Report of the 2012 ISSF Workshop to Review Spatial Closures to Manage Tuna Fisheries

Rome, Italy, July 20-21, 2012

Summary. The International Seafood Sustainability Foundation convened a workshop to review the available knowledge on spatial closures, including, MPAs, and to discuss their potential use in managing tuna fisheries. Scientists and other experts made a series of presentations to inform these discussions. The Workshop concluded that spatial closures alone would be an ineffective and inefficient means to manage tuna fisheries. However, if used in combination with other fishery management tools, closures can provide substantial benefits if the objectives are clearly identified, and there is a reasonable basis in support of deciding their temporal and spatial scale and for their monitoring and enforcement. In addition, participants concluded that pelagic closures may be most useful in bycatch mitigation. The Workshop concluded that adoption of MPAs should not become an excuse for not implementing other necessary/recommended management measures. Participants agreed on a series of recommendations with respect to the evaluation of closures and the importance of monitoring and enforcement in determining effectiveness.

1. BACKGROUND, OBJECTIVES AND ORGANIZATION

Spatial closures (also "time-area closures") are one of the tools commonly used by managers in all types of fisheries. They are also commonly used outside of fisheries for a variety of conservation, research and other purposes. Usually the objective of the closures in fisheries management is to reduce fishing mortality on one segment of the stock (e.g. juveniles, spawning aggregations, etc.). Spatial closures can also have other objectives such as reducing gear conflicts, re-distributing fishing effort, reducing gear impacts on sensitive or vulnerable fish habitats. The benefits and impacts of these closures, particularly relative to traditional management approaches, have not generally been studied in a comprehensive, comparative fashion. In addition, several environmental organizations are promoting oceanic Marine Protected Areas (MPAs) to achieve multiple objectives, including a reduction in fishing pressure on tuna resources. For the most part, however, the available body of scientific literature on MPAs corresponds to coastal and coral reef environments.

ISSF convened this workshop to review the knowledge gained from the use of spatial management, specifically as applied in the management of tuna fisheries. Such knowledge can be used to examine more closely what benefits, and what unintended consequences, if any, can be expected from various types of spatial closures. The objective of the workshop was to bring together scientists and stakeholders familiar with spatial management tools and tuna resources in order to review the current knowledge on MPAs and to make recommendations for future actions.

The workshop was held at the Hotel Capo d'Africa in Rome. Participants included members of the ISSF Scientific Advisory Committee, the ISSF Environmental Stakeholder Committee, staff from four Tuna RFMO Secretariats, scientists that actively participate in the RFMO scientific committees, and several other stakeholders: Brad Ack, Tundi Agardy, Robin Allen, Mark

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A number of participants made background presentations intended to inform the discussions, or statements to reflect their organization's views and advocacy policies. These are presented in **Section 3**. In addition, a number of scientific publications were made available as references (**Appendix 1**). **Section 4** reports the deliberations and conclusions by Workshop participants and **Section 5** lists the main recommendations.

2. NOTES ON TERMINOLOGY

The title of this Workshop uses the term "Spatial Closure" in reference to the actions frequently taken by fishery managers to restrict access by fishers to an area. There is a continuum in the types of restricted access. A closure could involve complete prohibition ("No-take zone") or partial prohibition that applies to only a fishing fleet/gear (such as prohibiting commercial fishing and allowing subsistence fishing). Or, the closure could either be permanent or apply during a limited time period each year, or apply only once, temporarily.

The term "Marine Protected Area" (MPA) is used frequently, primarily by environmental conservation organizations. The Convention on Biological Diversity defines MPAs as follows[1]:

> *"Any defined area within or adjacent to the marine environment, together with its overlying waters and associated flora, fauna and historical and cultural features, which has been reserved by legislation or other effective means, including custom, with the effect that its marine and/or coastal biodiversity enjoys a higher level of protection than its surroundings."*

As in fishery spatial closures, the above definition allows for great latitude as to what qualifies as an MPA. Workshop participants felt that the main difference between Spatial Closures and MPAs lies on an individual's preference to use one or the other. The term Closures is more commonly used by the fisheries community, while MPAs is more commonly used by the environmental community. In this report, both terms are used somewhat interchangeably.

The term "Marine Spatial Planning" (MSP) has also gained importance in recent years. In general, MSP is meant to convey a more integrated process where multiple users of the oceans (transportation, conservation, recreation, energy, fisheries, etc.) make coordinated decisions about the utilization of marine resources.

[1] Other more detailed definitions and categorizations exist. For example, IUCN's Protected Area Management Categories: http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/

3. PRESENTATIONS AND STATEMENTS

Use of Marine Spatial Planning in Fisheries (Tundi Agardy)

Presentation. Spatial management for fisheries has been used for a very long time. Historically, spatial management included marine tenure regimes, fisheries closures and spatial gear restrictions, marine reserves, and formal Protected Areas (as per the IUCN categories). Today, however, spatial management goes well beyond and includes MPA networks, Essential Fish Habitat protections, Integrated Coastal Zone Management targeting areas important for coastal and pelagic fisheries, ocean zoning, and Marine Spatial Planning (MSP) which, taken in the broadest context, includes all of the above.

MPAs can have benefits for fisheries management, but there are also costs associated with one-off marine closures. MSP can better deal with these costs and maximize benefits. These benefits include: clarity about rules, regulations, boundaries; certainty for investors (energy industry, fishers, tourism operators, etc.); reduced conflict among incompatible uses; biodiversity protection and maintenance of ecosystem services; enhanced production from closures and spillover; streamlined management, surveillance, enforcement, and possibilities for integrated multidisciplinary research. The constraints to using MSP for fisheries management include: poor data coverage and compatibility / information gaps; dynamics of species / systems not conducive to SM; complex jurisdictions, governance arrangements, and inadequate financial resources; lack of foresight on the part of management agencies; limitations of MSP in being able to tackle invasive species, pollution (esp. land-based sources) and climate change; and political views, including freedom of the seas, and 'right to fish' movements, and a general distrust of government. Nonetheless, practical examples of the utility of spatial management for fisheries provide demonstrations on how to overcome these limitations.

Discussion. It was noted that the Conventions that created the tuna RFMOs are concerned with maximizing yield while preventing collapse of fisheries, and monitoring and conserving certain non-target species. But these Conventions do not have a mandate for other elements in MSP such as transportation and energy, so it was felt that the RFMOs do not provide an appropriate legal framework for MSP. Agardy noted that one avenue available is through the Law of the Sea convention and there are possibilities in the regional seas context, such as the Barcelona Convention, as it has some latitude that could take into account regional seas network. It was noted that there was a lack of clarity from the process of planning to the implementation of the management plan. It was also noted that there is no over-arching authority that at the end of day will make sure compromises are made in order to get the management plan implemented. This raised a point on the major investment of effort and time in developing plans without consideration towards the feasibility of implementation. Where success with MSP has been seen, people think up front what is needed for planning and implementation. It is sensible to view the planning and implementation as an evolving process. It was also noted that transparent involvement by all stakeholders is a key to successful MSP.

