from shelf breaks, islands, or seamounts, and open ocean regions. Our findings highlight regional differences and rich structures in species diversity that might be used for future conservation issues.

Pelagic elasmobranch diversity and abundance in the Western Indian Ocean: an analysis of long-term trends from research and fisheries longline data

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Steady increase of the fishing pressure on open ocean fish communities worldwide is evident. However magnitude of human impact on the pelagic elasmobranchs (sharks and rays) is still poorly documented in many oceans. Long-term consistent time-series of quantitative and biological data are rare for the most of species due to lack of research efforts, under-reporting in the fisheries statistics and misidentification. We analysed an unique dataseries (from 1961 to 2011) on elasmobranch catches in the Western Indian Ocean (by species or higher taxa) in the pelagic longlines. Data were collected during ocean-wide research cruises and during onboard scientific observations of commercial longline fisheries. Temporal trends in the elasmobranch abundance and diversity were analysed for spatially stratified subsets: by biogeographic provinces, distance from the coast and vertical habitat. Our results demonstrate a decrease of species richness during observed period. However probable misidentifications during early years of research could distort real pattern. Declines of both nominal catch per unit effort and individual mean weight are also demonstrated for major species. The current status of the Indian Ocean pelagic elasmobranch community, its conservation and knowledge gaps are discussed.

Using fisheries data to identify pelagic predator hotspots in the North Atlantic

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Unwanted catches of important top level pelagic predators pose a major conservation concern for pelagic long line fisheries. Pelagic elasmobranchs (sharks and rays) represent one of the largest non-target groups that are routinely caught in long line fisheries. These species exhibit many different ecological characteristics but most will typically have low productivity and subsequently have a high vulnerability to exploitation. Popular regression methods for modelling fisheries data only allow a single species to be modelled at any one time with the model covariates. While results can be overlaid to locate multispecies hotspots they fail to consider any possible interactions in species spatial behaviour that might help identify these areas. Multivariate adaptive regression spline (MARS) models have developed interest as a viable alternative for habitat modelling in recent years. Multiresponsive MARS models allow for multiple species to be modelled within the same framework by minimizing the error between species for the shared model covariates. The method has proved to be successful in many ecological examples identifying essential species habitats and often outperforms the more commonly used regression techniques of GAM and GLM. Here we consider the use of multiresponse MARS as a novel method for identifying multispecies hotspots of sharks within tuna fisheries data collected between 2008 and 2011 in the North Atlantic. The results from this work will go towards informing future management decisions that will help maximise the effect of mitigation measures for a wider range of non target shark species.

Characterization of interactions between marine mammals, whale sharks and tropical tuna purse seine fishery in the Indian and Atlantic Oceans

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The tuna fishing industry holds an important place in the Indian and Atlantic Oceans. Considering complementary data collected by the captains of the French tuna purse seine fleet (1980-2011, AVDTH database) and scientific observers (1995-2011, ObServe database), we studied the relationship between fleet, whale sharks and marine mammals. These large marine organisms are indeed observed during activities and are sometimes encircled with the net when fishing tuna schools. The purpose of this study is to analyze the spatio-temporal distribution (season and year) of co-occurrence frequency between fishing activities and these large marine organisms, and the possible impact on their mortality. Distribution maps of activities and organisms, supported by multivariate data analysis (PCA), were performed. The results highlight a seasonal and annual variability in the distribution of activities and observations. Areas of aggregations of organisms and specific seasons were highlighted, certainly in relation to structuring environmental parameters. 96% of the whale shark sightings (AVDTH) were associated with fishing activity, and 25% (ObServe) to catches, which is particularly important in comparison to marine mammal sightings (respectively 76% and 6%). No particular association between fishing and dolphins was observed in contrast to the situation known in the Pacific Ocean. The impact of fishing on the mortality of whale sharks and mammals is extremely low, even zero depending the organism, in the studied oceans. The nature and abundance of the data used provide a unique vision of these organisms distribution and fishing activities

Bycatch recorded by the Mexican tuna purse-seine fleet in the eastern Pacific ocean

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This study analyzed the large pelagic species incidentally captured by the Mexican tuna purse-seine fleet during 1998 to 2007. This information was provided by Programa Nacional de Aprovechamiento del Atún y Protección del Delfín (PNAAPD), and covers about 50% of the trips made by this fleet over the study period. Bycatch records were compared among the three different set-types; tuna associated with dolphins, unassociated schools, and tuna associated with floating objects. Floating object sets exhibited significantly higher bycatch rates than the other set types, about 160 times greater than the other set types for the dolphinfish. Using a Generalized Additive Model (GAM) we evaluated the relationship between presence-absence of a particular by-catch species (dolphinfish, wahoo, silky shark, white tip shark, striped marlin, blue marlin, black marlin, and sailfish) and specific environmental variables recorded for each set. The predictor variables used in the model were longitude, latitude, Sea Surface Temperature (SST), chlorophyll-a-concentration, Sea Surface Height (SSH), Oceanic Niño Index (ONI), and month. Using the model predictions maps of the probability of capture were created for the different bycatch species. We found that the probability of billfish by-catch (blue marlin, black marlin, striped marlin, and sailfish) was highest in coastal waters, whereas catch rates for dolphinfish, silky shark, and wahoo, were greatest further offshore.

Patterns of turtle bycatch in tuna fisheries off southern Brazil: towards EBFM of pelagic fisheries in the southwest Atlantic ocean

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The incidental mortality of non-target species is an issue of particular interest in ecosystem-based fisheries management. In Southern Brazil, the pelagic longline fishery for tuna has concentrated between latitudes 22-33S where migratory turtles are caught incidentally. This study aims to show the different patterns detected for major turtle species based on a partial monitoring of fishing operations during the period 2003-2010. Data sampled in 110 fishing trips recorded a total of 1290 sets being mostly of loggerhead turtles (CPUE 0.76) followed by leatherbacks (CPUE 0.16). Almost half of the animals were caught by just 1/5 of the sampled fleet. Species feeding behavior was a factor influencing the site of insertion by the hook. Leatherback turtles were found entangled with a hook externally, while loggerheads were mostly hooked by the mouth. Correlation between the number of animals caught and environmental variables fishing depth, air temperature and SST was significant for the loggerhead turtle. Inter-annual variations were significant for both species. Higher catches of loggerheads corresponded to most oceanic fishing areas, mainly close to the Rio Grande Rise, while leatherback's mainly close to the slope. Loggerhead's abundance correlated mostly with cooler and deeper waters. Their carapace lengths ranged 50-70 cm indicating a pelagic juvenile stage of development, possibly in transoceanic migrations. In terms of seasonality, 68% of the animals were caught during autumn (CPUE 1.49) and winter (CPUE 0.94). Overall, the identified patterns will highlight important considerations to EBFM such as critical areas and key operational characteristics to impacts mitigation.

Pilot study of an electronic monitoring system on a tropical tuna purse seine vessel in the Atlantic Ocean

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The catch of non-target species (bycatch) and associated discards are becoming a concern in the fishery management community as bycatch may contribute to overfishing and may alter the structure of marine ecosystems.

Observer programs are an important tool to monitor fisheries, and are considered the most reliable source of information and, in the case of the bycatch and discard monitoring, the only source of information.

One challenge in implementing observer programs is the difficulty of ensuring an adequate observer statistical coverage, which may hamper the usefulness of observer data for management purpose. These constraints make it necessary to find alternative methods that can be, when combined with current observer programs, to improve data collection and reduce costs.

In recent years, Electronic Monitoring (EM) has become a viable alternative to observers in many fisheries and has been identified as a possible complementary method to use in tropical tuna purse seine fleet.

We carried out a study from December 2011 to March 2012 to examine the potential application of EM in the Tuna purse seine fishery in order to collect unbiased and precise catch and bycatch data. EM and observer were deployed simultaneously on 3 trips with a total of 60 events. Preliminary results indicate that EM and observer estimates of retained catch are not different; however, estimates of discarded catch are more variable and require further refinement. We also discuss the tradeoffs of both observers and EM, and the application of EM on a broad scale.

Schooling behavior of juvenile yellowfin tuna around a FAD in the Philippines

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To understand the schooling behavior of juvenile yellowfin tuna around a FAD, 13 juveniles (20.5-24.0 cm fork length) double tagged with ultrasonic transmitters (V7-2L-R256; Vemco Ltd.) and data loggers (DST-micro; Star-Oddi Ltd.) were released around a payao in the Philippines. A self-recording receiver (VR2-DEL; Vemco Ltd.) was attached on the mooring rope of the payao to follow the horizontal movements and data loggers recorded the vertical movements of tagged juveniles. Nine juveniles were recaptured simultaneously by ring net at the same payao after 4-7 days. One juvenile was recaptured by hand line at another payao 12 km away from the tagging site after 6 days. Recaptured juveniles showed a diurnal schooling pattern suggesting different school shape and foraging strategy between daytime and nighttime. Juveniles showed a diurnal horizontal moving pattern, concentrated near the payao during daytime, while they were distributed around the payao at nighttime. The fluctuations of swimming depth were synchronized among fish. Juveniles also showed a diurnal vertical movement pattern in surface mixed layer. They concentrated in a shallow and narrow range at nighttime, while they were distributed to a deep and wide range during daytime. The maximum vertical neighbor distance indicated the vertical thickness of the school and showed a peak around noon. Higher vertical movement speed during daytime indicated vertical foraging in a water column, while at nighttime the juveniles might forage horizontally following the diurnal migration patterns of prey in the surface layer.

