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A Review of the Occurrence of Fish Spawning Aggregations in the Caribbean and the Implications for Fisheries Management

by

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EXECUTIVE SUMMARY

Spawning aggregations have been noted in the Caribbean for decades. Fishers have traditionally fished these aggregations, in some cases causing the elimination of the stock. The purpose of this report is to review the occurrence of spawning aggregations, focusing primarily on demersal fish, within the Caribbean, to demonstrate the effects of fishing on the aggregation and to discuss implications for fisheries management.

Approximately seven Caribbean families are known to have species which form aggregations. Large-sized species appear to migrate long distances, usually to the outer edge of the shelf to form spawning aggregations. It is speculated that this allows the eggs and larvae to drift into deeper waters away from predation found in the inshore adult habitats. The smaller-sized species usually migrate shorter distances. Spawning for these species usually involves a rapid upward dash which may function to distribute the gametes out of the reach of benthic predators.

Intense fishing on an aggregation results in the removal of the mature and larger sized classes from the stock. Such an occurrence on a hermaphroditic stock may stimulate a sexual transition that could alter the reproductive potential of the population (Carter, Marrow & Pryor, in press). In addition, the removal of the reproductive adults from the stock can decrease future yields by reducing recruitment. Reports of decreased catches and even the elimination of some aggregations that were intensely fished are not uncommon in the Caribbean.

Management of a fishery involves the identification of all spawning aggregations within the region, the collection of relevant fisheries and environmental data and the introduction of measures aimed at controlling fish catch and effort. The identification of aggregating stocks should include the collection of information on the types of species that aggregate to spawn, including spawning locations and times. Such information may be obtained from local fishermen. Fisheries data include information on catch, effort, growth and mortality. This information can be used to assess the state of exploitation on a stock and can equip managers with information for adjusting fishing effort or size at first capture. The collection of environmental data such as temperature, tides, current information, weather and lunar periodicity are necessary to understand the occurrence of spawning aggregations and the importance of these factors in facilitating recruitment and larval survival. Many fisheries divisions do not have the resources to carry out the necessary oceanographic studies and are advised to collaborate with agencies and individuals involved in collecting and analyzing such information within the region.

Permanent and seasonal closures, limited entry, and in the case of a severely depleted fishery, a total harvest ban, are measures used to control fishing effort on a fishery. Other measures used to control effort directed at specific, usually smaller individuals within a stock are gear and size restrictions. Measures used to control catch are bag limits and catch quotas.

The social implications of managing a fishery must be taken into account before implementing a fishery management plan. Issues to be considered the inclusion of fishers in the management of the fishery and the availability of alternate work for fishers who may be displaced from the fishery.

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1. Introduction

This review is to be presented at the Large Pelagics Reef and Slope Fishes Assessment Subproject Specification Workshop. The workshop will be hosted by the CARICOM Fisheries Research Assessment and Management Project (CFRAMP) and will be held in January, 1994, in St. Kitts, West Indies.

The primary objective of this paper is to summarize the information available on families and species that aggregate for spawning purposes, with an emphasis on species aggregating within the Caribbean. Secondary objectives are to cite the effects of fishing on tropical spawning aggregations; to provide suggestions for the management of these stocks; and to compile a bibliographic list of spawning aggregations in the Caribbean and elsewhere in the tropics.

Many of the larger coral reef fishes of the western Atlantic produce planktonic eggs, which are shed into the open water. Families included in this group are the groupers (Serranidae), snappers (Lutjanidae), parrotfishes (Scaridae) and surgeonfishes (Acanthuridae), (Thresher, 1984a, Colin & Clavijo, 1988). The families of smaller fishes such as the gobies (Gobiidae), clinids (Clinidae) and damselfishes (Pomacentridae), generally produce demersal eggs which are attached to objects (Colin & Clavijo, 1988). A few coral reef species are viviparous or ovoviviparous, including certain brotulids (Bythitidae) and clinids (Bohlke & Chaplin, 1968).

Coral reef fishes may or may not migrate to spawn. Many of the smaller sized species do not migrate to spawn. These species remain close to the shelter of their habitat probably because small individuals are more vulnerable to predation than large ones (Johannes, 1978). This spawning behavior can be found in surgeonfishes and goatfishes (Mullidae) (Lobel, 1975, Colin & Clavijo, 1988). These species produce pelagic eggs which are dispersed, presumably out of the reach of benthic predators. They have been known to spawn in pairs (single male-single female) or to form groups (multiple males-multiple females or single male-multiple females) for the purpose of spawning (Colin, 1978, Colin & Clavijo, 1978, Colin & Clavijo, 1988). Some non-migration spawners produce demersal eggs. Examples of these are the damselfishes (Pomacentridae), puffers (Tetraodontidae), gobies (Gobiidae), combtooth blennies (Blenniidae), and clinids (Johannes, 1978). Guarding of the eggs against predators has been observed in most of these families (Johannes, 1978).

The migrating spawners typically move from their normal habitats to deeper waters to spawn. Such migrations have been documented for the groupers (Burnett-Herkes, 1975, Carter, 1986), snappers (Domeier, Koenig, & Coleman, in press), and parrotfishes (Choat & Robinson, 1975). During the spawning period they characteristically form large aggregations (Johannes, 1978). Spawning in these aggregations may occur in pairs or group spawning.

Spawning aggregations occur throughout the tropical Atlantic and Pacific Ocean. For the purpose of this study, spawning aggregations were defined as a concentration of primarily adult individuals at particular locations for a limited period of time. These aggregations occur for the purpose of reproduction. Many aggregating species also use certain migratory paths to reach their spawning locations. These locations are often known and exploited by local fishers (Johannes, 1980).

Several theories on the advantages of aggregations have been proposed. These include:

i) aggregations may be used as a means of enhancing fertilization by concentrating spawning in time and space (Johannes, 1978),

ii) aggregations may allow an individual to maximize its genetic recombination especially if the entire stock spawns at the same moment (Johannes, 1978),

iii) aggregations may allow for the removal of offspring inshore, in order to minimize predation found within the shelf area of the reef (Johannes, 1978),

iv) aggregations serve to maximize larval dispersal in order to facilitate chances of finding food in patchy environments (Barlow, 1981), and

v) spawning times and locations may serve the needs of the adults, allowing them to better coordinate their reproductive activities (Colin & Clavijo, 1988).

However, tests to show the advantages of times and location of spawning over other sites and locations are yet to be demonstrated (Shapiro, Hensley, & Appeldoorn, 1988).

2. Literature and Anecdotal Reports of Spawning Aggregations

2.1 Large-sized Species

Both large-sized and smaller-sized species aggregate to spawn. A review of the large-sized species that aggregate to spawn can be found in the following paragraphs.

2.1.1 Family Serranidae (groupers)

Grouper aggregations occur in large numbers, and reports of tens of thousands of individuals aggregating to spawn are not uncommon. Consequently, catches from these aggregations have yielded thousand of kilogram of fish making this a commercially important fishery activity for Caribbean countries such as the Bahamas, Belize, Cayman Islands, Cuba, Dominican Republic, Puerto Rico and the United States Virgin Islands. The aggregations formed by different grouper species are listed below.

Black grouper - *Mycteroperca bonaci*

Courtship behavior and an aggregation of the black grouper have been observed at a Nassau grouper aggregation site in Belize (Carter et al, in press).

