Transforming Coral Reef Conservation: Reef Fish Spawning Aggregations Component

Working Group Report

22 April 2002

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EXECUTIVE SUMMARY

The Nature Conservancy (TNC) and Conservation International (CI) are leading a broad, highly collaborative initiative to transform the way coral reef marine protected areas (MPAs) are selected, designed and managed. The Transforming Coral Reef Conservation (TCRC) program seeks to build the concept of **survivability** into large-scale planning and individual site strategies. This will allow governments and the conservation community to go beyond portfolios of sites based on representation of biological diversity, to construct MPA *networks* built on *natural factors* of mutual *replenishment* and *resilience*. One important ingredient of these networks is the protection of reef fish spawning aggregation sites (FSAS). An expert working group was assembled to propose components of the TCRC initiative related to FSAS protection. This is the report of that group's deliberations.

Among the planning parameters given to the FSAS working group were that the global initiative would focus on a relatively limited number of MPA networks (approximately 5-7), but would also fund cutting edge research of global significance and leverage experience in the priority focus networks to other coral reef MPAs and MPA networks around the world through a proactive program of learning and outreach. With this context, this group proposes the following **ten-year goals** for the fish spawning aggregations component:

- All high-priority spawning aggregation sites within the area encompassed by the TCRC focus MPA networks are fully protected and regularly monitored.
- Through leverage, a majority of high priority spawning aggregation sites globally outside of these networks are fully protected and regularly monitored.
- Scientifically competent knowledge base developed, through research, to guide preferred management options for reef FSAS and implementation and evaluation of MPA networks.

Characteristics of Spawning Aggregations

Two distinct types of spawning aggregation, Resident and Transient, have been broadly defined based on the frequency they form and the distance individual fishes travel to the aggregation site. A Resident spawning aggregation draws individuals from a relatively small and local area. The spawning site can be reached through a migration of a few hours or less and often lies within the home range of the participating individuals. Resident spawning aggregations usually (1) occur at a specific time of day over numerous days, (2) last only a few hours or less, (3) occur daily during an often lengthy spawning season, and (4) can occur year round. A single Resident spawning aggregation may represent only a fraction of the annual reproductive effort for participating individuals. A Transient spawning aggregation draws individuals from a relatively large area (tens to hundreds of kilometers). Individuals must travel days or weeks to reach the aggregation site. Transient spawning aggregations often (1) occur during a very specific portion of one or two months of the year, (2) persist for a period of days or at most a few weeks and (3) do not occur year round. A Transient spawning aggregation may represent the total annual reproductive effort for participation individuals. The distinction between Resident and Transient spawning aggregations is useful when discussing management measures.

There is a variety of threats to the perpetuation of spawning aggregations, both direct and indirect. The single greatest threat is from fishing. At many sites, this is compounded by additional threats facing coral reefs worldwide, including climate induced coral bleaching, coastal development, and upland sources of sediments and pollutants. Increased tourism is also putting pressure on reefs, both by indirect effects of coastal development but also by divers, anchors, and boat traffic disturbing the normal courtship and spawning behaviors of reef fish within spawning aggregations.

To prioritize sites for conservation, as an initial approach and based upon the information currently available, the working group selected five criteria to evaluate potential sites: (1) multi-species aggregation present, (2) transient aggregation present, (3) pristine, (4) heavy exploitation, and (5) relatively high levels of endemism. Chapter 3 includes an initial listing of sites in the Tropical Western Atlantic and Indo-Pacific according to these criteria.

A set of criteria was also developed to enable the identification of species that might be particularly at risk and require priority of conservation action, or further investigation. Seven criteria were selected. Large maximum size, long life and late sexual maturation (i.e., sexual maturation occurring after several to many years) were all considered to be particularly important life history characteristics for denoting vulnerable species. Although these characteristics often co-occur (particularly long life and late sexual maturation), this is not always the case. Transient aggregations were identified to represent more of a conservation concern than resident spawning aggregations, although some particularly vulnerable species appear to form resident aggregations. Because many reef fishes are not able to withstand more than light levels of exploitation, another criterion used to identify vulnerable species was heavy exploitation, now and/or predicted for the future. Also included as relevant criteria, albeit of lesser importance, were species already listed in the IUCN Red List, and low natural levels of abundance (uncommon or rare species). Based on these criteria, Chapter 3 identifies priority species for conservation by geographic region and family.

Management of Spawning Aggregation Sites

There is an urgent need to consider options for the protection, management, and conservation of spawning aggregations. Conservation success is linked to better understanding of the biological importance of spawning aggregations, experience in applying management options, and generating public interest in – and widely understandable economic benefits from – healthy reef fish spawning aggregations. Currently, there is little management of reef fish spawning aggregations in place globally, and, of that in place, little in the way of stated objectives and even fewer indications of the outcomes of management. Many management strategies have been put in place only after it has been recognized that fishers are targeting and over-fishing spawning fish.

In summary, the initiatives already in place address mainly seasonal combined with spatial (spawning season combined with spawning site) closures (season can be closed for days to months) for single or for multi-species sites. Less frequently is the application of spawning season-only closures, although sometimes these do not cover the entire temporal extent of spawning activity due to insufficient information on duration of spawning, or to lack of support from fishers or managers. Occasionally spatial-only regulations are in place and these are often already within MPAs. Less frequently, we see the use of gear restrictions on traditionally fished aggregations, including limits to, or complete restrictions on, spears, traps, or nets during the aggregation period and on the aggregation site. Other measures (such as quotas, size restrictions, and limits of foreign vessel access or export) have not been specifically used, although moratoria have occasionally been implemented in cases of extreme declines, and often too late.

Preferred Management Options

We suggest that **all aggregation sites that support transient spawning aggregations of multiple species be placed in permanent (year-round) no-take zones**. In addition, we recommend that all take of each aggregating species be prohibited during its respective spawning season. This insures the safety of FSAS that are not known to resource managers, lessens the likelihood of poaching, and simplifies enforcement. Moreover, multi-species sites should be afforded year round site protection (no take), and species that have many small aggregations at many sites over a wide area should be managed with seasonal restrictions during the reproductive period (e.g., *Plectropomus leopardus*). In all cases, inter-annual variability in the location and timing of FSAS need to be factored in to the final determination of the specific season/area to be protected. Other more general approaches might also be necessary as ancillary approaches through nested management and to aid compliance of species-specific spawning aggregation protection measures (examples are export controls, the prohibition of diving with hookah near spawning aggregations, or use of gill nets in migration routes to and from spawning aggregations which are not already incorporated under area closures).

Management of transient spawning aggregation sites that support a single species must be considered on a region-by-region basis. In regions where destructive fishing practices occur, the site should be included in a permanent no-take zone to protect the habitat as well as the aggregating fishes. We also recommend that all take of all species that form transient spawning aggregations be prohibited during their respective spawning seasons. Species that form many small aggregations at many sites over a wide-area represent a mid-point in our model contrasting transient and resident types of aggregation spawners. The only practical means of managing this type of aggregation is to enforce seasonal prohibition of catch and possession of the species during the reproductive period.

Resident spawning aggregations need to be evaluated on a region-by-region basis. Where these species are targeted management is required. In all cases, inter-annual variability in the location and timing of FSAS need to be factored into the final determination of the specific seasons/area to be protected.

Although management of the stock during the non-reproductive period is beyond the scope of this document, the working group recognizes the urgent need for general fisheries management plans to be enacted for all reef fishes and also recognizes that controlled non-aggregation fishing could itself act as an incentive to protect aggregations sufficiently to ensure the overall good health of the stock itself. In the absence of general fishery management measure(s) the stock remains at risk, despite measures introduced to protect the spawning aggregation.

Priority Research Questions

The working group identified six priority areas for further research, which are discussed in Chapter 5. They are:

- Connectivity. Connectivity with respect to spawning aggregations can occur through two distinct mechanisms. The first is the movement of fish as eggs and larvae from a spawning aggregation site to a settlement area via dispersal in the plankton lasting several weeks or more. The second is the movement of adults from their normal residence sites to a spawning site (= "catchment area"). Both must be studied to determine the relationship of a particular spawning aggregation or site to the surrounding area.
- Can over-exploited spawning aggregations recover?
- What features characterize a FSAS?
- Differences between and within species in spawning time, site, and behavior
- The impact of snorkeling, diving, and boating on FSAS
- What are sustainable non-FSAS catch levels?

Monitoring and Evaluation

Monitoring is essential to determine how populations respond to seasonal closures or total closures on high priority sites. Results can be used to trigger management responses, and to set performance indicators for adaptive management. It is inevitable that fishers restricted from fishing FSAS will demand evidence that such restrictions are effective and therefore warranted. Whenever possible, fishers and other stakeholders should be involved in all aspects of the design and implementation of monitoring and in the processing and dissemination of the generated information.

The objectives of a monitoring program must be carefully defined. Chapter 6 highlights key considerations that should be taken into account in monitoring FSAS. A manual of spawning aggregation monitoring methods is currently being developed by members of the Society for the Conservation of Fish Aggregations. Pending completion of this manual, the following should be considered priority objectives, with monitoring designed accordingly to:

- measure impacts of management regulations (e.g. closures)
- assess trends (declines/recovery) in aggregation populations
- establish long term datasets on aggregation use

- provide predictive power for other sites/species
- provide some insight into reproductive biology
- maintain field presence to deter poaching
- encourage ownership by traditional resource owners, government (rangers, fisheries officers), and fishers
- define multi-species versus single species aggregation sites

Implementation of Adaptive Management

Chapters 7 outlines the broad steps required to implement the identified actions for the conservation and management of reef FSAS, as a component of the TCRC initiative. Specific goals, benchmarks, and initial budget estimates are included in Chapter10. Chapter 8 discusses the importance of outreach to involve resource owners, stakeholders, and other users in the design and implementation of management activities. Chapter 9 lists global and regional partners that might be engaged in implementing FSAS management and conservation activities.

Three sets of activities are recommended:

Research. A research program is proposed to address questions that fall into two categories – those that are of global significance and those that are focused on issues related to one or more specific MPA networks. With respect to the former, the program should make available funds for competitively-awarded and peer reviewed research to be administered by a recognized and appropriate scientific organization. Research undertaken at the network level is focused more on management and conservation questions related specifically to particular networks and/or sites within those networks. Such research should be identified and administered within the network management structure. Where appropriate, and consistent with scientific merit, priority should be given to utilizing "in network" agencies, institutions, and individuals.

Implementation within TCRC focus networks. FSAS management requirements must be fully integrated into the overall design, establishment, and management of MPA networks. Access to prompt technical assistance will be required. A mechanism should be established for providing technical response "teams" within each network, where feasible. The following activities are needed as part of comprehensive FSAS conservation strategies in each network: (1) identify and prioritize sites within a network area; (2) initiate outreach activities; (3) establish the sites, incorporate into MPA and MPA networks (this may require extending existing MPA boundaries, or creating new MPAs around FSAS); (4) information needs on the FSAS must be collected, management related questions identified, and outreach programs fully implemented for an exchange of information; (5) monitoring, evaluation, feedback and adaptive management procedures established; and (6) lessons learned documented and disseminated.

Global Outreach/Leverage. There is a clear recognition that the TCRC focus networks will not protect enough reef FSAS globally. Therefore, it is essential that the activities conducted under this initiative be leveraged to areas and sites outside the focus networks through (1) supporting the development and maintenance of the Society for the Conservation of Reef Fish Aggregations (SCRFA) FSAS database; (2) developing and widely distributing best practices guidelines that have documented the lessons learned from both the research and management components; (3) identifying FSAS/areas of global significance that are not included in the networks and ensure that the methodologies, tools, best practices are applied by appropriate partners at those sites; (4) actively seeking out other FSAS conservation activities and learning from their experiences; (5) using modern communication techniques, local and international media to reach out to the public in order to mainstream FSAS conservation; and (6) identifying and participating in international and regional scientific, conservation, and management forums in order to influence and change a range of national, regional and international policies that affect successful conservation and effective management of aggregating reef fish at and outside spawning aggregations.

1. INTRODUCTION

The Nature Conservancy (TNC) and Conservation International (CI) are leading a broad, highly collaborative initiative to transform the way coral reef marine protected areas (MPAs) are selected, designed and managed. Our goal is to catalyze a worldwide effort to establish and protect networks of coral reef MPAs within high-biodiversity eco-regions that are ***designed to survive, managed to last, and connected like strings of pearls across our ocean planet.***

The initiative will focus marine conservation efforts on coral reefs and associated habitats. Coral reefs represent one of the greatest storehouses of biodiversity on Earth, and provide food and income to sustain more than hundreds of millions of people in Asia alone. They play a vital role in stimulating nature tourism—the industry's fastest growing segment worldwide. Coral reefs also provide critical ecological services, such as protecting our coasts from storms and erosion. An important source of medicinal products, coral reefs supply pharmaceuticals that fight cancer and heart disease, and materials for bone implants and sunscreens.

In principle, existing MPAs are designed to address a range of threats—e.g., destructive fishing practices, over fishing, pollution, coastal development, siltation, ineffective governance—that can be managed locally. In practice, however, many protected areas lack any form of effective management. They are selected opportunistically, without the benefit of a strategic framework or relationship to major sources of threats. Moreover, even the most effectively run MPAs may be vulnerable to the global threats of the new century, such as climate-related coral bleaching, which cannot be managed at site.

This initiative seeks to build the concept of ***survivability*** into large-scale planning and individual site strategies. This will allow us to go beyond portfolios of sites based on representation of biological diversity to *networks* built on *natural factors* of mutual *replenishment* and *resilience*, where networks implies connectivity and some mutually replenishing function, and resilient means that they are able to recover close to their former state following a catastrophic event. The initiative will provide the scientific basis for establishing networks of resilient MPAs and apply this new understanding to existing and new protected areas. In addition, it will mobilize significant resources to improve MPA management, increase the cost effectiveness of protected area operations, and assure long-term financial sustainability.

The global initiative will accomplish this in two ways:

1. Together with a range of local, national, and international partners, we will apply these new principles to design, effectively manage, and sustain MPA networks that encompass coral reef ecosystems that have the highest and most important biological diversity in the world. During the next ten years, the program will mobilize global efforts around 3-4 multinational MPA networks (e.g., Meso-American Barrier Reef, Gulf of California, Sulu Sea to Okinawa, Western Pacific/New Guinea to Sulu Sea, Banda Sea-Northern Maluku, Red Sea, the east coast of Africa from Somalia to

Mozambique) and 2-3 nationwide or sub-national networks in high priority areas (e.g., Palau, Brazil, Galapagos). In these high priority areas, we will seek to have viable MPA networks in place with substantial progress made on management effectiveness and long-term sustainability at the end of ten years.