Lipid class composition and energy allocation during reproduction of yellowfin tuna in the western Indian ocean: comparison between FADs and free-swimming schools

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One of the main challenges for marine science is to improve the understanding of factors affecting the relationship between population and recruitment as productivity is directly related to exploited population resilience. The increasing use of FADs has been hypothesized to affect the tuna movements/migrations leading them to low quality habitats, with potential detrimental effects on individual and/or population productivity. The objective of this study was to investigate body condition and tissue lipid class dynamics of yellowfin tuna in relation to their reproduction cycle as well as to evaluate the potential effects of school types (FADs vs. free-swimming schools) on these parameters. Morphometrics, condition factor, total lipid content as well as physiological indices (HSI, GSI) were measured on 102 females during the sexual maturation in the Western Indian Ocean in 2009/2010.

Results suggested that triacylglycerol, sterol- and wax-ester (WE-SE), phospholipids (TAG) and ketones were related to the processes involved in yellowfin sexual maturation. Moreover, a positive relationship between WE-SE and TAG distribution in gonads with GSI was shown, highlighting the importance of those lipid classes in the allocation energy strategy during maturation for this tropical tuna species. In contrast, no significant contribution of white muscle as energy resource for reproduction was observed. Finally, the preliminary results did not show any significant influence of fish associative behavior (FADs vs. free-swimming schools) on either tissue lipid class composition or total lipid content (Fatmeter analysis), which could suggest that the reproductive capacity of yellowfin tuna was not influenced by school type.

Skipjack reproductive capacity in relation to energy reserves: is there an influence of the school type?

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The increasing use of these drifting man-made FADs in the skipjack fishery may have modified tuna habitat and raised questions about their potential effects on the biology and, hence, reproductive potential of the species. Therefore, this work aims to first investigate the skipjack tuna bioenergetics in relation to its maturation, and then to evaluate the potential effect of its associative behaviour (FADsvs. FSCs) on the energy allocation strategy and body condition. A total of 673 individuals were examined histologically for reproduction studies. Tissue sample collection (gonads, liver and white muscle) was done on 103 females for biochemical analysis. Tissue lipid class composition (i.e., SE- WE, KET, TAG, ST, AMPL and PL) was determined with an Iatrosan MK-6s (Iatron lab, Tokyo, Japan) after being extracted by the modified Folch method.

Total lipid concentrations were 14.2 ± 8.0 $\mu\text{g}/\text{mg}$, 17.4 ± 10.6 $\mu\text{g}/\text{mg}$ and 5.3 ± 4.7 $\mu\text{g}/\text{mg}$ in gonads, liver and muscle of skipjacks, respectively. SE-WE and TAG results in gonads were highly variable in relation with the gonad maturation stages; indeed, they contributed to 32.4% of total lipids in immature females, and to 60.2% in individuals being in spawning capable phase. While tuna white muscle is known to represent the main energy (or lipid) reserves, our results didn't highlight any relationship between total lipids or lipid class distribution in muscle and the gonad maturation stages.

Temporal patterns of yellowfin and skipjack tuna associated with anchored and drifting FADs

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Using acoustic tagging data, we investigated temporal patterns of the association of yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) tuna with FADs in different situations and locations (anchored FADs in Mauritius, Maldives, Hawaii; drifting FADs in the Western Indian Ocean). We explore the temporal patterns of association characterized by the time of the day at which tuna arrive and depart from FADs to find behavioral trends within species, between species, at different study sites and different types of FADs. This fine scale analysis of behavior is used to determine the preferred time of association for the different species, a major parameter in the catchability of tunas at FADs by fishers.

Residence times and vertical behaviour of tunas around drifting fish aggregating devices (DFADs) in the Indian Ocean

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Most of studies on the associative behaviour of tunas were conducted around anchored FADs. We investigated the behaviour of yellowfin (*Thunnus albacores*), skipjack (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*) around drifting fish aggregating devices (DFADs) in the Indian Ocean between March 2010 and May 2012 using pressure sensitive acoustic transmitters and satellite-linked acoustic receivers. We examined the day/night vertical behaviour of each species. Using two different temporal scales to estimate the residency time, we document temporal patterns in residency times of the three species of tunas associated with DFADs. Estimating how much time tunas stay around DFADs is necessary to understand the role of floating objects on the ecology of these species, moreover, it helps us to assess the impacts of the deployment of FADs on these species.

Evolution of radio buoys technology for FAD, past, present and future.

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In the 1990s, the tuna seiner fleet started to fish using FADs. As these FADs are drifting, it became necessary to track these devices at sea.

The first radio buoys used were goniometric. The gonio receiver only detected the radio direction.

Year 1997: The GPS cost reduction allowed manufacturers to use this technology in radio buoys.

These GPS buoys informed the fisher of the position and the water surface temperature.

With the GPS radio buoys, an important step has been taken. Fishers have started to understand some relations between oceanic currents and FAD catches.

Year 2000 : the first solar buoys.

Year 2004 : the first GPS satellite buoys (inmarsat D+).

Year 2007 : the first radio buoys equipped with an acoustic sounder started to appear; it was a big technological step helping to achieve large fuel savings. Fishers headed towards the FADs knowing in advance the presence of fish.

Present:

Nowadays, radio buoys with an acoustic sounder give reliable information and are widely used in the tuna fleet.

In 2012, the first buoy with a multi-frequency echo sounder begins to be marketed. They aim not only at indicating the presence or absence of fish but also at establishing the species detected by comparing different acoustic signatures in different frequencies.

Future:

Radio buoys will give reliable information on sizes and species of tuna using multitransducer acoustic sounders helping fishers to take sustainable decisions before to go.

Using fishers' echosounder buoys for scientific studies

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Thousands of drifting Fish aggregating devices (DFADs) are world widely employed in the tropical tuna purse seiner (PS) fishery. Those devices are actively monitored by satellite linked buoys and most of them are equipped with echosounders which provides fishers with accurate geolocation information and some unbalanced biomass estimations. We believe that these instrumented buoys could be improved, in particular using knowledge on the vertical behavior of the different species found around FADs. In this work, we propose a multispecific biomass echo-integration. Using tagging and catch data, we provide estimates of aggregated biomass (in tons) by species (or groups of species, e.g. bycatch). With those improvements, echosounder buoys could be used as observatories for pelagic fish.

The behavioural ecology of two major bycatch species of the tuna purse-seine fishery: the oceanic triggerfish and the rainbow runner

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The rainbow runner (*Elagatis bipinnulata*) and the oceanic triggerfish (*Canthidermis maculatus*) are two of the main bycatch species of the FAD-based tuna purse-seine fisheries in the world. Within the framework of an ecological based management, baseline information of these species is required to assess the ecosystem impacts of tuna fisheries. To date, little information is available on the basic biology and behaviour of those two species. Acoustic telemetry on fish associated with FADs (57 oceanic triggerfish and 26 rainbow runners) provided information on their associative behaviour. Additionally, biological sampling on fish caught by purse seiners was used to investigate the diet of both species.

Behavior of fish aggregations assessed using fishers' echosounder buoys

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Thousands of drifting FADs (DFADs) are actively monitored by the tropical tuna purse seine fishery worldwide every year. DFADs are supplied with echo-sounder buoys that remotely provide fishers with real time positions and estimations of biomass underneath the FADs. Fish aggregations around FADs are composed of target tuna species and non-target species. We have modified data received from those buoys and improved the interpretation for the use of this data in scientific studies. Now, those DFADs could be used as remote observatory platforms to improve the knowledge about the behaviour of the species showing an associative behaviour to the object. Study choices are multiple: analysis of first colonization, excursions... However, we have focused on the behaviour of 4 groups (bycatch, skipjack, and both juvenile yellowfin and bigeye) and their relationship with the abiotic and biotic factors of the habitat and their environmental preferences. By means of dynamic echosounders' biomass samples, some kind of mitigation suggestions will be searched (i.e. areas with high bycatch/tuna rate; seasons in which juvenile tunas are more associated to DFADs...).

Behavioural plasticity displayed by tuna at fish aggregating devices (FADs)

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Knowing that several pelagic species associate with floating structures, fishers have been using man-made fish aggregating devices (FADs) to facilitate their catch of these species. However, our understanding of this associative behaviour and its adaptive value is poor and the scientific community is ill-equipped to provide fishery managers with science-based recommendations on the impacts of FADs on ecosystems. The durations of the FAD-associated and unassociated behavioural phases of 72 acoustically tagged yellowfin tuna (*Thunnus albacares*) in an array of FADs around Oahu, Hawaii, were studied during four years. Data were analyzed using survival curves with the objective of determining the behavioural dynamics of fish joining and leaving the FADs. Survival curves were best fitted with exponential models, meaning that underlying behavioural processes were time independent. FAD-associated phases were characterized by four behavioural modes with average durations of 13.1 min, 2.9 days, 13.8 days and 23.2 days. Two modes were observed for unassociated phases: short (2.8 days) and long (infinite). There was no predictive relationship among these phases. The duration of the associated period is likely to depend on local conditions existing around a FAD at a given time, whereas the durations of unassociated periods may depend on broader-scale oceanic conditions. In each case, the conditions may correspond to biotic factors and/or social interactions. Individuals exhibited behavioural plasticity, switching between short and long modes for the associated phase. This suggests that large pelagic fish display a range of responses to changing environmental circumstances, highlighting the complexity involved in this associative behaviour.

Role of social interactions on dynamics of fish aggregations in a multi-site system of fish aggregating devices (FADs)

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Metapopulation models describe the colonization and extinction of populations in inter-connected patches. In this general context, habitat selection is a complex decision making process that involved both responses to environment cues and congeners. In this study, we investigate how social behaviour affects distribution of population in multi patch environment. More precisely, based on the case study of temporal aggregation of tuna with surface heterogeneity such as Fish Aggregating Devices (FADs), we further examine the influence of increasing number of patches. Using both system of differential equations and stochastic simulations we demonstrate how social interaction in both settlement and departure processes significantly affect the dynamic and the distribution of population between patches. These results could have major implication in term of fisheries management that currently needs to propose measures to mitigate the effect of FADs deployment by tuna fishing industry.