Coney - *Epinephelus fulva*

Small aggregations as well as courtship behavior have been reported for the Coney among an aggregation of Nassau groupers in Belize (Carter et al, in press). Carter et al (in press), however, did not observe actual spawning of the coney. Burnett-Herkes (1975) also reported an aggregation of the coney in the early summer in Bermuda.

Jewfish - *Epinephelus itajara*

Local fishers in Belize have described a spawning aggregation of the jewfish which occurs in the late summer (August-October). This occurs south east of English Cay along the main barrier reef of Belize.

Aggregations of the jewfish that occur outside the Caribbean but within the Western Atlantic are:

The jewfish aggregates near wrecks in August off southwestern Florida (Colin, 1989). In Cartagena, Colombia, the jewfish aggregate during September and October in what is believed to be their main spawning season (Colin, 1989).

Nassau grouper - *Epinephelus striatus*

The most frequently reported aggregations in the Caribbean are those formed by the Nassau grouper. These aggregations have also been the subject of intense fishing pressure by local fishers for decades (Craig, 1966, Smith, 1972, Burnett-Herkes, 1975, Olsen & LaPlace, 1979, Carter et al, in press). Records show that the Nassau grouper aggregate at different locations in late November, in December, January, or in February. In some cases aggregations in May to July, (in Bermuda) have been reported. These aggregations seem to exhibit some lunar periodicity, occurring just before, during or after the full moon. Colin (1992) suggested that a close correlation exists between environmental conditions and reproduction which favours the survival of offspring. Although the relationships between factors such as: i) the geomorphology of spawning sites, ii) lunar periodicity, iii) current speed and iv) current direction, and the survival of offspring have not been tested. However, a correlation between the occurrence of spawning and water temperatures within the range of 25-26°C can be assumed (Colin, 1992).

Grouper aggregations tend to occur at or near the ends of islands or shelf edge within water depths of 25-38 m (Smith, 1972, Colin, 1992, Fine, 1992, Carter et al, in press). The exact reasons for the locations of aggregation sites are unknown. One assumption is that the site facilitates the removal of offspring from inshore, thereby minimizing predation found within the shelf area of the reef (Johannes, 1978). Information on aggregations of the Nassau grouper have been reported from several areas within the Caribbean. This section will therefore present the information known about the Nassau grouper aggregation on a country specific basis.

Bahamas: Spawning aggregations of Nassau grouper have been reported in various locations in the Bahamas (Colin, 1992, Smith, 1972, Sadovy, in press,b). These aggregating sites are (Sadovy, in press,b):

1) Cat Cay,
2) Andros (5 sites),
3) Long Island (3 sites),
4) the Berry Islands (4 sites),
5) Bimini,
6) New Providence,
7) Ragged Island,
8) Cay Sal,
9) Exuma,
10) Eleuthera (4 sites),
11) Acklins.

Belize: Six aggregation sites have been reported in Belize. Three of these sites can be found off the northeastern point of three promontories along the main spine of the barrier reef (Carter, 1986, 1988, Carter et al, in press). One site on the northern end of the Barrier Reef, was intensely exploited by local fishers but is no longer associated with an annual aggregation. Aggregations also occur at the northeastern ends of three oceanic atolls further offshore (Carter, 1988).

Bermuda: Aggregations of Nassau grouper were once found on the Challenger and Argus banks on the Bermudan platform (Burnett-Herkes, 1975). However, these aggregations have not been observed for at least a decade (Sadovy, in press,b).

Cayman Islands: Aggregations are known to occur at the eastern ends of the Grand Cayman, Cayman Brac and Little Cayman Islands (Colin et al, 1987). However, these aggregations do not form every year (Sadovy, in press,b).

Cuba: Numerous spawning aggregations have been reported off the Cuban platform (Claro, 1990, Sadovy, in press,b).

Dominican Republic: An aggregation on the north coast, near Punta Rusia, was discovered in the early 1980's (Colin, 1992). However, because of intense fishing, the aggregation disappeared and has not yet recovered (Colin, 1992).

Honduras: Craig (1966) noted an aggregation of Nassau grouper in the Little Hog Island banks, in the Bay Islands, off the shore of northern Honduras. Fine (1992) also documented a spawning site that was discovered in Guanaja, Bay Islands in 1988. This aggregating population was estimated to consist of 10,000 individuals. Yet, in 1991, the aggregation was visually estimated to consist of approximately 500 individuals (Fine, 1992).

Puerto Rico: An aggregation was found off the eastern side of Mona Island, Puerto Rico (Colin, 1980). Due to intense fishing pressure this aggregation has disappeared. Fishers in Puerto Rico remember two spawning aggregations which were fished until the late 1970's off southern Puerto Rico (Sadovy, in press,b).

United States Virgin Islands: Several aggregations which have been exploited by fishers for decades have been reported for this area. Beets & Friedlander (1992) reported the existence of five aggregations of Nassau grouper on the outer platform of the Virgin Islands. Olsen & LaPlace (1978) reported an aggregation in St. Croix that ceased to exist in the early 1970's. Similarly, an aggregation in St. Thomas also disappeared in the mid-1970's (Beets & Friedlander, 1992).

Similar aggregations of the Nassau grouper found outside the Caribbean but within the western Atlantic are:

Craig (1966) mentioned an aggregation around the Chinchorro Banks adjacent to the coast of southern Quintana Roo, Mexico. Sosa-Cordero & Cardenas-Vidal (in press) list several aggregation sites in Quintana Roo. Sadovy (in press,b) reports that spawning aggregations of Nassau grouper have been recorded from the southeastern Florida Keys in the winter months of 1979-1980.

Red hind - *Epinephelus guttatus*

Although aggregations of the red hind have occurred for many years, they only became commercially important after the decline of the Nassau grouper fishery (Beets & Friedlander, 1992). The red hind spawns in well defined aggregation areas where fish concentrate in patches over the substrate (Sadovy, Rosario and Roman, in press). However, specific sites of fish concentrations may vary from year to year within the identified aggregation area (Sadovy et al, in press). Aggregations of the red hind have replaced Nassau grouper aggregations at sites in St. Thomas and Long Bank north-northeast of St. Croix (Beets & Friedlander, 1992). Aggregations of the Red hind have also been reported in Bermuda (Burnett-Herkes, 1975), several sites in western Puerto Rico (Erdman, 1977, Colin, Shapiro, & Weiler, 1987, Sadovy et al, in press), and Tortola and Virgin Gorda, U.S. Virgin Islands (Appeldoorn, Dennis & Lopez, 1986, Beets & Friedlander, 1992). Aggregations have also been reported at the north end of St. Kitts, the east side of St. Lucia and north of Anguilla (Appeldoorn et al, 1986).

Rock hind - *Epinephelus adscensionis*

The rock hind appears to aggregate at the shelf edge reef of southwestern Puerto Rico in January in an area where the red hind used to aggregate to spawn (Colin et al, 1987).

Tiger grouper - *Mycteroperca tigris*

An aggregation of the tiger grouper was found on the eastern side of Puerto Rico (Sadovy, in press,a).