2. On the basis of up-to-date and cutting edge research, we and our partners will provide guidelines and improved capacity that will allow coral reef MPAs and MPA networks to be designed and managed to survive global – in addition to local – threats. In addition, the initiative will leverage experience in the priority focus sites to other coral reef MPAs and MPA networks around the world through an integrated and proactive program of learning and outreach.

1.1 Baseline/Starting Point

The initiative builds on the existing universe of MPAs and on existing guidelines and approaches to MPA design, management, and monitoring. There are two dimensions to this baseline:

- The current institutional and technical capacity of MPA managers and other key stakeholders, current management approaches, and current resources available for MPA management—or, perhaps more accurately, the shortfall between what exists and what is needed in each of these areas; and
- The range of threats that MPAs face and MPA managers are presently attempting to address.

To put into place lasting MPA networks, these current deficiencies and threats must be addressed *in addition to* the new concepts of resilience and survivability that will help these MPAs survive the emergent, threats unmanageable at site.

1.2 Components of the Initiative and Linkages Among Them

1.2.1 Priority setting and eco-regional planning

This component will refine and update information on marine biodiversity, bring together various planning and priority setting approaches, and seek to:

- identify priority marine eco-regions for focus under the initiative; and
- define specific steps to identify networks of MPA sites within these eco-regions, including at multi-national, nationwide and sub-national scales.

These networks will serve to protect diverse or relatively diverse reef communities, protect unique or special biological resources, and be designed with resilience of their component MPAs as a key strategy. Specifically, mechanisms will need to be incorporated in the procedures for identifying and establishing MPA networks to include the following elements of resilience, as additional data become available: resistance to coral bleaching, reef fish spawning aggregations, and connectivity. This component of the program will be integrated with others that address these three elements of resilience, and others may be added later as implementation of the program progresses. It will also provide the basis for identifying gaps in the current universe of MPAs that need to be filled in order to achieve the goal of resilient networks able to survive local and global threats.

1.2.3 Coral bleaching, fish spawning aggregation sites (FSAS) and connectivity

These science components will address identified emerging global threats to MPAs and MPA networks and/or enable these networks to better survive these global threats. In each area, actions will be taken to apply the best current science in revised guidelines on MPA selection, design, and management. In addition, there is a need for continuing research to further understand these phenomena. This is expected to be a continuing process, as our scientific understanding of these phenomena continually improves it will be reflected in successive iterations of guidance and application. New global threats may also be identified over the course of the program that need to be added to the science agenda and MPA guidance. The product of these components will:

- be used to review existing MPAs to ensure that, to the extent possible, they are reflected in the design and management of these areas, and
- feed into priority setting, eco-regional planning, and the identification of new MPAs that need to be included within networks.

1.2.4 Sustainable financing

The initiative will develop an integrated set of sustainable financing mechanisms, including approaches that:

- provide economic incentives for the creation of marine reserves;
- increase the cost effectiveness of management, build support for conservation action through community participation, and use market mechanisms to support conservation (e.g., joint planning, co-management, conservation concessions, privately owned reserves, delegation of management responsibility to third parties);
- support compatible enterprise development to provide alternative income to local communities and generate incentives and resources for conservation (e.g., eco-tourism and joint ventures/concessions with the tourism industry); and
- generate essential income to cover management, monitoring and operating costs (e.g., user fees, endowments).

These approaches must address both the current shortfalls in funding for MPAs as well as the additional costs needed to build and sustain resilient MPA networks. A key element of this component will be making available tools, skills, and other resources to MPA managers and others to identify, design, and implement an appropriate suite of sustainable financing mechanisms at individual sites and across networks.

1.2.5 Capacity building

To address the need for technical skills building, the initiative will establish mechanisms to continuously share, adapt, and deliver technical advice and training in marine conservation. These collaborative efforts will be linked, through strategic alliances with a range of learning centers and site projects, to the work of others worldwide. Like other components of the program, capacity building and institutional strengthening efforts must focus on addressing the current shortfall in skills and abilities to manage existing MPAs as well as the needs to integrate into MPAs and networks new concepts, guidelines, and mechanisms. In particular, the capacity building component is closely linked to other initiative activities aimed at improving our knowledge of global threats and factors of survivability, applying new understanding and guidelines to existing reserves, identifying portfolios of sites within MPA networks, and implementing sustainable finance and management approaches.

1.3 Definitions of Protected Areas

The working group collectively decided to adopt The World Conservation Union (IUCN) definitions of Marine Protected Areas (MPAs) for the purpose of this planning exercise. The definitions are:

- IUCN defines a protected area as "an area of land and/or sea especially dedicated to the protection of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means."
- IUCN has developed a compatible definition of an MPA: "any area of inter-tidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment."

IUCN categorizes protected areas by management objective and has identified six distinct categories of protected areas. It is expected that the individual networks may consist of a range of these categories. The categories are:

- Category I – Protected area managed mainly for science or wilderness protection (Strict Nature Reserve/Wilderness Area);
- Category II – Protected area managed mainly for ecosystem protection and recreation (National Park);
- Category III – Protected area managed mainly for conservation of specific natural features (Natural Monument);
- Category IV – Protected area managed mainly for conservation through management intervention (Habitat/Species Management Area);
- Category V – Protected area managed mainly for landscape/seascape conservation and recreation (Protected Landscape/Seascape);
- Category VI – Protected area managed mainly for the sustainable use of natural ecosystems (Managed Resource Protected Area).

1.4 Characteristics of Marine Protected Areas

The working group collectively recognized the following characteristics of MPAs:

- An MPA always includes the marine environment but may also include coastal land areas and islands. It is commonly called an MPA when the total area of sea it encompasses exceeds the area of land within its boundaries, or the marine part of a large protected area is sufficient in size to be classified as an MPA by itself;
- It has some form of protection, usually legal but not necessarily. For example, in the Pacific, many MPAs are established by customary means;
- The degree of protection is not necessarily the same throughout the area; indeed most large MPAs are of necessity zoned into areas of different impact and usage;
- The MPA (and so the provisions for its management) should cover not only the seabed but also at least some of the water column above with its flora and fauna;
- MPAs are not just relevant for natural features but also for protecting cultural features such as wrecks, historic lighthouses and jetties;
- MPAs cover a range of sizes, from small locally managed reefs to large reserves and national parks.

2. TEN YEAR GOALS: "FISH SPAWNING AGGREGATIONS" COMPONENT

2.1 Goal 1

All high-priority spawning aggregation sites within the area encompassed by the MPA networks are fully protected and regularly monitored

2.2 Goal 2

Through leverage, a majority of high priority spawning aggregation sites globally outside of these networks are fully protected and regularly monitored.

2.3 Goal 3

Scientifically competent knowledge base developed, through research, to guide preferred management options for reef FSAS and implementation and evaluation of MPA networks.

3. CHARACTERISTICS OF SPAWNING AGGREGATIONS

3.1 Description, importance, and vulnerability of spawning aggregations

A number of reef fish species are known to aggregate in large numbers at specific times and places to reproduce. Numerous hypotheses have been proposed to account for the occurrence of spawning aggregations, but it is likely multiple benefits are involved that are may be specific to each species. Because understanding the reasons why spawning aggregations occur is critically important for designing appropriate management approaches and determining the threats of impacts such as over-fishing, active investigation to further identify these reasons is urgently required.

The discovery of previously unknown spawning aggregation for many different species throughout the world is an extremely important aspect of any overall research program. At present our knowledge of spawning aggregation occurrence, much less the many other aspects of this important phenomenon, is minimal. Even where we have reports from traditional knowledge of possible spawning aggregations, we do not have the opportunity to investigate even a small percentage of these in the field with trained biologists. We can safely say that spawning aggregation occurrence is not well known for all the species occurring in any one area of the world, including developed countries such as Australia and the United States.

Two distinct types of spawning aggregation, Resident and Transient, have been broadly defined based on the frequency they form and the distance individual fishes travel to the aggregation site. A Resident spawning aggregation draws individuals from a relatively small and local area. The spawning site can be reached through a migration of a few hours or less and often lies within the home range of the participating individuals. Resident spawning aggregations usually 1) occur at a specific time of day over numerous days, 2) last only a few hours or less, 3) occur daily during an often lengthy spawning season, and 4) can occur year round. A single Resident spawning aggregation may represent only a fraction of the annual reproductive effort for participating individuals. A Transient spawning aggregation draws individuals from a relatively large area (tens to hundreds of km). Individuals must travel days or weeks to reach the aggregation site. Transient spawning aggregations often 1) occur during a very specific portion of one or two months of the year, 2) persist for a period of days or at most a few weeks and 3) do not occur year round. A Transient spawning aggregation may represent the total annual reproductive effort for participation individuals. The distinction between Resident and Transient spawning aggregations is useful when discussing management measures.

The predictable nature of spawning aggregations in time and space makes them extremely vulnerable to fishing. Fishers have discovered the timing and location of spawning aggregations in many areas of the Caribbean and Indo-Pacific and through unmanaged fishing, a substantial number of such reproductive gatherings have been severely depleted and in some cases, extirpated. Although scientific documentation is limited, especially in the vast Indo-Pacific region, considerable anecdotal evidence suggests that the live reef food fish trade, especially in Indonesia and the western Pacific, is systematically destroying many spawning aggregations. Many remaining aggregations throughout the tropics are seriously depleted and may soon disappear if they are not quickly protected. The conservation of these aggregations is critical for maintaining healthy populations of the species that form them over broad geographic regions.

3.1.1 Site characteristics

Site characteristics are discussed in detail in Section 5.3. Here, a brief summary is presented. Many spawning aggregations are known to have persisted at the same sites for many years. At present, the geomorphology, biological communities, and oceanographic parameters are known for only a limited number of FSAS and there has been considerable variability in certain characteristics documented among these. For example, some transient spawning sites may be used by several species, others by just one species. Or, tidal state has been identified as a principal factor for both types of aggregations. Our knowledge base, however, is insufficient to attempt to predict with confidence the occurrence of spawning aggregations based upon physical characters alone.

3.1.2 Regional differences and priority sites for conservation

Regional differences in aggregation timing (seasonal and lunar), aggregation and spawning behavior, and types of areas used for aggregations are reported to exist for a number of species. Therefore, generalizations about a species from one location are not sufficient to extrapolate to regional patterns and more information is needed to reveal patterns that are useful for prediction or application to management. To prioritize sites for conservation, as an initial approach and based upon the limited information currently available, the working group selected five criteria to evaluate potential sites. These criteria are: 1) multi-species aggregation present, 2) transient aggregation present, 3) pristine, 4) heavy exploitation, 5) relatively high levels of endemism. The following table addresses known data and data needs on a broad geographical basis with respect to these criteria (Table 1).

3.1.3 Priority species for conservation

Many reef fish species exhibit spawning aggregation behavior and some are likely to be more vulnerable than others to heavy fishing pressure. Thus, it is important to establish criteria by which those species that might require priority conservation action may be identified. Vulnerability may be due to one, or a combination, of the following factors: life history strategies, rarity, catchability, or consumer demand.

A set of criteria was developed to enable the identification of species that might be particularly at risk and therefore require priority of conservation action, or further investigation. Seven criteria were selected. Large maximum size, long life and late sexual maturation (i.e., sexual maturation delayed by several to many years) were all considered to be particularly important life history characteristics for denoting vulnerable species, based upon phylogenetic comparative analyses that have been carried out on several reef fish families and fishing histories. Although these characteristics often co-occur (particularly long life and late sexual maturation), this is not always the case so the characters do need to be considered separately. Another aspect of life history strategies that appears to render reef fish species particularly vulnerable to exploitation is the formation of the transient type of spawning aggregation. Transient aggregations, in

Table 1. Geographical areas of the Tropical Western Atlantic (TWA) and the Indo-Pacific (IP) where data on spawning aggregations exist or are needed. Mult. = multiple; spp = species; Trans = transient; agg = aggregation; Prist = pristine; Hvy = heavy; expl = exploitation; endm = endemism.

A. TWA

Locality	**Mult spp**	**Trans agg**	**Prist**	**Hvy expl**	**High endm**
Lesser Antilles, Windward	--	--	--	Yes	No
Lesser Antilles, Leeward	--	--	--	Yes	No
Puerto Rico/Virgin Islands shelf	Yes	Yes	No	Yes	No
Hispaniola	Yes	Yes	No	--	No
Cuba	Yes	Yes	No	Prob	No
Jamaica	--	--	No	Yes	No
Cayman Islands	Yes	Yes	No	Prob	No
Gulf of Honduras [1]	Yes	Yes	No	Var	No
Nicaraguan/Costa Rica shelf	--	--	No	Yes	No
N. coast of South America	--	--	No	Yes?	No
Islands off S. America [2]	--	--	No	Yes?	No
Turks and Caicos, eastern Banks	Yes	Yes	No	--	No
Bahamas, Southern	Yes	Yes	No	Yes?	No
Bahamas, Northern	Yes	Yes	No	Yes	No
Yucatan shelf	Yes	Yes	No	Var	No
Western Caribbean islands [3]	--	--	No	--	No
Gulf of Mexico, US coast	Yes	Yes	No	Yes	No
Gulf of Mexico, Mexican coast	Yes	Yes	No	Yes?	No
Florida Keys	Yes	Yes	No	Yes?	No
US Eastern Atlantic coast	Yes	Yes	No	Yes	No
Bermuda	Yes	Yes	No	Yes	No
Brazil (a huge area)	--	--	--	--	Yes

-- = No Data; Var = variable; M = Medium

1- includes Belize barrier reef, offshore atolls and Bay Islands
2- southern Netherlands Antilles, Venezuelan Islands.
3- San Andres, Providencia, numerous banks and atolls

B. IP - Note many of these single localities would encompass an area as large as or larger than the entire TWA region. We need to consider the IP as both political and geographic entities, in this case combined in this single table, where the entry chosen (Papua New Guinea versus New Guinea Island -which of course also include part of Indonesia) reflects political or biological "reality". Alternate division of this list could easily be made and supported. This list is an example. Mult. = multiple; spp = species; Trans = transient; agg = aggregation; Prist = pristine; Hvy = heavy; expl = exploitation; endm = endemism.