Establishing a reference point to assess the existence of an ecological trap for tropical tunas

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The deployment of thousands of drifting man made fish aggregating devices (FADs) by fishers over recent decades has modified the pelagic habitat where only natural floating objects (logs) could be encountered before. Previous studies highlighted that tunas associated with floating objects were in lower conditions than tunas in free-swimming schools (FSCs), concluding that FADs could act as ecological traps. However, the interpretations of these results require a reference point, i.e. the condition of tunas before the use of FADs. Considering that the associative behaviour of tunas with logs evolved to provide some advantages, it is generally assumed that before the fishery, tunas associated with logs would have been in a similar or superior condition to tunas in FSCs. In the Mozambique Channel, an area known to be naturally enriched with logs, with few FADs, we tested the hypothesis that the condition of skipjack tuna (*Katsuwonus pelamis*) associated with logs was similar or superior to those of tuna in FSCs. Our results reject this hypothesis. Morphometric and bioenergetic indices revealed poorer body condition for tuna associated with logs. These results preclude scientists from interpreting differences in fish health caught around floating objects and in FSCs as an unequivocal demonstration that FADs act as ecological traps. Biochemical and morphometric indices suggested that females could be more affected by the association with logs than males, a new hypothesis that deserves further investigation. Our study also provides new insights in our understanding of the evolutionary origins of this associative behaviour.

The role of FADs in the ecology of juvenile silky sharks

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Silky sharks (*Carcharhinus falciformis*) are the main elasmobranch species found around drifting FADs and as such, are commonly taken by purse seiners as bycatch. Here, we investigate the role that FADs play in the ecology of this species through the use of acoustic telemetry, pop-up satellite tags (miniPATs) and dietary analysis. Residence times and vertical data were collected from 21 silky sharks (73 -112 cm TL) tagged with acoustic transmitters equating to 328.5 d of observation around 7 drifting FADs between March 2010 and May 2012 in the western Indian Ocean. Sharks were found to associate with the same FAD for several days (mean = 15.6 d, range: 2.8 - 30.6 d) and typically undertook excursions away from the FAD at night, as has been found previously. While closely associated during the day, sharks typically remained shallow (under 30 m) often reaching a maximum depth around midday. Average day and night depths were not significantly different but data from 5 sharks double tagged with miniPATs indicate that the amplitude of vertical behaviour at night, during excursions, was far greater, suggesting nocturnal foraging away from FADs. In addition, stomach samples from 240 sharks incidentally caught around FADs by purse seine vessels provided useful information on the proportion of the diet consisting of prey items that commonly associate with FADs. Combining data from the behaviour (acoustic tags and miniPATs) and diet, we show that floating objects form a key component in the pelagic habitat for these sharks during their early life stages.

Linear growth of two oceanic sharks, *Prionace glauca* (blue shark) and *Carcharhinus falciformis* (silky shark) in the south western Indian Ocean assessed by back-calculation from vertebrae age readings

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A total of 190 blue sharks (36-275 cm fork length, FL) and 208 silky sharks (51-264 cm FL) were collected in the southwest Indian Ocean in 2009-2010. Whole and sectioned vertebrae were used for age determination. The relationship between fish length and vertebrae radius in particular age was developed for back-calculation of the length-age matrix. For both species the adjusted isometric model was significant, explaining 97% (*C. falciformis*) and 98% (*P. glauca*) of variance. von Bertalanffy's growth model was adjusted to back-calculated lengths at age. Our results revealed that the blue and the silky sharks' species had a relatively slow growth, attaining an average asymptotic size of about 250cm FL at an age of over 15 years. Models indicated that none of von Bertalanffy's growth parameters significantly differed among males and females. For the blue shark, a significant effect of sex could be detected by the non-linear mixed effect model (NLME): males grow faster than females as commonly occur among shark species. No significant effect of sex on growth for the silky shark was detected. Final models indicated individual growth parameters ranging from -1.94 to -0.07 years for t_0 , 0.086 to 0.215 year⁻¹ for k , 201 to 343 cm FL for in *P. glauca*, and from -3.69 to -1.56 years for t_0 , 0.056 to 0.082 year⁻¹ for k , 291 to 357 cm FL for in *C. falciformis*. The difference between the life history traits for both blue shark and silky shark populations are discussed.

Bomb radiocarbon dating of the Indian Ocean blue shark *Prionace glauca*: a preliminary test of ageing accuracy

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Bomb derived radiocarbon from nuclear testing in the atmosphere provides one of the best age validation approaches available for long-lived fishes. Vertebrae from two blue sharks caught in 1986 and 1983 were sectioned, aged and assayed for ¹⁴C content in particular annuli. The shark caught in 1986 was too young for detailed assay: estimated age 17-19 years. This was confirmed by post-bomb ¹⁴C concentration in the 1-2 annuli. The age of the blue shark caught in 1983 was estimated at 26 years. ¹⁴C chronology obtained from assays of series of annuli showed offset from reference chronologies of about 3 years. Second independent reading of sectioned vertebra brought an agreement between two readers 22 years. The shark was also too young for definitive validation. However adjusted ¹⁴C curve for this individual demonstrate good agreement with Indian Ocean reference chronologies. This study shows that the assumption of annual formation of growth bands on Indian Ocean blue shark vertebrae is correct and age interpretation is relatively accurate. However further studies are necessary to obtain validation of blue shark ageing using the ¹⁴C method. Another archival georeferenced and size referenced vertebra(e) from big blue shark caught in early 1980s is needed to obtain definitive validation of age estimates.

Fin to carcass weight ratios for the silky shark, *Carcharhinus falciformis*, in the south-western Indian Ocean

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The fin to carcass weight ratios were calculated on a sample of 53 complete sets of fins taken on dead specimens of silky sharks caught during the MADE program in the south-western Indian Ocean. The fins were dried with a food dehydrator until constant weight. The following ratios were calculated: wet weight of primary set of fins / total wet weight of the body and to the eviscerated wet weight of the carcass; wet weight of secondary set of fins / total wet weight of the body and to the eviscerated wet weight of the carcass. The results were compared to other published ratios obtained in other fisheries. The important differences sometimes observed, are mainly explained by the different methods of cutting the fins and the inclusion of the dorsal caudal lobe in the fin sets.

Can stable isotopes document trophic position, diet, and movement in pelagic sharks? Case studies in the Atlantic and Indian Oceans

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The blue shark *Prionace glauca* and the silky shark *Carcharhinus falciformis* are the two main shark by-catch in pelagic longline and purse seine fisheries, respectively. The high market demand for shark fins is currently the main driver of unsustainable fishing for sharks globally, with potential effects on ecosystem trophic functioning through top-down cascading effects. Knowledge of the species' trophic ecology is therefore crucial but is limited by the lack of data (e.g. stomach-content data). Stable isotope analysis was then performed on muscle tissues ($\delta\text{-N-15}$ and $\delta\text{-C-13}$) of these two shark species collected in the western Indian and the eastern Atlantic Oceans in order to examine their trophic positions and movement patterns. For the two species, we investigated body length, season, and zone effects on isotope signatures. In addition, we took into account the effect of the fishing gear (longline and purse seine sets made around floating objects, i.e. Fish Aggregating Devices) to explain the different patterns in the Indian Ocean. Our findings suggest niche partitioning between species, with silky sharks having a more inshore foraging habitat than blue sharks. We also interpreted the trophic position of these species in the light of other large predatory fishes in both oceans.

Recent Developments in Pop-up Tag Technology in Support of Fisheries Research

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The development of increasingly efficient miniature radio transmitters that can communicate with satellites has resulted in concomitantly smaller pop-up tags and higher data throughput. In the case of the Wildlife Computers MiniPAT, detailed temperature and depth time series data can reveal behavior patterns of target species and these very detailed data can be used to aid interpretation of results from other less sophisticated tags. The small size of the MiniPAT tag allows their use on smaller and smaller animals. The same technology has been incorporated into a simplified 'Survivorship PAT' (sPAT) specifically designed to measure whether animals such as sharks and billfish survive after they are released from sport and commercial fisheries. These tags report a summary of the animal's daily vertical behavior from which survivorship can be inferred. To simplify things for the user, these tags are pre-registered with Argos (CLS) and the cost of satellite service is included in the purchase of this tag. Finally, we have developed an even smaller satellite tag that simply reports where it pops off - an electronic 'spaghetti tag' that provides fisheries-independent measures of dispersal patterns and migration.

Migratory movements and environmental preferences of south Atlantic blue sharks

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In January 2009, we started a tagging project using Pop-up Satellite Archival Tags aiming to collect movement data of blue sharks tagged off the coast of Brazil and the West coast of Africa. To date, 24 blue sharks have been tagged. All tags deployed transmitted successfully after release from the shark. In the present study we used a modified version of the Brownian bridge movement model (BBMM) to quantify movement patterns of these tagged blue sharks. BBMM is a continuous-time stochastic model of movement. Using this model we estimated migration routes, the home range area, and probabilities of one individual or a population crossing for each of four geographical regions of the southern Atlantic Ocean (NW, SW, SE, NE). A Generalized Additive Model was used to quantify the effects of time, space, chlorophyll, depth of the thermocline, and sea surface temperature on the probability of crossing. Preliminary results indicate trans-oceanic migration of blue sharks, with individuals travelling from its tagging site near the coast of Brazil to the west coast of Africa. Latitudinal migrations were also observed in blue sharks tagged off the southern coast of Brazil and off west coast of Africa. Results from the model showed that while sea surface temperature and depth of the thermocline were important parameters, quarter of the year had the most significant effect on the probability of blue sharks crossing from one geographic region to the others.

