Development of a Caribbean Regional Conservation Strategy for Reef Fish Spawning Aggregations

BRIAN E. LUCKHURST
Division of Fisheries
P.O. Box CR 52
Crawl CRBX
Bermuda

ABSTRACT

Intensive fishing of spawning aggregations (SPAGs) has led to the degradation of many sites on a global scale. Recent scientific studies have confirmed the decline or demise of many aggregations. The need to take action to ensure the protection of spawning aggregations led to the formation of the Society for the Conservation of Reef Fish Aggregations (SCRFA). Many of the economically important reef fish species e.g. groupers and snappers, share life history characteristics which make these species particularly vulnerable to overexploitation. The formation of spawning aggregations by most of these species exacerbates this vulnerability. The documentation and evaluation of the status of spawning aggregations of groupers and snappers in the region indicates that most sites have been suffering declines in landings. In particular, the Nassau grouper has been significantly impacted by fishing pressure with the disappearance of a number of sites in different countries. A conservation strategy for spawning aggregations in the Caribbean region is presented comprising the following seven elements:

i) Elimination of fishing mortality at vulnerable SPAG sites,
ii) Incorporation of known SPAG sites into planning programs for Marine Protected Areas (MPAs) to provide permanent protection of the sites,
iii) Development and implementation of monitoring programs to evaluate the effect of management /conservation measures,
iv) Development of community-based management programs for SPAG sites,
v) Provision of viable economic alternatives to those user groups who are displaced from SPAG sites, and
vi) Application of gear restrictions to reduce catchability if closure of SPAG sites cannot be implemented, 7) Use of economic/market measures such as sales or export restrictions to reduce fishing activity at SPAGs.

KEY WORDS: Spawning aggregations, Caribbean, conservation, groupers, snappers

INTRODUCTION

Reef fish spawning aggregations (SPAGs) are severely threatened on a global scale. Intensive fishing of spawning aggregations by coastal fishing communities as well as the exploitation of SPAGs for the Live Reef Food Fish Trade (LRFFT) in the Indo-Pacific has degraded many SPAGs on a global basis. The results of recent

scientific studies have confirmed the decline or demise of many aggregations and there is growing international concern for the future of these sites. The need to take action to ensure the protection of spawning aggregations led to the formation of the Society for the Conservation of Reef Fish Aggregations (SCRFA). SCRFA came into existence at a meeting of the American Society of Ichthyologists and Herpetologists at La Paz, Baja California Sur, Mexico, in June of 2000 when a number of biologists with research experience with spawning aggregations in both the Atlantic and the Pacific met to consider a possible course of action. The Society held its first formal meeting at the 9th International Coral Reef Symposium during October 2000 in Bali, Indonesia. Members of SCRFA agreed that there are vast and growing threats to reef fish spawning aggregations, particularly groupers (Musick et al. 2000) and that a widely shared strategy for conservation of these aggregations is urgently needed. The members presently comprise research biologists, but they recognize the need to involve marine reserve managers, policy makers, and representatives from the fishing industry.

The Nature Conservancy (TNC), in sharing these concerns about the future of SPAGs, believes that the conservation of reef fish spawning aggregations is important to many marine sites and to the health of tropical marine ecosystems in general. In pursuance of this belief, TNC decided to support the development of a spawning aggregation (SPAG) conservation strategy for the Caribbean/Latin America region and to integrate this strategy with one being prepared for the Asia Pacific region to produce an international SPAG conservation strategy.

BACKGROUND

Many of the economically important reef fish species e.g. groupers and snappers, share a suite of life history characteristics which make these species particularly vulnerable to overexploitation (Koenig et al. 1996). Certain features of their reproductive behaviour and ecology tend to further exacerbate this problem. In general, these species exhibit the following characteristics as outlined by Coleman et al. (2000):

i) Slow growth,
ii) Late sexual maturity,
iii) High site fidelity,
iv) Spawning migrations to established sites,
v) Complex social structure, and
vi) Sex reversal (groupers).

The complex life history of many species of grouper and the formation of spawning aggregations by groupers and snappers helps to explain why conventional fishery management measures have largely failed to adequately address the problem of overfishing on these important groups (Sadovy 1994).