Locality	**Mult spp**	**Trans agg**	**Prist**	**Hvy expl**	**High endm**
Red Sea	--	--	Var	--	M
East coast of Africa	--	--	No	Yes?	No
Arabian Sea	--	--	No	--	--
Mascarenes	--	--	Var	--	--
Seychelles	Yes	Yes	Var	--	--
Madagascar	--	--	No	--	--
Chagos Archipelago	--	--	Var	--	--
Laccadive Archipelago	--	--	Var	--	No
Bay of Bengal islands/ coast	--	--	No	--	--
Maldives	Yes	Yes	Var	No	No
Christmas Is/Cocos Keeling	--	--	No	No	No
Western Australia	--	--	Var	--	M
Eastern Australia (GBR)	Yes	Yes	No	Var	M
Papua New Guinea	Yes	Yes	Var	No	No
Indonesia	Yes	Yes	Var	--	No
Malaysia - West (Peninsular)	--	--	No	--	No
Malaysia - East (Borneo)	Yes	Yes	No	Y--	No
Philippines	Yes	Yes	No	Yes	No
Vietnam/Cambodia	Yes	Yes	Var	Yes	No
Ryukyu Islands	--	--	No	Yes	No
Ogasawara and Bonin Islands	--	--	Var	Var	No
Japan (includes Izu Is.)	--	---	No	Yes	Var
Palau Islands	Yes	Yes	Var	Var	No
Western Caroline Islands	Yes	Yes	Var	Var	No
Central Caroline Islands	Yes	Yes	Var	Var	No
Eastern Caroline Islands	Yes	Yes	Var	--	No
Mariana Islands	--	--	Var	Var	No

Table 1b, continued

Locality	Mult spp	Trans agg	Prist	Hvy expl	High endm
Marshall Islands	Yes	Yes	Var	Yes	No
Gilbert Islands (Kiribati)	Yes	Yes	Var	Yes	No
Phoenix Islands (Kiribati)	--	--	Yes	No	--
Line Islands (Kiribati)	--	--	Var	No*	--
Ocean Island (Kiribati)	--	--	No	Var	--
Nauru	--	--	No	Var	--
Solomon Islands	Yes	Yes	Var	Var	No
Vanuatu	Yes	Yes	Var	Var	No
New Caledonia	Yes	--	Var	Var	No
Fiji Islands	Yes	Yes	Var	Var	No
Tonga Islands	Yes	Yes	Var	Yes	No
Samoan Islands	--	--	Var	Var	No
Cook Islands	--	--	Var	Var	No
Society Islands	--	--	Var	Var	Var
Tuamoto Archipelago	--	---	Var	Var	Var
Austral Islands	--	--	Yes	No	--
Hawaiian Islands	Yes	Yes	Var	Yes	Yes
Eastern Pacific Islands	--	--	Var	Var	Yes
Central American Pacific Coast	--	--	No	Yes	Yes
Gulf of California	--	--	Var	Var	Yes

-- = No Data; Var = variable; M = Medium * = export grouper fishery proposed.

general, were identified to represent more of a conservation concern than resident spawning aggregations, although some particularly vulnerable species, such as the wrasse *Cheilinus undulatus*, appear to form resident aggregations. Because reef fishes are not able to withstand anything other than light levels of exploitation, another criterion used to identify vulnerable species was heavy exploitation, now and/or predicted for the future. Also included as relevant criteria, albeit of lesser importance, were species already listed in the IUCN Red List, while low natural levels of abundance (uncommon or rare species) might need to be accorded conservation priority if targeted heavily.

Based upon these criteria, priority species for conservation were identified and are listed below by geographic region and family.

Tropical Western Atlantic (TWA) - Priority Concerns by Family

Serranidae (groupers and allies)

The Epinephelinae is the only subfamily of TWA serranids for which there is need for priority. Two genera are involved, *Epinephelus* and *Mycteroperca*. Larger species have more predictable seasonal and lunar aggregation times.

Epinephelus striatus - High priority species with formerly large aggregations, heavily exploited throughout region.

E. guttatus - High priority species with formerly many aggregations, important subsistence fish heavily exploited in many regions.

E. itajara – Largest TWA serranid, vulnerable, not particularly common, exploited in many areas.

E. adscensionis - Medium sized with poorly known aggregation habits, exploited when found.

Mycteroperca venenosa - Large species with poorly known aggregations, uses multi-species sites, exploited in many areas, but often ciguatoxic.

M tigris - Species known to form large aggregations, heavily fished in some areas.

M. bonaci - May form aggregations, poorly known, exploited.

M. microlepis - Large continental species, heavily exploited, distorted sex structure in some areas, habitat impacted by destructive fishing.

Lutjanidae (snappers)

Some of the larger snappers are known to form aggregations and are sometimes heavily exploited. Some are certainly priority species. Smaller species are generally not in need of conservation priority.

Lutjanus cyanopterus - The largest TWA lutjanid forms large aggregation and is moderately exploited

L. jocu - Also forms large aggregations and is heavily exploited.

L. analis - Forms large aggregations, heavily exploited and an important general food fish in the TWA region.

Haemulidae (grunts)

There is some anecdotal evidence that some haemulid species may form spawning aggregations; further study is indicated.

Albulidae (bonefishes)

Bonefishes are popular and economically-valuable gamefishes. Forms aggregations; vulnerable to gill nets, often as by-catch.

Mugilidae (mullets)

Mullets are important food and bait fishes that form aggregations.

Other families and species:

A number of other species may form significant spawning aggregations. Some are resident aggregation spawners, but for many we simply do not know how they reproduce. Families with species that are used as food fishes, such as porgies (Sparidae), jacks (Carangidae), and croakers (Sciaenidae), may form aggregations, but this needs to be determined. Some of these may become priority species for conservation action once we have a sufficient understanding of their biology to indicate any threats.

Indo-Pacific - Priority Concerns by Family

Serranidae (groupers, rock cods, coral trouts and their allies)

The subfamily Epinephelinae includes a number of larger Indo-Pacific serranids that form significant spawning aggregations. The two principal genera are *Epinephelus* and *Plectropomus*. It is not yet known, however, how many serranids aggregate to spawn in the Indo-Pacific region.

Plectropomus: The species of this genus are heavily exploited and important economically in some areas and much remains to be learned about their aggregations.

Plectropomus areolatus - Found at multi-species aggregation sites, heavily exploited in some areas.

P. laevis- Heavily exploited.

P. leopardus - Usually aggregates to spawn in relatively small aggregations and may have many sites. Heavily exploited by the live and frozen reef fish trades.

P. maculatus - Inhabits fringing reef habitats; little is known about its spawning behavior; heavily exploited in some coastal areas.

P. oligocanthus - Aggregation characteristics poorly known, but distinctive

P. pessuliferus – Aggregation characteristics unknown; can mimic *P. laevis*; targeted for subsistence and for the live reef fish trade.

Epinephelus: the larger species of this genus may form aggregation, however, this is only known with certainly for a few species.

Epinephelus fuscoguttatus - Often aggregates with *E. polyphakedion*, some knowledge of its timing, heavily exploited some areas.

E. lanceolatus - Anecdotally reported to aggregated, large species of economic importance when caught.

E. polyphekedion - Best known of Pacific *Epinephelus*, forms large aggregation some areas, heavily exploited in some areas.

Other genera: The generally smaller species of genera such as *Cephalopholis*, *Variola*, *Chromileptes*, *Aethaloperca*, and *Anyperodon* are usually not reported to aggregate, but knowledge of these is so rudimentary many may eventually be found to aggregate.

Labridae (wrasses)

Only a single IP species, *Cheilinus undulatus*, is of priority concern. This species recently been found to be a resident aggregator, unusual for such a large fish, and is highly exploited in many areas and is a high value species in the live reef fish food trade.

Scaridae (parrotfishes)

Bolbometopon muricatum is exploited in much of its range, usually by night spearfishing, and based on limited observations is, like *C. undulatus*, probably a resident aggregator. Some other large parrotfishes are targeted both for subsistence and live reef fish trade.

Lethrinidae (emperors)

Some large species may aggregate and be of priority concern, but little is known about this.

Haemulidae (sweetlips and grunts)

Plectorhinchus obscurus and some other large species would have some priority interest, but not enough is known about their potential for aggregation to really say.

Lutjanidae (snappers)- *Lutjanus bohar* occurs in schools, but it is unknown whether these are truly spawning aggregations. Potential for priority concern, but not enough known. Ciguatoxic in many areas.

Caesionidae (fusiliers)- One species known to spawn in probable resident aggregations, but otherwise poorly known.

Carangidae (trevallys and jacks)- Little known, but may have an aggregation component to spawning in some species.

Siganidae (rabbitfishes)- Important food fishes; some species reported to form aggregations; demersal rather than pelagic eggs.

Acanthuridae (surgeonfishes and tangs)- Important food fishes that form spawning aggregations.

Albulidae (bonefishes)- Popular and economically-valuable gamefishes. Forms aggregations; vulnerable to gill nets, often as by-catch.

Mugilidae (mullets)- Important food and bait fishes that form aggregations.

Mobulidae (manta rays)- Manta rays have become important to eco-tourism and form aggregations (i.e., Yap; Christmas Is., Kiribati; Gulf of California). The nature of these is not well understood. Live-bearers and not pelagic spawners.

3.2 Threats to Spawning Aggregations

There is a variety of threats to the perpetuation of spawning aggregations both direct and indirect. The single greatest threat to spawning aggregations is from fishing. At many sites, this is compounded by additional threats facing coral reefs worldwide. In general, coral reefs are under threat from climate induced coral bleaching, coastal development, and upland sources of sediments and pollutants. Increased tourism is also putting pressure on reefs, both by indirect effects of coastal development but also by divers, anchors, and boat traffic disturbing the delicate behaviors within spawning aggregations.

3.2.1 Fishing

By far the most significant threat to the persistence of healthy spawning aggregations is fishing directly on the aggregation, but also along migration routes to and from the aggregation, and via the use of destructive fishing methods, or heavy fishing, at times and locations away from the aggregation sites.

3.2.2 Global warming and coastal development

Global warming and coastal development are increasingly damaging coral reef ecosystems via direct and indirect impacts. Climate induced coral bleaching is having catastrophic effects on the health of corals around the world (see section on bleaching). Sediments, nutrients, and pollutants, derived from upland sources are also negatively affecting coral reef ecosystems. All of these stressors have the potential to impact upon the success of spawning aggregations.

3.2.3 Tourism

Tourism can have negative effects on spawning aggregations via indirect effects of coastal development (see above) but also from boat anchoring and disruption of spawning behaviors by divers and snorkelers at the sites and times of reproduction. Large numbers of tourists diving and snorkeling, associated with structures such as pontoons, mooring sites and anchorages positioned in or close to FSAS could disturb the normal spawning behavior of aggregating fish. Fish feeding may change the predator-prey relationships at a FSAS although the effects of these changes upon spawning aggregations remain to be adequately studied. Indeed, the effect of humans in the vicinity of spawning aggregations, as divers, snorkelers, and boaters, is poorly known. The ability of aggregating fishes to spawn in the presence of disturbances has been documented anecdotally to vary with species but further work is needed to truly understand such effects, if any. Thus, it may be advisable to protect some species from human disturbances such as diving and snorkeling, in addition to fishing, during their aggregation times.

3.3 Examples of Spawning Aggregations Fished to Extirpation

There are many anecdotal accounts of the destruction of spawning aggregations but there are few accurately documented cases in the published literature. Perhaps the best-studied species is the grouper *Epinephelus striatus*. In the western Atlantic, a minimum of 10 of 50, and possibly considerably more (definitive information is lacking), known aggregations have been reported destroyed by over-fishing. In Belize, the aggregation at Emily Caye Glory that was reported to have produced two tons per day in the late 1960's maintained only 21 individuals in the peak of the 2001 spawning time for this species. *Epinephelus striatus* spawning aggregations have also been eliminated at Rise and Fall Bank, and Mexico Rocks in Belize, and at Majual on the Yucatan coast of Mexico. An aggregation in Guanaja, Honduras, was destroyed by fishermen in only three years after its discovery. In Puerto Rico, this grouper was a common and very important food fish, but the fishery had collapsed by the late 1980s. Recent surveys in the Bahamas have shown that *E. striatus*, which may travel up to 110 km to a FSAS at High Cay, have been heavily exploited by fishing; aggregations no longer occur, except for a few fish scattered in shallow water.

In Palau, various grouper spawning aggregations, such as the Denges Channel aggregation, were lost from fishing and have not recovered.

On the Great Barrier Reef (GBR), commercial and recreational fishers have expressed concern to the Queensland Fisheries Service (QFS) and the Great Barrier Reef Marine Park Authority (GBRMPA) over the targeting of spawning aggregations and over-exploitation of demersal fishes in the Cairns and northern regions of the GBR. Recently, it has been verified that one of two main spawning aggregations of common coral trout on reefs near Cairns has diminished over the past two years, most likely due to over-fishing. Similarly, *Plectropomus laevis* has also been depleted at some sites in the Cairns Section over the past 10 years, with aggregations no longer being formed at Ribbon and

Jewell Reefs. There is concern about the sustainability of fishing *Plectropomus* spp. spawning sites on the GBR.

The Live Reef Food Fish Trade (LRFFT) has been targeting spawning aggregations throughout the Indo-Pacific. This targeting effort is resulting in a significant rate of degradation of these aggregations throughout the region where the trade is active. As for the GBR, however, accurate records are unavailable.

4. MANAGEMENT OPTIONS

4.1 Introduction

Given the recognition that reef fish spawning aggregations, and in some cases the aggregation sites themselves, are highly vulnerable to targeted fishing and that targeting of spawning aggregations is expected to increase and intensify throughout the tropics with the development of the live reef food fish trade in the Indo-Pacific and increasing pressure on fisheries in general, there is clearly an urgent need to consider options for the protection, management and conservation of spawning aggregations. It is also critical to understand that success in spawning aggregation conservation is linked intimately to better understanding of both the biological importance of spawning aggregations (i.e., why they form) through carefully focused scientific research, success in applying management options, and generating public interest in, and widely understandable economic benefits from, intact (healthy) reef fish spawning aggregations. Management options must also be refined by the results generated by focused research.

Currently, there is little management of reef fish spawning aggregations in place globally, and, of that in place, little in the way of stated objectives and even fewer indications of the outcomes of management (Table 2). Many management strategies have been put in place only after there has been a problem recognized that fishers are targeting and over-fishing spawning fish. In summary, the initiatives already in place address mainly seasonal combined with spatial (spawning season combined with spawning site) closures (season can be closed for days to months) for single, or for multi-species sites. Less frequently is the application of spawning season-only closures although sometimes these do not cover the entire temporal extent of spawning activity due to insufficient information on duration of spawning, or to lack of support from fishers or managers. Occasionally spatial-only regulations are in place and these are often already within MPAs. Less frequently, we see the use of gear restrictions on traditionally fished aggregations, including limits to, or complete restrictions on spears, traps or nets during the aggregation period and on the aggregation site. Other measures (such as quotas, size restrictions, and limits of foreign vessel access or export) have not been specifically used although moratoria have occasionally been implemented in cases of extreme declines, and often too late (it would seem).