Marine Protected Areas: The Good, the bad and the ugly. A fisheries Perspective (Mike Sissenwine)

Presentation. The presentation gave a general overview of the use of MPAs as a tool in fisheries management. It did not focus on tuna, but the general conclusions apply. MPAs are not a panacea when it comes to fisheries management, but they are, and have been long before the term was popularized, a useful fishery management tool. They fall within a class of fishery management methods known as "input controls." In general, input controls are more scientifically robust, enforceable, and intuitive than output controls (like catch quotas), but they make fisheries less efficient. In terms of the biological performance of MPAs, there is strong evidence that abundance and size of relatively immobile species is higher inside MPAs than outside. Biodiversity may also be higher. Spillover of fish from inside MPAs often enhances fisheries outside. There is some evidence that MPAs export eggs and larvae, but there is little evidence that recruitment is enhanced. Populations can be sustained within an MPA if an MPA is large enough to retain some of the eggs and larvae produced within it. To sustain an entire stock subject to intense fishing outside the MPA, 20-40% of the stock area must be protected for sessile species. An unrealistically large proportion of the stock area must be protected for mobile species. If enough area can be protected to sustain a stock, the potential yield in weight from fishing the stock outside the MPA is likely to be lower than with TAC management, and the cost of fishing is likely to be higher. In spite of these disadvantages of MPAs for managing fishing on target species, MPAs are increasingly important in an ecosystem approach to fisheries management to reduce bycatch and habitat and biodiversity alterations. When using MPAs, context matters in terms of costs, benefits, rationales, and strategies. For many small-scale fisheries in developing countries (especially reef fisheries), MPAs may be the only practical approach to managing fisheries. For high seas pelagic fisheries, MPAs may be an effective tool to reduce bycatch. However, the "push" to met arbitrary targets for ocean area enclosed in MPAs does not justify using them if there are other tools available that perform better.

Discussion. It was noted that pelagic MPAs for bycatch species may be more effective than for target species. For example, in the longline fisheries in much of the southern hemisphere, gear restrictions are in place to limit incidental catches of seabirds. There was a discussion on the need to examine impacts of the displacement of fishing effort, as sometimes the displaced effort creates new problems elsewhere.

Large scale horizontal movements of bluefin, albacore, skipjack, bigeye, and yellowfin tunas in the Pacific Ocean. (K. Schaefer)

Presentation. The two primary types of tags, plastic dart tags, and electronic data storage tags (archival tags), utilized in recent years in tagging experiments with tunas were discussed regarding their pros and cons as it relates to understanding large scale horizontal movements of tunas. Life history characteristics, including movements and behavior, are extremely diverse among tuna species. The tropical tunas including skipjack, bigeye, and yellowfin characteristically exhibit restricted movements, low levels of dispersion, and site fidelity, whereas the temperate Pacific bluefin and north Pacific albacore tunas are highly-migratory species, exhibiting transpacific migrations, and exhibit

spatio-temporal spawning habits. Based on the available archival tag data sets for bigeye tuna in the equatorial eastern Pacific Ocean, and yellowfin tuna off Baja California and the Revillagigedo Islands, Mexico, it appears that marine protected areas of appropriate spatial scales could provide tuna conservation benefits for those species within those areas. It is essential to undertake multi-year tagging experiments, preferably utilizing archival tags, within the specific areas of interest, to evaluate whether there is a scientific basis for any policy recommendations towards marine protected areas for tuna conservation. Rational management policies, intended to obtain maximum sustainable yields from stocks of tunas, are dependent on the understanding of species-specific tuna biology, including their movements and behavior.

Discussion. It was noted that there was a need for stock assessments with a finer spatial resolution than used today, as the level of mobility for certain species can be restricted to regions within a Convention Area. In addition, the use of genetic studies has had limited results in terms of the ability to detect sub-populations (meta-population structure) of tunas, although new genetic mark-recapture experiments are being developed and could prove useful. In terms of the potential use of closed areas to protect spawners, it was noted that spawning areas were extremely large (generally tropical waters with sea surface temperature of 24°C or greater) and the closures would need to be huge. It was also noted that the presentation neatly exemplified how generalizations are often made, but the same movement patterns do not apply everywhere. Movements and tuna behavior can be very different depending on where the tunas were actually tagged and released.

A review of the conservation benefits of marine protected areas for pelagic species associated with fisheries. (Sarah Martin)

Presentation. The science underpinning pelagic MPAs is still very much in its infancy yet there is a small but growing body of evidence supporting the use of area-based conservation in specific situations. There are a number of potential mechanisms by which MPAs might be expected to work in terms of providing both conservation and fisheries benefits and specific challenges these face in the pelagic realm. Three mechanisms through which conservation benefits might be realised were identified. The first is the protection of individuals in an MPA for a proportion of their life span large enough to allow populations to recover. Differences in mobility between pelagic species appear to make some more predisposed to protection within MPAs than others and so spatial management in the pelagic environment is likely to provide the greatest benefits to less mobile species groups (small oceanic pelagics; large and small nearshore pelagics) which may gain from relatively small closures if the majority of their distribution is protected. It has been argued that variation in patterns of dispersal between individuals might allow some pelagic HMS to benefit from MPAs, however, this mechanism has yet to receive significant theoretical or empirical backing. It has also been suggested that improvements in habitat quality due to MPAs diminishes the dispersal of mobile species, but this has not been well explored in the pelagic realm.

The second mechanism, protection of a particular life history stage through targeted MPAs, offers perhaps the greatest potential for area-based management of very highly

mobile and large oceanic pelagic species. However, the success of this type of closure is dependent on whether the gains are greater than the losses generated from effort displacement outside the closure and is also highly dependent on the identification of the most appropriate areas to protect in order to provide the greatest conservation benefit and the response of fishing fleets to area closures. The third mechanism is the elimination of incidental impacts of fishing on non-target species and benthic habitats, a key challenge of which is the displacement of fisheries impacts into other sensitive areas.

Benefits to fisheries yield might also be realised through spill-over of adults into adjacent fishing grounds and net export of eggs and larvae, which are closely linked to the conservation benefits. Undoubtedly the role of pelagic MPAs in the conservation and management of pelagic species will remain a major topic of discussion until many more documented empirical studies appear in the literature. In the meantime, whether pelagic MPAs constitute a precautionary measure in the conservation of highly mobile and large oceanic pelagic species should be explored more thoroughly by means of theoretical modeling.

Discussion. There was a discussion on how to measure the percentage of a region that is protected by MPAs. It is difficult to assemble the data from both national and international fishery management organizations. This is made difficult by the fact that some closures are permanent while others are seasonal, or that only some gears are restricted. It was also noted that the presentation's estimate of the number of stocks that are overexploited seemed too high with regards to the RFMO stock assessments. In response, it was explained that these came from an FAO SOFIA Report, which uses definitions that have been under strong criticism by some FAO members and which will likely change to be better aligned with the RFMO definitions. It was also noted that while some tuna species do move vast distances, as noted in Kurt Schaefer's presentation, range shifts occur on a year-to-year basis and fixed-area closures could be beneficial one year and detrimental the next. There was also a discussion of whether certain closures could be detrimental due to behavioral polymorphisms whereby selection would favor less-mobile individuals. It was concluded that more research is needed.