Yellowfin grouper - *Mycteroperca venenosa*

Peak aggregation period for the yellowfin grouper has been known to occur from February through to April at two sites near the shelf edge in north St. Thomas (Beets and Friedlander, 1992). An aggregation off St. Thomas has been reported at the same bank immediately following the Nassau grouper and red hind aggregations (Olsen & LaPlace, 1979). Other sites of aggregation have been reported for the Bahamas (Appeldoorn et al, 1986), and Belize (Miller, 1984, Carter et al, in press).

The information on aggregations of *Mycteroperca spp* and *Epinephelus spp* other than the *E. striatus* and *E. guttatus* is largely incomplete. This may be because the size of aggregations of other groupers are smaller and less conspicuous than the Nassau grouper and the red hind, thus they lacked the commercial importance of the Nassau grouper and red hind. Aggregations of groupers found in the Western Atlantic but not reported in the Caribbean are:

Red grouper- *Epinephelus morio*

The red grouper is a continental species rarely caught in the West Indies (Appeldoorn et al, 1986). Aggregations of the red grouper have also been reported off the edge of the continental shelf of the Yucatan (Colin, 1989).

Gag - *Mycteroperca microlepis*

Spawning aggregations have been observed in February in the eastern Gulf of Mexico (Koenig, Coleman, Collins, Sadovy, & Colin,in press). These aggregations occur in water depths of between 50 - 120 meters (Koenig et al, in press).

2.1.2 Family Lutjanidae (snappers)

Few observations of snapper spawning have been observed in the wild (Grimes, 1986). The snapper is assumed to spawn after dusk near open water (Carter pers. comm.). A key feature of reproduction is an extensive spawning migration to a select area along the outer reef in the week or so prior to the full moon (Thresher, 1984a).

Cubera snapper - *Lutjanus cyanopterus*

Aggregations of the cubera snapper have been reported off Buttonwood Cay and Cay Bokel in Belize (Domeier,in press). These aggregations took place during the full moon to the last quarter in June and July (Domeier, in press).

Dog snapper - *Lutjanus jocu*

Carter (pers. comm.) reported the aggregation of the dog snapper for spawning purposes in January at a site approximately 50 meters from a well known Nassau grouper aggregation site. Carter (pers. comm.) observed spawning in 27-30 meters of water. The observation was made after dusk, at 1600-1800 hours. Interestingly, the local fishers had never noticed an aggregation of dog snapper near the Nassau grouper aggregation in previous years (Carter, pers. comm.). An aggregation of the dog snapper was also found near English Cay, along the main barrier reef in Belize (Domeier, in press). The aggregation was found between the full and last quarter moon in July (Domeier, in press).

Grey snapper - *Lutjanus griseus*

Grey snappers have been found to aggregate on offshore reefs in June to August (Appeldoorn et al, 1986). Spawning is assumed to occur at night at or near full moon (Starck & Schroeder, 1971). In October 1990, fishers fished an aggregation of grey snapper which occurred in Ambergris Cay, north Belize (personal observation). Fishers state that this aggregation occurs annually, and they believe that the spawning time is closely correlated with lunar periodicity.

Aggregation of grey snapper found outside the Caribbean but within the Western Atlantic:

An aggregation of grey snappers have been reported off Florida in September, at dusk (Starck & Schroeder, 1971). During this time, material similar to snapper milt was seen when squeezed from a ripe male (Starck & Schroeder, 1971). A collection made the morning following spawning showed mostly spent fish (Starck & Schroeder, 1971).

Lane snapper - *Lutjanus synagris*

The lane snapper aggregates in the summer along the main barrier reef in Belize (personal observation). Aggregations of the lane snapper have also been reported in Cuba (Appeldoorn et al, 1986).

Aggregations of the lane snapper found outside the Caribbean but within the Western Atlantic:

Wicklund (1969a) observed a spawning aggregation of the lane snapper off south Florida. Just before sunset the snappers went through their spawning ritual which culminated in spawning. The spawning activity ended just before dark after which the snappers dispersed to feed (Wicklund, 1969a).

Mutton snapper - *Lutjanus analis*

Mutton snapper aggregations have been fished by local fishers in Belize for several decades (Craig 1966). Craig (1966) reported an aggregation in August, along the main barrier reef in Belize. This aggregation still exists today. Additionally, in May, 1990, another aggregation, further south along the outer barrier reef crest, was observed (personal observation). Reports of aggregations of mutton snapper in August have also been reported in Cuba (Rojas, 1960). Peak aggregation periods have also been reported as March through May at the southwestern end of St. Croix (Beets & Friedlander, 1992). An aggregation during the full moons of April and May was found off West Caicos, Turks and Caicos, on the edge of a steep drop off (Domeier, in press).

Aggregations of the mutton snapper found outside the Caribbean but within the Western Atlantic are:

A spawning aggregation is found 25 km southwest of the Dry Tortugas, around the full moon of May and June (Domeier, in press). Similar aggregations are reported to have occurred along the Florida Cays.

Silk snapper - *Lutjanus vivanus*

Aggregations of silk snapper have been reported east of St. Kitts in winter (Appeldoorn et al, 1986).

Yellowtail snapper - *Ocyurus chrysurus*

Yellowtail snappers are known to aggregate in Anegada and Anguilla in summer (Appeldoorn et al, 1986). A concentration of ripe yellowtail snappers was observed in Belize in June (personal observation).

2.1.3 Family Carangidae (jacks)

There is very little information on the possibility of jack aggregating to spawn.

Blue runners - *Caranx fusus*

A concentration of blue runners was found in a state of spawning on the northwestern edge of Pedro Bank, Jamaica in May, 1971 (Thompson & Munro, 1983).

2.1.4 Family Haemulidae (grunts)

The literature on spawning aggregations of grunt is quite sparse.

Blue-stripped grunt - *Haemulon sciurus*

A concentration of blue-stripped grunts, which contained eggs and milt, were caught by fishers in December in Ambergris Cay, north Belize (personal observation).

Species reported to form spawning aggregations outside the Caribbean but within the Western Atlantic:

White grunt - *Haemulon plumieri*

Moe (1966) reported concentrations of the white grunt off the coast of Florida in May.

2.2 Other Reef Species

Other reef families such as the Acanthuridae, Mullidae, and Scaridae produce pelagic eggs, and are also known to aggregate to spawn. These species spawn close to their habitats (Johannes, 1978). Actual spawning involves a rapid upward dash, with the release of gametes occurring in a fraction of a second at its culmination (Johannes, 1978). This spawning rush may function to distribute the gametes out of the reach of benthic predators (Johannes, 1978, Robertson ,1983).

A review of the smaller species that aggregate to spawn can be found in the following paragraphs.

2.2.1 Family Acanthuridae (surgeonfishes)

The surgeonfishes exhibit two different patterns of spawning, pair and group (Robertson, 1983).

Blue tang - *Acanthurus coeruleus*

Colin & Clavijo (1988) also found that the blue tang group spawned in a specific area close to the ocean surgeonfish off southwestern Puerto Rico. Aggregations of 6000-7000 individuals spawned in late afternoons in most months of the year except June and November (Colin & Clavijo, 1988). Colin & Clavijo (1988) reported a correlation between spawning aggregation and lunar periodicity.