Studies have indicated that natural mortality rates are very low in many of these large, long-lived species (Coleman et al. 2000), and this implies that to maintain populations at sustainable harvest levels that only a small proportion of the species

biomass (possibly only 10%) can be harvested annually (Coleman et al. 2000). In contrast, fishing mortality rates are generally much higher, and fishing effort typically removes the oldest and largest individuals. Over time this leads to a truncation of the size distribution in the population with the largest size classes absent. The largest fish typically make the greatest contribution to the reproductive output of the population, e.g. a single gag grouper (*Mycteroperca microlepis*) at age eight produces as many eggs as 48 gag at age three (Collins et al. 1998). In particular, the catchability at spawning aggregation sites is much higher than during non-aggregation periods and thus, the level of fishing mortality which can be inflicted with directed fishing is extremely high. This vulnerability is further increased by the high level of site fidelity exhibited by most groupers (e.g. red hind *Epinephelus guttatus*, Luckhurst 1998, 2000) and snappers (e.g. cubera snapper *Lutjanus cyanopterus*, Heyman et al. 2001). This aspect of their reproductive biology makes fishes returning to the same SPAG site susceptible to harvest on a repeated basis.

SUMMARY OF CURRENT STATUS OF SPAWNING AGGREGATIONS BY COUNTRY IN THE GREATER CARIBBEAN REGION

A first step in determining SPAG status was to generate a list of the species documented to form spawning aggregations in the region, based on the criteria outlined by Domeier and Colin (1997). This list is dominated by the commercially important groupers (Serranidae) and snappers (Lutjanidae) although, other commercially important species in the region e.g., jacks (Carangidae) and grunts (Haemulidae) are also known to form SPAGS (Auil-Marshalleck 1993). However, there are relatively few observations of these latter two groups. As a consequence, the list is restricted to groupers and snappers only, with eight and seven species respectively (Table 1).

The documentation and evaluation of the status of SPAGs of groupers and snappers in the region (Table 2) is based on the best information available. The documentation of SPAGs in the different countries or jurisdictions in the region is variable. Some SPAG sites have been exploited for decades (Carter et al. 1994) while others have only recently been documented (Aguilar-Perera and Aguilar-Davila 1996). Evaluation of their current status is highly variable. In some instances, there is published information and data on given sites while for many others, there is only anecdotal information.

It is clear from Table 2 that the majority of SPAG sites appear to be suffering declines in landings and that the Nassau grouper in particular has been significantly impacted by fishing pressure with the disappearance of a number of SPAGs in different countries (Sadovy and Eklund 1999). The only species /sites which appear to be stable are those which have specific management measures in place for SPAGs (principally seasonal area closures). It is not possible to prove cause and effect, but these findings strongly suggest that active management of SPAGs (centered on limiting fishing mortality) can be highly beneficial to the populations under exploitation (Bohnsack 1989).

Table 1. List of grouper and snapper species documented to form spawning aggregations in the greater Caribbean region. These species are included on the basis of published accounts of spawning or documentation by scientific observers of one or more of the criteria associated with spawning aggregations as designated by Domeier and Colin (1997).

Family	Species	Common Name
Serranidae	*Epinephelus adscensionis*	Rock hind
	E. guttatus	Red hind
	E. itajara	Goliath Grouper
	E. striatus	Nassau grouper
	Mycteroperca bonaci	Black grouper
	M. microlepis	Gag grouper
	M. tigris	Tiger grouper
	M. venenosa	Yellowfin grouper
Lutjanidae	*Lutjanus analis*	Mutton snapper
	L. apodus	Schoolmaster
	L. cyanopterus	Cubera snapper
	L. griseus	Gray snapper
	L. jocu	Dog snapper
	L. synagris	Lane snapper
	Ocyurus chrysurus	Yellowtail snapper

CARIBBEAN REGIONAL CONSERVATION STRATEGY FOR REEF FISH SPAWNING AGGREGATIONS

The ability to undertake the strategy which has been developed will be dependent to some degree on the governmental and legislative framework existing in each country. If legislation for a resource management action already exists in a given jurisdiction, then the main element necessary to carry out the action is political will. In a related manner, this same element must be present to create the necessary legislation if it does not already exist. The conservation of SPAG sites will have to be evaluated on an individual basis to determine the community and national impacts before selecting the appropriate management elements of the strategy.

A guiding principle of this strategy is that SPAGs should be managed as an integral part of the entire reef ecosystem. The removal of a large biomass of top predators e.g. groupers and snappers, at SPAG sites is likely to have a significant effect on reef fish community structure and function. Conservation measures implemented in isolation will likely have a lower probability of long term success if the effects on ecosystem function are not taken into account.