Objectives of managing spawning aggregations and the outcomes of so doing have rarely been explicit or provided, respectively. Most frequently, a need to conserve and to reduce fishing effort, following observed declines in aggregation catches, is cited as the basis under which management has been implemented. Most management has been based on little or no biological information and rarely is there any follow-up or monitoring. In general there is little specific spawning aggregation policy in management plans. Finally, the lack of follow-up information after management implementation represents a severe handicap for building the case for aggregation protection and its likely advantages in general. The few follow-up studies that have been done have shown that long-term (multi-year), standardized, and appropriately designed studies and monitoring are needed to demonstrate the outcome of aggregation protection. Long-term datasets are needed because of the high longevity of the majority of aggregation-forming species and at least one has demonstrated the positive effects of aggregation protection.

4.2 Management options for fishes that form spawning aggregations

4.2.1 Options specifically for spawning aggregations

<u>a. Seasonal closures-no area closure (the fishery for the managed species is completely closed for the spawning season with no catch or sales of the species permitted; there is no attempt to protect the actual spawning area)</u>

Pros: relatively easy for enforcement since fish should not be for sale in markets or in possession; site-specific information not needed since seasonal closure will protect species; good if significant catch occurs outside the spawning aggregation during the reproductive season; protects spawning aggregation male/female social structure; intuitive so relatively easy to accept. Protects fish that are aggregating in deep waters (and which would be used for live reef fish trade) from high levels of wasteful mortality; protects other species that aggregate at the same time, but little is known about these species spawning behavior.

Cons: which species should be protected (i.e. which season[s] or species must be selected for seasonal closures); could be circumvented by having fish held alive until season is over; spawning aggregation site could be damaged by other activities.

Information needs: timing variability of reproductive season that could vary even within a relatively small area for a single species

<u>b. Short-term area closure-no seasonal closure (the aggregation site is closed for the duration of the spawning season of the managed species but fishing for this species can continue outside the spawning aggregation area)</u>

Pros: this will protect habitat in the short-term (since focus in area may only be during spawning aggregations) and the fish that spawn there; protects spawning aggregations male/female social structure; protects multi-species; protects fish that are aggregating in deep waters (and which would be used for live reef fish trade) from high levels of wasteful mortality; intuitive so relatively easy to accept.

Table 2. Examples of protected fish spawning aggregations and aggregation sites.

Tropical WA Species*	**Location (stated objective for management)**	**Management measure**	**Introduced**	**Outcome/ follow-up**
Epinephelus guttatus	Bermuda (partly to limit sale of illegal fish)	Seasonal (now 3 SA) (May-Aug) Seasonal quota Minimum legal sizes	1974/1990 1990 1996	Landings stabilized later after trap ban; increase in mean size
	Puerto Rico (Federal waters? Fishery management)	Seasonal closure of 4 SA (dates?)	1995	Increase in mean size and CPUE (1996-9)
	U. S. Virgin Is. St. Thomas (state waters – within a Marine Conservation District)	Seasonal closure of SA (Dec-Feb)	1990	Mean TL**/No. increased to 2002. Also, other species increased
Epinephelus striatus	Bermuda	No take/possession	1996	
	US (?)	Moratorium (part)	1997	
	Puerto Rico (Federal waters)	Moratorium	1990	
	Dominican Republic	No catch/sale in spawning season	mid 1980s	
	Bahamas	Seasonal closure of 3 SA (10 days/3 FM)/min size	Between 1998-2001/1989	
	Cayman Is. (reduce Fishing effort)	Spearing banned at SA, trapping banned in spawning season	1985 &??	
	Belize (conservation)	Seasonal closure at SA	1990?	
	Mexico	Spearing banned at SA; Gill nets banned at SA	1993; 1995	
	Cuba	Quota	mid 1980s	
Lutjanus analis	US Virgin Islands	Seasonal SA closure	1995?	
Tropical WA Non-specific**				
Groupers/snappers	Belize (conservation)	Permanent closure of 13 SA	2002?	
Groupers	Bermuda (SSB/abundance)	No take/possession	1996	
Groupers	Bahamas (protect SSB)	Minimum size	1986	
Snappers	Florida (?) (multi-species SA site)	Area closure permanent	2001	
Groupers (*Epinephelus* spp. and *Mycteroperca* spp.)	Florida (Federal waters	MPA (does not always encompass SA)/1month closure Gulf of Mexico (no hold/sale) – also a collective grouper quota	2000?	Evaluation of whether reserves protect SA, protection of males

Indo-Pacific Non-specific**	**Location (stated objective for management)**	**Management measure**	**Introduced**	**Outcome/ follow-up**
Groupers (*E. fuscoguttatus, E. polyphekadion, P. areolatus*)	Pohnpei (no clear SA policy – aggregations can extend beyond protected period)	8 Protected areas (3 SA)/ seasonal ban for commercial sale or take (also no foreign vessels in general)	More regulation considered, incl. extending area/season	
Groupers (*E. fuscoguttatus, E. polyphekadion, P. areolatus, P. laevis, P. areolatus*)	Palau (note that aggregations extend at least one month beyond protection)	No take/sale in spawning season/ seasonal closures of several SA (some traditional)/ Exports monitored/no foreign fishing vessels/entry restriction for divers at one site (voluntary?)	Initially 1976 (seasonal site closure)	Species probably still in fair condition
Groupers (*also other species i.e., mugilids, siganids, lethrinids*)	Papua New Guinea (stated as conservation)	Some traditional non-fishing of SA. National Fisheries Authority taking SA into account/traditional effort control		
Groupers and wrasses (*E. fuscoguttatus, P. areolatus, some others*) & *Cheilinus undulatus*	Indonesia (Komodo)	SA protected in no-take zones with seasonal closure recommended for traditional use zones. Concerns over damage to SA site. Seasonal no fishing of *Cheilinus undulatus*	2001	Monitoring (UVC)
Indo-Pacific Species*				
Focus on *P. leopardus* but also other vulnerable species of concern, i.e., *C. undulatus*	Australia (concerns over impacts of fishing and tourism) Need to protect vulnerable species. Need to protect spanwing fish and reduce fishing effort.	PROPOSED/ seasonal area closures (9 days each of 3 months at least), no take of vulvernable species such as *Cheilinus undulatus*, *Cromileptes altivelis, Epinephelus tukula,* and smaller grouper species/inclusion in no-fishing zones Size/bag limits. Effort restrictions.	Restrictions of locations of tourism activities. Bag and size limits. In Western Australia, the take of *Cheilinus undulatus* is prohibited.	Small site protection considered to probably not be enforceable. Some FSAS will be incorporated into the Representative Areas Program. Queensland reef line fishery management plan in development.
Siganus canaliculatus (rabbitfish) *Cheilinus undulatus*	Palau	*Seasonal spawning closure* No export/size limits		

* this is not a complete species list but just a series of examples – as just one example, is missing.** examples of multi-species protections
TL = total length in mm; ? = details could not be confirmed; CPUE – catch per unit of effort; TWA, Tropical WA – tropical western Atlantic.

Cons: this option has high compliance costs if spawning sites are remote and widely spaced; decision must be made over which areas to close and vessel monitoring systems (VMS) may be needed to ensure compliance and these can be expensive; not useful if most of the catch is taken outside of the spawning aggregation. Provides only short-term protection of the spawning aggregation site from physical damage. When an area is re-opened to fishing, fish stocks that might have replenished will be depleted quickly unless strict management controls are implemented.

Information needs: connectivity of sites and the areas which the adults use within the spawning season will determine the most relevant sites and their sizes for protection if all spawning aggregations cannot be protected – this means that year to year variability in use of specific spawning aggregation areas must be determined; area to be protected might have to incorporate migration routes of adults into the spawning aggregation.

<u>c. Short-term time and area closures (the managed species is protected both at its spawning aggregation site and from being fished anywhere throughout much, or all, of its reproductive season)</u>

See the two measures given above; solves the problem of having to decide specifically closure times and areas; probably easier to enforce overall.

<u>d. Fully-protected area (the managed species is protected from fishing year-round in the designated MPA)</u>

Pros: protects habitat permanently; global support for fully protected areas is growing and such protection is intuitive in some communities; very probably a higher overall fishery advantage than short-term closures because the protected area could act as a source of young for a wide range of species not otherwise protected by seasonal or short-term area measures; ensures complete protection of aggregations considering the uncertainty of spawning seasons and locations; ensures protection of spawning site habitat; needs research to identify appropriate areas for protection.

Cons: harder to justify than a short term area measure since impact on nearby fishing communities likely to be greater; if area is not properly placed or large enough, benefit may not be apparent or sufficient and the approach difficult to support in the long term; enforcement more onerous than short-term protection.

Information needs: connectivity with other areas or biological importance of protected area; are key habitats being included; how big should the area be? If there are many FSAS in an area, maybe the whole area needs to be included in a closure rather than many small closed areas that are very hard to enforce.

4.2.2 *Additional or nested management measures*

a. Export controls

Pros: good for Pacific Islands where export is a major part of the trade and where there are adequate controls or where administrative control is feasible and where export is a major part of the trade; export controls especially relevant for threatened species which cannot sustain export trade; requires adequate infrastructural support. Complete export bans not too difficult to monitor and enforce where points of export are many and little controlled.

Cons: export controls not practical for many places, such as SE Asia, given lack of controls (i.e., regulations and enforcement) and multiple export sites and methods and multi-species character of the trade. Often very hard, if not impossible, to estimate both sustainable catch levels and current levels of local resource use for wide range of species and to control exports at appropriate levels.

Information needs: estimation of sustainable catch and determination of proportion of catch that can be used for export (as opposed to local use), and estimation of current levels of local resource use for number of species; identification of threatened species; need to determine to what extent export is controlled (totally or according to a limited licensing system for exporters) and how effective export controls are. One approach might be to mandate that if a fishery does not get certified as managed sustainably, it will not get export approval

b. Quotas (overall fishery quota on catch)

Pros: quotas, if properly managed, could theoretically allow for sustainable fisheries. The concept of species-specific quotas for the live fish export trade has been proposed to or by some Pacific Island custodial resource owners suggesting potential community acceptability.

Cons: enforcement and monitoring of multi-species, multi-gear fisheries are difficult and there are demanding information needs which may make collection of sufficient information impossible, at least for classic stock assessment approaches. Assignment of quotas might be difficult under certain management or local tenure systems. Not considered by the working group to be a viable approach for the fisheries or issues under consideration.

Information needs: some estimate of sustainable catch is needed that may have to be produced by non-standard stock assessment approaches, such as ecosystem modeling approaches that utilize underwater visual census estimates of abundance or other forms of relevant data. Furthermore, detailed information on catch per species is needed although this may be prohibitively difficult and expensive to obtain.

c. Gear Restrictions

Pros: general recommendations that bear on spawning aggregation protection are that all destructive gears should be banned from fisheries of aggregating species even outside of aggregation areas and times to ensure no negative impacts of such gears on habitat integrity or on non-target species.

Cons: enforcement difficult especially for gears permitted in other fishery sectors.

Information needs: identify destructive gears (which include hookah and scuba fishing, traps, small mesh nets, spear fishing, cyanide, other poisons, dynamite).

d. Control of fishing effort (i.e., limiting the number of licenses; traditional marine tenure)

Pros: recognizing that under some circumstances a subsistence component to spawning aggregation fishing might be advisable or would contribute to overall spawning aggregation conservation, and recognizing that a spawning aggregation fishery may be able to persist at low levels of fishing effort, control of fishing effort may be recommended to ensure that low levels of fishing effort do not expand beyond acceptable levels – this is particularly likely to be applicable under conditions of traditional marine tenure. In many fisheries, there is too much effort for not enough fish. Effort reduction will reduce the overall impact upon spawning stock.

Cons: fishing effort controls can be circumvented by increasing gear use, or gear efficiency by licensed fishers so gear types permitted must be specified; requires enforcement of licensed fishing; unlikely to be effective if strong conditions of traditional marine tenure are not in place.

Information needs: need to establish acceptable level of subsistence fishing (see quotas, above); need to determine how to assign fishing licenses.

e. Minimum and maximum size limits

Pros: protect juveniles (reduce growth over-fishing) and large, mature or highly fecund adults (reduce recruitment over-fishing). Minimum size limits that are set to ensure all spawning stock have the opportunity to spawn at least once may help prevent depletion of mature fish aggregating to spawn in short-lived species. Maximum size limit will leave larger mature fish in the population.

Cons: minimum and maximum size limits are highly effective fisheries management tools in certain circumstances (e.g., the Great Barrier Reef) but are not believed to be a suitable approach for the direct protection of spawning aggregations of reef fishes. Moreover, minimum size limits that are set to ensure all spawning stock have the opportunity to spawn at least once will not prevent depletion of mature fish aggregating to spawn in longer lived species because many reproductive years are needed to fulfill reproductive potential.

f. Moratorium for highly threatened priority species and on fisheries that target fish spawning aggregation sites (FSAS)

In cases of highly threatened priority species, a complete moratorium on capture, disturbance and possession may be necessary to ensure recovery and must supersede all other management options. Likely candidates in the Indo-West Pacific that received lower rankings than expected in Table 2b are the wrasse *Cheilinus undulatus* and the parrotfish *Bolbometapon muricatum.* These fishes are highly vulnerable and targeted heavily for exploitation; they spawn, however, in resident aggregations and not transient aggregations, and their life history characters appear to make them particularly vulnerable to fishing. Thus, they should be accorded a high conservation priority. Similarly, moratoriums on fisheries that target specifically FSAS, or a range of aggregating reef species, provide a temporary time period in which more specific and longer term management options can be developed and implemented.

Cons: Moratoriums are usually temporary, and easily removed through political pressure.

4.3 The role of eco-tourism

To ensure the perpetuation of spawning aggregations of many reef fish species, and recognizing that the major threat to that persistence is fishing, alternative economic incentives such as tourism are recognized to have significant potential. The potential impacts of such alternatives are not known, therefore, a precautionary approach is strongly advised for limited diving tourism activities pending a better understanding of the effects of divers and related boating activities. Any management arrangements for eco-tourism activities must include provisions that allow for immediate mitigation of the impact. For example, closure of a FSAS to eco-tourism activities if negative effects should be demonstrated.

