Manual for the Study and Conservation of Reef Fish Spawning Aggregations

by

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While effort has been made to verify and check the information included in this manual, no guarantees are made as to the accuracy or utility of any information included herein. It is essential that all activities undertaken on or in the water be properly planned and carried out. The methods described in this manual have been based on the experiences of the authors and others, however all users are advised to remember the conditions they encounter may not be the same and should take appropriate measures to modify the contents of this manual based on their local conditions. The authors are grateful to Ken Lindeman and Melita Samoilys for their comments on sections of the manuscript, and to Environmental Defense for funding the first print run of the manual.

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The obvious place to start when seeking current local legislation is with government offices, most likely fishery departments or divisions or those that deal with fishery issues. Local fishery coops might also be helpful. Whatever approach is used or most convenient, it is advisable to obtain a paper copy of the relevant legislation. The reason for this is that often people who should know the law may not be up to date or may not be fully familiar with all the fine details of the law. How well do you know your own country's fishery laws? Note also that different jurisdictions may have different laws (e.g., State and Federal laws in the United States), or that some widely respected regulations may not be officially documented such as those where there is traditional marine tenure.

To determine the effectiveness of fishery-related regulations, one must determine the level of enforcement, numbers of enforcement personnel, and it might be valuable to ask about the number of convictions that have been effected. It is also important to determine how information on regulations is disseminated, how familiar local fishers and local judiciary are with the laws and how management might be modified as new information becomes available (i.e., the approach to co-management).

In some regions fisheries are managed at a local level through historical or cultural traditions. Documenting the history and effectiveness of these traditions could be useful for long-term management or allocation disputes as outside fishery influences change the dynamics of the fishery.

All of this information is important, especially if management recommendations are to be made, for understanding what kind of management might be effective, what is likely to be socially acceptable and how robust the recommendations might have to be. Summarizing and documenting management practices is helpful to other scientists/resource managers not familiar with the area you are studying. Finally, summarizing the level of enforcement is important to understand the effectiveness of any management.

Section VII. Spawning Aggregation Conservation Methods and Long Term Monitoring

VII. A. The Need for Conservation

Spawning aggregations are predictable in time and space and are particularly vulnerable to fishing. Moreover, many of the more vulnerable reef fish species (i.e., long lived, late maturing) are the ones that aggregate to spawn and are also particularly valued for food. The World Conservation Union (IUCN) Red List of Threatened Species includes a number of reef species that aggregate to spawn; several are presently listed as endangered or vulnerable, or are being considered for such a listing by the IUCN (http://www.redlist.org). These include the Nassau grouper (*Epinephelus striatus*), the humphead wrasse (*Cheilinus undulatus*), and several other groupers. Their inclusion in the Red List has much to do with their tendency to form spawning aggregations that are targeted by fishermen. In the Indo-Pacific, threatened or vulnerable species have been listed largely because of declines associated with demand for them in the Live Reef Fish Trade (LRFT). The LRFT is discussed below.

Most effort going into studying reef fish spawning aggregations is focused ultimately on their preservation through complete protection or management. Intelligent conservation decisions

require good biological knowledge. Although it would be shortsighted to attempt to plan detailed conservation and management initiatives without the appropriate scientific underpinning, we do already understand enough to know that all exploited aggregations must be protected or managed in some way, otherwise there is a good chance that they will decline and ultimately cease to form. **With very few exceptions, it is non-precautionary to exploit spawning aggregations that are not managed**. To fine-tune conservation and management measures, however, to ensure the best possible protection, solid knowledge regarding the timing, duration, location, migration distances, physical oceanography of sites, and other aspects of spawning aggregations are essential, knowledge to be gained through sound science.

So, should aggregations be fished at all? Although aggregations have been exploited for long periods at very low levels of fishing in the past, and although there are sizeable social and economic incentives to continue to exploit spawning aggregations, we do not know what are sustainable levels of exploitation for any aggregation. Most importantly, it is patently clear that aggregations can not withstand modern levels of fishing pressure or modern techniques of fishing. Until we understand more about aggregation dynamics and the effects of the total sum of fishing pressure on a species both on their spawning aggregations as well as at non-aggregating times, the literature and experiences elsewhere strongly suggest that unmanaged aggregations should not be fished at all. All aggregations that are being monitored are showing probable decreases in abundance of fish, increasing bias in sex ratios (e.g., Koenig *et al*., 1996) or other changes, although unfortunately relatively few are currently being monitored over the long term, or in a consistent and standardized way.