Given the lack of in-depth knowledge of the dynamics of SPAGs, the precautionary approach to fisheries management has been invoked throughout this strategy. The greater the uncertainty in the understanding of SPAGs, the more conservative the management /conservation measures should be.

Table 2. Summary of current status of spawning aggregations (SPAGs) in the greater Caribbean area by country and species. Only the commercially exploited species of grouper and snapper are listed. Countries (or jurisdictions) with documented spawning aggregations are listed from north to south. Status refers primarily to documented fishery landings but may include fishery independent evaluation of given aggregation sites. Status reflects an overall trend in recent years but may not accurately reflect the current status (2001) as changes can occur rapidly at SPAG sites.

Country/ State	Total SPAG Sites	Species Involved	Current Status (Landings)	Reference / Source
Bermuda	3	Red Hind	Stable	Luckhurst, 1996; MS
	4	Nassau Grouper	Disappeared	Luckhurst, 1996
Bahamas	22	Nassau Grouper	Declines Heavily expl.	Braynen, pers. comm., Ray et al., 2000
Turks and Caicos Islands	5	Nassau Grouper	Lightly exploited	Clerveaux, pers. comm.
Florida	3	Cubera snapper	Declines	Lindeman et al., 2000
25 total sites including :	1	Dog snapper	?	Lindeman et al., 2000
Dry Tortugas	8	Gray snapper	?	Lindeman et al., 2000
Key West area	1	Lane snapper	?	Lindeman et al., 2000
Gulf Coast	4	Mutton snapper	Declines	Lindeman et al., 2000
	2	Schoolmaster snap	?	Lindeman et al., 2000
	1	Yellowtail snap	?	Lindeman et al., 2000
	?	Black grouper	Declines ?	Eklund et al., 2000
	2?	Gag grouper	Declines	Coleman et al., 1996
	?	Scamp	Declines	Coleman et al., 1996
	>4?	Goliath grouper	Protected	Sadovy & Eklund, 1999
Cuba (21 total sites)	10	Cubera snapper	Declines	Claro and Lindeman, in press
	3	Dog snapper	Declines	Claro and Lindeman, in press
	3	Gray snapper	Declines	Claro and Lindeman, in press
	13	Lane snapper	Declines	Claro and Lindeman, in press
	12	Mutton snapper	Declines	Claro and Lindeman, in press
	5	Black grouper	Declines	Claro and Lindeman, in press

Table 2 (cont.)

Country/ State	No. SPAG Sites	Species	Current Status (Landings)	Reference / Source
	9	Nassau grouper	Declines	Sadovy & Eklund, 1999
	6	Yellowfin grouper	Declines	Claro and Lindeman, in press
Mexico - Quintana Roo	7	Nassau grouper	Declines / 1 Disappeared	Aguilar-Perera and Davis, 1996
Campeche	1	Yellowfin grouper	Heavily expl.?	Tuz-Sulub, in press
Bank	1	Red hind	Mod. expl. ?	
Belize	1	Cubera snapper	Heavily expl.	Heyman, pers. comm.
(13 total sites)	4	Dog snapper	Heavily expl.	Heyman, pers. comm.
	3	Mutton snapper	Heavily expl.	Heyman, pers. comm.
	?	Yellowtail snap.	?	Heyman, pers. comm.
	9	Nassau grouper	Declines / Disappeared	Paz and Grimshaw,2001 Sala et al., 2001
	5	Black grouper	Lightly expl?	Heyman, 2001
	4	Tiger grouper	Lightly expl?	Heyman, 2001
	2	Yellowfin grouper	Lightly expl?	Heyman, 2001
	?	Red hind	Lightly expl?	Heyman, 2001
Honduras - Guanaja	1	Nassau grouper	Disappeared?	Fine, 1992; Sadovy & Eklund, 1999
Cayman Islands	6	Nassau grouper	Declines	Bush et al, MS
	5	Tiger grouper	Lightly expl.	Bush, pers. comm.
	2	Mutton snapper	Lightly expl.	Bush, pers. comm.
Jamaica	1	Lane snapper	Heavily expl	Aiken, pers. comm.
Dominican Republic	1	Nassau grouper	Disappeared?	Sadovy & Eklund, 1999
Puerto Rico	4	Red hind	Declines	Matos-Caraballo, 1997
	1	Tiger grouper	Declines	Matos-Caraballo et al, MS
	3	Nassau grouper	Disappeared	Sadovy & Eklund, 1999
	1	Mutton snapper	Declines?	Garcia-Moliner, 2000
U.S. Virgin Is.	3	Red hind	Stable	Beets & Friedlander, '99
	3	Nassau grouper	Disappeared	Olsen & Laplace, 1976
British Virgin Islands	3	Red hind	Lightly expl.	Eristhee, pers. comm.
	1	Nassau grouper	Lightly expl.	Eristhee, pers. comm.