Ocean surgeonfish - *Acanthurus bahianus*

The ocean surgeonfish was found to group spawn in a portion of the reef about 50 m wide from the reef top to the drop off of a coral reef off southwestern Puerto Rico from 1976-1980 (Colin & Clavijo, 1988). It was estimated that approximately 20,000 were aggregated in that area for spawning (Colin & Clavijo, 1988). Spawning occurred from November to April in the afternoons, peak spawning was from December through March (Colin & Clavijo, 1988).

2.2.2 Family Mullidae (goatfishes)

Little is known of the reproductive strategy of the goatfish. The information that exists suggests that both pair and group spawning can occur (Colin & Clavijo, 1988).

Spotted goatfish - *Pseudupeneus maculatus*

Colin and Clavijo (1978) observed the mass spawning by a group of approximately 300-400 spotted goatfish in March in St. Johns, U.S. Virgin Islands. The site was previously investigated by Randall and Randall (1963) who were studying the spawning habits of the yellowtail parrotfish, *Sparisoma rubripinne*. However, they did not observe the aggregation of the spotted goatfish (Colin & Clavijo, 1978). Therefore they may not have aggregated to spawn at that time (Colin & Clavijo, 1978). The spotted goatfish has also been seen to pair spawn at a shelf edge off southwestern Puerto Rico (Colin & Clavijo, 1988).

2.2.3 Family Scaridae (parrotfishes)

Striped parrotfish - *Scarus iserti*

The striped parrotfish, formerly *S. croicensis* (Randall and Nelson, 1979) is reported to engage in both group and pair spawning (Colin & Clavijo, 1988). A large spawning aggregation was encountered in August 1971 on a deep coral platform (24 m) offshore from the Discovery Bay Marine Laboratory on the north coast of Jamaica (Colin, 1978). This group consisted of several hundred individuals. Observations made from 1971 to 1975 showed the continual presence of a spawning group. Spawning rushes in June were six times greater than those occurring in January (Colin, 1978). Kaufman (1983) reported an aggregation on the coral pinnacle within three weeks after the passage of Hurricane Allen in

1980.

Reports of aggregations of about 100 individuals were reported at the shelf edge coral reef off southwestern Puerto Rico (Colin & Clavijo, 1988). Spawning occurred actively during the winter and at reduced levels during the summer (Colin & Clavijo, 1988).

Yellowtail parrotfish - *Sparisoma rubripinne*

Randall and Randall (1963) observed an aggregation of about 200 of the yellowtail parrotfish. This aggregation occurred in April on the west end of Reef Bay, St. Johns, U.S. Virgin Islands. Colin (1978) revisited the site in March 1977 (17 years later) and found an aggregation of similar numbers of yellowtail parrotfish.

Appendix I summarizes the location and species that aggregate to spawn in the Caribbean. Appendix II maps the locations of spawning aggregations of the commercially important Nassau grouper, red hind and mutton snapper. There is more information available on the spawning aggregations of these three species than on other species reported to form spawning aggregations in the Caribbean.

Spawning aggregations also occur in the Pacific. However, a lot of the information available on these aggregations can be obtained from anecdotal and regional reports and was beyond the scope of this report. Information obtained in the scientific literature on aggregations of some Pacific species can be found in Appendix III.

3 Fishery Management Implications of Spawning Aggregations

3.1 Effects of Fishing on Spawning Aggregations

Groupers appear to be the most commercially important family to aggregate in the Caribbean. This may be because it forms the most prominent aggregations, with some species forming aggregations comprising tens of thousands of individuals. As a result, the literature and anecdotal information primarily describe the effects of intense fishing on aggregations formed by this family.

Aggregations appear to be quite a stable occurrence, forming on a periodic and predictable basis; the literature gives many examples of aggregations that have been occurring for decades (Craig, 1966, Johannes, 1980, Colin, 1978). Similarly, for decades, these aggregations have been targeted by local fishers (Craig, 1966, Smith, 1972, Johannes, 1978, Olsen & LaPlace, 1978, Carter, 1986, Beets & Friedlander, 1992). For example, in Belize, annual finfish catches are obtained primarily from aggregations of snappers and groupers.

Burton (in press) found a strong correlation between spawning seasons and catches for select species of snappers and groupers, suggesting that spawning stock may be differentially vulnerable to fishing effort during spawning. Similarly, Johannes (1988) refers to a "spawning stupor" exhibited by aggregating fish which makes them less likely to be frightened from fishers than they would be during interspawning periods.

Intense fishing may have the following effects on an aggregating stock:

i) As fishing targets the larger sized classes of a species, fishing pressure may eventually produce catches consisting of smaller sized classes. For example, landings from the red hind showed a significant decline in average size and the apparent loss of large sized classes due to extensive fishing on the stock in the U.S. Virgin Islands (Beets & Friedlander, 1992). Similarly, Carter et al (in press) found smaller sized classes among individuals in exploited aggregations than found in an unexploited aggregation or outside the spawning banks.

ii) Fishing on aggregations also causes the removal of reproductive adults from the population which decreases future yields (Shapiro, 1986). Consequently, intense fishing may affect the resulting recruitment and the renewal of spawning stocks (Colin, 1992). Johannes (1980) suggests that intensive fishing on aggregations creates a selective pressure which tends to favour the survival and reproduction of individuals that do not spawn at times and areas typical for the species. The significance of this may be tremendous especially for species such as groupers which are not known to spawn outside the aggregation. Also, the effects of such a occurrence have yet to be evaluated.

iii) Carter (1986) suggested that a minimum population size is needed for groupers to aggregate and aggregations may cease to exist if the population falls below this critical level (Carter, 1986). Examples of aggregations that have been eliminated possibly as a result of intensive fishing have been reported for many areas within the Caribbean. Furthermore, it is not known whether the disturbed aggregation will regroup for spawning purposes in other areas (Sadovy, in press,a).

The elimination of a grouper aggregation has been reported in the eastern side of Mona Island, Puerto Rico, in Bermuda, and in the Dominican Republic near Punta Rusia (Colin, 1980, 1992, Bannerot, Fox & Powers, 1986). A spawning aggregation of Nassau grouper in Belize, on the northern province of the barrier reef, disappeared, this may have been due to intense fishing by local fishers. Olsen & LaPlace (1979) also reported intense fishing on an aggregation of Nassau grouper for ten years before the groupers ceased to aggregate. They also noted an increase in trap effort for an aggregation in St. Thomas which resulted in a decrease in trap catch and CPUE. In St. Thomas a red hind aggregation subsequently replaced a Nassau grouper aggregation that had disappeared as a result of intense fishing (Colin, 1989). Currently, the Red hind stock is producing declining size classes and the absence of males during the 1988-1989 season which may suggest spawning failure, was observed (Beets & Friedlander, 1992). Other areas to report a drastic decline is Bermuda, in the 1950's grouper catches accounted for 70% of fish catch, in 1989, it comprised of 19% of the catch (Butler, Burnett-Herkes, Barnes and Ward, 1993). Fishing on aggregating groupers in Belize has also caused a decline in stocks, commercial catch has decreased from 130,000 lbs to less than 27,000 lbs over the last 10 years (Carter, 1988). In the Bahamas, at a site in southern Long Island catches have declined from at least a few thousand to less than 100 fish (Sadovy, in press,b). Reports from Cayman Islands and Cuba have also reported declines in numbers and sizes of groupers caught from local aggregations (Sadovy, in press,b).