If aggregation sites are known, it might be feasible to close only the aggregation sites to fishing with no other management measures needed. However, this does little to protect fish that might be migrating to the site (e.g., lane snapper, *Lutjanus synagris*; Claro *et al*., 2001), or fish occurring at an aggregation that is not widely known. In such cases, a seasonal closure on the species may be appropriate, so that all aggregation sites (known and unknown) are protected. In some extreme cases, where a species does aggregate to spawn but overall its populations are under heavy fishing pressure, it might be advisable to close the entire species to exploitation. This was the case for the goliath grouper (jewfish), *Epinephelus itajara*, in Florida, where in 1990 the species was declared a no-take fish. Incidental fish caught on hook and line had to be released. For possible management options other than seasonal and spatial closures see Domeier *et al*., (2002).

In some locations regulations have been put in place that have not fulfilled their objectives due to insufficient scientific information. In Palau, western Pacific, a closed season was initially instituted for various groupers, extending from April through the end of July. Subsequent observations of aggregation presence indicated, however, that these fishes continued to aggregate until at least the end of August, leaving them open to fishing during a portion of their aggregation period (Johannes *et al*., 1999).

Rhodes (1999) detailed a number of management steps that were taken in Pohnpei (Federated States of Micronesia) to modify existing regulations protecting grouper aggregation after a survey indicated they were not adequately protecting the aggregations. This sort of active revision of regulations in light of new biological information is important for any management program. In the case of Pohnpei, various fishers were able to access much of the total aggregation legally (up to one third of the aggregation in 1999) at times and locations outside of those protected by regulations (Rhodes, 1999).

Such examples illustrate the importance of having sound information on which to base management action if it to fulfill its intended protection effectively. They also illustrate why regulations always need to be open for amendment, to continually improve protection and management initiatives as new information becomes available or as new markets, and hence new pressures, open up.

Figure 55. This male humphead wrasse, *Cheilinus undulatus****, is a prime target for the Live Reef Fish Trade (PLC).***

The Live Reef Fish Trade (LRFT) represents a relatively new and heavy pressure on reef fish resources of the Indo-Pacific (Fig. 55). Prior to its emergence, fishing on aggregations was limited to subsistence and modest freezing or export levels. However the LRFT has been growing steadily since the early 1990s and is now big business, currently worth over a billion US$ annually (Sadovy and Vincent, 2002). The LRFT involves the capture of a relatively small number of reef fish species, predominantly groupers, that are maintained alive until they reach

Figure 56. A large humphead wrasse, *Cheilinus undulatus****, freshly dead on a sidewalk in Hong Kong. Taken from a coral reef somewhere in the vast Indo-Pacific, shipped alive from the point of capture to Hong Kong, held in a tank until someone willing to pay the premium price (sometimes>US$100 a kg), then dispatched and quickly cooked and eaten as a special meal to impress business clients or celebrate special events, the Live Reef Fish Trade threatens survival of fishes such as these in many parts of their ranges (PLC).***

demand centers such as Hong Kong and mainland China where they are sold as food. Consumers are prepared to pay a premium price for these fish and so business can be extremely lucrative for traders and importers. As wealth increases in China, so demand for these live fish is predicted to increase (Fig. 56). There is growing evidence that fishers and traders are looking to source live reef fish at spawning aggregations for these are lucrative and efficient to target. In most places in the Indo-Pacific there is no management of spawning aggregations at all, and, given the high demand for live fish and the large size of the live fish transporter vessels (Fig. 57), large numbers of fish are likely to be removed if a spawning aggregation should be targeted (Fig 58). Indeed, there are already several examples where aggregations have been fished out as a result of being targeted for live fish. Moreover, mortality of fish removed from aggregations can be high maybe because they are stressed at this time (Johannes, 1997; Johannes *et al*., 1999; Johannes and Lam, 1999). Aggregations should not be targeted for the LRFT.

Mapstone *et al.* (2001) felt that *Plectropomus leopardus* populations were at relatively low risk from targeted harvesting for the live reef fish trade because of the small size of its spawning aggregations, their scattered locations and the limited percentage of the total population present at aggregations at any given time. They felt, however, that species with larger, more predictable aggregations may be more vulnerable to fishing pressure on aggregations.