Where would we put closed areas to protect juvenile bigeye tuna? (Shelton Harley)

Presentation. Analyses for the eastern and western Pacific Ocean that examined the potential for time area closures to address the issue of catches of small bigeye tuna in purse seine fisheries were presented. A range of metrics can be used to define hotspots, but the favoured indicators explicitly included economic / target species considerations, e.g., finding areas that could reduce bigeye catches while minimizing loss of skipjack catch. For the western Pacific in particular, different hotspot metrics implied very different hotspot areas which could have very significant implications given the large area covered by EEZs. Overall, the analyses indicated that closed areas were unlikely to provide sufficient reductions in bigeye catches without unacceptable losses in skipjack catches. This is due to the degree of overlap and therefore other fisheries management tools (e.g. fisheries technology solutions) offered more promise.

Discussion. A question was raised if the relative productivities of skipjack and bigeye were the same and as they are not, it is difficult to implement management plans with two valuable stocks that have similar habitats with different productivity.

Shark movements, bycatch distribution, area closures, and the Indian Ocean. (Laurent Dagorn)

Presentation. This was work from studies from John Filmalter and Justin Amandè. Knowledge on the spatial dynamics of animals (at different sizes/ages) is key to design MPAs. Through joint effort of the EU funded MADE project, ORTHONGEL and ISSF, around 50 miniPATs have been deployed on small and large silky sharks in the Western Indian Ocean for various purposes. Although some of these tags were used to investigate the survivorship of sharks released by purse seiners, all these tags (with varying time at liberty) provided information on the movements of sharks in this ocean. Small individuals are capable of moving large distances (1,000-1,500 km in 100 days) but they do not always do this. Similarly some larger individuals do move great distances but the majority seem to show greater fidelity to an area. Using a ZIGAM on data collected by observers onboard European purse seiners and catch data in the Indian Ocean, bycatch per unit of effort (BPUE) has been mapped on the entire fishing grounds of the European purse seine fishery. A South-North gradient appears, the area north of 5°N showing the highest BPUE. Simulations were done to assess the effects of 2 closed areas on bycatch and target species: the IOTC closure area and the area north of 5°N, for different periods of closure.

Discussion. It was noted that in the Indian Ocean the gillnet fishery accounts for 40% of the tuna catch (compared to 25% for the purse seine fishery) and there is practically no bycatch data available for that larger fishery.

Time and area closures for FAD fishing in the Atlantic tropical tuna fisheries. (Daniel Gaertner)

Presentation. Time-area closures have become a frequently used tool to control fishing effort and protect feeding and spawning areas. However, because time-area closure strata are mainly based on biological and ecological considerations, and do not account for fishermen's behavior-at-sea, this type of regulation tool may not entirely achieve its objectives. With the aim of comparing the impact of two different time-area regulations: (1) a moratorium on Fish Aggregating Devices (FAD) sets (1997–2005) and (2) a no-take area for surface fleets (2005–2010) on the dynamics of the European (EU) tuna purse seine fleet operating in the eastern tropical Atlantic, several fishery indicators were evaluated through a Before-After, Control-Impact (BACI) approach. The results showed that prior to any regulation, the fleet used to be concentrated within the Gulf of Guinea area. During the first years of the moratorium on FAD (from November to January within a large region in the eastern Atlantic) there was a movement towards outside the protected area, increasing the total sets on FAD (restricted fishing activity). In general, this moratorium fulfilled its objectives; however, it was not respected during the last years of this regulation. The no-take time-area closure restricted all tuna catches for the surface fisheries but only in November and within a small area (i.e., the Picolo zone). As a result, there was an increase in activities on free schools outside the no-take area. Our findings suggest the use of some simple fishery indicators to understand fleet dynamics as a complement of ecological information before implementing new time area closures.

Furthermore, since tunas are highly mobile species, anticipating the possible re-allocation of effort of purse seiners to adjacent areas in response to the spatial regulation is required to design different candidate time-area closures and to evaluate their effectiveness to protect juvenile tunas.

WCPFC: spatial closures and gear restrictions (purse seine). (Shelton Harley)

Presentation. While there has been some spatial management of longline fisheries (through seabird mitigation), the focus of the talk was on purse seine. The presentation covered both measures introduced by the WCPFC and also the measures introduced separately by the Parties to the Nauru Agreement (PNA) which in most instances proceeded action by the WCPFC. When assessing the success of the high seas pocket closure and the FAD closure it was noted that observing industry response to the measures, in particular effort redistribution, was important. For specifically addressing bigeye tuna bycatch in the purse seine fishery, it was noted that a well-enforced FAD closure produced far greater overall benefits for the fishery than a total closure. Protection of bigeye could occur without significant losses in skipjack tuna catches. Overall the presentation concluded the importance of using empirical data to evaluate the potential impacts of closures, but also closely monitor fishing behavior responses.

Spatial closures in the EPO. (Mark Maunder)

Presentation. The IATTC has implemented two spatial/temporal closures to manage tuna in the EPO. These closures have very different objectives. The first is a temporal closure of the whole EPO to purse seiners classes 4-6 in conjunction with vessel capacity limits to restrict fishing mortality limits to levels that correspond to maximum sustainable yield. The second is a small spatial closure to purse seiners classes 4-6 aimed at reducing the catch of small bigeye tuna. This second closure provides a small additional reduction in fishing mortality for bigeye tuna, which is less productive and therefore requires lower exploitation rates than yellowfin and skipjack tuna. Tagging data suggests that movement of tropical tunas is somewhat restricted and implies that spatially concentrated fishing effort may cause local depletion. Preliminary research for bigeye tuna using spatially structured stock assessment models suggest that local depletion is occurring implying that spatial management may be required. Research continues to be conducted looking at the spatial distribution of silky shark catch and catch rates to identify possible spatial closures to reduce the bycatch in the purse seine fishery. Dynamic closures or spatial prediction of bigeye catch rates related to oceanographic conditions in association with vessel catch limits are being investigated to reduce the catch of bigeye tuna while maintaining the catch of skipjack tuna.

A preliminary investigation into the effects of Indian Ocean MPAs on yellowfin tuna, Thunnus albacares*, with particular emphasis on the IOTC closed area*. (Sarah Martin)

Presentation. A network of large-scale closures with a range of objectives, not all related to fisheries, were introduced in the Indian Ocean during 2010, encompassing the region occupied by IOTC managed tuna fisheries. The impact of this network of closures on the status of yellowfin tuna stocks was evaluated using an age-structured simulation model.

Scenarios examined included the extant situation with the IOTC area closed for one month of the year each to the longline (February) and purse seine (November) gear, and a scenario where the IOTC area was closed all year for both the longline and purse seine fisheries. In both of these scenarios the Chagos and Maldivian closures also applied year round. The extremes of potential changes in fishing behaviour were used: complete elimination of effort that may have occurred inside the closed areas, and total redistribution of effort, based on relative catches in each area and the surrounding ocean (for purse seine fleets only). Model results suggested that the extant network with has little impact on yellowfin tuna either with the effort eliminated or redistributed. However, with a year-round closure of the IOTC area, the network could deliver conservation benefits increasing the spawning stock biomass of yellowfin tuna under the assumption of total elimination of effort from the network area. Nevertheless, in the scenario of a year round IOTC closure with effort reallocated evenly outside the area there was little impact on yellowfin stock status. This analysis suggests it would therefore be precautionary to supplement closures with additional supporting management measures.