iv) Fine (1992) effectively demonstrates the vulnerability of an aggregation to fishing gears. An aggregation of Nassau grouper discovered in 1990, was, in 1991, fished with large wire traps which were brought to surface "choke full" of fish, and a fisher, using handlines, took 144 fish in two days (Fine, 1992). Fishing effectively reduced the aggregation from an estimated population of 10,000 in 1991, to approximately 500 individuals in 1992. In Mahahual, Mexico, an aggregation was fished by hook and line since the 1940's, yet catches did not decline until the introduction of spearguns in the late 1960's (Sadovy, in press,b). Similarly, Olsen and LaPlace (1979) found a discontinuity in the size-frequency distribution between the 1967 year class and older fish whose estimated ages were between 15 and 20 years, coincidentally, this gap began with the first year of trap fishing. Appeldoorn et al (1986) reported that tiger groupers were susceptible to spear fishing because of their curiosity to divers.

v) Carter et al (in press) reported that intensive fishing of grouper or other hermaphroditic species may stimulate a sexual transition that could alter the reproductive potential of the population. Also, one sex can be differentially targeted which could conceivably reduce the population to a critical level, possibly causing a decline of the population and the eventual disappearance of the aggregate (Carter et al, in press). However, the factors that control sex change may ultimately determine the impact of fishing on the stock. For example, it is conceivable that if sex change is controlled by age - using a protogynous grouper as an example - if males are a limiting factor for successful reproduction then a heavily fished stock may not be able to compensate for the fishing-altered sex ratio (Appeldoorn et al, 1986). However, if sex change is behaviorally controlled, then the removal of males by fishing may cause females to switch sex to retain an ideal sex ratio, therefore having no effect on reproductive success (Appeldoorn et al, 1986). Studies need to be carried out in order to determine a hermaphroditic species' reaction to intense fishing.

3.2 Fishery Management Information

The apparent vulnerability of aggregations to heavy fishing pressure has led to severe depletion of stocks and in some cases caused the disappearance of an entire stock (Olsen & LaPlace, 1979, Sadovy, in press,b). However, before a management plan that addresses the biological parameters of a species can be developed, a better understanding of the species population structure, social organization, breeding behavior and larval recruitment is needed.

The following paragraphs give the data requirements needed to monitor stocks that aggregate to spawn, provide management options for these stocks, and seek to prevent overfishing and the collapse of a spawning aggregate. Fisheries divisions have the option of choosing an approach that varies with the needs, policies, technical and economic resources available.

3.2.1 Data Requirements:

i) Identification of spawning aggregations

The disappearance of aggregations due to intense fishing has been documented by many authors (Olsen & LaPlace, 1979, Beets & Friedlander, 1992, Sadovy, in press,b). However, it can be assumed that some aggregations have not yet been discovered because they are found on shelf edges far from any coastal communities, and still others, although not scientifically documented are known and exploited by local fishers. The first step towards the management of spawning aggregations is to identify the spawning aggregations occurring within an area, including spawning times, locations and species. Some species may migrate to a spawning site along specific routes, these routes must also be identified. Such information can be obtained from local fishers, for it is only the aggregations that fishers are aware of that are exploited and are in need of management.

Information on the reproductive strategies of a species is also important in managing spawning stocks. Many families have various forms of reproductive strategies, such as pair and group spawning; fishery managers need to establish how much of a fish's annual

Rico are self-recruiting. Unfortunately, there is little oceanographic data to support the hypotheses on spawning location and dispersal of eggs and larvae. Furthermore, a given site will be subject to a set of conditions which may not necessarily be applicable elsewhere (Shapiro et al, 1988).

3.2.2 Management Measures

The social implications of managing any stock must always be addressed before implementing management measures designed to control fishing catch or effort. A primary issue to be considered is alternate employment for fishers who have traditionally harvested spawning aggregations and who are dependent on the earnings obtained from these stocks. Other issues exist and will have to be addressed on a country by country basis. In all countries, however, managers must allow for input by all user groups. An educational component needs to be incorporated into any fishery management plan if it is to succeed. Also, the plan must have the support of the government and provisions must be made to have the accompanying enforcement mechanism, infrastructure and technical support available.

The development of a mariculture program used to cultivate commercially valuable spawning stocks such as the snappers and groupers has been recommended (Carter et al, 1991). The farm raised fish would fill the demand of the product and would provide an alternate source of employment for fishers. However, the viability of grouper and snapper culture in the Caribbean is unknown and the social implications of employing these fishers in this industry will need to be evaluated.

The following measures mentioned below are designed specifically to control effort or catch of the fishery.

i) Permanent Fishery Reserves

Such a measure controls effort by designating areas where no fishing can occur; these can be located in areas known for spawning aggregations. Fishery reserves serve to protect intraspecific and interspecific genetic diversity and ensure recruitment supply by protecting the spawning stock biomass (Plan Development Team-PDT, 1990). Normal pelagic dispersal of eggs and larvae are assumed to supply surrounding harvested areas (PDT, 1990). Carter & Marrow (1991) recommended a fishery reserve be established for 20% of the marine and coastal spawning banks in Belize, their goal is to protect a minimum of 30% of all reef fish spawning stock biomass. Permanent fishery reserves should be large enough to include mangrove areas, seagrass beds, and coral reefs in order to protect both adult and juvenile stocks.

To successfully manage a permanent fishery reserve, managers would need to set up an accompanying infrastructure for monitoring of the area. However, a marine fishery reserve may be a realistic option for managing a multispecies fisheries given the limitations for carrying out enforcement and monitoring within an entire region (Sadovy, in press,a). In addition, marine reserves can become successful tourist attractions.

ii) Seasonal Closure

Such a measure is designed to decrease effort in order to protect the spawning stocks at times and locations chosen when aggregations are known to be deferentially vulnerable to fishing pressure. Since aggregations occur at restricted locations, enforcement would need to be carried out during these times and the cost will be substantially less than full time enforcement. An additional advantage of a permanent or seasonal closure is that such a measure would not interfere with fishers fishing for other species in other areas (Beets & Friedlander, 1992).

Seasonal closures are in effect for aggregations in Bermuda, Dominican Republic, Honduras and St. Thomas (Colin 1989, Fine, 1992, Sadovy, in press,a). A similar strategy has been proposed for spawning aggregations of the *Epinephelus guttatus* off western Puerto Rico and *E. striatus* in the U.S. Virgin Islands and Puerto Rico (Sadovy, in press,a, Caribbean Fishery Management Council, 1985). In the Cayman Islands, aggregations are restricted to fishing by local fishers (Sadovy, in press,a).

iii) Total Harvest Ban

Utilizing such a strategy would allow managers to eliminate effort on a fishery that has been severely depleted. A total harvest ban has been applied to the Jewfish in the U. S. federal waters of the Gulf and South Atlantic, and in Florida state waters (Sadovy, in press,a, Colin, 1989).