Ideally conservation organizations and fishery management authorities should adopt and promote the concept that reef fish aggregations should be protected from nearly all direct fishing effort, at least as a precautionary position in the absence of effective management and appropriate biological information. Aggregating fishes are often easily disturbed and until we have a clear understanding of the effects that fishing (and other human) activities have on reproduction, we need to reduce overall fishing effort. This requires, at the minimum, that all known aggregation sites not effectively managed already be protected and/or that all relevant species are not fished during their reproductive season(s). Concepts, such as "pulse fishing" (Graham 2001) or other more complex forms of exploitation that require tight compliance and heavy enforcement are unlikely to be feasible in most fisheries and may, instead, be detrimental to aggregations overall.

VII. B. Archiving of Information

It is important to be able to archive and consolidate information concerning reef fish spawning aggregations. This can include anecdotal information and observations, "hard" data from catches from aggregations, photographs, film and video footage, and other types of information.

The Society for the Conservation of Reef Fish Aggregations has a database on reef fish aggregations world-wide and intends to serve as a repository for other types of information. In connection with the overall database, certain criteria have been established that observations must meet before a given aggregation of fish is included in the database as a spawning aggregation (see Section II.C). The intention of these criteria is not to exclude information, but rather to put confirmed and tentative information into different tables, so that what is confidently known is not confused with the tentative and unconfirmed. If an observation does not meet these criteria, it is still possible to include the observation as "probable", "possible" or some other relative estimation of the confidence associated with the observations or data, and efforts can later be made to confirm or otherwise such reports. The instructions for making additions to the SCRFA database are available on the SCRFA website (www.scrfa.org).

Figure 57. A Live Reef Fish Trade vessel, photographed in North Male Atoll lagoon, Maldive Islands. Copious water pours from the tanks inside the vessel, indicative of the amount of effort required to keep its large cargo of reef fish alive prior to steaming to a distant port such as Hong Kong (PLC)

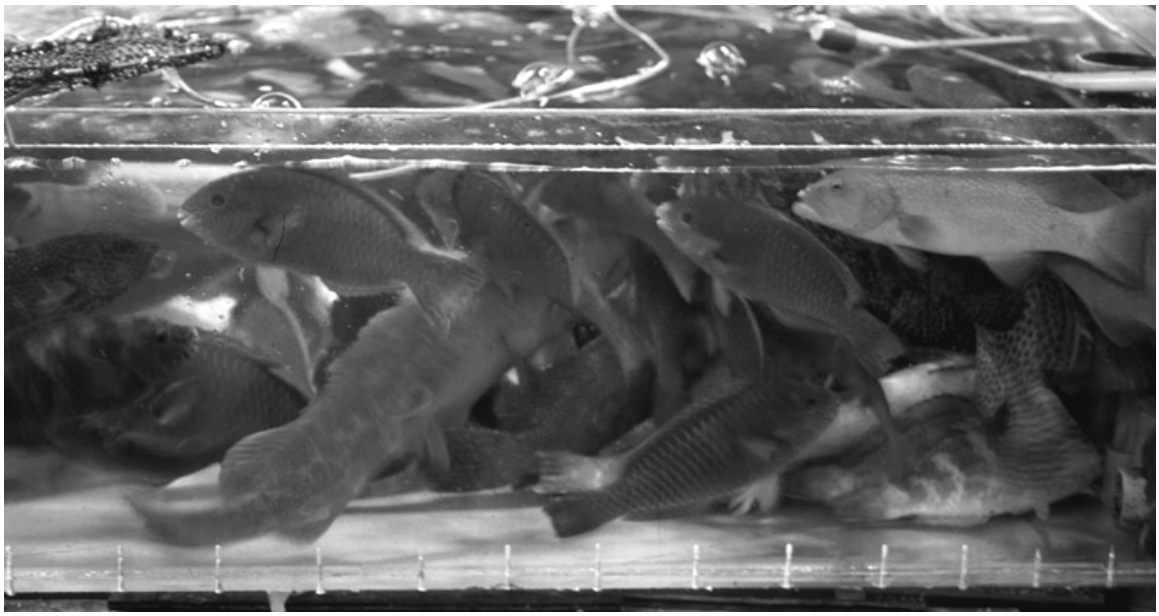

Figure 58. Live reef fishes, mostly parrotfishes and small groupers in a streetside aquarium in Hong Kong (PLC)

VII. C. Conservation of Spawning Aggregations

Does Protection of Aggregations Help?