Discussion. It was noted that the motivation in creating the Chagos protected area was not fisheries management but rather for general biodiversity protection.

Southern bluefin tuna and fisheries. (Mark Chambers)

Presentation. Southern bluefin tuna (SBT, *Thunnus maccoyii*) is a large, long-lived temperate tuna distributed widely throughout the oceans of the southern hemisphere between latitude of 30o south and 50o south. The global population consists of a single stock and within the range of the species population density is highest on feeding grounds off southern Africa, the south-east Indian Ocean and the Tasman Sea. Adults spawn in warmer waters in a single, spatially confined area south of Java roughly between the months of October and March. Juveniles are harvested by Australian purse seine fishers in the Great Australian Bight off the southern coast of Australia and fattened in tuna farms prior to being exported predominantly to Japan. A wider range of age classes are harvested by international longline fleets. Historically the stock has been subjected to high levels of fishing mortality for extended periods and the stock is presently overfished. The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) has responsibility for managing the stock and rates of exploitation are managed by a specified global Total Allowable Catch. In 2011 a management procedure was adopted incorporating a harvest control rule aimed at achieving a specific goal based on spawning stock biomass by 2035. Management of the fleet that commercially harvest SBT do not incorporate any formal spatial management measures beyond the restrictions that stem from the individual Exclusive Economic Zones of individual nations. Efforts to address bycatch in SBT fisheries are largely focused on bycatch mitigation practices with compliance monitored by observers on vessels.

In 1971 a voluntary agreement between Japanese longline fishers designated specific combinations of areas and months that would be excluded from longline fishing to reduce catch of small SBT and hopefully increase yields. The voluntary measures adopted by the Japanese fishers did not require an overall reduction in fishing and ultimately was unsuccessful in achieving increased catch rates.

Popup satellite archival tags attached to adult SBT have been used to model temperatures and depths preferred by SBT. Models fitted to these data are used to define dynamic zones off eastern Australia to manage bycatch of SBT by Australia's Eastern Tuna and Billfish Fishery. The zones are updated regularly based on near real-time oceanographic data and access of ETBF vessels to the buffer and core zones is dependent upon quota for SBT catch.

Status of tuna stocks. (Victor Restrepo)

Presentation. ISSF maintains an up-to-date report on the status of the 23 major commercial tuna stocks worldwide. This includes all the skipjack, yellowfin, bigeye, albacore and bluefin tuna populations. The status information is based on the stock assessments and deliberations conducted by the scientific bodies of the RFMOs where the best available science and more comprehensive information exists. Stock status is generally quantified on two scales: Fishing mortality and spawning stock biomass. Since the objective of fisheries management tools such as MPAs is often stated to be the control of fishing mortality, it would be useful to see how many stocks have F levels that exceed F_{MSY} and would therefore be the priority stocks. As of the dates of this Workshop: Fifteen 15 of the 23 stocks experience levels of F that are below F_{MSY} and 4 others have F levels only slightly (~5%) above F_{MSY}. The remaining 4 stocks experience levels of F that are substantially higher than the MSY level: WCPO bigeye, IO albacore, and the two Atlantic bluefin stocks. However, the F data for the bluefin stocks is for 2009, before very intensive management controls were put in place, and it is anticipated by many that the updated September 2012 assessment will show reduced F levels for these. This information shows that most commercial tuna stocks are not in such a dire situation as portrayed by some groups. With few exceptions, RFMOs are controlling fishing mortality levels with an array of management tools, including spatial closures as one of them.

The Phoenix Islands Protected Area (PIPA). (Tukabu Teroroko)

Presentation. The Phoenix Islands are a group of eight atolls and two submerged coral reefs lying in the Central Pacific Ocean, an area covering 408,250 km^2. It is the largest marine protected area in the Pacific, and the largest conservation effort to date by a Least Developed Country, the Republic of Kiribati. It represents one of the world's last intact oceanic coral archipelago ecosystems. Most of the area of PIPA is deep-water habitat, with water depths averaging >4000 m. All of the islands of PIPA are uninhabitable for humans without outside support, which is one of the reasons why the habitats have remained so healthy and pristine to date.

Phase 1 of the PIPA includes a total of 12,714 km^2 no-take zones around all of the islands as well as 37,197 km^2 purse seine exclusion zone centered around Kanton. Tuna is the most important natural resource that the Kiribati people have. Approximately 40% of the nation's GDP comes from the selling of tuna fishing licenses to foreign purse seine and longline fleets. For this reason, Kiribati cannot currently afford to make the entire PIPA a no-take reserve if the result of doing so is to reduce tuna fishing license revenues, because fees from tuna licensing are so important to the economy. We and our collaborators, the New England Aquarium and Conservation International, plan to raise

money to create an endowment which would produce interest payable to the Government of Kiribati to offset any tuna fees that Kiribati would forego by closing PIPA to all fishing. To-date, the trust has been set up though not fully funded. There are a number of collaborators working on a valuation of average annual tuna landings from the reserve area, so that we can agree on an annual value to offset tuna revenue.

The current plan for Phase 2 would increase the no take zone to 102,063 km^2. However, these areas were decided upon without a lot of good data on the actual distribution and behavior of tuna in and around the Phoenix Islands and other important structural features, such as sea mounts. As further analysis is conducted, we may determine that other no-take configurations could produce the same or greater ecological benefits than the current default approach of simply increasing the perimeters of existing protected areas. There is a need to develop a detailed research plan with testable hypotheses for tunas that address the questions of distribution, abundance and habitat preferences. In addition, continued monitoring will be needed after implementation to assess outcomes of closures.

Discussion. A point was raised about the phased approach to closures, which in fisheries currently only apply to prohibiting commercial purse seining around some islands where small scale fisheries occur. It was explained that if an endowment of sufficient magnitude is found to replace income from fishing licenses, larger areas will be closed. There were also questions about how monitoring and surveillance were undertaken. It was mentioned that the licensed vessels including purse seiners and longliners have VMS and Fisheries Observers onboard, and there are also aerial and vessel patrols. The U.S Government under the Shipriders Agreement also provides assistance in patrolling PIPA waters.

WWF's views on MPAs as related to tunas. (Bill Fox)

Presentation. WWF is a major global player in establishing and supporting MPAs. It is currently working with governments in 19 regions to establish roughly 10 million Km^2 of MPAs. Focused on the concept of MPA Networks moving forward, including high seas MPAs like the Charlie-Gibbs MPA Network in the Northeast Atlantic. With regard to MPAs for tunas, WWF is working with governments in the Coral Triangle region to identify and create MPAs to protect very tiny tunas. In addition, WWF sits on the Board of ISSF which approved the ISSF Position: "ISSF supports protective closed areas of sufficient size and duration, as determined by sound science, to accomplish clear conservation objectives for tuna populations and the ecosystem upon which they depend" and supported the IATTC large closed area to protect small bigeye in the Eastern Pacific.