Spatial ecology and fisheries of juvenile blue shark (*Prionace glauca*) in the mid-North Atlantic

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Blue shark (*Prionace glauca*) is an abundant and cosmopolitan pelagic shark species, inhabiting tropical and temperate regions of the world's oceans. However, blue shark populations are subjected to an increasing pressure as a consequence of the growing international demand for shark products. They are the mostly caught shark species worldwide, mainly as bycatch in the longline fisheries for tuna and swordfish. While their stock status in the North Atlantic remains ambiguous, demographic and risk analyses showed that overall population growth is strongly dependent on the survival of the juvenile segment. Given their complex sexual and life stage segregation in both space and time, this could represent an opportunity for managing this species in a sustainable way. Juvenile blue sharks are very abundant in the waters around the Azores, in the central North Atlantic. This nursery function could provide the region with a key role for the management of this species, but very little is known about the spatial behaviour of juveniles and their movements in and between nursery areas. Here we present an analysis of their spatial ecology based on a combination of data from fisheries and satellite tracking. The results reveal the dynamic nature of the juvenile habitat, covering large parts of the North Atlantic and the function of the region as an alternating seasonal nursery for male and female blue shark.

Identification of nursery areas of the blue and the oceanic whitetip sharks in southwestern Atlantic Ocean

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All around the world there has been increasing concern about the deterioration of shark's population status due to a very high fishing effort on tuna stocks and consequently on sharks caught as by-catch. Our contribution to reduce the impact on these species was to identify nursery areas for two relevant species in the Southwestern Atlantic Ocean: blue (*Prionace glauca*) and oceanic whitetip (*Carcharhinus longimanus*) sharks. Size, catch and effort data was collected by on-board observers of the National Observer Program that surveyed the Brazilian chartered tuna longline fleet from 2005 to 2010. The spatial distribution of juveniles was predicted using the catch rates CPUEs (Capture per Unit of Effort). Juveniles were defined using the length at first maturity obtained from previous studies as criteria (blues shark: 226 cm total length, oceanic whitetip shark: 180 cm). A general additive model was then applied, with the CPUE as the response variable. Latitude, longitude and fishing strategy (factor that represents the fishing operation) were considered as the explanatory variables. A very clear pattern was observed for the blue shark with the CPUE increasing southwards and peaking in the area bounded by 18° to 28° S of latitude and 36° to 26° W of longitude. For the oceanic whitetip shark, the GAM identified two potential nursery areas, one just above the equator and another between the latitudes of 10° and 15° S.

Horizontal and vertical behavior of the oceanic whitetip shark in the western Atlantic ocean

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The oceanic whitetip shark (*Carcharhinus longimanus*) is a circumtropical species known as one of the main pelagic sharks worldwide. This species is caught as a bycatch by a variety of pelagic fishing gears such as tuna and swordfish pelagic longlines, pelagic gillnets and purse seines. However, despite its worldwide distribution and frequent catches in most of the high-seas fisheries, little has been published on the species biology and ecology. Particularly, information regarding oceanic whitetip migration, vertical movements and temperature preferences are still almost inexistent. In this context, through the use of pop-up satellite archival tags, the present study provides findings on the species depth distribution, temperature ranges and horizontal movements in the western Atlantic Ocean. Ten sharks were tagged by on board observers during fishing cruises of commercial tuna longliners from the Brazilian fleet. Five tags already transmitted and five are still on the sharks. Tags were attached through a fin loop and retention periods were from 60 up to 180 days. Tagged sharks showed marked preference for warm and shallow waters of the mixed layer. These findings are in favor of promoting deep longline hooks (> 100 m) in order to mitigate the bycatch of this species.

Horizontal movement behaviour of silky and oceanic whitetip sharks in the Indian Ocean.

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The horizontal movements of the silky and oceanic whitetip sharks in the Indian Ocean were investigated through the use of pop-up satellite tags. Tagging was conducted either during commercial operations on tuna purse seine vessels or during research cruises on board longline vessels, a tuna purse seine vessel or vessels chartered for studying fish behaviour around drifting FADs. Pop up tags were either MK 10 PATs and MiniPATs from wildlife computers. To increase the probability of obtaining movements beyond the resolution of the estimates provided using such tags, only tags deployed for more than three weeks were analysed. As such, data from a total of 28 silky sharks and 1 oceanic whitetip were analysed. The principle focus of this work was on juvenile silky sharks that typically associate with drifting FADs (n = 23) however some larger sub-adult and adults, that are more regularly taken by long line vessels (n = 5), were also tagged. The total number of days of observation was >1300 d for silky sharks (data collection continuing) and 100d for the oceanic white tip. Horizontal movements were obtained using light-based geolocation methods and most probably tracks were generated using the Tremblay Iknos-Walker method.

The respective role of vessels, skipper and environment in tuna catches

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The firm's management in production is a critical, but unobserved input. Within a panel data framework, the firm's management and firm effects have to date been conflated. Exploiting variability in the managerial dimension, this paper identifies the firm's management from firm and time effects in a production function using a three-way fixed effect model and a unique panel data set tracking multiple managers for each firm in each year for an industry over 27 years. The model is applied to the French purse-seine fleet harvesting tunas in the Indian Ocean. The results indicate the importance of distinguishing firm and management effects and contribute to public regulation of industries exploiting common resources.

Ecological Risk Assessment for species incidentally caught by fisheries managed by the Indian Ocean Tuna Commission (IOTC)

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Ecological risk assessment (ERA), and specifically Productivity-Susceptibility Analysis (PSA), is a useful methodology for assisting the management of fisheries from an ecosystem perspective in a data poor situation. Indian Ocean tuna and tuna-like fisheries, managed by the Indian Ocean Tuna Commission (IOTC), are economically important both at local and international scales and interact with several non-target or bycatch species. In spite of these interactions, no comprehensive ERA has been conducted for bycatch species caught by IOTC fisheries so far. We followed a two stage approach with the objective of assessing the relative risk of species being impacted by Indian Ocean tuna fisheries. An analysis of the available data from observer programs in the Indian Ocean (focused on bycatch species incidentally caught by major tuna fishing gears) revealed that most of these species are caught by longline fisheries, followed by gillnets and purse seines.

A PSA for the various longline and purse seine fleets operating in the Indian Ocean revealed two groups of species with high relative risk scores. The first one includes pelagic and coastal sharks, characterized by relatively low productivity, and the second one included teleosts, characterized by higher productivity but high susceptibility to purse seine and longline gears. Recognizing that IOTC community begins to pay more attention to shark conservation, the analysis suggests that sharks at higher risk may deserve more comprehensive scientific monitoring and management actions. Some alternative approaches to conduct PSA in the context of ERA are discussed.

How much do fish aggregating devices (FADs) modify the habitat of tropical tunas?

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Natural floating objects such as logs or branches have always been a component of the habitat of tropical tunas. However, the introduction of artificial floating objects (fish aggregating devices - FADs) modifies this habitat. In order to quantitatively and qualitatively assess how much those FADs modify the offshore pelagic habitat, we compared the spatial distribution of natural and artificial floating objects. We used data from Spanish and French observers onboard tuna purse seiners in the Western Indian Ocean from December 2006 to December 2008. We divided the Indian Ocean into cells using grids of 1°, 5° and 10° and calculated the percentage of FADs being in cells without logs. FADs and logs appear to have different spatial distributions at the scale of 1°, but similar ones from the scale of 5°. The major change due to the introduction of FADs concerns the number of floating objects. Except in the Mozambique Channel and Chagos, the number of FADs is multiplied by 2 at least everywhere, and can reach up to 20 and 40 (Somalia area). These results are discussed in relation to the Ecological Trap hypothesis.

On the fast track to managing FADs

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Floating objects, known as fish aggregating devices (FADs), are used in both purse seine and pole and line tuna fisheries, and can be either anchored to the ocean floor or drifting at sea. In purse seine fisheries alone, more than one third of the world's tuna is caught in association with naturally occurring and manmade floating objects.

While the efficiency of FADs is well documented, there are many aspects that remain unknown, largely due to a lack of reliable data. For one, there is no educated estimate of the number of FADs currently drifting or anchored at-sea. This knowledge gap makes it difficult for fishery management plans to effectively address the use of floating objects. As a result FAD management has been extremely limited, mainly restricted to closures and bans in instances where the fishery may be negatively impacting a targeted tuna population.

In 2012, the International Seafood Sustainability Foundation (ISSF) developed and launched FADTrak, a new tool that gathers information on an individual vessel's deployment, usage and recovery of FADs. This life cycle information is critical to developing better management plans. The FADTrak electronic logbook application utilizes touch screen and GPS technology to help industry collect credible data itself and submit the information directly to regional fishery management organization scientific bodies.

The discussion "On the fast track to managing FADs" will explore where the technology is being used and how ISSF is working with the processing sector to encourage vessels to adopt FAD logbooks as a standard operating procedure.

Using FADs to derive fishery independent indices for monitoring ecosystem impacts from industrial fishing

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Several pelagic species aggregate around floating objects and to date fishers have been more efficient in the exploitation of this behavior than scientists. Here we propose a new use of FADs: in addition to fishing aids, FADs could be used as scientific tools to collect data and improve our knowledge of pelagic ecosystems. Firstly, FADs concentrate pelagic diversity and therefore provide an excellent opportunity to investigate the pelagic biodiversity in a cost effective manner. We report results on biodiversity indices estimated from underwater visual census on FADs, compare them to observer data, and discuss how FADs could be used to monitor pelagic biodiversity. Second, FADs can be used to provide fishery-independent indices of the abundance of tuna and other associated species. The principle is very simple: the abundance of tuna (or other fish) associated with FADs within a region is related to the total abundance of tuna (or other fish) in the same region. However this relationship, as well as its dependence on the number of FADs, is not known. Here, we present a model on the behavior of tuna associated with FADs, which could provide insight into this relationship based on experimental measurements. This model could (i) provide local indices of abundance and (ii) predict the effects of increasing the number of floating objects on the ratio between the associated biomass and the total biomass. We discuss how the parameters of the model can be estimated through echosounder buoys and electronic tagging experiments.