In a number of places, various types of protection have been put in place to conserve aggregations. Do they help and what means can be utilized to show that they help? While it is not within the scope of the present manual to cover these protections in detail, we would like to comment on the types of protection put into place in some areas. Protection can include a prohibition of fishing in a given site, usually the aggregation area and nearby reefs, and protection of species by closed seasons during the spawning period. A combination of both types of restrictions seems most likely to have a positive effect and has been implemented in several places. The former seems the most obvious when fish(es) at certain sites are rapidly being wiped out. Closed seasons are particularly relevant where aggregations can not be patrolled or site protection readily enforced. The latter type of regulation covers aggregations that are unknown to anyone, except perhaps a few fishermen, but may have great importance in reproductive success.

Various methods can be used to prevent overexploitation of aggregations. Johannes and Kile (2001) recommended banning the catching and holding of live groupers (for the live reef fish trade) during the months of spawning aggregations, instead of trying to protect the aggregation sites which are widely dispersed and far from settlements. The type of protection implemented depends on the local social and cultural contexts as well as species and fishery conditions involved (Domeier *et al*, 2002). Presently the most widely applied approaches to protecting aggregating fishes are seasonal (no fishing and/or no commercial sale of the species during the spawning season) or spatial (the spawning site itself is protected during the aggregation period or is incorporated into a marine protected area).

Figure 59. These fishermen in the Cayman Islands have made a good catch of Nassau groupers from the spawning aggregation, but how long will this last. This photo was taken in 1977, a time of no regulation of the spawning site and declining catches. In earlier years, many more fish were caught, but those days were already gone. At present the fishery is closely regulated, but catches have yet to improve.

There are some signs that protection can result in increased fish size when non-aggregated populations are still fished. Beets and Friedlander (1999) documented a case where declining catch and size, plus a highly skewed sex ratio (in favor of females) among red hind, *E. guttatus*, in the U.S. Virgin Islands reversed after protection was put in place. They reported an increase from 295 mm SL to 395 mm SL for red hind after seven years of spawning site closure to fishing, while the sex ratio change from 1:15 males to females to 1:4.

The protection of aggregation sites also tends to provide some protection for spawning segments of other species of fishes. Johannes (1998) says that "more than 40 species of reef fish spawn at the three aggregation sites" of groupers he studied. The spawning of these additional species is not limited to the grouper aggregation site, but protection of a site, as opposed to a species, means that other fishes derive secondary protection.

Fostering (the right type of) Protection

Many instances of disappearances of spawning aggregations are known (Sadovy and Domeier, in prep). In most cases fishers of a given aggregation have been aware of the declines leading to the extirpation. Sometimes the loss is rationalized by saying the fish have moved elsewhere or were disturbed and don't come anymore. While these are possible, most likely the aggregation has been fished out and most fishermen know it. In many cases, calls for protection come from those who suffer most from the loss, the fishers themselves. This is particularly true of older fishermen, who have a longer experience and have more likely seen an aggregation fishery in its prime.

In the last decade, the importance of spawning aggregations to fishery success and the level of exploitation in many areas have raised awareness, at least among monitoring agencies, of the importance of spawning aggregations in many species used for human food. Awareness needs to be raised at the level of government and the individual fisher. Without the support of fishers, it is considerably more difficult for government to put in place the controls needed to prevent loss of aggregations and ultimate decline of the fishery.

To encourage protection, communities need to identify with local aggregation sites as "theirs" and something to protect for their own sake. Certainly any community fishing the area where fishes are drawn from to spawn at the aggregation has a stake in the future of that aggregation. This is why tagging studies can be particularly important for making people realize that the fate of the aggregation affects both their short-term ability to catch fish (none will be left if the entire aggregation is fished out) and the long-term health of the fishery of the aggregating species. Such studies are also important to illustrate how far fish can move and that over-fishing an aggregation in one community can affect catches in the non-reproductive season in a distant community.

Spawning aggregations within marine parks have potential value added components. Ruitenbeek (2001) reported that the value of spawning aggregations within the Komodo National Park, Indonesia was roughly $600,000 USD at 100% protection, a level similar to the direct recreational value of the park, famous for the Komodo dragon. Sala *et al*. (2001) determined that dive tourism on aggregations in Belize could be worth 20 times the value of extracted fish. However, care is needed before blindly converting an aggregation into a tourist attraction in case uncontrolled disturbance should have a negative impact on reproduction or tourist dollars bypass local communities. Studies can be conducted to determine such potential impacts.