MAIN ELEMENTS OF CONSERVATION STRATEGY

The elements of the SPAG Conservation Strategy listed below are generally in priority order but the strategy will need to be adapted to the individual conditions determined for each site under consideration:

i) *Eliminate fishing mortality at vulnerable SPAG sites* — Limited data suggests that fishing at a number of SPAG sites in the region is not sustainable in the longer term with the existing gear types in use and the fishing effort presently being exerted (Sadovy 1999). Permanent closure of a SPAG site will lead to the elimination of fishing mortality at the site. However, if this is not possible, seasonal (temporary) closure of a SPAG site should be pursued as an essential alternative as it will help substantially reduce fishing mortality during the critical spawning period. Temporal and /or spatial buffer zones should be included in seasonal closures. Fishing at the SPAG site (or along established spawning migration routes) in the period leading up to the closure, as fish are starting to aggregate, may still lead to substantial fishing mortality. Thus, permanent closure is the preferred option (see #2).

A sense of urgency should be invoked for management /conservation action bearing in mind that SPAGs have historically shown dramatic declines, often in a short time frame. Data suggests that the groupers appear to be more vulnerable to fishing pressure than the snappers (Sadovy 1996, Coleman et al. 2000) and Nassau groupers have been shown to exhibit dramatic declines (e.g. Luckhurst 1996) over a 3 - 5 year period under sustained heavy fishing pressure (Olson and LaPlace 1979, Sala et al. 2001). The removal of a large proportion of the spawning fish at a given site in several consecutive years has led to the disappearance of a number of SPAGs in the region (Sadovy and Eklund 1999). Limited information about these sites suggests that they do not re-appear. This finding indicates that there may be a threshold effect whereby reproductive behaviour is negatively impacted if a given minimum number of fish are not present at the SPAG site.

ii) *Incorporate known SPAG sites into planning programs for marine protected areas (MPAs) to provide permanent protection of the sites* — In general, the enforcement of fisheries regulations in the Caribbean has not been particularly successful due in part to the lack of resources and infrastructure and also the number of different regulations which address taxon or area-specific issues. The creation of MPAs addresses a number of ecological and regulatory issues (Plan Development Team 1990). In general, the enforcement of the no-take provision of an MPA is easier when the boundaries of the given area are well-defined and the rationale for its creation is understood by the various resource user groups. The incorporation of SPAGs into no-take MPAs would accomplish several of the objectives presented here including protection of the spawning populations from fishing pressure and helping to maintain ecosystem

structure and function (Lindeman et al. 2000). The longevity of SPAG sites (Colin 1996) makes their incorporation into an MPA an attractive conservation /management option.

The documentation of multi-species use of the same SPAG site greatly strengthens the rationale for incorporation of the site into an MPA. This is because a proportion of the spawning population of a number of different species will all be afforded protection during the period of maximum vulnerability and this protection will help ensure normal ecosystem structure and function. A number of such multi-species SPAG sites have already been identified in Belize (Heyman pers. comm.) and the recognition of the ecological importance of such sites is being promoted to help ensure their protection. Furthermore, the identification of the key features of these SPAG sites will allow researchers to predict and evaluate sites throughout the region including perhaps SPAG sites which are as yet undetected. The identification of such sites could afford researchers the opportunity to study such unfished sites to better understand their dynamics and to be pro-active in affording them protection.

iii) *Develop and implement monitoring programs to evaluate the effect of management/conservation measures* — Scientists, managers, and fishermen need to gather more information to better understand the dynamics of SPAGs and to examine different management /conservation measures as applied to a given SPAG site. Careful monitoring of selected sites should be planned when measures are implemented. These measures when applied should be viewed as fishery experiments from which much can be potentially learned about the system under study. The involvement in the monitoring process by different user groups should increase the sense of stewardship of the resources and provides direct feedback to the community about management and conservation actions.