Discussion. There was a question about how the target percentage of ocean area to be protected by MPAs was calculated. It was noted the percentage would be higher if time-area closures and gear closures were considered. It was also noted that the differing definitions of MPAs may affect how closures are quantified in different databases. WWF's efforts in the Coral Triangle to prevent growth overfishing were discussed and it was noted that countries were being approached to set aside areas where that is occurring and it was hoped that an overlay system of rights-based management could be put in

place to benefit each country. It was noted that in certain areas, time-area closures could be as effective as permanent closures.

Conservation International's views on the utility of MPAs for managing tuna fisheries. (Elizabeth Selig)

Presentation. Marine protected areas should be considered in a toolbox of options for managing tuna fisheries. They can be useful for streamlining implementation where maintaining spatial exclusions can be less labor intensive than monitoring catch or effort. MPAs can also help to manage bycatch and other ecological impacts of fishing. In addition, MPAs can be used to act as a buffer against uncertainty by reducing the risk of stock collapse, particularly in the absence of good stock abundance estimates. When done in a consultative process, MPAs can also be used to help catalyze political will and management cooperation between countries. MPA effectiveness will depend on the degree of aggregation and migration behavior of different stocks and populations as well as the level of enforcement of MPA regulations. MPAs may provide significant benefits when they are used in conjunction with direct catch or effort controls as part of comprehensive spatial planning.

Discussion. It was noted that for fully optimized spatial management in RFMOs there is always a linkage with the stock assessment and the management. If the management is spatial, then the stock assessment has to be spatially structured. However, the spatial structure of the stock assessments is not fine-scale enough to inform small-scale management. It was noted that in order for something to be optimized, specific goals have to set.

New England Aquarium work on PIPA. (Peter Shelley)

Statement: The New England Aquarium has been working in partnership with the Government of Kiribati and Conservation International on the Phoenix Islands Protected Area since our first expeditionary work in 2002. Our shared goals in that work are three-fold: first, to protect and conserve PIPA as an important oceanic biodiversity reserve; second, to establish PIPA as research baseline to help better understand human impacts on archipelagic and oceanic ecosystems; and third, to develop a sustainable PIPA eco-tourism and marine exploration sector.

The PIPA partnership will be supported through the PIPA Trust. The PIPA Trust is a Kiribati non-profit trust, created to finance the management and monitoring of PIPA as well as providing compensatory support to Kiribati to offset opportunity costs associated with closing PIPA waters to commercial exploitation. No-take reserves have already been established for seven of the eight atolls in PIPA with some subsistence reef fishing allowed on Kanton to support the Kiribati administrative unit stationed there. The government has indicated its interest in closing all of PIPA to commercial fishing as quickly as feasible. NEAq and Conservation International support this strategic objective and are working with the government to that end.

The establishment, expansion and enforcement of “no-take areas” is a critical management tool in PIPA, both for the protection of PIPA’s living marine resources and as

an administrative buffer zone to avoid user conflicts and reduce the risks of illegal activity on the atolls by foreign fishing vessels.

The PIPA partners have an active research agenda to improve our understanding of the likely impacts, both fiscal and environmental, of closing PIPA waters to all tuna fishing. We are at an early stage of understanding how the different tuna species use PIPA waters during their various life stages, the ecological circumstances controlling the presence/absence of different tuna species in PIPA waters, the presence and importance of any resident sub-groups of tuna in PIPA, by-catch issues in the foreign tuna fishery, and the potential impacts of fleet effort displacement in response to closures. We will use this research to help us to optimize the management approaches and protection protocols in PIPA and to direct future research at the highest priority questions.

Discussion. It was discussed if the government received a large enough endowment, the closed area could be extended to affect tuna fisheries. It was noted that they were still at the stages of determining what the tuna conservation benefits of larger closures would be. It was noted that, given the species concerned and the area, it would be relatively inexpensive to tag tunas to figure out their relative residence within the PIPA. Tags are data limited with how much can be stored, though it does appear there is less dispersion for yellowfin tunas tagged at seamounts and islands in the EPO, which would need to be tested in PIPA. It was noted that the resource valuations for things other than the tuna fishery did not amount to much. It was noted that SPC could provide some useful information for the analyses.

The views of the Zoological Society of London. (Matthew Gollock)

Presentation. Recent analysis carried out at ZSL indicates that ~3.2% of the ocean is protected with ~0.2% being no-take marine reserves. My view is that well managed MPAs contribute to biodiversity protection whether this is the primary driver or not. MPAs should be science-lead, include stakeholder collaboration, and implemented and monitored using the ecosystem approach where appropriate. Further, while MPAs are only one in a suite of measures that are required to conserve marine biodiversity, it is important they are established to assess their efficacy and to collect data to ensure they are meeting their objective.

Large area MPAs are a recent development with the Chagos marine reserve being the world's largest no-take MPA (~640,000km2). While the coastal zone of Chagos is relatively well understood, the pelagic realm occupies a huge area of MPA, and the little data we have is derived from fisheries dependent data of variable quality. The Chagos tuna fisheries ceased in October 2010 and there was concern that the MPA was not fit for purpose due to the "highly migratory" nature of target and bycatch species. In reality, it has been shown that tropical tuna species such as yellowfin and skipjack show a great deal of site fidelity and that an MPA the size of Chagos could be very effective in protecting them. As such, it essential to develop fisheries independent monitoring systems to assess the status of pelagic species within the MPA.

After hosting a management workshop relating to Chagos, in collaboration with MRAG UK, two medium term monitoring options were identified: Satellite tagging and fixed-point monitoring stations. Satellite tagging will be used to determine residence in the

MPA, site fidelity and habitat use. The fixed point monitoring stations ZSL is working in collaboration with the University of Western Australia to develop will utilize videography for species I.D., indices of abundance and morphometrics. Demersal baited remote underwater video systems (BRUVs) were modified for pelagic use (Stereo Imaging System for Shark and Tuna Assessment – SISSTAs) and trialed in Western Australia. This pilot study found that these systems were able to function at a range of depths to capture pelagic species on video. Secondary trials will be carried out in the pelagic realm of the Chagos MPA, and it is hoped that they will be used for pelagic monitoring across the Indian Ocean and beyond.

Discussion. The goals of creating the Chagos reserve was discussed, which include biodiversity protection and the area acting as a reference point. It was also discussed what monitoring, control and surveillance efforts were and if a baseline study had been done, although it was noted no baseline study was conducted before the reserve was set up.

Birdlife International perspective. (Phil Taylor)

BirdLife would support the identification of a network of sites aimed at strengthening protection of the high-seas and promotes the inclusion of non-target species in the design and placement of these sites. In fact BirdLife will be presenting its own critical sites for seabird conservation at CBD COP in October of this year. However, BirdLife states that these sites should not be protected at the cost of applying best-practice fishing across wider regional or seascape scales because mortality across any part of a seabirds range will impact populations.

Shark Advocates International (SAI) perspective. (Sonja Fordham)

SAI is generally supportive of the points and goals with respect to MPAs presented by NGO colleagues (particularly Conservation International and WWF). SAI focuses on sharks and rays which are generally in need of basic management measures, so SAI priorities tend toward catch limits and species-specific protections, including some time/area closures, rather than broader and more permanent MPAs. Although more research is needed, it seems that MPAs can best aid conservation of sharks and rays if they cover bycatch hotspots and minimize exploitation of aggregations, particularly at key life stages. For many highly threatened, particularly coastal shark and rays species (such as sawfishes, hammerheads, and dusky sharks), closed areas appear to be key to recovery.