Monitoring programs on tourism activities on FSAS should be introduced as a matter of course. This should provide data sets over time of fish behavior, numbers, species, interactions with divers, and indications of fishing (spear scars, hook and line wounds, etc.). These data can be fed into an overarching research program monitoring the status of FSAS. Also, this may encourage dive operators to seek to identify other FSAS, or variations in locations and timing. Consideration needs to be given to the minimum distance tourism facilities should be positioned relative to FSAS

Given our current level of understanding of potential impacts, eco-tourism should not be actively encouraged where not already in place but its possible application should be carefully evaluated regarding potential positive impacts on long-term FSAS protection and conservation.

A "Code of Best Practice" should be developed in conjunction with the tourism industry (per region) to raise awareness and recognize the importance of protecting FSAS near tourism facilities. The code may include but not be limited to: a minimum number of divers; a minimum distance from fish; a minimum distance from substratum, guidelines for drift or swim dives; time-of-day restrictions; restrictions on water-based activities in the vicinity of FSAS during peak spawning months.

4.3.1 Possible advantages of eco-tourism to FSAS protection

Possible advantages of eco-tourism to protection of FSAS are:

- The presence of tourism activity at FSAS may reduce fishing pressure (assuming the site is open to fishing); if closed to fishing, visits may reduce the chances of poaching may be reduced
- Increased awareness of the importance of spawning aggregations to reef fish populations.
- By identifying the tourism economic and educational importance of FSAS, there is likely to be greater economic and political incentives to support and fund FSAS conservation and research.

4.3.2 Possible disadvantages of eco-tourism to spawning aggregation protection

Normal spawning behavior, and subsequently the reproductive success of aggregating fishes, may be affected. Using the GBR example, primary FSAS for key species are being afforded greater protection – a buffer zone around the FSAS for installation of moorings, pontoons and reef anchorages. Also, guidelines, such as a code of best practice, will be necessary to prevent over-exploitation.

4.4 Preferred Management Options

All spawning aggregations should be protected. In general, a combination of seasonal area closures and seasonal catch restrictions of priority species is generally the preferred option as a minimum. Permanent areas closures are considered to confer greater protection and should be introduced wherever possible. There are, however, some exceptions (below). Any type of possession of high priority aggregating species should be illegal during closed seasons.

The purpose of this section of the document is to outline and suggest management options for the protection of reef fish spawning aggregations. The nature of many spawning aggregations makes fish stocks extremely vulnerable to over-fishing when fishes are migrating to and at the aggregation site. For this reason the aggregation period and site require specific management measures to ensure the survival of the spawning aggregation and, therefore of fish populations. Although management of the stock during the non-reproductive period is beyond the scope of this document, the working group recognizes the urgent necessity for general fisheries management plans to be enacted for all reef fishes and also recognizes that controlled non-aggregation fishing could itself act as an incentive to protect aggregations sufficiently to ensure the overall good health of the stock itself. In the absence of general fishery management measure(s) the stock remains at risk, despite measures enacted to protect the spawning aggregation. Above all else, we recognize the need to eliminate all destructive fishing practices from our world's oceans. Additional or nested, fishery-related, measures to supplement/complement management measures directly applicable to spawning aggregation protection are included in the options above.

At the most general level we recommend that all transient spawning aggregations be afforded some type of protection. More specifically, we suggest that all aggregation sites that support transient spawning aggregations of multiple species be placed in permanent (year-round) no-take zones. In addition we recommend that all take of each aggregating species be prohibited during its respective spawning season. This insures the safety of aggregation sites that are not known to resource managers, lessens the likelihood of poaching and simplifies enforcement. Moreover, multi-species sites should be afforded year round site protection (no take), and species that have many small aggregations at many sites over a wide area should be managed with seasonal restrictions during the reproductive period (e.g., *Plectropomus leopardus*). In all cases, inter-annual variability in the sites of formation and the timing of formation need to be factored in to the final determination of the specific season/area to be protected. Other more general approaches might also be necessary as ancillary approaches through nested management and to aid compliance of species spawning aggregation protection measures (examples are export controls, the prohibition of diving with hookah near spawning aggregations, or use of gill nets in migration routes to and from spawning aggregations which are not already incorporated under area closures).

Management of transient spawning aggregation sites that support a single species must be considered on a region-by-region basis. In regions where destructive fishing practices occur, the site should be placed in a permanent no-take zone to protect the habitat as well as the aggregating fishes. In regions where destructive fishing methods are not prevalent these single species sites can be protected through a seasonal area closure linked with a seasonal prohibition of take of that species.

We also recommend that all take of all species that form transient spawning aggregations be prohibited during its respective spawning season. This ensures the safety of aggregation sites that are not known to resource managers, lessens the likelihood of poaching, and simplifies enforcement.

Species that form many small aggregations at many sites over a wide-area represent a mid-point in our model contrasting transient and resident types of aggregation spawners. Currently, our only known example of this reproductive strategy exists in *Plectropomus leopardus*, but others may be discovered in the future. It is impractical to create no-take zones around these aggregations because it would require the closure of huge areas of reef (the entire GBR in our *P. leopardus* example). The only practical means of managing this type of aggregation is to enforce seasonal prohibition of catch and possession of the species during the reproductive period.

Resident spawning aggregations need to be evaluated on a region-to-region basis. In regions where these species are not targeted no special management is required. Where these species are targeted management is required. Because of the possibility of daily and year-round occurrence of resident spawning aggregations, some targeted sites must be placed in no-take zones.

In all cases, inter-annual variability in the sites of aggregation formation and the timing of formation need to be factored into the final determination of the specific seasons/area to be protected.

Other more general fisheries management approaches might also be necessary through nested management to aid compliance of species spawning aggregation measures (examples are the prohibition of diving and spearing with hookah or scuba near spawning aggregations, or use of gill nets and traps on migration routes to and from spawning aggregations that are not already incorporated under area enclosures).

5. PRIORITY RESEARCH QUESTIONS

A program of focused spawning aggregation investigation, what could be termed the "discovery phase" is essential to any rational progression of knowledge needed for conservation of the fishes and habitats involved. Traditional knowledge should be gathered and as much as possible, followed up on with a team of trained biologists investigating every known and suspected major aggregation site around the world. Additionally there are opportunities to search for aggregations where none are presently known through opportunistic investigation. At present our knowledge of the timing (seasonal, lunar, daily) is such that we can predict when aggregations might occur in certain (but not all) species and therefore could focus effort to find the aggregation sites for those species during the times most likely to have aggregations. Such searches could be undertaken through fisheries organizations in countries, or more flexibly through the multitude of tourist diving operations found throughout the world today. A small group of researchers could spend periods of a week or so of the most likely season and times investigating the most likely sites in various countries. The overall expense would not be particularly high, and the presence of search teams in countries will undoubtedly turn up much new biological information that will increase our overall understanding of aggregations.

5.1 Connectivity

Connectivity with respect to spawning aggregations can occur through two distinct mechanisms. The first is the movement of fish as eggs and larvae from a spawning aggregation site to a settlement area via dispersal in the plankton lasting several weeks or more. The second is the movement of adults from their normal residence sites to a spawning site (= “catchment area”). Both must be studied to determine the relationship of a particular spawning aggregation or site to the surrounding area.

Identifying the dispersal mechanisms, pathways and settlement patterns of recruits – The eggs and larvae of aggregating reef fishes are planktonic and, at least in their early stages, are carried by water currents. The water mass where the gametes are released is also the water mass where the eggs and larvae will develop unless some active movement is initiated by the larvae. The movement of water masses theoretically containing eggs and larvae can be determined in a number of ways and at various levels of technical sophistication. At the high end, satellite-tracked current-following (Lagrangian) drifter buoys, can track currents for months. Tracking is accomplished by transmissions of position as a result of surface water movement an appropriate satellite array. Although these drifters are relatively expensive they do provide invaluable information regarding possible recruitment pathways over a time scale suitable for comparison to that of time to settlement of planktonic reef fish larvae. The advantage to using satellite tracked drifter is that they can be used anywhere and they provide precise locations on a precise timeline.

Similar drifter buoys that transmit other radio frequency (VHF for example) can also be constructed and tracked from a vessel or aircraft. At the low end, drifters can be deployed with no tracking aids and simply followed for a period of hours or days, their position determined by hand-held GPS units from a tracking boat. In areas of relatively high population density it is possible to use a much cheaper method that uses ballasted laboratory scintillation vials and a label. The ballast prevents the bottle from being blown across the surface by the wind (only a few mm of bottle bobs above the water line) and the label includes information that allows anyone who finds the drifter to contact researchers. This method has proven to be very effective in developed countries but must be evaluated on a case-by-case basis for use in developing regions.

Short term data (up to a few days) immediately after spawning are particularly useful in that these are the days in which eggs and larvae would tend to become entrained in offshore circulation or, alternately, retained in near shore waters and have a high likelihood of recruitment reasonably close to their source. At this stage, eggs and early (yolk sac) larvae are passive drifters. Later, they may be able to actively move against currents and this makes the coupling of drifters to “larval reality” more tenuous.

One difficulty with using these data is that once larvae have developed the ability to swim and vary their depth, the accuracy of drifter tracks at representing the movements of the larvae become increasingly suspect. This is a problem with all drifters, however, it only becomes especially worrisome with satellite drifts because they are able to report their positions for much longer periods of time compared to other methods.

We have an incomplete picture of the behavior of reef fish larvae and the impact of these behaviors on dispersal. Studies of larval biology should be an essential component of the overall research program and can be under taken using a variety of methods. For most larval stages, ichthyoplankton surveys, using discrete depth sampling nets and plankton purse seines can be informative. Studies designed to address the question of larval behavior and sensory abilities are also needed to validate or correct methods used for tracking water masses. Tools that could be used to address larval behavior include moored larval traps, light traps and plankton tows. Large larval rearing facilities may also be determined to be useful for laboratory-based studies.

Identifying the catchment area of adults – Although species that form resident spawning aggregations are not believed to travel great distances, those that form transient spawning aggregations have been documented to move hundreds of kilometers to or from an aggregation site. In fact, tagged individuals sometimes travel directly through conspecific spawning aggregations to return to their specific aggregation site. The catchment area, that is the region from which the spawning aggregation population is drawn, should be identified for each aggregation site. Not only is this an important piece of information for the issue of connectivity, it also identifies the region where that particular stock is susceptible to year round threats and whether aggregations are consistently used by the same individuals.

The catchment area can be identified by tagging individual fishes when they are on the aggregation site and tracking them to their home area. Again, there are high tech and low-tech approaches to these studies. The use of conventional tags is a very inexpensive and effective means of determining the catchment area in developed regions where local fishers are have the means and knowledge to report tag returns. In developing regions the use of these tags must be considered on a case-by-case basis. Reliable results can be gained through the use of electronic telemetry; this includes both the use of pop-up satellite archival tags (PSATs), archival tags and acoustic tags. Satellite tags and archival tags both log temperature, depth and geo-position data on a daily basis. The archival tags must be recovered (can be done by the researcher the following year at the aggregation) while the PSAT automatically detaches from the study fish and transmits the data to the research via an appropriate satellite array. Archival tags can be used on medium to large species while current PSAT technology can only be applied to large species (greater than 30 kilos). Acoustic transmitting tags can be used to manually track fish as they move to and from an aggregation site, but they can also be monitored remotely through the use of strategically placed hydrophones that log the presence of acoustically tagged fish. In fact, some of these systems log not only the presence of the tagged fish, but also the depth at which the fish is swimming, allowing for some valuable behavioral and habitat use analyses.

Alternate methods may be used to tag and track fish. For example, fishes may be captured away from an aggregation site, marked with simple tags, and then released; later, fishes may be recaptured at an aggregation site and both the home area of a fish and the site it utilizes can be determined. This simple method has been successful with the grouper *Epinephelus striatus* in the Tropical Western Atlantic and has provided a record of the greatest migration distance for this species.

Molecular methods are increasingly being applied to determine population structure in fishes. The resolution of these approaches, however, even when based upon microsatellite analysis, can be limited. This means that the finding of significant differences indicate population structuring, while the absence of significant differences does not necessarily preclude population structuring. Molecular approaches, therefore, need to be used and interpreted with care.

5.2 Can over-exploited spawning aggregations recover?

It is not known whether or not aggregations that have been fished to virtual extirpation can recover if management measures are put in place after their demise. Close monitoring (using methods described in Section 6 of this document) of the traditional spawning aggregations/sites that have collapsed is needed to determine whether or not recovery is possible. The degree of exploitation from which an aggregation can recover could be examined by comparing several sites at varying degrees of collapse over time. Experiments that test the mechanism that allows the persistence of a spawning aggregation (transfer of site knowledge among fish, for example) should also be conducted for a better understanding of how spawning aggregations form.

5.3 What features characterize a FSAS?

There are a number of quantifiable physical and oceanographic features that can be described for every FSAS. Most scientists have attempted to gather basic information on features such as the current at time of aggregation and spawning or the general geomorphology of the reef site. Certain "myths" have grown up concerning spawning aggregation sites that may well not be generally applicable to FSAS, but still persist due to a lack of detailed published information showing their lack of rigor. Advances in technology now allow us at low cost to characterize spawning sites in much greater detail to allow more informed comparison of sites used by a single species, across geographic regions, or within the entire spectrum of this biophysical phenomena. The characterization of FSAS falls into a few different categories. The geomorphology of FSAS is variable, among known sites, even within a single species. Some are known to be channels leading from ocean to lagoon, while others are areas of reef along longer outer reef slopes facing the ocean. Others occur in areas without any particular distinctive features, such as promontories, which seem to a human observer like just any other portion of reef. Detailed bathymetric charts are not available for most FSAS areas and to have any useful mapping on which to base all subsequent work, it is critical to prepare maps, ideally bathymetric, using a portable, low cost GPS based mapping system. Once the base map is prepared, it can be used to plot out the distribution of habitat types at the FSAS using underwater surveys and photographs, aerial photographs, and other data to provide a bathymetric habitat map which is used as a reference for future aggregation location and size surveys. This base map can also be used for plotting the distribution of the aggregation at any given moment and to track the potential movements and changes in the area occupied by the aggregation over the duration of a single aggregation and between years.