Enforcement would be needed to ensure that the ban is being observed and alternate fishing stock or source of employment must be available for the fishers who traditionally fish the fishery.

iv) Permanent Limited Entry

Permanent limited entry can reduce fishing mortality by reducing fishing effort to some predetermined level (Plan Development Team - PDT, 1990). Such a measure would allow a one-time salable, transferable license to a fisher with a buy back scheme (Munro & Williams, 1985). The advantages of such a management approach would be to protect the livelihood of those fishers who traditionally fish the aggregation. It would also facilitate the collection of fisheries data from each licensed fisher and it may become self-regulating, as licensed fishers would ensure that unlicensed fishers do not poach in their territory (Munro & Williams, 1985, Carter & Marrow, 1991).

Issuing a license to fish would give fishery managers an indication of fishery effort and the socio-economic status of the fishers. A license system could also facilitate a data collection program. Such a scheme also makes it possible for fishers to participate in the development of policies aimed towards managing the fishery.

Permanent limited entry would be feasible only for fisheries that were not over-exploited and in areas where alternate forms of employment exists (Munro & Williams, 1985). In addition such a management measure would not protect the larger sized classes from selective fishing (PDT, 1990). However, it would allow fishery managers to have control of fishing mortality by keeping fishing effort at a specific level (PDT, 1990). Such a scheme would need constant monitoring and enforcement if its implementation is to be successful.

v) Size Limits

A minimum size limit has been used in the management of aggregating stocks. With this measure, managers reduce fishing effort on a stock giving a greater proportion of the stock an opportunity to mature and breed. However, setting appropriate size limits requires a knowledge of the growth and mortality parameters of the species (PDT,1990). Also the effect on size limits on aggregates known to be hermaphroditic (such as groupers or parrotfishes) needs to be evaluated (Sadovy, in press,a). Fishing that targets larger individuals may cause a disproportionate decrease in one, the larger bodied, sex. The success of size limits also depends on compliance with the law and the rate of survival for released species (PDT, 1990). Although survivorship after capture is unknown, it is assumed to be low for grouper stocks particularly for those taken from deep water (Sadovy, in press,a). Similarly, size limits should be applied to a fishery whose methods of capture do not seriously injure the fishes, methods such as handline or trap (Munro and Williams, 1985). Imperfect survival of released fish reduces the expected increase on yield-per-recruit resulting from size limit regulations (Sadovy, in press,a). Size limits may also encourage a reduction in breeding year classes to one or two classes and may produce size-selective forces with unknown consequences (PDT, 1990). Most importantly, the proper enforcement mechanism must be in place for managers to successfully implement such a strategy.

Size limits are used to manage the grouper fishery in the Bahamas, Bermuda,the U.S Virgin Islands and the snapper-grouper fishery in the South Atlantic region (Colin, 1989, Sadovy, in press,a, in press,b).

vi) Gear Restrictions

This strategy is traditionally used to restrict effort on smaller individuals, giving them a chance to grow to maturity. Gear restrictions can also be used to prevent the over exploitation of a stock that aggregates in a small area. In this case, restrictions may be placed on gear capable of depleting an entire aggregation in a short period of time. Such destructive gear include traps, spears and nets. If gear restrictions were to be applied to a fishery, an ongoing monitoring system would have to be implemented to assure such measures are adhered to.

Prohibition of various forms of spearfishing, such as the use of scuba gear, spear guns, or power heads, and the use of poisons or explosives are commonly applied in the Caribbean (Bannerot et al, 1986). Belize prohibits the use of traps and nets on a spawning aggregation. Spear guns are prohibited from use at coastal aggregation sites in Mexico (Sosa-Cordero & Cardenas-Vidal, in press). In the Cayman Island fishers are restricted to hook and line fishing (Sadovy, in press,a).

vii) Catch Quota

Bag limits have been implemented in Bermuda and in some U.S. mainland waters (Sadovy, in press,a). Such a scheme should be applied only to a select and valuable aggregating species and is geared at controlling fish catch. However, applying such a measure requires an accurate knowledge of catch, effort and the mortality of released individuals (PDT, 1990, Sadovy, in press, a). Also, this measure would not protect the larger sized classes from selective fishing.

Catch quotas would require a comprehensive monitoring program in an effort to manage fish brought into all landing sites. Therefore such a strategy would not be economically viable for many Caribbean countries under present circumstances.

4 CONCLUSION

Spawning aggregations have proven to be a valuable fishery for fishers in the Bahamas, Belize, Cayman Island, Puerto Rico and the U.S. Virgin Islands.

Aggregations have been reported for species of groupers, snappers, grunts, jacks, surgeonfishes, goatfishes, and parrotfishes. Yet, much of the information known about spawning aggregations have been obtained from studies on the Nassau grouper spawning aggregations. This may be because of the species economic value and because they form large aggregations that are easy to detect. Still, the information on spawning aggregations is largely anecdotal and there is a need for more research and documentation on this phenomenon. Specifically, information is needed on the types of species that aggregate to spawn, including times and locations of aggregations. Studies are also needed to determine breeding behaviour, size and range of a spawning aggregation, life-history of the larvae, and recruitment of juveniles into the fishery. Stock assessment models designed specifically to assess species that aggregate to spawn, particularly, hermaphroditic species, must be developed. However, it must be emphasized that research in these areas require sizeable sums of money, and personnel and produce results which are often uncertain.

Although quantitative data are lacking, it has been demonstrated that fishing on a spawning aggregations removes the larger reproductive adults from the spawning stock. For hermaphroditic species, the removal of these individuals may alter the reproductive potential of the population. In addition, the reduction and eventual extinction of an aggregating stock as a result of intense fishing have been documented in Belize, the Dominican Republic, Puerto Rico, and the United States Virgin Islands.

Because of the lack of information on spawning aggregations, measures introduced to manage the fishery should be conservative. Permanent fishery reserves are recommended as they allow aggregations to occur without any fishing pressure. Measures recommended to decrease fishing effort on an aggregation are seasonal closures, total harvest ban, permanent limited entry, size limits and gear restrictions. Catch can be controlled with the introduction of bag limits and catch quotas.

The type of measures to be adopted by a country will depend on the social needs and economic resources available to the country. However, any measure introduced to control a fishery must be monitored to determine its effect on the spawning stock. Allowances should be made to adjust management measures as the need arises.