SAI agrees that perceptions and presentations of MPA coverage on a global scale are rather inconsistent, often depending on who is involved in securing them and associated priorities. An overview of measures that illustrates the permanence of each closure as well as distinctions between no-take and limited use areas would be useful, although ISSF is probably not the body to spearhead such a project.

Whereas SAI is science-based, we do not agree that all the scientific objectives and expected outcomes need to be laid out before areas are protected. Certainly fishing and other forms of extraction are not held to the same standard and the precautionary approach can be used to justify action in the case of uncertainty, particularly when public support is strong.

It is important to recognize that, for many NGOs (perhaps not represented here), MPA promotion is not based primarily on creating spillover for enhancing fisheries or other uses, but rather on securing permanent protection of ocean wilderness and biodiversity for inherent value. These perspectives can have considerable weight with politicians and other decision-makers and should be considered.

An overarching concern is the need to avoid measures that sound good, but don't have the promised effect in reality, as this can lead to complacency and, in some cases, give governments a pass to avoid and/or thwart other more effective measures. Follow up initiatives including funding, enforcement, monitoring, impartial evaluation, and resulting adaptations are essential to ensuring that MPAs make the intended contributions to the overall conservation of marine ecosystems and/or key species.

Marine Stewardship Council (MSC) perspective. (Brad Ack)

As a standard setter and fisheries certification program, the MSC does not advocate for any particular forms of fisheries management beyond that which is explicitly called out in our standard. MPAs are not specifically called out in our standard but they certainly may contribute to fisheries being able to meet the standard in some cases. My attendance at this workshop is in the interest of better understanding the role of MPAs as a management tool. In addition, we are doing some of our own research on how Marine Protected Areas may or may not contribute to stock dynamics and whether their existence can be used as a proxy for spawning information in the case of data deficient fisheries.

About the Indian Ocean. (Jan Robinson)

The Indian Ocean faces constraints in terms of data collection, availability and quality, but a precautionary approach is increasingly being adopted, including time/area closures and adoption of precautionary reference points and harvest control rules. It was highlighted that time/area closures require rigorous assessment to determine their efficacy as conservation or management measures. If initial time/area closures are shown to be ineffective, it will be difficult to gain support for further application of spatial measures as part of the manager's toolbox. A recent workshop held in Seychelles on the effects of piracy on fisheries in the western Indian Ocean identified shifts in the type, amount and distribution of fishing effort that have occurred in many fisheries. The implications of piracy for fisheries management in the region are far reaching, including an increase in FAD fishing and a shift in effort to more vulnerable stocks such as albacore. While some have advocated that piracy has created de-facto marine protected areas, it is clear that piracy has instead created new problems in the Indian Ocean. Spatial management must therefore take account of the dynamic nature of these fisheries, with both external threats such as piracy and climate variability leading to rapid changes in fishing and outlook for the stocks.

FISHWISE perspective. (Matt Owens)

One of my primary roles is to advise US retailers about environmentally responsible seafood, which overlaps with the topic of marine protected areas. We have been

supportive of coastal MPAs such as those in California due to the availability of data that demonstrates their value, and recommended that our retail partners also support such protections. However, we have not provided any recommendations on pelagic MPAs due to a lack of data, so this workshop has been very informative and I appreciate the opportunity to learn from all of the experts here.

It appears that based on the tagging data of tropical tunas (skipjack, yellowfin, and bigeye), that these species are not necessarily "highly migratory" and pelagic MPAs in some areas may be a feasible conservation tool. Also, more spatially specific (e.g. smaller geographic units than the entire Indian Ocean or Western and Central Pacific Ocean) stock assessments and management plans would be useful. Another note from Bill Fox's presentation on Indonesia is that FADs used in combination with pelagic MPAs where they are not fished on could help prevent growth overfishing of tunas like bigeye and yellowfin. However, it appears that recent research shows limited residence time of tunas around FADs in some areas, so more research on how arrays of both anchored and drifting FADs and their placement affect tuna behavior would be helpful.

4. CONCLUSIONS

Spatial closures are one of many tools available in fisheries management. There are other "input controls" (gear modifications, closed fishing seasons, and limits on fishing capacity) and "output controls" (such as catch quotas) that are part of the traditional fisheries management toolbox. In fact, many tuna fisheries are managed with a combination of several tools, each of which may work more effectively than others to tackle a particular issue or may be more effective in conjunction with each other.

The Workshop concluded that spatial closures alone would be an ineffective and inefficient means to manage tuna fisheries. However, closures can provide substantial benefits if the objectives are clearly identified, and there is a reasonable basis in support of deciding their temporal and spatial scale and for their monitoring and enforcement. Spatial closures may be more effective when implemented with other catch or effort controls.

Workshop participants also felt strongly that adoption of MPAs should not become an excuse for not implementing other necessary/recommended management measures. MPAs should be used when they are the best option to achieve an objective concerning sound management of tuna fisheries (including their ecosystem), not primarily to achieve targets for the percentage of ocean area protected.

4.1 Objectives of closures (MPAs)

MPAs can have different objectives. The list below provides the Workshop's views on the most common objectives.

Reduce fishing mortality (F) on tunas

- If used alone to reduce F, MPAs probably need to be very large for tropical tunas and huge for temperate tunas. Archival tagging experiments conducted throughout a stock's range of distribution could help to identify appropriate scales and locations.
- If used together with other management measures, closures may provide a buffer to reduce the risk of overexploitation.
- Spatial closures basically act to make fishing less efficient if they are placed in areas of high tuna density.
- If the fishing effort that occurs in an area to be closed is shifted outside or if the closed area is not large enough, the intended benefits will not be accrued. In addition, the displaced effort may create new problems that were unforeseen when the closure was being planned.
- When used in isolation, closures will be a blunt and inefficient means of controlling fishing mortality. Other measures (e.g., effort limits, catch quotas, etc.) will often perform better by themselves.

Increase productivity of tuna fisheries

- Higher yield-per-recruit (and hence sustainable yields) can be obtained for most tuna species if the catches of small fish are minimized. Small bigeye and yellowfin tunas are distributed over very large areas, and therefore reduction of their catches will generally be better achieved through gear restrictions or fishing operation limitations. Some of the bluefin tunas have areas of small fish concentrations, where closures could work.
- For stocks that have a reduced spawning biomass, reducing fishing mortality on spawners could result in increased recruitment and productivity. Spawning areas of tropical tunas cover vast distances, so this tool would likely be ineffective. However, the bluefin tunas have restricted spatial spawning distributions and seasonal closures could be used.
- Targeted closures aimed to protect the spawners in different places at different times would probably be more efficient than permanently closed areas.

Protect genetic diversity for tunas and other species

- Fishing is usually a selective process, for example by taking the faster growing individuals of a cohort. An MPA can help reduce this impact but, for tunas, the area may need to be very large. Alternatively, controlling fishing mortality, as discussed above, may be more effective.
- In the case of meta-population structure, a series of strategically located MPAs could aid in maintaining that structure. However, difficulties remain in understanding the meta-population structure in the first place.