Physical oceanographic parameters must be measured at both FSAS and at surrounding areas, and similarly at times of aggregation and outside of aggregation periods. Since FSAS have been thought to have characteristics that distinguish them from surrounding areas, hence are "chosen" for a reason, it is critical to gather the same physical information inside and outside spawning sites and periods to have any hope of assessing whether there really are spatial and time differences in FSAS versus nearby areas. Oceanographically FSAS sites ideally need to be characterized for water temperature, currents, tides and waves. Certain sites that might be influenced by inshore (non-oceanic) water might require measurement of salinity, turbidity and sediment load.

Because sea water temperature has been found to be a major factor correlated with spawning season in many species, it is an essential parameter to characterize and can be easily done with inexpensive recording thermographs located at the aggregation site. At a minimum, the annual water temperature regime at the site needs to be documented, and ideally such annual monitoring should extend over several years. If this is done at several sites for a particular species over a broad geographic range, it can be determined whether there is any correlation between aggregation and/or spawning and a particular temperature regime. Such a correlation has been shown for the Nassau grouper and explains the observed geographic variation in spawning season of this important aggregating species.

The measurement of annual temperature cycles, easily accomplished with recording thermographs, enables determination of whether aggregation/spawning occurs on rising or falling temperatures, at yearly minimums or maximums. In essence, continuous monitoring allows us to place aggregation in the context of the annual temperature cycle, a critical thing to know.

Currents are also very important to characterize because they may provide cues to spawning and are the mechanism to remove pelagic eggs from the spawning site. They are, however, a much more complicated parameter to quantify and can exhibit much variation in a single aggregation site. Recording current meters typically cost $8,000-15,000 each and sufficient instrumentation for a single FSAS would require several such instruments. Simpler instruments (i.e., flow meters) can be used at an aggregation site, but must generally be read by a human observer. Water flow away from FSAS is important and can be examined in the short term (a day or two) by low-cost current drifters with GPS logging and radio beacons for locating. For longer tracking of water with larvae, satellite tracked drogues are probably necessary at much greater expense. Questions remain about the ability of drogues or drifters to mimic the track of eggs and larvae, and are of great relevance to questions of connectivity. In regard to FSAS, the initial track of egg bearing water away from FSAS and the mechanisms for entrainment of that water containing gametes into general oceanic circulation is critical to assessing the importance of FSAS to geographically wide spread recruitment.

5.4 Differences between and within species in spawning time, site, and behavior

Variation and plasticity in intra-specific spatial and temporal patterns of spawning time, FSAS, and behavior have been identified for a number of fish species, many of which are subject to heavy exploitation. Effective management of these and other species will be strongly dependent upon the determination of these patterns, an assessment of their significance (i.e., are they real and, if so, how important are they?), and the ability to predict them in time and space.

Spawning times may vary because of latitudinal variation in water temperature, tidal states, diurnal shifts (onset of dusk and dawn), and other influences. For example, the spawning time of a grouper in the southern GBR may differ from that of the same species on the Northern GBR. Spawning time differences may also occur at localities at or near the same latitude, such as has been reported at two relatively adjacent sites in the Solomon Islands. Differences will also be dependent upon the mode of aggregation (transient versus resident). Determination and prediction of spawning times of species across the range of these species, under hypothesis testing, is crucial for establishing seasonal closures as a management tool. Methods for studying spawning times could include time series measurements of fine-scale differences in water temperature in relation to latitude and tidal state and the measurement of spawning events in relation to water temperature, sunset and sunrise patterns, and tidal states. Market samples may be examined to determine time of spawning if it can be determined that fish all come from the same source.

FSAS may vary within species because of habitat structure, tidal influences, and other factors. Differences will also be dependent upon the mode of aggregation (transient versus resident). Determination and prediction of spawning site locations across the range of these species, under hypothesis testing, is crucial for establishing site closures as a management tool. Methods could include descriptions of FSAS in relation to spawning events, comparisons of aggregation site habitats across the range of a given species, measurements of egg and larval transport patterns in relation to site locations, determinations of site selection in relation to population and aggregation sizes, and measurement of recruitment patterns, settlement rates, age determinations of settling larvae, larval behavior in relation to patterns of habitat selection, and genetic composition of larvae at specific reefs in relation to the location of FSAS (but see Section 5.1, above).

Spawning aggregation behavior may vary in relation to population size under natural and impacted (= fished) conditions, mating system plasticity, geography, and phylogenetic constraints. For example, a number of species that form spawning aggregations also reproduce in small mating groups that may spawn independently of spawning aggregations that are present or in the complete absence of spawning aggregations. Determination and prediction of patterns of spawning behavior and mating system plasticity, under hypothesis testing, are essential for predicting minimum population levels necessary for the formation and maintenance of aggregations over time, and reproductive success (i.e., do fish spawn and by how much?) of populations across the range of a given species.

Methods for behavioral studies could include comparisons of reproductive behavior of species in fished versus un-fished populations. Comparisons could also be made for un-fished populations with naturally low or high abundance. Additional methods could include the careful determination of sex ratios within aggregations from fished and un-fished populations and relate this to reproductive success over time (i.e., long-term assessment and monitoring of aggregations with skewed sex ratios).

5.5 The impact of snorkeling, diving, and boating on FSAS

Studies are needed to ascertain the impact of water-based tourism upon spawning aggregations as a basis for introducing regulations, policy and codes of best practice for particular fish families, species, transient and resident aggregations, and individual FSAS.

Research questions include:

- Different reactions of various species, both transient and resident aggregating types, to divers at various times of day. Data would be used to determine minimum approach distances for divers
- The effects of boat noise on aggregating fishes
- The effects of drift diving versus stationary observations upon various species and under varying conditions
- The effects of feeding fishes at FSAS
- Determination of which aggregating type (transient vs resident) is better suited for eco-tourism activities
- Determination of the minimum distance for positioning water-based tourism facilities from FSAS (may vary with different species).

5.6 What are sustainable non-FSAS catch levels?

While the focus of the present plan concentrates on the protection, conservation and management of spawning aggregations and FSAS, a comprehensive protection of exploited aggregating species is incomplete without management of the non-aggregating component of the fishery. Even when spawning aggregations are protected, in many, if not most, cases, exploitation is likely to continue upon aggregating species. To ensure sustainable use of populations that aggregate to spawn, and to preclude or mitigate over-exploitation, it is essential that fishing effort is at a sustainable level. Thus, sustainable levels of total catch (this total to include the sum of local and export catch) need to be determined.

The use of standard stock assessments (e.g., per-recruit type analyses) for reef fishes is generally thought to be infeasible due to insufficient data and the low likelihood of being able to gather sufficient data on a timely basis. In addition, the multi-species nature of most coral reef fisheries, combined with the complex interspecific interactions of the species taken by these fisheries, are likely to make standard stock assessment tools inappropriate. Therefore, alternative means of assessing sustainable levels of take need to be determined. One possibility is to use an ecosystem modeling approach to determine likely levels of total take per unit of reef area, which would then have to be allocated to local and export (if export occurs) sectors. Levels of take should be evaluated per location because spatial differences in reef productivity are large. Measures of population densities for population modeling may be obtained through underwater visual census surveys rather than conventional catch and effort research surveys. Of particular utility is the use of long timed-swims at fixed depths and fixed start/stop points, determined by GPS readings, for estimating relative abundance of fishes, particularly larger or less-cryptic species. This method allows for surveys in habitats where the use of other UVC methods, especially transect lines, is prohibitive or unwieldy. Data from these and other UVC methods could be entered into the ecosystem model. Ecosystem models need to be evaluated for practical utility, however.

It is essential that there be some degree of catch monitoring introduced to determine whether recommended levels of take are being maintained. An alternative might be based on long-term underwater visual census monitoring programs to follow patterns, such as recruitment, in the resource base of interest.

5.7 A note on the role of traditional knowledge

In addressing all these questions, it should be emphasized that traditional knowledge from fishers can be extremely useful for providing guidance to researchers and managers, particularly in areas where there is no information available, or where conservation is urgently required, or where in-depth research cannot be conducted immediately because of a lack of resources. Methods in obtaining and vetting traditional knowledge from fishers are now well developed and there is a growing body of literature available. Traditional knowledge should, however, be a stimulus for further work and not the end-product that is accepted as biological fact without further investigation.

6. MONITORING AND EVALUATION

6.1 Objectives

The objectives of a monitoring program must be carefully defined, because they will determine the design of the program. In addition, monitoring is usually expensive, and therefore the questions need to be clearly defined. Monitoring is essential to determine how populations respond to seasonal closures or total closures on high priority sites. Results can be used to trigger management responses, and to set performance indicators for adaptive management. It is inevitable that fishers restricted from fishing aggregations sites will demand evidence that such restrictions are effective and therefore warranted. Whenever possible, fishers and other stakeholders should be involved in all aspects of the design and implementation of monitoring and in the processing and dissemination of the generated information.

Where there are other management regulations in place for aggregating species, such as minimum size limits, bag limits, marine protected areas and various other effort restrictions, ascribing population trends to aggregation management regulations may be difficult, and will require a carefully designed monitoring program. For example, fished versus un-fished areas can provide a mechanism for teasing apart the impacts of management regulations.

A manual of spawning aggregation monitoring methods is currently being developed by members of the Society for the Conservation of Fish Aggregations. In the interim, the following objectives should be considered as priority objectives with monitoring designed accordingly:

- to measure impacts of management regulations (e.g. closures)
- to assess trends (declines/recovery) in aggregation populations
- to establish long term datasets on aggregation use
- to provide predictive power for other sites/species
- to provide some insight into reproductive biology
- to maintain field presence to deter poaching
- to encourage ownership by traditional resource owners, government (rangers, fisheries officers), and fishers
- to define multi-species versus single species aggregation sites

6.2 Locating Fish Spawning Aggregations

Three key parameters need to be defined to design a specific monitoring program for a particular species:

- How is an aggregation defined or recognized?
- What is the timing or season of the aggregations?
- Where are the aggregations located?

6.2.1 Defining a spawning aggregation

The presence of an aggregation is verified by either recording a several fold increase in density in a given area (e.g. >3 fold), and by confirmed observations of spawning rushes. The latter may also be confirmed by the presence of hydrated oocytes and/or post-ovulatory follicles in the gonads of females taken from the aggregation. Spawning related behavior such as courtship, gravid females and male-male aggression (e.g. bite marks if these marks are demonstrated as related to courtship and not territorial behavior) are potential indicators that should be verified as leading to actual spawning rushes.

6.2.2 Establishing spawning periods

To help design the monitoring protocol, information on the likely timing of spawning aggregations can be sought from fishers, observation of gravid fish in markets, increased numbers of fish in live holding pens, and from gonad histology (e.g. fishery samples)

6.2.3 Locating spawning sites

All aggregations for the species and area under consideration should be located. Again, a number of methods can be used to help locate aggregations if they are not yet known. Nautical charts, satellite imagery, aerial photographs and aerial reconnaissance may be useful for assessing potential aggregations sites, once a bathymetric and oceanographic profile of aggregation sites for a particular species is known. The presence of local aggregations of fishing boats synchronized with moon phase can provide a useful indication of spawning aggregations, and interviews with fishers are particularly helpful. Broad scale surveys on snorkel or manta-tow can also be used, though they are slow and labor intensive.

6.3 Monitoring methods

Monitoring must measure densities of spawning fish on an aggregation site, and therefore requires both an estimate of the size of the aggregation area as well as repeated estimates of the number of fish on the aggregation site. Methods must be standardized, rigorous and repeatable, and therefore comparable across sites, observers and time.

6.3.1 Aggregation site area

Each spawning aggregation must be mapped to define the extent of the aggregation and its surface area. Note that numbers of fish in this area are typically expressed as a density per surface area of benthic habitat, whereas in reality the fish are occupying a volume. This is standard practice in UVC methods and is not of concern since results are relative and therefore comparable. GPS and electronic depth plotters are very effective for creating bathymetry maps to define the bathymetry and area of the aggregation site. Archaeological methods using tape measures may also be used.

6.3.2 Fish numbers

The highly aggregated and localized numbers of fish in spawning aggregations poses particular challenges to estimating fish density. Visual surveys have been widely used for monitoring aggregations, can address a wide variety of situations and are therefore recommended. Conventional underwater visual census (UVC) methods for measuring fish abundance, such as fixed length and width belt transects, and fixed radius point counts, are largely inapplicable to highly-aggregated and localized fish in spawning aggregations. Visual surveys need to be modified to either do total counts of fish over the entire aggregation site, or to sub-sample the site. Further, acoustic surveys (e.g. side scan sonar), as yet not utilized for spawning aggregations, may prove to be very effective for deep, high-density aggregations. Other techniques that may be applied include manually operated video for recording behavior, for verification, and for outreach, and remotely operated video for low light conditions, extreme depths, strong currents, and multiple synchronous deployment.

6.3.3 Guidelines and criteria to select methods for visual surveys

Visual surveys census fish within a fixed path that traverses the aggregation site. The path is designed to cover the entire aggregation site, or a section of the site depending on the magnitude of the aggregation (see below). In some situations, such as with-diver shy species, observers may be tethered at a fixed location recording all fish within a prescribed area within view. Note that timed swims are not recommended because they provide qualitative non-comparable estimates of density. A number of criteria will determine which methods are used for counting aggregating fish: depth, magnitude of fish numbers, currents. The following provide guidelines for selecting appropriate methods.

<u>a. Site depth</u>

- snorkel depth (<10m) e.g. resident spawners
- SCUBA depth range (0-40m)
- beyond safe SCUBA depths (>30-40 m) – submersible, ROV, remote techniques

<u>b. Density of fish</u>

- 10-100s of individuals: Total counts are recommended for aggregations of this magnitude. Species that typify these aggregations include many serranids in the Asia-Pacific region (*Epinephelus* spp. and *Plectropomus* spp.) and the wrasse (*Cheilinus undulatus*).

- 1000s of individuals: It is recommended that a sub-sample of the aggregation is counted for spawning aggregations of this magnitude. Examples include certain serranids in the Asia-Pacific region (~1500 - 4000 fish per aggregation), *Epinephelus striatus* in the Caribbean (up to 6000 fish per aggregation), lutjanids in Caribbean, lethrinids, and certain acanthurids and scarids. Fish in these numbers are generally counted in batches e.g. in 20s, 50s etc (similar to bird counts, and aerial counts of mammals).

<u>c. Currents</u>

- If currents are <60 cm/sec then monitoring can occur at anytime and are recommended to coincide with the time of spawning or close to it.

- If currents are >60 cm/sec (e.g. Komodo, Indonesia) the slack tide must be used as there is no alternative. Note that the latter is not suitable for species that exhibit diurnal patterns such as the coral trout *P. leopardus*.