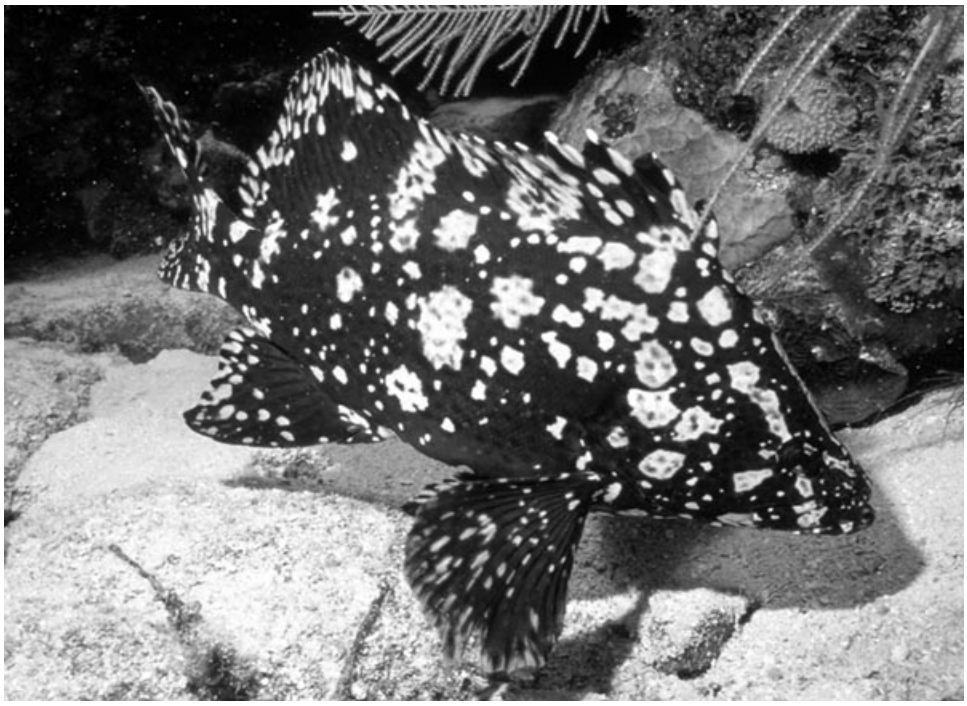

Figure 60. Groupers such as this marbled grouper, *Dermatolepis inermis****, from the Florida Keys are often thought to be rare, because they are seldom seen. They may just occur in an environment that is seldom fished or visited by divers, but they may also have had their populations driven down by fishing pressure. Determining such things is one of the hardest aspects of working on species of fishes that aggregate to spawn.***

It is also essential to look at fisheries of those species that aggregate in their entirety and not to solely focus on the aggregation. In many cases fishing pressure occurs on both aggregated and non-aggregated individuals, both of which may be important to consider when examining population status and determining appropriate management. For example, managing an aggregation of a species that is also heavily fished at other times may ultimately contribute little to the overall problem of over-fishing of the species. As just one possible example, in Palau, aggregations of *Plectropomus* and *Epinephelus* were found to be predominantly males, to the point that any females in the aggregation were continuously harrassed by the many males (Johannes *et al*., 1999). This may have disrupted spawning, although the spawning behavior of the species involved is not well known. The question also arises over how such a distorted sex ratio could occur. Johannes *et al*. (1999) did not have an explanation for this, but speculated perhaps that this might have resulted from heavy fishing of females at non-aggregated times in more built-up, and therefore, more heavily exploited areas. This emphasizes a point that is often not explicitly considered: that changes to aggregation numbers, sexes and fish sizes at aggregations could also result from non-aggregation fishing pressure. This means that the entire fishery often needs to be considered for management, research or other interventions.

Education Issues

Although historical data on aggregation status is critically important for understanding the effects of targeting these gatherings, video is one of the most powerful ways to convey the message of the fragility of spawning aggregations today. Videos could include interviews with fishermen telling of their experiences, particularly older fishermen who are likely to have seen many changes in their lifetime. Video should have underwater and spawning footage if at all

possible since most fishermen have probably never seen aggregations underwater and are unlikely to have witnessed spawning. It is, of course, important to explain scientific work in a simple manner but everybody understands the reproductive imperative and so spawning aggregations represent an excellent opportunity to teach of the importance of allowing fish to reproduce to replenish their kind.

A second video might be prepared to assist fishermen or divers who want to help on a project. One of us (PLC) previously used a video showing people how to remove gonads and otoliths for grouper work in the Gulf of Mexico.