iv) *Develop community-based management programs for SPAG sites to the fullest extent possible* — Historically, a "top-down" approach to the management of tropical marine resources has generally been ineffective. Rarely have sufficient resources, either human or material, been available to carry out government mandates in the context of marine resource management. User groups, mainly fishers, generally view management regulations as government attempts to reduce their ability to make a living from harvesting fishery resources. They are not often in support of restrictions of their fishing activities. From the government perspective, there is a need, in fact a responsibility, to manage the fishery resources of the country as these are common property resources belonging to all citizens of the country. Unfortunately, an adequate explanation as to the need for the management of fishery resources is often not provided to the user groups affected by the management measures.

Full participation in the management process by all of the user groups affected by management measures will greatly increase the probability of

success. Scientists (particularly those from outside government service) can help to provide the conceptual framework to the affected communities for the recommended management action. Fishers are empiricists and it often requires much discussion to gain their support for a measure based on a concept. However, the concept of protecting the reproductive process is so fundamental to human thinking that the conservation of SPAGs is usually not very difficult to accept. A full discussion of the proposed action and its consequences is a necessary step to garner the support of the community (King and Faasili 1999). Partnerships between government departments and NGOs is frequently an effective means of increasing support for management measures.

v) *Provide viable economic alternatives to those user groups who are displaced from SPAG sites as a result of management action.* — This is an important and necessary step in helping to ensure the long term success of management measures implemented for conserving SPAGs. An evaluation of the economic importance of the landings from SPAGs, as a proportion of the annual revenue earned by fishers (e.g. Sala et al. 2001) should be undertaken to assist with planning and training activities. Unless adequate provisions are made for fishers for the transition away from SPAG fishing, there is likely to be continued economic pressure on fishers to continue harvesting at SPAGs. The employment opportunities for displaced fishers providing alternative sources of income will most often take advantage of the skills and experience gained by fishers over the years, e.g. knowledge of coral reef fauna, boat handling, etc. In Belize, training is being provided to fishers as SCUBA diving guides and as fishing guides for sportfishing as an alternative to SPAG fishing (pers. obs., Heyman pers. comm.). Additional alternate activities are the development of aquaculture, particularly floating cage culture, which is already well-developed for groupers in southeast Asia. This form of mariculture can be conducted primarily as a low-tech grow-out operation and can be readily adopted by fishermen. However, careful consideration must be given to promoting aquaculture as it can have significant negative effects on the marine environment through pollution and destructive fishing practices to obtain juveniles for grow-out.

vi) *If permanent or temporary closure of SPAG sites cannot be implemented, then gear restrictions should be applied to reduce catchability.* — There is evidence which suggests that the use of certain gear types, e.g. Antillian fish traps (Luckhurst 1996) and spearfishing for harvesting at SPAG sites increases fishing mortality rates. Marked declines in catches have been noted at sites following the introduction of these gear types. Fish traps are a passive gear type and fish 24 hours a day thus applying constant fishing pressure on aggregated fish in contrast to an active gear such as hook and line fishing. Spearfishing is a form of selective predation with the largest fish usually being the targets. Therefore, the only gear type which should

be permitted at SPAG sites is hook and line fishing. As sea conditions can often disrupt this active form of fishing activity, there may be a reduction in fishing pressure during the critical aggregation period and thus a reduction in fishing mortality.

vii) *If other forms of restriction of fishing activity at SPAGs cannot be implemented, then use economic/market measures such as sales or export restrictions.* — The most commonly used measures are a seasonal ban on possession or sale of a given species or an export ban for those high value species which are shipped out of the country. However, interventions in the marketplace should be secondary to reducing or preventing the harvest of the target species at SPAG sites, which is the primary goal. Where strong economic incentives exist for SPAG fishing, some intervention in the market will almost certainly be necessary.