Reduce conflicts between user groups

- Examples of closed areas to reduce conflicts between different fisheries are plentiful, especially in coastal areas (for example, between commercial and subsistence fisheries). Success of such MPAs in reducing conflict is higher when stakeholders are involved in the decisions. In the high seas, it may be more difficult to implement closures for this purpose.

- When conflicts are between different types of users (fishers, shipping, etc.,) Marine Spatial Planning may be a more comprehensive approach.

Reduce bycatch of associated species

- Pelagic area closures could be relatively more effective in achieving this objective than the other objectives listed in this report.
- There may be different issues and reasons for reducing bycatch (e.g. protected species versus species of no market value), which can vary in time and area and need to be taken into account.
- In many cases, other management measures (e.g., gear modifications) may be more effective to reduce bycatch.
- In general, many of the same issues in reducing fishing mortality for tunas apply to bycatch species e.g. deciding when, where and how large a closure is. Identification of "hot spots" should involve examining both areas of high bycatch:catch ratios, but also areas of high total catch. Examining ensembles of species could help identify potential closures that reduce bycatch of more than one species.
- Care should be taken to avoid transferring the problem elsewhere or to another species due to redistribution of fishing effort.
- Dynamic closures may be necessary in some cases to accommodate temporal changes in species distributions.

Sustain biodiversity

- Sustaining biodiversity is often the stated reason behind calls for MPAs. The connection between tuna fisheries management and biodiversity protection is somewhat attenuated. In the oceanic environment, closures could potentially have to be very large to ensure meeting this goal, depending on the location and features of interest.
- In practice, it may be easier to use targeted closures to deal more directly with species of concern (see reducing bycatch, above).
- In some cases, a closure can potentially reduce biodiversity if fishing effort is redirected and concentrated outside the closed area.

Maintain relatively undisturbed ecosystems

- As in the previous objective, oceanic closures would probably have to be very large to meet this goal.
- This objective may also include maintaining ecosystem processes.
- Other than the effect of removal of target and non-target species by the fishery and although there is active debate over hypotheses surrounding potential ecosystem-level effects by drifting FADs themselves, there was no evidence presented at the workshop that tuna fisheries disturb ecosystems (e.g., such as altering habitat or ecosystem function.

4.2 Evaluation of spatial closures

Evaluation of the effectiveness of spatial closures is important. Otherwise, there is a potential risk to "feel good" about hypothetical but non-existent benefits, and lose focus on other management tools that could be more effective.

- Evaluating MPAs can be difficult, especially if no baseline data are collected before the area is closed. For example, if the objective is to sustain biodiversity, it would be ideal to quantify biodiversity in the candidate area before it is closed so that progress can be evaluated in subsequent years. The baseline data should be as detailed as possible.
- In some cases baseline data will be unavailable. Still, monitoring should be conducted to learn if there need to be adaptations in order to meet the objectives. Trend data from inside and outside MPAs can be used in conjunction with catch or effort distribution statistics.
- Evaluation should be based on the best available science. Sometimes evaluations are made using unreasonable or inconsistent assumptions. For example, a study that examines multiple species may use assumptions for the tuna stocks that are not consistent with the best available science for these stocks.

4.3 Implementation and enforcement issues

Without monitoring and enforcement, closures can be quite ineffective. Addressing the following issues should help to improve effectiveness:

- Compliance with the rules is usually much higher when stakeholders are involved in setting them.
- In the high seas, closures probably need to be established with the RFMO (but sometimes RFMOs don't have a clear mandate, e.g. for some bycatch species). Also, there needs to agreement and cooperation by the countries involved (UNCLOS Article 118).
- Many important Marine Spatial Planning activities of today are not really taking fisheries into account, perhaps in part because RFMOs are well established and they only have a mandate for fisheries. This should be addressed.
- There are several enforcement tools such as VMS, patrolling, port State inspections and observer programs. There is substantial variability between countries both in monitoring and enforcement (including mechanisms to ensure compliance). Enforcement will be more successful if funding mechanisms are considered from the start, at the design stage.
- As noted elsewhere above, fishing effort is often redistributed after closures are imposed, creating problems that were not foreseen initially. Management outside the closures is therefore also important to consider.
- Spatial closures can be static or dynamic in space. Environmental influences can change the distribution of the species of interest, and this should be considered in the design of the closures.

- Opportunities for cooperation and improved implementation would arise through better communication between fisheries and biodiversity specialists, both at the scientific and government levels.

5. RECOMMENDATIONS

Based on these discussions, the Workshop recommended that:

1. The ISSF produce a report quantifying the extent to which spatial closures are used by tuna RFMOs to manage fisheries and bycatch species.
2. The ISSF and others promote the use of an analyses that compare and contrast the effectiveness of MPAs (closures) with other fishery management tools and in combination, with a focus on tunas. Depending on the levels of uncertainty, some management tools may be more effective than others; simulation and other types of analyses could be useful to address this. The analyses should take into account implementation and enforceability issues and the potential costs of the different management options.
3. Fishery managers and stakeholders in general do not just consider MPAs in isolation, but in conjunction with other types of management tools.
4. The design of spatial closures be based to the degree possible on site-specific studies for species of concern. Spatially-structured assessments that incorporate fish movement should be used in exploring management alternatives.
5. Some RFMOs collect and receive fine-scale, high-resolution fisheries data. Detailed operational data (e.g. set-by-set) should be made available to RFMO scientific bodies in order to enable these analyses.

6. ADJOURNMENT

The Chairman thanked all the participants for their constructive engagement in discussions, and especially the presenters. The Workshop was adjourned on July 21. The report was adopted by correspondence.

Appendix 1. References and background reading material

Agardy, T., di Sciara, G. N., and Christie, P. (2011). Mind the gap: Addressing the shortcomings of marine protected areas through large scale marine spatial planning. Marine Policy, 35(2), 226-232.

Agardy, T., Bridgewater, P., Crosby, M. P., Day, J., Dayton, P. K., Kenchington, R., Laffoley, D., McConney, P., Murray, P. A., Parks, J. E., and Peau, L. (2003) Dangerous targets? Unresolved issues and ideological clashes around marine protected areas. Aquatic Conservation: Marine and Freshwater Ecosystems, 13(4), 353-367.

Apostolaki, P., Milner-Gulland, E. J., McAllister, M. K., and Kirkwood, G. P. (2002) Modelling the effects of establishing a marine reserve for mobile fish species. Canadian Journal of Fisheries and Aquatic Sciences, 59(3), 405-415

Block, B.A., Jonsen, I.D., Jorgenson, S.J., Winship, A.J., Shaffer, S.A., Bograd, S.A., Hazen, E.L., Foley, D.G., Breed, G.A., Harrison, A.-L., Ganong, J.E., Swithenbank, A., Catleton, M., Dewar, H., Mate, B.R., Shillinger, G.L., Schaefer, K.M., Benson, S.R., Weise, M.J., Henry, R.W., and Costa, D.P. (2011). Tracking apex marine predator movements in a dynamic ocean. Nature, 475: 86-90.

CCSBT (2011) Report of the Sixteenth Meeting of the Scientific Committee. 19-28 July 2011, Bali, Indonesia.

Chaboud, C., and Galletti, F. (2007). Les aires marines protégées, catégorie particulière pour le droit et l'économie ? Mondes en Développement, 35, 27-43.