6.4 Timing of monitoring

Having established a temporal pattern in the occurrence of the aggregation, monitoring should be stratified to reflect this pattern. For example, if aggregations coincide with the new moon then this moon phase should be selected for monitoring to minimize the number of surveys. However, monitoring should also be done periodically during the non-spawning season to record aggregation sites outside the aggregation periods.

6.5 Observer training

Observers need to be trained for aggregation monitoring. Various training schemes currently in place (i.e., GBR, Indonesia and Belize) should be utilized. Observer bias, training in length estimation, recognition of species and spawning behavior, disruption of fish behavior by divers, and SCUBA capability are all factors to be considered. Whenever possible, fishers and other stakeholders should be involved in observer training programs.

6.6 Parameters measured

6.6.1 Number of fish per unit area

The total number of fish in an aggregation is recorded, together with the area of the aggregation so that density may be estimated. Replicate counts are essential to determine mean densities and associated error estimate.

6.6.2 Size

Fish size should be estimated visually to within 2-3 cm FL (or TL). Regular training using model fish is required to ensure that observers provide consistent estimates and to assess observer differences. It may be necessary to start training on land with trainees very unfamiliar with length estimation.

6.6.3 Sex

Sex of individuals should be recorded wherever possible. Some species exhibit gender specific color (e.g. male colors) or morphology, particularly when spawning such as in coral trouts (*Plectropomus* spp.) and the grouper *Epinephelus fuscoguttatus*. Care should be taken in these cases because the color may not be constantly displayed such as in *Plectropomus* spp. and *Epinephelus fuscoguttatus* that show color patterns only when courtship takes place. Dominant males of *P. laevis* seem to be showing color patterns for the duration of the spawning days and the spawning season.

6.6.4 Behavior

Various behavioral parameters may be measured. The following are recommended (but not limited to) for recording by frequency of occurrence:

- Group vs. pair spawning
- Courtship
- Spawning Rushes
- Gravid Females
- Male-male aggression and chasing (if they are determined to be related to courtship-related behavior and not strictly territorial interactions).

- Bite marks on males (if they are determined to be related to courtship-related behavior and not strictly territorial interactions).

6.6.5 Location on site (mapping)

Using maps of the aggregation site, counts of individuals or groups may be marked on the datasheet to record position of fish within the aggregation site. This information may determine aggregation site usage and may be useful for determining potential tourism viewing locations.

6.7 Parameters calculated

Aggregation monitoring will record numbers of fish in aggregations, temporal patterns in spawning activity, and aggregation formation. From these data the following parameters can be calculated:

- aggregation density (number of fish per unit area)
- aggregating population size and sex structure
- temporal patterns in spawning activity and aggregation
- total number of fish at spawning site

These parameters reflect aggregating fish and may be compared with the population densities and size/sex structure of the total population (determined elsewhere). A number of physical parameters should also be recorded during all visual surveys of spawning aggregations:

- Temperature: this may be done using a digital thermograph or hand held mercury or red spirit thermometer.
- Current: current strength and direction should be recorded using current meters or drogues with a GPS. This may be done before, during or after the dive.
- Wind speed and direction
- Sea state

6.8 Tagging

Tagging techniques provide an excellent means of obtaining additional information on aggregating fish and are addressed elsewhere in this document (see Section 5, Research). In terms of monitoring aggregations, tagging may provide a means of estimating aggregation density through mark-recapture analyses. Whenever possible, fishers and other stakeholders should be involved in all aspects of the design and implementation of tagging programs.

6.9 Difficulties in monitoring spawning aggregations

Two key factors affect the effectiveness of monitoring spawning aggregations:

- monitoring more than one aggregation site can require teams of people if aggregations are restricted to narrow windows of time, which is often the case with transient spawning fishes;
- monitoring spawning aggregations only monitors a portion of the total population, and/or a portion of all aggregations. In the former situation, community-based monitoring programs, can provide one solution, which also has a strong outreach benefit. The second factor is relevant to assessing the significance of any change detected by the monitoring.

7. IMPLEMENTATION OF ADAPTIVE MANAGEMENT

This section outlines the broad steps required to implement the identified actions for the conservation and management of reef FSAS, as a component of the Transforming Coral Reef Conservation (TCRC) initiative. The following sections are not intended to be isolated components, but rather integrated and mutually supportive.

7.1 Research

The research questions and activities fall into two broad categories: those that are of a global nature (both "pure" and "applied" research); and those that are focused on issues relating more specifically to one or more networks and/or sites within a network (network level "applied" research).

7.1.1 Global Level Research

The research to be undertaken under this component addresses questions of global significance, and that cannot, or should not, be restricted to sites within the networks. To ensure scientific rigor and quality of the results, this part of the program should be administered through contracting a recognized and appropriate scientific organization. The Society for the Conservation of Reef Fish Aggregations (SCRFA) could be designated as that organization. Under contract, that organization will:

- Establish an international science panel
- Establish or delegate the establishment of policies and procedures for a competitive research grants program
- With input from the TCRC initiative [manager], determine the FSAS research priorities (these priorities need to be reviewed and updated annually)
- Designate an impartial and independent administrative entity for the award and administration of research grants that also includes monitoring progress, under an open and competitive process, and thus removing SCRFA, if it serves as that organization, and its membership from the possibility of conflicts of interest
- Establish a peer review process, through designates, for completed research
- Establish mechanisms, through designates, for timely documentation and distribution of the results.

7.1.2 Network Level Research

The research to be undertaken at this level is focused more on management and conservation questions related specifically to particular networks and/or sites within those networks. Such research will be identified and administered within the network management structure, however, use will be made of the scientific panel [see (i) above] to review proposals and the results as necessary. Implementation principles guiding this component include:

- Research must be applied and targeted to network and/or site questions and top priority given to good quality science
- Where appropriate, and consistent with scientific merit, priority will be given to utilizing "in network" agencies, institutions and individuals
- Fishers and other local stakeholders must be included in the research program
- Where the capacity is limited within the network area, partnerships between agencies, institutions, or individuals from outside the network area should be encouraged to build the capacity of the local institutions and/or individuals
- Linkages between the network level applied research and the global level research program must be developed and maintained
- The timely documentation and distribution of the results must occur

7.2 Implementation Within Networks

In developing the networks there is a need for a clear mechanism to ensure that FSAS management requirements are fully integrated into the overall design, establishment and management of the networks. In designing the network and with implementing the preferred management options, there will be a requirement for access to prompt technical assistance. That assistance may or may not be available locally (e.g. a set of advisors for monitoring). A mechanism needs to be established for providing technical response "teams" within each network, where feasible. This will require:

- Establish an international management advisory committee
- Identifying the appropriate institutional and human resources that can be accessed for or within a network
- Development of partnerships for this assistance (government, institutional, etc.)
- Capacity building components to build that expertise where it is not available

Within networks processes will need to be established that are appropriate for the size and region where the network is located:

- Identify and prioritize sites within a network area
- Initiate outreach activities
- Establish the sites, incorporate into MPA and MPA networks (this may require extending existing MPA boundaries, or creating new MPAs around FSAS)
- Information needs on the FSAS must be collected, management related questions identified, and outreach programs fully implemented for an exchange of information

- Monitoring, evaluation, feedback and adaptive management procedures established
- Documentation and dissemination of lessons learnt

7.3 Global Outreach/Leverage – programs outside the TCRC focus networks

There is a clear recognition that the proposed series of networks will not protect enough FSAS globally. As such it will be essential that the activities conducted under this initiative be leveraged to those areas and sites outside the networks through:

- Supporting the development and maintenance of the Society for the Conservation of Reef Fish Aggregations (SCRFA) FSAS database
- Developing and widely distributing best practices' guidelines that have documented the lessons learnt from both the research and management components
- Identifying FSAS/areas of global significance that are not included in the networks and ensure that the methodologies, tools, best practices are applied by appropriate partners at those sites
- Actively seeking out other FSAS conservation activities and learning from their experiences
- Use modern communication techniques, local and international media to reach out to the public in order to mainstream FSAS conservation
- Identifying and participating in international and regional scientific, conservation and management forums

7.4 Policy Forums at the Global and Regional Levels

To ensure support for FSAS protection there will be a need to influence and change a range of national, regional and international policies, as many of the conservation threats to FSAS come from outside the network (e.g., as from the Live Reef Fish Food Trade). At the national, regional and global levels:

- Identify and fully participate in appropriate policy related forums
- Contribute to policy and management planning for the Live Reef Food Fish Trade
- Develop a regional and global listing of the conference and meetings opportunities for the next 10 years
- Establish procedures to "mainstream" FSAS conservation at the national and regional levels

7.5 Program Management

Coordination will be required at a range of different levels:

- global – overall MPA networks initiative
  - integrate research results into management
  - management issues integrated into research priority setting
  - connecting and exchanging information among networks
- network level and site level

- research – contracting SCRFA or another qualified entity as the appropriate scientific organization
- consultation with partners and the agreed distribution of tasks
- management advice- SCRFA and other entities should provide management advice.

8. OUTREACH

8.1 Introduction

In any conservation programs involving resource owners, stakeholders and other users, there is a strong need for a understanding, trust and good relationships in order for the work to be implemented successfully. This has definitely been demonstrated for MPAs. Dealing with spawning aggregations is no exception. In this sense there are two main levels of awareness. One has to first, ensure that the community has a good understanding of the subject, and second, to ensure that the community understands the work to be conducted and why. An effective outreach program is one that involves resource owners or users as collaborators or participants in conservation and management activities. There are three main advantages to such a participatory approach: (1) stakeholders may have specialized knowledge relevant to resource management that is accessible only through collaborative approaches; (2) the process transfers knowledge and builds stakeholder management capacity; and (3) compliance with resource management decisions is more likely if stakeholders participated in their establishment.

Apart from an overall generic outreach program, it will be necessary to have specific outreach programs planned for the different activities of this global initiative. Additional outreach activity is required before, during and after each respective activity to be able to measure perceptions of its success among stakeholders. Benefits of developing and implementing effective outreach programs are given below. The early and complete involvement of stakeholders will:

- Create a sense of ownership over the work we will be doing and therefore encourage community support and co-operation
- Encourage the sharing of ideas, between researchers, managers, resource users and other stakeholders
- Facilitate the collecting of traditional knowledge and spawning aggregation information such as seasons, timing, and spawning areas, as a start to any scientific investigation of known spawning aggregation sites and to investigate the potential for discovery of new sites
- Improve the understanding of the subject by local communities, leveraging support for management and monitoring measures

8.2 Implementation

The design of an outreach program for implementation would need to be done on a case-by-case basis given the variations in the issues and the different social, economical and cultural factors found between and within regions. Some of the important factors that should be considered are described below.

8.2.1 Target audience

It is important to define the target audience so that the most appropriate and effective level of the language to use, the messages, tools and strategies are selected accordingly. For example, the message and tool used for a politician would be very different to the message and tool used for a fisher with very little or no formal education at all.

8.2.2 Messages

As described above, different messages need to be targeted differently to different audiences in relation to their association with the subject or issue. Politicians might need more policy-related messages whereas fishers would need basic biological understanding of spawning aggregations in clearly understandable terms. The role of researchers would be to develop outreach materials that are scientifically accurate. Communication specialists may be required to deliver these materials to the community.

8.2.3 Tools for delivery

Delivery would depend on the site. The development and delivery of video and DVD materials would be exceptionally useful in many places throughout the region because video and DVD machines are commonplace. In remote places, however, the use of television or videos might be limited and probably posters or one on one consultation would be more appropriate. The role of scientists in an outreach program would be in developing the contents of the outreach materials so that they are accurate. To deliver these materials and ideas to the community, communication specialists are required.

8.2.4 Strategies

To extend the outreach program as widely as possible, an implementation strategy needs to build local capacity building in order to be able to extend the outreach program extensively throughout the local community. This could mean running training workshops for trainers and incorporating the outreach subject materials in educational curricula.

8.2.5 Follow-up and Evaluation

This is often neglected but is essential, therefore a systematic follow-up and evaluation should be strongly emphasized. The effectiveness of an outreach program cannot be evaluated if there is no mechanism for measuring its success in achieving its goals. Such an evaluation mechanism would also be very useful as feedback in refining the initial outreach program to make it more effective or in planning future programs.

9. PARTNERS, ROLES AND RESPONSIBILITIES

9.1 Global

Society for Conservation of Reef Fish Aggregations (SCRFA)

- Research Planning, Administration, and Evaluation
- Development of global data base on spawning aggregations
- Development of methods for studying reef fish spawning aggregations manual
- Management advice

Global Non-Governmental Organizations: Conservation International (CI), International Marinelife Alliance (IMA), The Nature Conservancy (TNC), World Resources Institute (WRI), World Wildlife Fund (WWF), The Oceans Conservancy, and the Wildlife Conservation Society (WCS)

- Planning and design of management and policy
- Capacity building, training, outreach, awareness and constituency building
- Monitoring and evaluation
- Administration, coordination, logistics, implementation and co-management
- Research and science support, fisheries sociology and socio-economics

Pfleger Institute of Environmental Research

- Research

Coral Reef Research Foundation

- Research and monitoring

Cooperative Research Centre-International Marine Projects and Activities Centre (CRC-IMPAC) Townsville, Australia

- Research, fisheries sociology, socio-economics
- Management, implementation and awareness

The World Conservation Union (IUCN)

- MPA Network development by World Commission on Protected Areas (WCPA)
- Awareness-raising through specialist groups (coral reef fish / grouper & wrasse)
- Capacity building with focus upon, among other things, aspects of the live reef fish trade in food and ornamental fishes
- Assessment of species status and the promotion of conservation-related research and conservation action

International Coral Reef Initiative (ICRI)

- Supporting coordination of coral reef initiatives

National fisheries sectors and seafood producers in all regions

- Planning of co-management, outreach and constituency building
- Market transformation

9.2 Australia

Great Barrier Reef Marine Park Authority (GBRMPA)

- Marine park planning and management, implementation of zoning and policy
- Identification and assessment of FSAS
- Awareness and constituency building
- Management advice and capacity building

James Cook University School of Marine Biology and Aquaculture (JCU)
(Also Southeast Asia, Western Pacific and Western Indian Ocean)

- Research, fisheries sociology and socio-economics

Australian Institute of Marine Science (AIMS) (also Western Pacific, Southeast Asia)

- Research

CRC Reef Research Centre

- Research

Fisheries Services of Queensland, Northern Territory and Western Australia

- Fisheries management and implementation of fisheries closures
- Research, awareness and constituency building

Queensland Parks and Wildlife Service

- Day-to-day management of the GBRMP
- Identification and assessment of FSAS in the GBRMP