The implementation of this SPAG Conservation Strategy will require the cooperation of many different agencies throughout the region including various government agencies, NGOs involved in marine conservation, research institutions such as marine stations and academic institutions. In each country or jurisdiction, conservation and management plans will have to be developed (if they do not already exist) according to the priorities of each individual country (e.g. Belize, Paz and Grimshaw 2001). In addition, the time frame for the execution of each individual plan will have to be established. Partnerships and funding mechanisms for implementation of the plans will also have to be established. Partnerships with international organizations e.g. UNEP (United Nations Environment Program), National agencies, Universities and NGOs will have to be formulated. The Society for the Conservation of Reef Fish Aggregations (SCRFA) is identified as an important partner for the scientific aspects of SPAG conservation and management. The experience of some SCRFA members in the Asia-Pacific can be very helpful in providing perspectives on the current situation in the Caribbean.

A concerted effort needs to be made to disseminate information about the existence and status of SPAGs throughout the region to raise awareness and develop a commitment for action. The use of the electronic media, the Internet, and the production of pamphlets and articles should all be viewed as mechanisms to broadly distribute this information about SPAGs and their status in the region.

ACKNOWLEDGMENTS

The following persons, listed by country or jurisdiction, provided information and data (much of it unpublished), which were invaluable in producing this report: The Bahamas - Michael Braynen, Kathleen Sullivan-Sealey; Turks and Caicos Islands - Wesley Clerveaux; Cuba - Rodolfo Claro, Ken Lindeman; Florida - Ken Lindeman, Peter Gladding; Belize - Will Heyman; Cayman Islands - Philippe Bush; Jamaica - Karl Aiken; Puerto Rico - Daniel Matos-Caraballo; U.S. Virgin Islands - Rick Nemeth; British Virgin Islands - Newton Eristhee. I thank all of these persons for their time and effort in providing information but any errors in the compilation

of this information or in the interpretation are solely my responsibility.

LITERATURE CITED

Aguilar-Perera, A. and W. Aguilar-Davila. 1996. A spawning aggregation of Nassau grouper *Epinephelus striatus* (Pisces:Serranidae) in the Mexican Caribbean. *Environmental Biology of Fish* **45**:351-361.

Auil-Marshalleck, S. 1993. A review of the occurrence of fish spawning aggregations in the Caribbean and the implications for fisheries management. CFRAMP – Large pelagics, reef and slope fishes assessment subproject specification Workshop (LPRSF Assessment SSW/WP/24. 48 pp.

Bohnsack, J.A. 1989. Protection of grouper spawning aggregations. National Marine Fisheries Service, Coastal Resource Division, Contrib. No. CRD-88/89-06. 8 pp.

Carter, J., G.J. Marrow, and V. Pryor. 1994. Aspects of the ecology and reproduction of Nassau grouper, *Epinephelus striatus*, off the coast of Belize, Central America. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:65-111.

Coleman, F.C., C.C. Koenig, G.R.Huntsman, J.A. Musick, A.M. Eklund, J.C. McGovern, R.W. Chapman, G.R. Sedberry, and C.B. Grimes. 2000. Long-lived reef fishes: The grouper-snapper complex. *Fisheries* **25**:14-20.

Colin, P. 1996. Longevity of some coral reef fish spawning aggregations. *Copeia* **1996**(1):189-192.

Collins, L.A., A.G. Johnson, C.C. Koenig, and M.S. Baker, Jr. 1998. Reproductive patterns, sex ratio and fecundity in the gag, a protogynous grouper (Serranidae:*Mycteroperca microlepis*) from the northeastern Gulf of Mexico. *Fisheries Bulletin* **96**:415-427.

Domeier, M. and P.L. Colin. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Science* **60**(3):698-726.

Heyman, W.D., R.T. Graham, B. Kjerve, and R.E. Johannes. 2001. Whale sharks *Rhincodon typus* aggregate to feed on fish spawn in Belize. *Marine Ecology Progress Series* **215**:275-282.

King, M. and U. Faasili. 1999. Community-based management of subsistence fisheries in Samoa. *Fisheries Management and Ecology* **6**:133-144.

Koenig, C.C., F.C. Coleman, L.A. Collins, Y. Sadovy, and P.L. Colin. 1996. Reproduction in Gag (*Mycteroperca microlepis*) (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregations. Pages 307-323 in: F. Arreguin-Sanchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.) *Biology, Fisheries and Culture of Tropical Groupers and Snappers.* ICLARM Conference Proceedings 48. 449 pp.

Lindeman, K.C., R. Pugliese, G.T. Waugh, and J.S. Ault. 2000. Developmental patterns within a multispecies reef fishery: management applications for essential fish habitats and protected areas. *Bulletin of Marine Science* **66**:929-956.