Yellowfin tuna as an indicator of ecosystem state in the eastern tropical Pacific

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Biodiversity is believed to be positively correlated with ecosystem resilience. Because biodiversity data can be challenging to collect, biodiversity indicators are valuable predictors of ecosystem state. This is particularly true for oceanic ecosystems. We explore the potential for using yellowfin tuna (*Thunnus albacares*) as an indicator of biodiversity by linking ecological characteristics of tuna (e.g. distribution and abundance) to diversity indices calculated from an existing dataset. These data were collected from NOAA Fisheries ships at sea during 10 years over a 19-year time span (1988-2006) in the oceanic eastern tropical Pacific, an area of 21 million square km that includes waters of 12 nations and the oceanic commons. We characterize diversity of cetaceans, seabirds, larval fishes, and flyingfishes and relate these to yellowfin tuna metrics. Because of the close ecological association of these tuna with dolphins in this region, our results have particular relevance to depleted populations of spotted and spinner dolphins (*Stenella attenuata* and *S. longirostris*, respectively), but more broadly, to ecosystem-based management of oceanic systems. These ecosystems present a complex set of management challenges. The living marine resources they include are often transboundary; enforcement of international agreements is difficult; and the ecosystem goods and services they provide are global. Yellowfin tuna is a commercially important species and tuna information is widely available through fisheries datasets, providing the potential to predict ecosystem state for this system into the future.

Ecological metrics of biomass removed by three methods of purse-seine fishing for tunas in the eastern tropical Pacific Ocean

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An ecosystem approach to fisheries management is a widely recognized goal, but describing and measuring the effects of a fishery on an ecosystem is difficult. We used data from the well-documented purse-seine fishery for tunas in the eastern tropical Pacific Ocean to examine the fishery's ecological effects. Purse-seine fishing in the eastern tropical Pacific is conducted in 3 ways that differ in the amount and composition of target species and bycatch. The choice of method depends on whether the tunas are swimming alone (unassociated sets), associated with dolphins (dolphin sets), or associated with floating objects (floating-object sets). Among the fishing methods, we compared catch on the basis of weight, number of individuals, trophic level, replacement time and diversity. Floating-object sets removed 2-3 times as much biomass as the other 2 methods, depending on how removal was measured. Results of previous studies suggest the ecological effects of floating-object sets are thousands of times greater than the effects of other methods, but these results were derived from only numbers of discarded animals. Management of the fishery has been driven to a substantial extent by a focus on reducing bycatch, although discards are currently 4.8% of total catch by weight, compared with global averages of 7.5% for tuna longline fishing and 30.0% for midwater trawling. An ecosystem approach to fisheries management requires that ecological effects of fishing on all animals removed by a fishery, not just bycatch or discarded catch, be measured with a variety of metrics.

Ghost fishing of silky sharks by drifting FADs: highlighting the extent of the problem

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Juvenile silky sharks (*Carcharhinus falciformis*) often associate with drifting FADs throughout the world's tropical oceans. These FADs regularly include portions of submerged netting, which aid in slowing their drift and are believed to improve their aggregating efficiency. Juvenile silky sharks are known to become entangled in this netting, however the frequency of this occurrence has never been investigated. Here we adopt a multi-technique approach, including underwater surveys and acoustic and satellite tagging to provide the first quantitative assessment of silky shark mortality induced through ghost fishing by FADs. Underwater visual assessments were conducted at 53 FADs while 35 sharks were tagged at FADs with satellite tags and observed for > 1225 d (data collection on going). Additionally 7 sharks were tagged with pressure sensitive acoustic tags and monitored at 4 FADs for 55 days. By coupling visual assessment data with acoustic tagging data we were able to derive the average number of sharks entangled on a daily basis for a given number of FADs. Furthermore, by combining acoustic and satellite tag data we could estimate the conditional probability of a shark becoming entangled once associated with a FAD. Finally, through comparison with a stochastic model based on both the distribution of the number of sharks at FADs and the experimental conditional probability of entanglement, derived above, we were able to assess the accuracy of the visual assessment data as well as possible interactions between conspecifics.

Full Retention in tuna fisheries: Benefits, costs, and unintended consequences

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Calls for full retention of target and non-target species by longline and purse seine gear types have been made throughout the tuna world by a variety of influential actors and institutions. For example a recent draft conservation and management measure for yellowfin, skipjack and bigeye tuna in the western and central Pacific ocean (WCPO) included a provision calling for full retention of all species caught by longline and purse seine gear types. ISSF's resolution 11-03 also calls for «total retained catch on board except those individuals that are released alive or those whose retention is prohibited by a RFMO resolution or a flag state's national law». Full retention policies may be considered by several of the tuna regional fisheries management organizations in the coming year.

This paper will review the benefits and costs of a retain-all strategy for tuna fisheries in the WCPO. Using bycatch data from observers and logbooks from the United States purse seine and longline fleets operating in the WCPO, we will explore the types and magnitude of fish discarded. For the purse seine fishery, this information will be used to estimate direct impacts of off-loading at the initial point of landing in key Pacific Island ports. We will explore implications by drawing on experience from U.S ports in the region. We will also examine implications of a retain-all strategy on WCPO longline fisheries. The intent of this effort is to allow participants in tuna RFMOs the ability to more fully consider the implications of retain-all policies.

Understanding fisheries credit systems: do they offer something new to existing management arrangements?

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Credit systems are used in a range of environmental and resource management settings, including carbon, water and biodiversity, for achieving specified sustainability goals. Proposals to apply a credit system to fisheries management have been made. But these generally do not provide a well-defined framework for the potential of a fisheries credit system and in what way such a system would differ from other related management arrangements as individual transferable fishing quotas (ITQs/IFQs) or transferable vessel days. However, examples of credit systems applied to fisheries do exist: the Scottish Conservation Credit Scheme (SCCS), the Agreement on the International Dolphin Conservation Program (AIDCP), fish banking credits, and the case of California Drift Gillnet Fishery Pacific Sea Turtles Tax. This paper analyses these cases and explores to what extent a credit system differs from other fisheries management arrangements. In doing so we define what a fisheries credit system is, identify what incentives, mechanisms, elements and measures are needed to make a credit system effectively function, and discuss what a credit system could add to prevailing fisheries management tools.

How the MSC fisheries certification program assesses environmental issues of tuna fisheries and minimizes their impacts on the ecosystems

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The Marine Stewardship Council (MSC) is a non-profit organization who sets an environmental standard to assess and certify sustainable fisheries worldwide. The sustainability of the fisheries activities is evaluated through an independent third-party methodology measuring 31 performance indicators structured into 3 principles, the status of the stock, the environmental impact and the management system. Through a gradual and dynamic scoring system, defined by the MSC's Theory of Change, every fishery must fulfill minimal requirements in order to be certified but, moreover, it must also accomplish with additional conditions to improve its performance along the 5 years period of the certificate. This methodology, assured by annual surveillance activities carried out by independent Certification and Assessment Bodies (CABs), not only guarantees the sustainability of the fisheries, but also becomes a driving force to minimize their impacts and improve the global management of the activity. The present document analyzes the main environmental impacts of the tuna fisheries engaged in the MSC program and the actions undertaken for each fishery to overcome the certification requirements and the improvement conditions established. This analysis is based on the several reports elaborated along the certification process of the tuna fisheries in the program, that means mainly public determination reports and annual surveillance reports, but also on the results obtained by the study «Researching the Environmental Impacts of the MSC certification program» carried out in 2011 by the consultancy body MRAG, which analyzed 447 fisheries involved within the MSC and assessed the implementation of the Theory of Change.

Is spatial closure efficient for reducing silky shark bycatch by purse seiners?

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The silky shark (*Carcharhinus falciformis*) is the most occurring and abundant shark species in the tuna purse-seine fishery in the Indian Ocean. The spatial structure of the species was analyzed using a zero-inflated generalized additive model (ZIGAM). This model shows that the bycatch of silky sharks are most important in the northern hemisphere and in the Mozambique Channel, which are fishing zones particularly dominated by floating objects. The analysis of the effect of timely closure of areas identified as being most impacted by the fishery was conducted using a simulation procedure for the reallocation of fishing effort after closing.

Prediction of spatial distribution of the catches rates of sharks in southwest Atlantic

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In the southern Atlantic, many vulnerable shark species is caught as by-catch by tuna longline fleets. In this study, the spatial distribution of shark catch rates was predicted to identify the most sensitive areas, where the incidental catch is higher. Catch and effort data was collected by on-board observers of the National Observer Program that survey the Brazilian chartered tuna longline fleet. A total of 14,800 sets were recorded from 2004 to 2010 and analysed. The Brazilian longline effort was spread over a broad area in the equatorial and South Atlantic Ocean, with a higher concentration from 10°N to 30°S and from 20°W to 40°W. General additive models were used to predict the catch rates of 4 species that frequently occur within the operation area: the blue (BSH), mako (MAK), silky (FAL) and oceanic whitetip (OCS) sharks. The catch per unit of effort (CPUE) of each species was used as the response variable. The factors trimester, strategy (that characterises the fishing operation), latitude and longitude were the explanatory variables. Due to the very low amount of data on MAK, the trimester factor was not considered. The models prediction shows changes in catch rates of BSH along the year being higher in the northern area in the first half of the year going south afterwards. Catch rates of MAK are low mainly in the south part of the fishing area. Catch rates of FAL and OCS are restricted spatially near the coast and seasonally (first half of the year).

Spatio-temporal distribution pattern of juvenile swordfish in the eastern Mediterranean

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A time-series of observers data on board fishing vessels targeting swordfish in the eastern Mediterranean by means of surface long-lines has been analyzed to identify areas/seasons with relatively higher catch/rates of juvenile fish. Analysis revealed high intra-annual variability and identified juvenile «hot spot» areas in certain months.