Childers, J., Snyder, S., and Kohin, S. (2011) Migration and behavior of juvenile north Pacific albacore (*Thunnus alalunga*). Fish. Oceanogr. 20(3): 157–173.

Davies, T.K., S. Martin, C. Mees, E. Chassot and D.M. Kaplan (2012) A review of the conservation benefits of marine protected areas for pelagic species associated with fisheries. ISSF Technical Report 2012-02. International Seafood Sustainability Foundation, McLean, Virginia, USA.

FAO. Fisheries Management. 4. Marine Protected areas and fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 4, Rome, FAO. 2011. 198p.

Farley, J. H., Davis, T. L. O., Gunn, J. S., Clear, N. P., and Preece, A. L. (2007). Demographic patterns of southern bluefin tuna, *Thunnus maccoyii*, as inferred from direct age data. Fisheries Research, 83(2-3), 151-161.

Game, E. T., Grantham, H. S., Hobday, A. J., Pressey, R. L., Lombard, A. T., Beckley, L. E., Gjerde, K., Bustamante, R., Possingham, H. P., and Richardson, A. J. (2009) Pelagic protected areas: the missing dimension in ocean conservation. Trends in Ecology and Evolution, 640 24(7), 360-369.

Grüss, A., Kaplan, D. M., Guenette, S., Roberts, C. M., and Botsford, L. W. (2011) Consequences of 655 adult and juvenile movement for marine protected areas. Biological Conservation 144(2), 692-702.

Harley, S. J. and Suter, J. M. (2007) The potential use of time-area closures to reduce catches of bigeye tuna (*Thunnus obesus*) in the purse-seine fishery of the eastern Pacific Ocean. 670 Fishery Bulletin-National Oceanic and Atmospheric Administration, 105(1), 49.

Hartog, J. R., Hobday, A. J., Matear, R., and Feng, M. (2011). Habitat overlap between southern bluefin tuna and yellowfin tuna in the east coast longline fishery – implications for present and future spatial management. Deep Sea Research Part II: Topical Studies in Oceanography, 58(5), 746-752.

Hilborn, R., Stokes, K., Maguire, J., Smith, T., Botsford, L., Mangel, M., Orensanz, J., Parma, A., Rice, J., Bell, J., Cochrane, K., Garcia, S., Hall, S., Kirkwood, G., Sainsbury, K., Stefansson, G., and Walters, C. (2004) When can marine reserves improve fisheries management? Ocean and Coastal Management, 47: 197-205.

IOTC (2010) Estimates of the Catch Reductions that might have been achieved historically through the application of the Time/Area Closures proposed in IOTC Resolution 10/01. 705 IOTC-SC-2010-14. [Available at: http://222.iotc.org/files/proceedings/2011/sc/IOTC-2011-SC14-R%5BE%5D.pdf]

ISSF (2012). ISSF Stock Status Ratings, 2012: Status of the world fisheries for tuna. ISSF Technical Report 2012-04A. International Seafood Sustainability Foundation, Washington, D.C., USA.

Itano, D.G., and Holland, K.N. (2000) Movement and vulnerability of bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) in relation to FADs and natural aggregation points. Aquat. Living Res. 13(4): 213-223.

Kaplan, D.M., Chassot, E., Gruss, A., Fonteneau, A. (2009) Pelagic MPAs: The devil is in the details. Science 313: 43–44.

Koldewey, H. J., Curnick, D., Harding, S., Harrison, L. R., and Gollock, M. (2010). Potential benefits to fisheries and biodiversity of the Chagos Archipelago/British Indian Ocean Territory as a no-take marine reserve. Marine pollution bulletin, 60(11), 1906-15.

Le Quesne, W. J. F. and Codling, E. A. (2009) Managing mobile species with MPAs: the effects of mobility, larval dispersal, and fishing mortality on closure size. ICES Journal of Marine Science: Journal du Conseil, 66(1), 122-131.

Martin, S.M., Mees, C., Edwards, C., and Nelson, L. (2011) A preliminary investigation into the effects of Indian Ocean MPAs on yellowfin tuna, *Thunnus albacares*, with particular emphasis on the IOTC closed area. In: IOTC Proceedings IOTC–2011–SC14–40.

Mees, C., Fonteneau, A., Nishida, T., Dagorn, L., Robinson, J., Mosquiera, I., Murua, H., Goujon, M. (2009) The potential role of pelagic Marine Protected Areas for tropical tunas in the Indian Ocean. IOTC-2009-SC-INF18.

Polacheck, T. (1990) Year around closed areas as a management tool. Natural Resource Modeling, 4(3), 327-354.

Powers, J. and Abeare, S. (2009) Fishing effort redistribution in response to area closures. Fisheries Research, 99(3), 216-225.

Rassweiler, A., Costello, C., and Siegel, D. a. (2012). Marine protected areas and the value of spatially optimized fishery management. Proceedings of the National Academy of Sciences of the United States of America, 109(29). doi:10.1073/pnas.1116193109

Schaefer, K.M., and Fuller, D.W. 2009. Horizontal movements of bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean, as determined from conventional and archival tagging experiments initiated during 2000-2005. Inter-Amer. Trop. Tuna Comm. Bull. 24(2): 191-247.

Schaefer, K.M., Fuller, D.W., and Block, B.A., 2011. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the Pacific Ocean off Baja California, Mexico,

determined from archival tag data analyses, including unscented Kalman filtering. Fish. Res. 112(1-2): 22-37.

Shingu, C. (1979) Ecology and stock of Southern bluefin tuna. Japan Association of Fishery Resources Protection. Fisheries Study 31.

Sibert, J., and Hampton, J. 2003. Mobility of tropical tunas and the implications for fisheries management. Mar. Pol. 27(1): 87-95.

Stefansson, G. and Rosenberg A. A. (2006) Designing marine protected areas for migrating fish stocks, Journal of Fish Biology 69 (supplement C): 66-78

Sibert, J. et al (2011) Prospects for effective conservation of bigeye tuna stocks in the Western Central Pacific Ocean. In: Western and Central Pacific Fisheries Commission Scientific Committee WCPFC-SC7-2011/MI-WP-05. pp. 1-26.

Sumaila, U. R., Zeller, D., Watson, R., Alder, J., and Pauly, D. (2007) Potential costs and benefits of marine reserves in the high seas. Marine Ecology Progress Series, 345, 305-310.

Torres-Irineo, E., Gaertner, D., de Molina, A. D., and Ariz, J. (2011) Effects of time-area closure on tropical tuna purse-seine fleet dynamics through some fishery indicators. Aquatic Living Resources, 24(4), 337-350.

Watson, J. T., Essington, T. E., Lennert-Cody, C. E., and Hall, M. A. (2009) Trade-Offs in the Design of Fishery Closures: Management of Silky Shark Bycatch in the Eastern Pacific Ocean Tuna Fishery. Conservation Biology, 23(3), 626-635.

West, C. D., Dytham, C., Righton, D., and Pitchford, J. W. (2009) Preventing overexploitation of 890 migratory fish stocks: the efficacy of marine protected areas in a stochastic environment. ICES Journal of Marine Science: Journal du Conseil, 66(9), 1919-1930.