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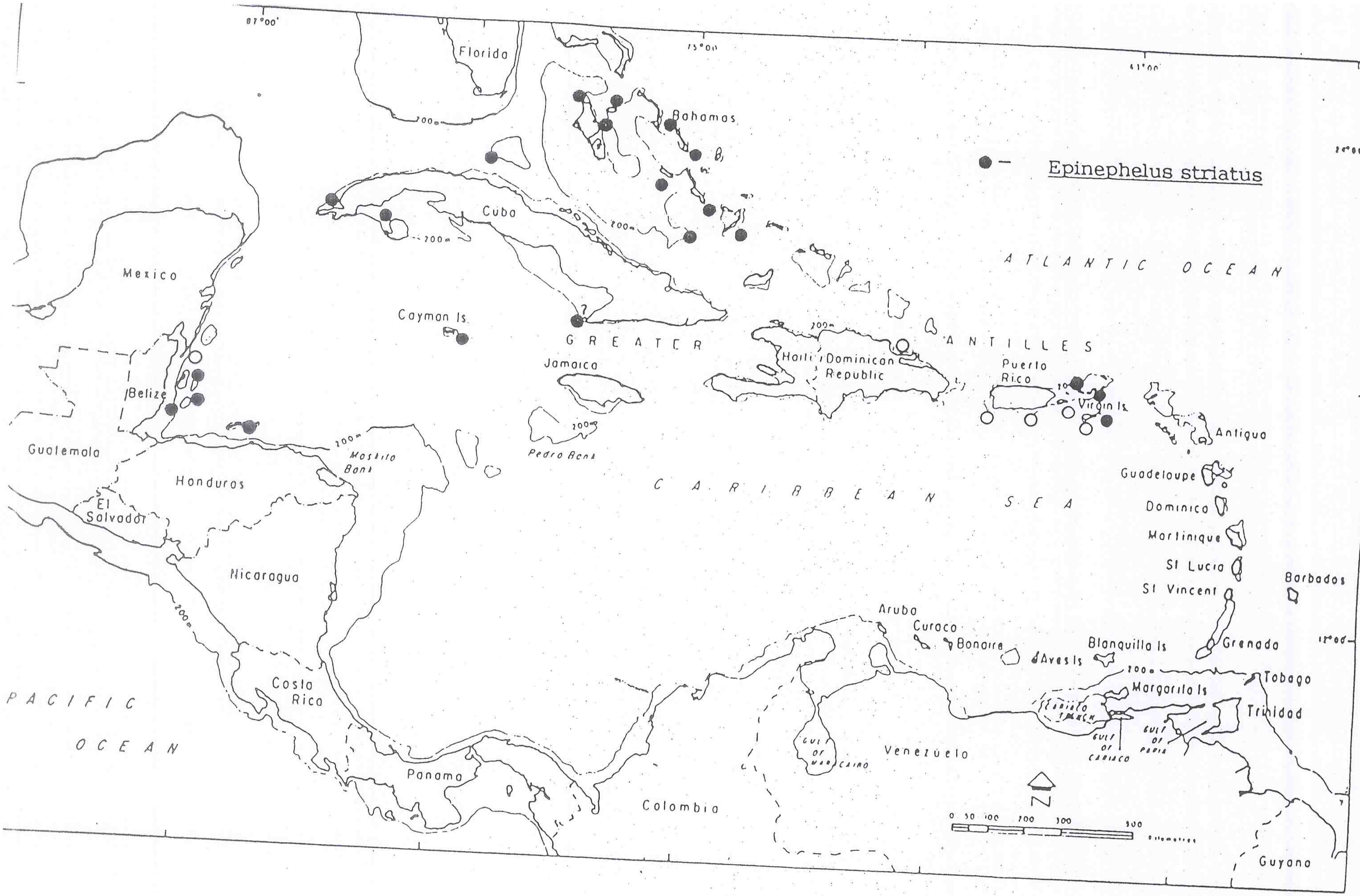
APPENDIX I: Summary of scientific information on species that form spawning aggregations within the Caribbean.

SPECIES	LOCATION	SOURCE
Epinephelus adscensionis	S. W. Puerto Rico	Colin, Shapiro & Weiler, 1987
E. fulva	Belize Bermuda	Carter, Marrow & Pryor, in press Burnett-Herkes, 1975
E. guttatus	Puerto Rico Tortola, Virgin Gorda, N. St. Kitts, E. St. Lucia U.S. Virgin Islands	Erdman, 1977; Colin et al, 1987; Sadovy et al, in press; Appeldoorn et al, 1986 Appeldoorn et al, 1986 Appeldoorn et al, 1986 Burnett-Herkes, 1975; Beets & Friedlander, 1992
E. itajara	Belize	Local fishers
E. striatus	Bahamas Belize Bermuda Cayman Island Cuba Dominican Republic Honduras Puerto Rico U.S. Virgin Islands	Smith, 1972; Sadovy in press,b Carter, 1986; 1988; Carter et al, in press; Burnett-Herkes, 1975 Colin et al, 1987 Claro, 1990 Colin, 1992 Craig, 1966; Fine, 1992 Colin, 1980; Sadovy, in press,b; Olsen & LaPlace, 1978; Beets & Friedlander, 1992
Mycteroperca bonaci	Belize	Carter et al, in press
Mycteroperca tigris	Puerto Rico	Sadovy (in press,a)
Mycteroperca venenosa	Bahamas Belize St. Thomas, U.S. Virgin Islands	Appeldoorn et al, 1986 Miller, 1984; Carter et al,in press Beets & Friedlander, 1992

APPENDIX I: Summary of scientific information on species that form spawning aggregations within the Caribbean (Continued).

SPECIES	LOCATION	SOURCE
Lutjanus analis	Belize Cuba W.Caicos, Turks & Caicos Islands St. Croix, U.S. Virgin Islands	Craig, 1966 Rojas, 1960 Domeier, in press Beets & Friedlander, 1992
Lutjanus cyanopterus	Belize	Domeier, in press
Lutjanus griseus	Belize	personal observation
Lutjanus jocu	Belize	Carter (pers. comm.) Domeier, in press
Lutjanus synagris	Cuba Belize	Appeldoorn et al, 1986 Personal observation
Lutjanus vivanus	St. Kitts	Appeldoorn et al, 1986
Ocyurus chrysurus	Anegada & Anguilla Belize	Appeldoorn et al, 1986 Personal observation
Caranx fusus	Jamaica	Thompson & Munro, 1983
Haemulon sciurus	Belize	Personal observation
Acanthurus bahianus	Puerto Rico	Colin & Clavijo, 1988
Acanthurus coeruleus	Puerto Rico	Colin & Clavijo, 1988
Pseudupeneus maculatus	St. Johns, U.S. Virgin Islands	Colin & Clavijo, 1978
Scarus iserti	Jamaica Puerto Rico	Colin, 1978 Colin & Clavijo, 1988
Sparisoma rubripinne	St. John's, U.S. Virgin Islands	Randall & Randall, 1963

APPENDIX II: Maps of the location of known Nassau grouper, Red hind and Mutton snapper spawning aggregation sites. Each symbol may represent more than on site in the general area. Closed circle = active aggregation site; opened circle = extinct aggregation site, ? = exact location of site unknown.