Using multi-scale electronic tracking data to evaluate spatial protection measures for juvenile (undersized) bycatch of longline fisheries

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In spite of the RFMOs efforts, the substantial by-catch of juvenile individuals from target and accessory species is a major problem in the management and conservation in the surface longline fishery. This is the case of undersized (under 25 kg) juvenile swordfish, the target species, but also of blueshark, nowadays the most important species in the Atlantic fishery. Both are caught in large numbers due to the low selectivity of the gear, which threatens the sustainability of the fishery and the conservation of some populations. Of particular concern is the possibility that nursery areas ? essential fish habitat - are disproportionately targeted by the fisheries. Knowing the spatial distribution and the patterns of habitat use of these juveniles are of primary importance to identify and quantify the stability of these EFHs, which can be provided by tracking data. Here we present novel data on satellite tracking of juvenile swordfish and blueshark in the Atlantic and Mediterranean to estimate their residencies and home ranges, and to evaluate seasonal movements. We use this data to evaluate the potential efficacy in protection of the juvenile population segments of existing and possible future spatial-temporal closures in these two oceans.

Stress response and post-release survival of longline captures sharks

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Research on fishing-related stress indicates that the physiological effects and survival of released fish after capture is not well understood. This study investigates the stress response in sharks captured by pelagic and demersal longline operations and documents the post-release survival for some species. Blood stress parameters (electrolytes and metabolites) were collected from sharks after capture on longline gear and, when possible, pop-up satellite archival tags were used to determine post-release survival. In general, the level of stress increased with the duration of time on the line and the magnitude of the stress response was species specific with pelagic sharks having a more pronounced stress response relative to demersal species. However, the at-vessel mortality for demersal species ranged from as little as 3 to as much as 12 hours of being hooked on the on the longline. Taken together, the blood properties of longline-captured sharks appear to be useful indicators of interspecific variation in the stress response to capture, and offer insight into the post-release survival when verified with satellite tags.

Bait innovation as a new challenge in pelagic longlining

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For the pelagic longline fisheries (PLF) knowledge of both behaviour and distribution of fish for target species (mainly tunas and swordfish) are not sufficient to mitigate: i) non-sustainable fisheries interactions with endangered, protected and threatened marine top predators and ii) the impact of the fishing pressure on non-managed bycatch species. Furthermore, PLF have another indirect impact on marine ecosystems: removal of marine resources used as bait. Many bait species might serve as important source of natural protein for direct human consumption while in the meantime, most of bait used in the tuna industry as well as non processed dead discards and post processing fish remains are source of organic wastes in the oceanic ecosystems. In the context of the ecosystem approach to fisheries the substitution of natural bait with artificial analogue is apparently a major issue to be addressed by gear technologists. Development of artificial bait is one of the major challenges for PLF in the nearest future. Such an innovation might alternate extremely negative perception of longline gear by: i) decrease of volume of capture fisheries yields directed to bait, ii) decrease of discards by transformation of wastes produced by tuna fishing industry into by-products, iii) improves the selectivity and performance of the longline gear both in the size of targeted fish and species caught.

Targeting objective to develop artificial bait for PLF we present the bait prototype developed in the MADE project and preliminary results obtained from fishing trials, which are still ongoing.

Vertical behavior of juvenile swordfish revealed by electronic tags

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In the context of the MADE project (Mitigating Adverse Ecological impacts of open ocean fisheries) 14 swordfish juveniles ranging from 85 to 124 cm, were tagged with electronic tags in the Atlantic (Azores 4), central (Italy 6) and Eastern Mediterranean (Aegean Sea 4) during 2010 and 2011. Juvenile swordfish catches represent an important problem for the longline fisheries in these areas. The study of their vertical migration can provide potentially useful elements leading to the definition of fishing strategies and technical measures (line depth, fishing period and timing) reducing the undesirable juvenile catches. Elements on the vertical distribution of the fishes transmitted via satellite from the pop-upped tags and extended and detailed time series from three recovered tags (65 to 135 days, 1-2 min recording interval) are analysed. A regular diel pattern of the vertical movements appeared clearly after some days during which the fish behaviour was probably affected by the tagging action. The maximum depth reached during day time showed an important variability which also characterized the vertical movements in shallower areas. The timing of the upward and downward movements is described by a model linking the sun's angle to the vertical position of the fish. In this way the fish depth can be estimated by the geographic position and time. The recorded patterns are analysed and discussed in the context of definition of technical measures aiming at the reduction of the juvenile catches.

Effects of environmental parameters and fishing practices on long-line swordfish catches in the eastern Mediterranean

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Surface long-lines are extensively used for swordfish fishing in the Mediterranean and a large proportion of their catches is composed of juvenile individuals. It has as been repeatedly stressed during various ICCAT meetings that the reduction of the number of juveniles in the Mediterranean swordfish catches is essential to ensure the sustainability of the stock. In order to obtain a full picture of the swordfish vulnerability in the commonly used long-line gear, a series of fishing trials with long-lines equipped with temperature depth recorders (TDR) and hook timers (HT) were carried out in the eastern Mediterranean. The effects of temperature, depth and time of capture on swordfish size were studied by means of Generalized Additive Models (GAMs), considering also the moon phase prevailing during each trial.

Is the fishing time an appropriate bycatch mitigation measure in swordfish-targeting longline fisheries?

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Within the two recent decades many coastal and island countries have developed longline fishery targeting swordfish in their EEZs and international waters. Nowadays this fishing gear is a primary worldwide method for landings of largest size of pelagic fishes. While swordfish is the target species, this fishery yields numerous species of epipelagic predatory community such as scombrids, billfish, sharks and rays, other teleost fish, reptiles, and birds. Incidental catch (bycatch) is a crucial management issue for LSF in an Ecosystem Approach to Fisheries context since many of the non-target species are discarded dead. Many of these non-target species are susceptible to fishing pressure and cannot sustain current level of non-targeting exploitation. In this study we explore the fishing time as a mitigation measure to reduce bycatch in LSF. Fishing surveys with a longline equipped with time depth recorders and hook timers were carried out in the South West Indian Ocean. Capture time for swordfish and non-target species were analysed, in order to investigate potential time difference in the hooking contacts among different species. Moreover, an optimal time window optimizing the Catch per Unit Effort (CPUE) for the target species with respect to the ratio between bycatch groups and the target species was identified. Finally, the opportunity of changing the fishing strategy (setting and hauling periods, soaking time) to mitigate the impact of LSF on bycatch focused on both sharks and commercial bycatch species was discussed.

Spatio-temporal patterns of hooking contacts in pelagic longlining : Do they depend on the catch composition (target species versus bycatch)?

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We analyzed spatio-temporal distribution patterns of large pelagic fishes in interaction with the pelagic longline gear. Data were collected during scientific surveys carried out in the Central South Pacific (French Polynesia) by using an instrumented longline (ILL) equipped with both hook timers and time depth recorders (TDR). A total of ~ 160 ILL survey operations targeting tuna species (*Thunnus alalunga*, *T. albacares* and *T. obesus*) were performed. Data downloaded from TDR attached to the expected deepest point of the mainline basket confirmed that the major part of the vertical habitat of large pelagic fishes was prospected. Each hooking contact was characterized by four variables: horizontal position along the mainline, hooking depth, time and the species caught for hooking successes. Results of our data analysis based on spatial point process displayed clear spatial and temporal patches of both hooking contacts and captures. They revealed locally clustered interactions between the large pelagic fish and the gear. We examined the relation between the catch composition (target species versus bycatch) and the structure of identified clusters. We discuss possible implications of these spatio temporal patterns of catches in pelagic longline ecosystem-based fisheries management and bycatch mitigation measures.

Evaluation of electropositive metal for reducing shark bycatch in a commercial pelagic longline fishery

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The indiscriminate capture of non-target organisms (bycatch) in commercial fisheries undermines the sustainable development of marine resources. In the Northwest Atlantic, blue sharks (*Prionace glauca*) account for most of the bycatch in the Canadian pelagic longline swordfish fishery. Minimizing the capture of this species is of interest to conservationists as well as the fishing industry because the high incidence of shark bycatch negatively affects fishing operations through bait loss and increased handling time. Electropositive metals (e.g., lanthanide) oxidize in seawater and create electric fields, which can alter the swimming and feeding behaviors of several species of sharks. Although electropositive metals appear to have the potential to reduce shark bycatch in pelagic longline fisheries, there have not been any controlled trials reported from a commercial fishery. A total of 7 sets (6300 hooks) with 3 hook treatments (standard hooks, hooks with electropositive metals (neodymium/praseodymium), and hooks with lead weights) were deployed in 2011 on the Scotian Shelf in the Northwest Atlantic. The results of this study show that electropositive metals did not reduce the catch of blue sharks and do not appear to be a practical bycatch mitigation measure in the Canadian fishery.

Economic challenges of the mitigation measures

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The aim of this paper is to analyse the economic performance of Basque and French purse seiner tuna fisheries in open oceans exploitation through taking into account spatial and inter-temporal dimensions. In particular, a cost-benefit analysis of different mitigation measures, MM, will be developed with special emphasis on the deployed of eco-FADs by purse seiners.

A CBA informs the decision-making process by estimating the Net Present Value (NPV) of the different MM. The purpose is to determine whether the different MM create or not additional surplus or value for fishers (marginal benefit ? marginal cost). The first step in a CBA is to identify and quantify all relevant costs (incl. opportunity costs) and benefits of the different MM. The NPV is then found as the sum of the discounted flows of costs and benefits over the lifespan of the MM. The risk or uncertainty of the variables entering a CBA will affect the precision of the estimated expected NPV. It is therefore important to consider the effects of risk and uncertainty. This paper also analyses the different contribution to the economic sustainability when fishing is around Fish Aggregation Devices (FADs) instead of free-swimming schools. FADs are increasingly used by tuna purse-seine fleets all around the world and the contribution or not to the economic sustainability could be considered to be an important determinant factor for policy makers and fishers.