Sociological Issues

Support from fishers is of the utmost importance to the long-term success of protecting aggregations. It is important to communicate the results of studies on aggregations to the fishers involved. This is usually not easily done, but when it can be shown clearly that aggregations are of benefit to retaining local populations, this may drive home the message that is in the fishers own best interests to conserve the aggregation.

VII. D. Publication of Information

It is important for scientists to get technical information out into the general scientific literature and open to peer scrutiny as a basis for sound conservation action. It is also important that some of this information is also made available to a wider public as well as to the fishing community. **On the other hand, certain kinds of information, such as the specific locations of aggregations should not be released unless for the express purpose of management and conservation, to ensure that the information does not facilitate yet further uncontrolled aggregation exploitation**.

To get information into the hands of practitioners, it might be more useful to make it available in video form, rather than printed documents, although brochures and posters are also very important. The video is a powerful tool and even the most remote islands, if they have a human population, almost always have a video system for watching movies.

VII. E. Long Term Monitoring

In one sense we really don't know how to do long term monitoring of spawning aggregations, as we do not necessarily know what is the essential information to acquire now that we will want in the future. It is, therefore, better to document as many things as possible, in a thorough, quantitative and repeatable manner, in the hopes we are doing the right things now, following clear and simple guidelines and adopting sound scientific principles. Since we are seeing a general decline in spawning aggregations worldwide (there are relatively few that are growing or recovering), we should work to gather as much baseline information as possible now.

If a firm basis for monitoring is established, then long term monitoring becomes feasible. Maps, GPS location information, other "hard" documentation is crucial. Our technology of obtaining this information may improve significantly in the future, but today we need to do the best job we can with the tools available.

Finally, we know little about the recovery of aggregations, once fished out. Protection has been applied to some areas that no longer support aggregations and we can learn some very important lessons from watching what happens to such areas. Will such areas ever recover? Once

protection is in place, they will come back? In Palau, one aggregation that was possibly fished out was subsequently protected and shows signs of recovery, although too little is known of its natural, pre-fished, state to be able to evaluate the significance of the changes taking place. It is very tempting to focus just on aggregations that still appear to be in good condition but, given the very likely connectivity between reefs and possibly between aggregations, it is also important to consider the need to restore seriously depleted or even extirpated aggregations as part of the bigger picture. Therefore, the monitoring of extirpated sites is useful and important, especially in areas where the populations of aggregating species appear to be depleted and where aggregations were once substantial. It might seem like a futile exercise (the authors have all been through it many times), but the importance in the medium to long term might be great.

VII. F. Concluding Comments

If we really want to set up global long-term monitoring of aggregations, it is going to be necessary to continue the "discovery component" of aggregation work at as fast a rate as possible. At present there are only a handful of sites that could even remotely be considered as adequately quantified to serve as true long-term monitoring sites. We need to be establishing such sites now, and many of the sites needed are not yet even known to scientists or managers. The sites that are known need to be studied and quantified in more, and in sufficient, detail, one of the major reasons we have gone to the trouble of writing this manual.

VIII. References Cited

Aguilar-Perera, A. 1994. Preliminary observations of the spawning aggregation of Nassau grouper, *Epinephelus striatus*, at Mahahual, Quintana Roo, Mexico. Proc. Gulf and Carib. Fish. Inst. 43: 112-122.

Appeldoorn, R.S. D.A. Hensley, D.Y. Shapiro, S. Kioroglou and B.G. Sanderson. 1994. Egg dispersal in a Caribbean coral reef fish, *Thalassoma bifasciatum*. II. Dispersal off the reef platform. Bull. Mar. Sci. 54(1): 271-280.

Beets, J. and A. Friedlander. 1999. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. Env. Biol. Fish. 55: 91-98.

Bell, L.J. and P.L. Colin. 1986. Mass spawning of *Caesio teres* (Pisces: Caesionidae) at Enewetak Atoll, Marshall Islands. Envir. Biol. Fishes 15(1): 69-74.

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Tech. Rep. NMFS 41:1-15.

Bolden, S.K. 2000. Long-distance movement of a Nassau grouper (*Epinephelus striatus*) to a spawning aggregation in the central Bahamas. Fish. Bull. 98: 642-645.

Carter, J, G.R. Marrow and V. Pryor. 1994. Aspects of the ecology and reproduction of Nassau grouper, *Epinephelus striatus*, off the coast of Belize, Central America. Proc. Gulf and Carib. Fish. Inst. 43: 65-111.