Epinephelus striatus
ATLANTIC OCEAN
GREATER ANTILLES
CARIBBEAN SEA
PACIFIC OCEAN
Florida
Bahamas
Cuba
Mexico
Cayman Is
Jamaica
Haiti
Dominican Republic
Puerto Rico
Virgin Is
Antigua
Guadeloupe
Dominica
Martinique
St Lucia
St Vincent
Barbados
Grenada
Tobago
Trinidad
Margarita Is
Blanquilla Is
Aves Is
Bonaire
Curaco
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Nicaragua
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Guatemala
Belize
Pedro Bank
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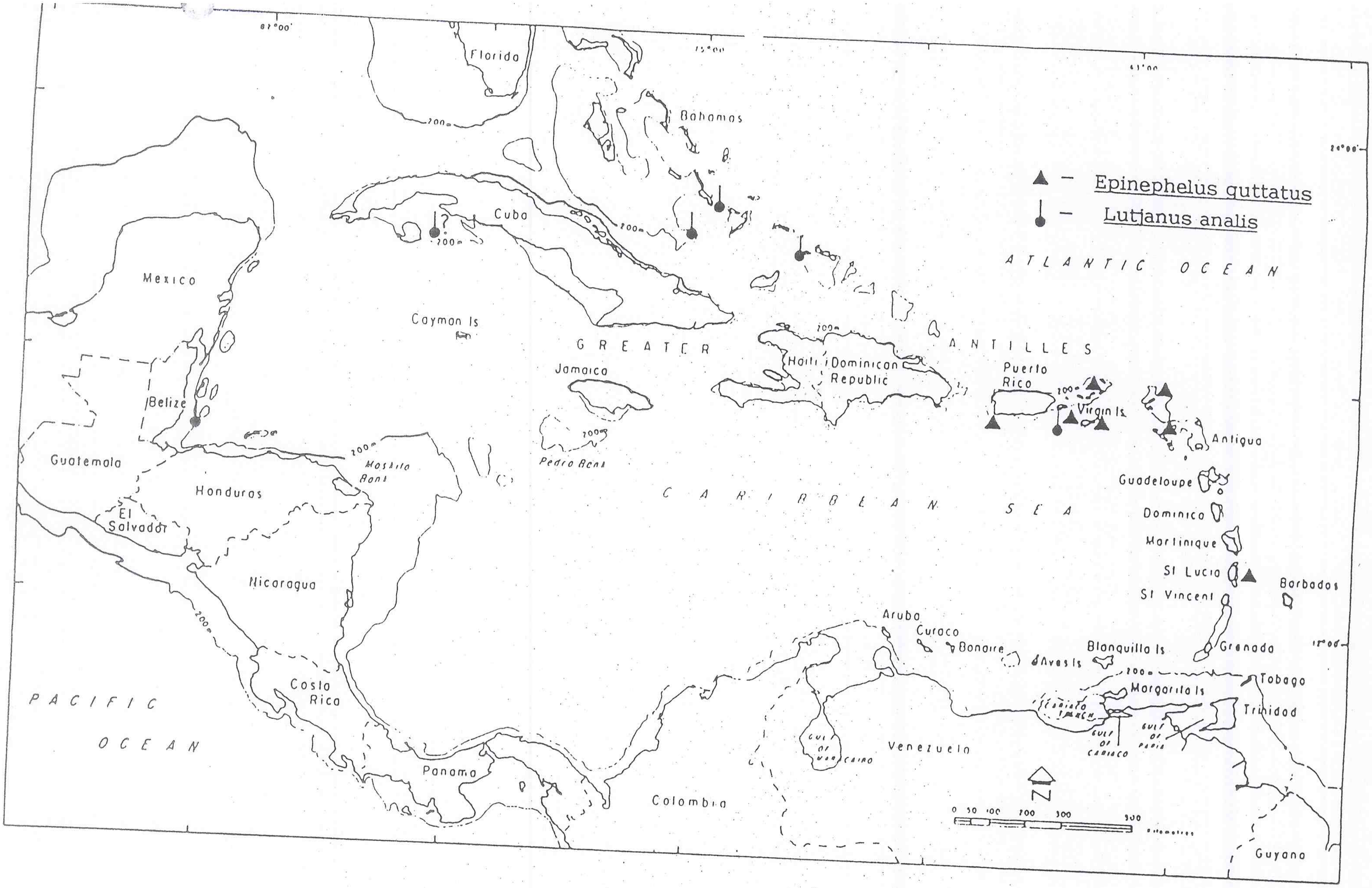
▲ – Epinephelus guttatus
● – Lutjanus analis
ATLANTIC OCEAN
GREATER ANTILLES
CARIBBEAN SEA
PACIFIC OCEAN
Florida
Bahamas
Cuba
Cayman Is
Mexico
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Colombia
Venezuela
Guyana
Jamaica
Pedro Bank
Mosquito Bank
Haiti
Dominican Republic
Puerto Rico
Virgin Is
Antigua
Guadeloupe
Dominica
Martinique
St Lucia
St Vincent
Barbados
Grenada
Tobago
Trinidad
Margarita Is
Blanquilla Is
Aves Is
Bonaire
Curaco
Aruba
Gulf of Paria
Gulf of Cariaco
200m
0 50 100 200 300 500

APPENDIX III The Occurrence of Spawning aggregations in the Pacific

Johannes (1980) wrote about spawning aggregations occurring in the Palau District of Micronesia, in the Pacific. These aggregations are well known and have even influenced the local names of certain days of the month. The grouper, milkfish, mullet, rabbitfish, jack, snapper, surgeonfish, mojarra, and bonefish have been found to aggregate in the Pacific.

Table 1 demonstrates the occurrence of spawning aggregations within the tropical Pacific. A comprehensive report on the characteristics, occurrence and longevity of aggregations in the Pacific is beyond the scope of this discussion. However, the literature does show a correlation between the behavior and occurrence of an aggregating family in the Atlantic to its relatives found in similar ecosystems in the Pacific.

Table 1. The occurrence and sites of spawning aggregations in the Pacific (Randall, 1961, Johannes, 1978, 1988, Robertson, 1983, Shapiro, 1986).

Species	Country of reported aggregation	Site of Aggregation
Bonefishes		
Albula vulpes	Palau, Micronesia	sand flats close to reef crest
Emperors		
Lethrinus sp.	Palau	lagoon reef slopes (off fringing reefs only)
Goatfishes		
Mulloidichthys flavolineatus	Palau	outer reef slope
Groupers		
Epinephelus fuscoguttatus	Palau	n/a
Epinephelus merra	Palau, Chuck, Nukuoro Ponape, Micronesia	n/a
Epinephelus tauvina	Palau	outer reef crest
Plectropomus areoltus	Palau	n/a
Plectropomus leopardus	Palau	outer reef crest
Grunts		
Plectorhynchus goldmani	Palau	outer reef slope
Herrings		
Herklutsichthyes sp.	Palau	mangrove creeks

Table 1. The occurrence and sites of spawning aggregations in the Pacific (Continued).

Species	Country of reported aggregation	Site of Aggregation
Jacks		
Carangoides fulvoguttatus	Palau	outer reef slope
Caranx melanpygus	Palau	outer reef slope
Mojarras		
Gerres abbreviatus	Palau	sand slopes close to reef slopes
Gerres oblongus	Palau	sand slopes close to reef slopes
Mullets		
Chelon varigiensis	Palau	outer reef slope
Crenimugil crenilabis	Palau	outer reef slope
Mugil cephalus	Taiwan, Headlands of Australia	n/a
Rabbitfishes		
Siganus canaliculatus	Palau	reef crest
Siganus lineatus	Palau	sand beach on outer reef crest
Siganus punctatus	Palau	reef crest
Snappers		
Lutjanus argentimaculatus	Palau	lagoons & outer reef crest
Lutjanus gibbus	Palau	outer reef crest
Symphorus spilurus	Palau	outer reef slope
Surgeonfishes		
Acanthurus lineatus	Palau,	outer edge of reef
	Escape Reef	outer edge of reef
Acanthurus nigrofuscus	Aldabra Atoll, Indian Ocean	n/a
	Lizard Island	outer reef edge
	Palau	outer reef crest
Acanthurus triostegus	Aldabra Atoll	n/a
Ctenochaetus striatus	Tahiti	reef edge
	Aldabra Atoll	reef slope
	Lizard Island	reef slope
	Palau	reef slope

Zebrasoma scopas	Society Islands	n/a
Tuskfish		
Choerodon anchorage	Palau	outer reef crest