Size selectivity of small-scale purse seine in the Philippines

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In the Philippines small-scale purse seine nets are used near anchored fish aggregating devices (FADs) (payao) to capture small pelagic fish. These gears sometimes capture juveniles of tuna together with small pelagic species that also associate with the payao. To evaluate the sizes of small pelagic fish relative to tuna juveniles that are captured by small-scale purse seines, a mesh selection experiment was conducted using a typical gear by replacing its bunt with an experimental bunt bearing 21 pocket nets that open to 1.5 m x 1.5 m square net panels. All net panels had the same hanging ratio and twine diameter but had 11 different mesh sizes. These panels were randomly arranged horizontally and vertically into a T-shaped section that was cut out from the experimental bunt. Over 30 species including round scad, bigeye scad, sardines, and tuna species like yellowfin, bullet and frigate tuna formed part of the catch; the most abundant species were roundscad and bigeye scad. The selectivity curves of roundscad, which has a circular cross section, were sharper than bigeye scad, which has a slightly elliptical cross-section. Based on the recommended mesh size of 15.2 cm for tuna seiners in the West and Central Pacific Ocean, 50% of bigeye scad and only 10% of the captured roundscads were retained. This result indicates that mesh selection is difficult even among fish with slightly similar body forms and highlights current challenges in pelagic fisheries management in Philippine waters where matured small pelagic species mix with tuna juveniles .

ISSF Skippers Workshops: finding best practices in bycatch reduction with the collaboration of tuna purse seine fishers.

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In 2010 the International Seafood Sustainability Foundation (ISSF) started facilitating bycatch reduction workshops worldwide for tuna purse seine skippers. Captains and navigators with understanding in FAD (Fish Aggregating Devices) fishing were targeted. Other important fleet members such as ship-owners, fleet managers, deck bosses, and crew with technical knowledge are also invited. These «Skipper Workshops» pursue the identification of best fishing options to reduce bycatch of small tuna, turtles and sharks with the help of fishers. The workshops feed into the ISSF's broader Bycatch Project, which supports the chartering of commercial purse seiners for research trips to develop and test better bycatch reduction solutions. At the workshops scientists present skippers with results of the trials conducted at sea (Eastern Pacific, Indian Ocean, and Western Pacific Ocean trips to date), and planned activities for forthcoming trips. The concepts discussed include the development of non-entangling FADs, attraction of sharks away from the FADs, use of selective echo-sounder buoys, manipulation of bycatch species in the net, or best release practices for sharks and turtles. The fisher's feedback is carefully considered at the ISSF Bycatch Steering Committee, influencing decisions on which investigation areas to prioritize in future research cruises. In addition, the local regional knowledge provided for each ocean and type of vessels they use, helps identify important differences between fleets and regions to create «tailor-made» measures. Direct involvement of skippers in finding bycatch solutions improves results and promotes ready adoption of measures.

An alternative drifting FAD for reducing turtle and shark mortality in Atlantic Ocean

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Experimental drifting FADs have been tested in eastern Atlantic waters with the main objective of reducing turtle and shark mortality. These sensible species are usually entangled in traditional FADs by the polyamide netting of the submerged structure. The main characteristic of the experimental FADs is that this netting has been replaced by ropes of sisal, a natural fiber. A total number of 56 experimental FADs all of them carrying satellite buoys with echosounder have been deployed until now from November 2010 to May 2012 in an area of Atlantic Ocean limited by coordinates 9° 56'N - 8° 59'S in latitude and 26° 05'W - 6° 00'W in longitude. The final prototype is 100 meters deep and is almost entirely biodegradable made of bamboo canes, palm leaves and sisal ropes. Drift and biomass of the experimental FADs have been monitored and compared with traditional FADs and are discussed for future implementation of the experimental FAD in commercial fishing.

Outcomes of the French program aiming at a widespread use of "non-entangling FADs"

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Since August 2010, the French tuna purse seiners operating in the Indian Ocean have deployed more than 1000 modified FADs to be non-entangling. The work done by the crews with the help of IRD scientists also involved in the MADE program, resulted in the identification of three designs of FADs, which present characteristics that allow to reduce or even eliminate the risk of entanglement of turtles and sharks and are widely accepted by the crews without significantly increasing the manufacturing cost of these FADs.

The catch data collected on these non-entangling FADs have shown that the yields do not appear to be altered by the changes of the FAD design.

A small number of entanglements observed in these first generation "non-entangling FADs" suggests, however, that the efforts made by the boatowners should be continued. The discussion of these results therefore also relates to the responses proposed by the sector in order to achieve the goal of zero entanglement in a sustainable and economically viable manner.

Targeting bigger schools can reduce ecosystem impacts of fisheries

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Sustainability of living resource exploitation relies on an ecosystem management approach. Within tropical tuna purse seine fisheries using FADs, such an approach incorporates the reduction of bycatch, in particular vulnerable species such as elasmobranchs. The levels of total bycatch (in weight) from fishing operations using FADs is known to be 5 times higher than when tuna are caught in free-swimming schools. We intend to find practical solutions to reduce bycatch in FAD sets through the investigation of the relationships between the ratio of bycatch to target catch across different set size classes in all oceans. Ratios were always highest when catches were small, with the smallest class of catches responsible for the highest total portion of bycatch (23-43%) while only contributing negligibly to the total target catch (3-10%). Reducing the effort whilst maintaining the same total yield could contribute to a significant reduction in the impacts of human activities.

Simultaneous behavior of bigeye, skipjack and yellowfin tunas associated with drifting fish-aggregating devices in the Equatorial eastern Pacific ocean

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A 73-day research cruise was undertaken by scientists of the Inter-American Tropical Tuna Commission, during the period of 11 May to 23 July, 2011 to the equatorial eastern Pacific Ocean aboard the Ecuadorian-flag purse-seine vessel Yolanda L., under a charter agreement between the vessel owner and the International Seafood Sustainability Foundation. The objectives of the cruise included attempting to reveal practical solutions for reducing the fishing mortality of undesirable sizes of bigeye and yellowfin, sharks, and other species of concern commonly captured during fishing operations by purse-seine vessels setting on mixed-species aggregations associated with drifting fish-aggregating devices (FADs).

One of the research activities during the cruise was to elucidate fine-scale spatial and temporal differences in the behavior of bigeye, skipjack, and yellowfin tunas within mixed-species aggregations associated with drifting FADs. Ultrasonic telemetry experiments were undertaken at ten drifting FADs, with large mixed-species tuna aggregations present. Experimental methods included the capture and tagging with VEMCO V13P coded ultrasonic transmitters, of up to 3 each of bigeye, skipjack, and yellowfin tunas, and continuous ultrasonic transmitters, in up to 3 additional skipjack. VEMCO VR2 and VR28 acoustic receivers were utilized for the passive and active ultrasonic telemetry experiments. Each experiment was intended to be conducted for a minimum of 48 h. Analyses of the ultrasonic telemetry data obtained from these experiments will be presented, along with evaluations and discussion of the simultaneous behavior of the three tuna species.

Can the fishing time at FADs be adjusted to reduce bycatch by purse seiners?

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Fish aggregations at FADs are multi-specific in nature and comprise both targeted tuna species and several bycatch species. We acoustically tagged the three major tuna species - yellowfin tuna (*Thunnus Albacares*), bigeye tuna (*T. obesus*), skipjack tuna (*Katsuwonus pelamis*) - and some major bycatch species - silky sharks (*Charcharinus falciformis*), oceanic triggerfish (*Canthidermis maculatus*) and rainbow runners (*Elagatis bipinnulata*) - at the same drifting FADs (10 FADs). We investigated the temporal and spatial dynamics of the different species simultaneously to assess a potential time-dependent vulnerability. We specifically explored the fine scale diel patterns of association of the tagged species to determine if there are specific times of the day when only certain species are present at the FAD. Additionally, we used depth data (transmitted by pressure sensitive acoustic tags) to determine whether distinct diel patterns exist in the vertical distribution of the various species. These data are discussed in the light of a mitigation approach where the fishing time of tuna purse seiners could potentially be adjusted to reduce the capture of bycatch.

Evaluating a purse-seine captain's ability to accurately predict species composition, sizes and quantities of tunas prior to setting around drifting fish aggregating devices

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Scientists from the Inter-American Tropical Tuna Commission (IATTC) in collaboration with the International Seafood Sustainability Foundation conducted a 73-day research cruise on board the Ecuadorian-flagged purse-seine vessel Yolanda L. during 11 May to 23 July, 2011. One objective during the cruise was to evaluate the captain's ability to accurately predict species composition, sizes, and quantities of tunas present at drifting FADs prior to setting.

Experimental procedures included the captain estimating the quantities (in tons) by species and size classes for skipjack, bigeye, and yellowfin tunas immediately prior to setting around a drifting FAD. The captain made estimates utilizing SONAR, Echo-sounder, visual observations, and radio communications with a crewman in a light boat, equipped with an echo-sounder, adjacent to the FAD. Tunas loaded from sets were partitioned in wells to facilitate tracking through the unloading and sorting process. IATTC personnel were present during the unloading of the vessel and the sorting process at the StarKist® GALAPESCA Facility in Manta, Ecuador. Weights by species and size classes provided by StarKist® were compiled to match three size classes utilized in the pre-set estimates. The measured quantities were compared to the captain's estimates and his accuracy evaluated. A total of eight purse-seine sets were evaluated and the results presented. Additionally, estimates of species composition by scientists utilizing a Simrad ES70 Echo-sounder and a SEABOTIX LBV 200 Remotely Operated Vehicle were compared to those of the captain's for 6 of 8 sets to evaluate potential improvements in accuracy with the use of additional equipment.