University of Queensland

- Research

University of Sydney

- Research

Museums of Northern Queensland, Australia, Western Australia, Northern Territory

- Research and awareness

Coastal And Land Management (CALM)

- Day-to-day management of closures and fisheries management strategies
- Awareness

Commonwealth Science and Industry Research Organization (CSIRO)

- Research

Dive Tourism Sector

- Awareness, constituency building and assistance

9.3 Southeast Asia

Tropical Research and Conservation Centre (TRACC), Kuchiing, Sarawak, Malaysia
- Research

Kyushu University Department of Fisheries (also Western Pacific)
- Research

University of the Ryukyus, Sesoko Station, Tropical Biosphere Research Centre, Okinawa (also Western Pacific)
- Research

Sekai National Fisheries Research Institute, Ishigaki, Okinawa, Japan (see also Western Pacific)
- Research

Mie University Department of Human Geography and Ecological Anthropology (Dr. Ken-ichi Nonaka)
- Fisheries sociology

National and Regional Universities (i.e. Philippines, Indonesia, Malaysia-Sabah)
- Research, fisheries sociology, socio-economics and capacity building

Project Seahorse
- Research
- Fisheries sociology

INCUNE – Indonesian Coastal Universities Network
- Research, capacity building and outreach

The World Fish Center (ICLARM)
- Training, capacity building, outreach

International Coral Reef Action Network (ICRAN)
- Promotion and leverage of best practices in MPA management
- Facilitation of community participation and promotion of eco-tourism

Network of Aquaculture Centers in Asia (NACA)
- Research & development for marine aquaculture alternatives

The Conservation and Community Investment Forum (CCIF)
- Development of economic business models for alternative fisheries
- Development of capital investment strategies
- Syndication and local supervision of capital investments

- Management capacity development

RARE CENTER for Tropical Conservation
- Design and implementation of MPA conservation awareness
- Education and small-scale eco-tourism development

National Non-Governmental Organizations
- Monitoring, outreach, training, capacity and constituency building

National and Local Governments
- Planning, policy, legislation, management, implementation
- National park and MPA implementation and enforcement

Tourism and Dive Industry
- MPA financing partnerships
- Outreach and awareness

International Donors and Development Agencies and Projects
- Promotion and support for stakeholder-based co-management systems
- Planning and design of MPAs and MPA networks
- Capacity building, institutional strengthening, training and awareness

National And International Media
- Outreach and constituency building

9.4 Western Pacific

Secretariat of the Pacific Community (SPC), Noumea, New Caledonia
- Policy and planning
- Administration, coordination and management
- Research and monitoring
- Outreach and capacity building

National Fisheries Departments (SPC island member countries and territories)
- Policy and planning
- Management, administration, coordination and logistical support
- Research and monitoring

Institute of Research & Development (IRD), Noumea, New Caledonia
- Research, monitoring and capacity building

Community Conservation Network (CCN), Honolulu, HI & Koror, Palau
- Planning, monitoring, management, outreach and capacity building

University of Guam Marine Laboratory

- Research, outreach, awareness and capacity building

University of Hawaii Department of Zoology, Hawaiian Institute of Marine Biology, and U.S. Cooperative Fishery Unit

- Research, outreach, awareness and capacity building

B.P. Bishop Museum, Honolulu

- Research and awareness

University of the South Pacific, Suva

- Research
- Outreach
- Awareness
- Capacity building

University of Papua New Guinea

- Research
- Outreach
- Awareness
- Capacity building

Regional Universities and Community Colleges

- Research, outreach, awareness and capacity building

Palau International Coral Reef Center, Koror, Palau

- Policy, research and monitoring
- Logistical support, outreach and capacity building

Palau Conservation Society, Koror, Palau

- Monitoring, management, outreach and capacity building

Conservation Society of Pohnpei, Kolonia, FSM

- Monitoring, implementation, management, outreach and capacity building

South Pacific Geo-Science commission (SOPAC), Suva, Fiji

- Planning, research and capacity building

National Environment Departments

- Planning and policy
- Administration, coordination and logistical support
- Management, outreach and capacity building

South Pacific Regional Environment Programme (SPREP), Apia, Samoa

- Policy and planning
- Administration, coordination, management and monitoring
- Outreach and capacity building

Forum Secretariat, Suva, Fiji

- Policy and planning

9.5 Eastern Pacific

Scripps Institute of Oceanography

- Research

University of California, Berkeley

- Research

University California, Santa Barbara

- Research

California State Universities at Northridge and Long Beach

- Research

University of Arizona

- Research

Mexican Fisheries Department

- Management, monitoring and enforcement
- Policy

Mexican NGOs

- Co-management and monitoring of MPAs
- Outreach

Mexican local and municipal governments

- Co-management and monitoring of MPAs
- Outreach
- Policy

9.6 Tropical Western Atlantic

Gulf and Caribbean Fisheries Institute

- Regional coordination and data management
- Regional policy forum

Regional Coastal Monitoring and Management Projects
PROCAM (Central American Regional Conservation Project), Mesoamerican Barrier Reef Systems Project, CARICOMP network, CARICOM fisheries, Association of Marine Laboratories of the Caribbean

- Central American coastal management and policy
- Regional coordination, policy and monitoring

National Coastal Zone Management Programs
(i.e. Coastal Zone Management Authority and Institute, Belize)

- Management, implementation and monitoring
- Policy and outreach

National Fisheries Departments
(need awareness raising and means of implementation)

- Ensure sustainable resource use, fishery management and enforcement
- Fishery assessment, implementation, monitoring and capacity building

Marine Reserves

- Management, implementation, monitoring and enforcement
- Outreach and awareness

National and Private Academic Institutions

- Research

Environmental Defense (ED)

- Policy and management

Federal and State Enforcement Agencies (US Coast Guard, Florida Marine Patrol, Florida Dept. of Marine Resources, Puerto Rico Dept. of Natural Resources)

- Implementation and enforcement

National Non-Government Organizations
Belize (Green Reef, Belize Audubon Society, TIDE, Friends of Nature), Mexico (Ecosur, Amigos de Sian Ka'an), Bahamas (Andros Conservation Alliance and Trust, ANCAT)

- Awareness, outreach and capacity building
- Co-management and monitoring of marine reserves

South Atlantic and Gulf Marine Fisheries Councils

- Management

9.7 Western Indian Ocean

J.L.B. Smith Institute of Ichthyology, South Africa

- Research

Coral Reef Degradation in the Indian Ocean (CORDIO)

- Implementation

Government of Seychelles Division of Environment

- Implementation, management, research

Seychelles Marine Resources (SMRT), Marine Park Authority, and Fishing Authorities

- Management of fisheries and implementation of FSAS component
- Research and monitoring

National Parks

- Management and monitoring

Marine Park Authorities (Seychelles, Tanzania, Kenya, Maldives, Mozambique, etc.)

- Management and monitoring

National Fisheries Departments

- Management

Kenya Marine Fisheries Research Institute (KMFRI)

- Monitoring and research

Institute of Marine Science (University of Dar es Salaam)

- Research and monitoring

Coral Reef Conservation Project (Kenya)

- Research

10. GOALS, BENCHMARKS, TIMELINE AND BUDGET

Ten Year Component Goals:

1. All *high-priority*[1] spawning aggregations and spawning aggregation sites within the area encompassed by 5-7 *MPA networks*[2] are *fully protected*[3] and *regularly monitored*[4].
2. Through leverage, a majority of high priority spawning aggregation sites globally outside of these networks are fully protected and regularly monitored.
3. Scientifically competent knowledge base developed, through research, to guide preferred management options for FSAS and implementation and evaluation of MPA networks.

2 YEAR BENCHMARK	5 YEAR BENCHMARK	10 YEAR BENCHMARK
Initial guidelines for the management of FSAS and for the incorporation of aggregation sites into MPAs and resilient MPA networks are developed and disseminated for application and testing worldwide; includes monitoring methods.	Guidelines for the management of FSAS and for the incorporation of aggregation sites into MPAs and resilient MPA networks revised based on experience with initial application, additional research results, and the precautionary principle, and distributed worldwide.	Guidelines for the management of FSAS and for the incorporation of aggregation sites into MPAs and resilient MPA networks further revised based on experience, additional research results, and the precautionary principle, and distributed worldwide.
All high priority spawning aggregation sites within the area encompassed by at least 2 MPA networks identified and strategies designed for their protection.	All high-priority spawning aggregation sites within the area encompassed by at least 2 MPA networks are fully protected and regularly monitored.	All high-priority spawning aggregation sites within the area encompassed by 5-7 MPA networks are fully protected and regularly monitored.
	All high priority spawning aggregation sites within the area encompassed by at least an additional 3-5 MPA networks identified and	All high priority spawning aggregation sites within the area encompassed by at least an additional 10 MPA networks identified and

[1] "high priority" = sites scoring in top 35% of species and/or site priority selection criteria
[2] the MPA networks selected for focused attention under the TCRC program
[3] by management interventions as described in chapter 4.5, Preferred Management Option
[4] by monitoring programs designed and implemented as described in chapter 6, Monitoring

2 YEAR BENCHMARK	5 YEAR BENCHMARK	10 YEAR BENCHMARK
	strategies designed for their protection.	strategies designed for their protection.
	At least 25% of high priority spawning aggregation sites globally outside of TCRC focus networks are fully protected and regularly monitored.	At least 50% of high priority spawning aggregation sites globally outside of TCRC focus networks are fully protected and regularly monitored.
Competitive peer-reviewed research program focused on priority research questions on spawning aggregations established and first set of proposals funded.	The spawning habits, site characteristics, larval dispersal potential, adult movements, and regional variation of 10 key target species identified. Hypotheses with respect to why spawning aggregations occur have been scientifically tested.	Scientifically competent knowledge base developed, through research, to guide preferred management options for FSAS and implementation and evaluation of MPA networks.
Input from the global SCRFA database of high priority fish spawning aggregation sites that is being developed can be used to update priority species and sites for conservation status is being compiled following a standardized format and will be made available on the Internet.	In at least two MPA networks, there are a minimum of 10 local national scientists trained at the graduate level in relevant disciplines, and at least three local or national institutions, effectively playing active roles in spawning aggregation site protection and monitoring.	In 5-7 MPA networks, there are a minimum of 10 local national scientists trained at the graduate level in relevant disciplines, and at least three local or national institutions, effectively playing active roles in spawning aggregation site protection and monitoring.
	At least two regional or international policies are significantly changed to be more conducive to effective protection and monitoring of spawning aggregation sites.	At least two additional regional or international policies are significantly changed to be more conducive to effective protection and monitoring of spawning aggregation sites.

Activities and Budget Table, Spawning Aggregations Component

ACTIVITIES >> ACCOMPLISHED BY >> BUDGETTED AT >>	Yr2	Yr5	Yr10	LEADING PARTNER	BUDGET ($000,000)
1. Research				**SCRFA / Global**	**35.5**
Global process (Global "pure" and "applied", Sub-Total)					**25.0**[5]
❖ Contract(s) with appropriate organization(s) to manage research component	X				
• Establish international science panel; establish policies and procedures	X				0.5
• Determine research priorities; conduct an open and competitive process for the selection and disbursement of research grants	X				0.5
• Research Implementation	X	X	X		23.5
• Administer the research grants, including monitoring progress; establish a peer review process for completed research	X	X	X		0.5
Network level ("applied" Sub-Total)					**10.5**
❖ Research targeted to network and other high priority site questions		X	X	**LOCAL/SCRFA**	10.0
❖ Administration of management of research grants to network implementers		X	X	**LOCAL/SCRFA**	0.5
2. Implementation of management within TCRC focus networks				**GLOBAL NGOs**	**32.0**
❖ In network capacity building for research and management	X	X	X		1.0
❖ Establish mechanisms for timely documentation and distribution of research outputs, monitoring results, lessons learned and management evaluation reports; develop linkages to other networks and outreach activities		X	X		0.5
❖ Establish a mechanism for providing technical 'response' re FSAS Establish an international management advisory panel • Identify appropriate institutional and human resources that can be accessed for/within a network, e.g. a set of advisors for monitoring • Capacity building • partnership development (govt., institutional, etc.)	X	X			0.5

ACTIVITIES >> ACCOMPLISHED BY >> BUDGETTED AT >>	Yr2	Yr5	Yr10	LEADING PARTNER	BUDGET ($000,000)
Development and Implementation of Network Management (Sub Total)				GLOBAL NGOs	30.0
• identify and prioritize sites within network areas	X	X			2.0
• planning and design of management, incorporation in MPA management plans	X	X			3.5
• develop, initiate and implement outreach activities	X	X	X		3.0
• establish the sites – incorporate into MPA and MPA networks	X	X	X		2.0
• information needs collected, management related questions identified and feedback to outreach, research and management programs		X	X		0.5
• monitoring, evaluation, feedback to management	X	X	X		8.0
• adaptive management and enforcement		X	X		10.0
• documentation and dissemination of lessons learned		X	X		1.0
3. Global Outreach/Leverage – programs outside the TCRC focus networks				**Global NGOs**	**13.0**
❖ Capacity building for research and monitoring – institutional/individual		X	X		2.0
❖ Establish mechanisms for timely documentation and distribution of research outputs, monitoring results, lessons learned and management evaluation reports; linkages to other networks and outreach activities	X	X			0.5
❖ Guidelines (including monitoring) development, distribution, documentation of lessons learned, revision	X	X			0.5
❖ Identify FSAS/areas of global significance that are not included in the networks and ensure methodologies, tools, etc. are provided	X	X			3.0
❖ Protect and monitor FSAS outside focus networks		X	X		4.0
❖ Identify and participate in international and regional scientific, conservation and management forums	X	X	X		0.5
❖ Actively seek out other FSAS conservation activities and learn from their experiences, including South-South exchanges		X	X		2.5

ACTIVITIES >> ACCOMPLISHED BY >> BUDGETTED AT >>	Yr2	Yr5	Yr10	LEADING PARTNER	BUDGET ($000,000)
4. Policy forums at the global and regional levels				**Global NGOs**	**3.0**
❖ Identify and fully participate in appropriate global and regional forum for policy engagement	X	X	X		1.0
❖ Mainstream FSAS conservation at national and regional levels		X	X		2.0
5. Program Management				**Global NGOs**	**2.0**
❖ Coordination at different levels • global – overall MPA network program - integrate research results into management - management issues integrated into research priority setting - connecting and exchange of information among networks • network level and site level • research – contracting appropriate scientific organization	X	X	X		2.0
6. Total Budget					**85.5**

Annex 1: Participants

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