Mitigating bycatch of Bigeye on purse seine FAD operation using light stimuli

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Mitigating bycatch of juvenile Bigeye on purse-seine FAD operation is an urgent issue. Feasibility of using light stimuli to force Bigeye escape from the net was examined. Cage experiments showed that Skipjack tend to evade more from intermittent light than Bigeye does, which makes separation between both species. Combination of intermittent and continuous lights were applied at the FAD fishery ground. Reactions of both Bigeye and Skipjack to the light stimuli were tracked with coded pingers. Some preliminary results will be discussed.

Behavior of target and non-target species when encircled by tuna purse seine gear

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Observational and photographic data were collected from 31 sets made from a tuna purse seine vessel during the International Seafood Sustainability Foundation's (ISSF) WCPO #BycatchProject. A range of studies were undertaken to test ways to avoid undersize tuna and to reduce/minimize the incidental mortality of sharks, sea turtles and other finfish that associate with drifting FADs used by tuna purse seine fisheries. Untested assumptions relating to natural behavior of encircled finfish and sharks in purse seine gear were clarified; divers observed spatial separation of target tuna species by species as well as size. Additionally, non-target species consistently separated themselves from target species and remained shallow. This species segregation was consistently observed during all sets and lasted throughout the duration of the haul until the beginning of sacking was reached, at which point individuals and schools were forced to intermingle. These observations provide much needed insight to behavioral patterns of non-target and unwanted species, which may inform further research and development of options to selectively release or sort these from the net before these animals sustain mortal injuries.

Preliminary results of bycatch mitigation techniques before and during setting in the tuna purse seine fishery

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In order to effectively reduce bycatch mortality in the tuna purse seine fishery, the bycatch could be separated, and released, before it is brought on deck. There are two temporal windows during the purse seining process when bycatch can be separated to maximise their survival: either before the start of the set or during the set but before the catch is brought on deck.

We investigated the potential use of behavioral manipulation of several bycatch species, using the FAD and bait as stimuli, to attract them to designated areas. Firstly, we investigated whether sharks and other bycatch species could be attracted away from the FAD by using bait as a stimulus. Following these trials, similar experiments were conducted within the net, to determine whether the bycatch can be attracted out of the net using both the FAD and bait as stimuli. The outcome of these trials led to the proposal of a different mitigation method consisting of an escape panel placed the middle of the net.

Part of the Solution: Industry's Role in Research & Science

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According to a study conducted on the size of the tropical tuna purse seine large-scale fishing fleet, 678 vessels have the capacity to catch nearly 4 million tons of tuna in any given year ? roughly the entire global catch generated by all fishing gears combined. Onboard each purse seine vessel is an experienced crew with a unique understanding of the ocean region, its ecosystem and the best methods for achieving optimal fishing results.

Practical solutions to mitigating unintended environmental impacts are highly desired by both industry and the marketplace, and the fishing industry is poised to play an important role in advancements in research and science. The firsthand knowledge developed by each vessel's crew has the potential to advance the use of modern technology in order to better collect data, improve fishing gear design and share best practices with vessel all over the world.

"Part of the Solution: Industry's Role in Research & Science" details the experiences of TriMarine International and the feedback the vessel owning company receives from its customers. As the TriMarine fleet partners with the scientific community to explore the potential for new opportunities to reduce its own environmental footprint, and the collective impact of an entire fleet of fishing vessels, this discussion explores the challenges of change and the opportunities that exist for vessel owners willing to make a commitment to progress.

Selectively releasing sharks from Purse Seine gear: development and testing a release panel concept

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A research cruise was conducted in the central equatorial Pacific onboard a tuna purse seine vessel during 2012 in support of the International Seafood Sustainability Foundation's #BycatchProject; formed to develop technical options to reduce bycatch in industrial tuna fisheries. A range of studies were undertaken to test ways to avoid undersize tuna and to reduce/minimize the incidental mortality of sharks, sea turtles and other finfish that associate with drifting FADs used by tuna purse seine fisheries. Preliminary data suggested that ways to avoid or selectively release non-target species from the net should be prioritized, as condition and post-release survival at latter stages of purse seining is very low. Dive surveys conducted inside the net documented a clear separation of tuna by size and species and between tuna and bycatch suggesting a potential for selective release. Silky sharks (*Carcharhinus falciformis*) were observed to aggregate in a pocket of net that forms during the latter stages of net retrieval where an experimental release panel was tested; designed to be opened and closed without disrupting the fishing operation and with low risk of losing target catch. Only a small number of sharks exited the panel during trials but groups of sharks were observed very close to the opening suggesting they may exit if appropriate stimuli could be applied or different environmental conditions prevailed. Although the panel failed to release significant quantities of non-target catch during the research cruise we feel that further refinement of this concept with additional testing and experimentation is warranted.

Post-release survival of silky sharks caught in tuna purse seine gear

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A recent stock assessment of silky sharks (*Carcharhinus falciformis*) in the western and central Pacific Ocean (WCPO) showed significant declines in spawning biomass, total biomass and recruitment (WCPFC-SC8-2012). As a result silky shark interactions with tuna purse seine gear have become a subject of concern amongst scientists, managers and fishers. To address this and other bycatch issues the International Seafood Sustainability Foundation (ISSF) has initiated the #BycatchProject that supports research cruises in the world's oceans on commercial tuna purse seine vessels to develop ways to reduce fishing mortality on non-target species. One of the research objectives during the #BycatchProject cruise in the WCPO was to identify the point in the fishing operations when post-release survival rates of silky sharks is compromised. To answer this question blood chemistry analysis was done on animals landed during the different stages of the fishing operation with their post-release condition and survival verified with pop up satellite tag technology. Initial results indicate that animals landed and released early in the fishing operations (while still free swimming or entangled in the net during the net haul) had higher survival rates than animals landed during the brailing stages. Tag and blood chemistry data also show post-release survival to be significantly reduced once animals are confined in the sack.

Thus efforts to promote the live release of sharks caught in the net need to be conducted during the early stages of the fishing operations.

Survival rate of silky sharks (*Carcharhinus falciformis*) caught incidentally onboard French tropical purse seiners.

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Currently, French tropical purse seiners in the Indian Ocean release all sharks and rays that are caught incidentally. Through participation in two commercial fishing trips, we first recorded the number of sharks (primarily silky sharks, *Carcharhinus falciformis*) that were alive or dead, once they had been sorted by the crew on the upper and lower decks. More sharks were observed in the lower deck (73%) than in the upper deck. The silky sharks observed on the upper deck were significantly larger than the ones found in the lower deck. The immediate mortality (sharks that were dead at the time of observation) rates appeared to be linked with the location of the individual, as more sharks were found dead on the lower deck than the upper deck. The immediate mortality rates also increased with the set size (tonnage). 20 silky sharks were tagged with MiniPATs (Wildlife Computers, Redmond, WA, USA) to study their survival after release. In addition, 12 silky sharks were tagged with the same type of electronic tags during a scientific cruise. Of a total of 32 silky sharks, 8 tags clearly showed mortality directly after release, while data from five tags suggested delayed mortality after 2 to 35 days. 15 tags showed that the sharks survived. Four tags failed to report data. A 'best practices' manual for fishers has been prepared to increase rates of survival of sharks caught by purse seine vessels. However, other methods prior to the sharks being brought onboard must also be investigated.

Post-release survival of sharks capture by purse seine in the eastern Pacific Ocean

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A growing management tool aimed at increasing the worldwide sustainability of large-scale fisheries is the release of bycatch species. However, the effects of such fishing practices on the post-release survival of incidentally caught species is poorly understood. Historically, pelagic sharks have had a significant presence as bycatch in purse seine fisheries and this study seeks to better understand how sharks captured with commercial gear may experience a combination of physical trauma and large physiological perturbations that may affect their post-release survival. Sixteen satellite archival tags were deployed on purse-seine captured pelagic sharks (silky sharks, n=13; scalloped hammerheads, n=3) during 2011 and 2012 in the eastern Pacific Ocean. The tags monitored the post-release diving behavior (e.g., depth and temperature preferences) of sharks for 30 to 45 days. All hammerheads appear to not have survived post-release, despite showing little or not physical trauma and being considered strong while on deck. Two silky sharks, deemed strong on the deck, appeared to have not survived, six showed immediate post release mortality, two snagged sharks appeared to have survived and three more recent tags have not reported to date. Taken together, the post-release survival for all sharks ranged from 0% for hammerheads to 35% for silky sharks, with approximately 69% of all sharks not surviving the capture event. The low post-release survival of the pelagic sharks captured with a purse seine suggests that in order to minimize the potential impact on these incidentally captured species, all direct (physical) gear interactions may need to avoided.

Good practices to reduce the mortality of sharks and rays caught incidentally by the tropical tuna purse seiners.

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The reduction of the bycatch mortality is an objective of the ecosystem approach to fisheries and a request by consumers. The involvement and the participation of the resource users is necessary to develop efficient and practical mitigation techniques. Fishers handle animals as a part of their job duties and it is essential to identify good practices that ensure the safety of the crew and optimize the survival of the released animals. Combining scientific observations and fishers (French purse seine fleet) empirical knowledge, handling/release guidelines are proposed for sharks and rays, including large ones like whale sharks and manta rays incidentally caught by tropical tuna purse seine fleet vessels. New ideas emerging from scientists/fishers exchanges are also proposed although not yet tested. These best practices on decks of fishing vessels should contribute to reduce the fishing mortality of some vulnerable species. Mitigation research is by definition an iterative process and different complementary methods must be carried out at the different steps of the fishing process to significantly reduce the mortality of these animals.

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