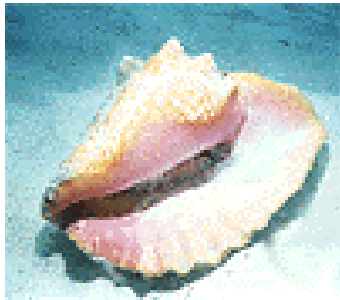


**NASSAU GROUPER AND QUEEN CONCH
IN THE BAHAMAS
STATUS AND MANAGEMENT OPTIONS**



BY

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FOR

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GENERAL SUMMARY

The biology of grouper and conch (long lived, slow growth, slow to mature, increasing reproductive rate with time) makes scientists predict that their populations will be vulnerable to fishing pressure. Both grouper and conch populations have the potential to collapse if they are heavily fished; grouper because spawning aggregations do not return once they are eliminated and conch because they do not reproduce at low density.

A review of scientific data on grouper and conch populations in the Bahamas shows that there is strong cause for concern for both species:

- Nassau grouper reproduce by forming large spawning aggregations at predictable times and places from December to February. Recent research (2000-2002) on spawning aggregations in Long Island shows that some have already disappeared and some are disappearing very rapidly, with only a few tens of fish aggregating where there were formerly thousands or tens of thousands. In one aggregation studied in the winter of 2000-2001, every single aggregating fish was caught by trapping; this aggregation did not form in the winter of 2001-2002. The aggregation at High Cay is probably also an order of magnitude smaller than its historical size (hundreds of fish rather than thousands or tens of thousands). Evidence from the Exuma Cays Land and Sea Park shows a clear difference in the number and size of all large grouper species between fished and non-fished areas.
- Comparisons of conch populations in the Exuma Cays Land and Sea Park (where fishing has been forbidden since the mid 1980s) and the southern Exuma Cays show that conch populations in fished areas are probably at or below the Caribbean Fisheries Management Council definition of overfished. Even deep water populations in fished areas are close to the definition of overfished, probably because conch are taken before they can migrate into deep water, and/or because the population has a lower rate of reproduction (conch do not reproduce at low density).

Case studies of grouper, conch and similar species across the world lead to the following main conclusions:

- Their populations are vulnerable and do collapse if there is insufficient management of the fishery. Grouper populations have collapsed in most of the Caribbean, and the Nassau grouper is now considered an endangered species in many areas. Conch populations have collapsed in parts of the Caribbean, Florida and Bermuda.
- Once populations have collapsed they do not return, at least on a time scale of years to decades. Both Nassau grouper and conch have been protected from all fishing in Florida for about two decades, but both species are still rarely seen. Conch are extremely rare in Bermuda despite protection for 24 years.
- Fishing on grouper spawning aggregations leads to population collapse. Carefully controlled fishing on spawning aggregations (e.g. locals with handlines only in the Cayman Islands) can still be enough to make aggregations disappear. Once aggregations have disappeared Nassau grouper becomes very rare or extinct.

- Since populations cannot easily recover from low levels, management is only successful if it is put in place while populations are still healthy.
- Several kinds of management have been successful in different situations, including closed seasons, networks of no-take reserves and community management systems.

The case studies give useful suggestions for the management strategies that will be most successful in protecting grouper and conch populations in the Bahamas. Management needs to be pre-emptive (before populations suffer any further). It is critical for protecting grouper populations that there is no more fishing on spawning aggregations. It has proved difficult to close individual aggregations in the Bahamas on a long term basis (High Cay), so the only way to achieve the necessary protection for grouper spawning aggregations seems to be an annual closed season for Nassau grouper from November to February inclusive. The scientific data and the case studies show that if there is no action to protect spawning aggregations in the near future, Nassau grouper populations in much of the Bahamas are likely to collapse.

For conch, the best approach is to develop a network of permanent no-take reserves. This has been a successful conch management tool in the Turks and Caicos Islands. It also helps other species, including grouper and crawfish. Reserves in St. Lucia have led to higher fish catches, despite reducing the area available for fishing. Both the Turks and Caicos and Belize use their network of marine reserves extensively in tourism marketing, since the reserves are strongly favoured by divers and snorkellers.

In the longer term, education and the development of closer ties with communities are critical in making fisheries management a success. Profitable fishing businesses (e.g. commercial crawfish boats) should pay a fairer contribution to the cost of management through licence fees or taxes on landings, and tax breaks to commercial fisheries should be discontinued.

GROUPEL SUMMARI

Grouper are slow growing, live several years before reaching sexual maturity and have naturally low mortality. All these factors make them vulnerable to overfishing. Nassau grouper are particularly vulnerable because they form large spawning aggregations in predictable areas and at predictable times; in the Bahamas this happens from December to February. Fishing on spawning aggregations has a large impact on the population for three reasons:

- i) It increases the mortality dramatically by taking large numbers of fish;
- ii) Fishing activities disrupt spawning behaviour;
- iii) Newly mature fish need to follow experienced fish to the aggregation site, so if all experienced fish in an area are taken the aggregation will disappear and not re-form.

There are two sources of scientific evidence that grouper populations are declining in the Bahamas:

- Comparisons between fished and unfished areas (the Exuma Cays Land and Sea Park) show clear differences in grouper population density and grouper size, with fewer and smaller grouper in fished areas.
- Two scientific studies of spawning aggregations (one study of a series of aggregations around Long Island and one study of the aggregation at High Cay, Andros) show that some aggregations have disappeared and others are in serious decline. None of the aggregations studied had more than a few hundred fish in them, while most of those that still exist had only a few tens. In the 1970s, aggregations were recorded as containing tens of thousands or hundreds of thousands of grouper.

Case studies of Nassau grouper fisheries in the Caribbean show that the species is in decline or collapse almost everywhere. In US waters, such as the Florida Keys and around Puerto Rico and the USVI, **all spawning aggregations have disappeared**. In these areas Nassau grouper are very rare and has been listed as an endangered species by the US federal government. In 2000, the Nassau grouper was red listed as an endangered species by IUCN. Spawning aggregations of other grouper species, such as the red hind, are strictly protected in Puerto Rico and the USVI to try and prevent a collapse in this species as well. In Bermuda, an early ban on fishing spawning aggregations have maintained the fishery for red hind, but a failure to protect Nassau grouper spawning aggregations has resulted in a 95% decline in the population, which is now commercially extinct. The main factor driving population collapses in the Caribbean seems to be fishing on spawning aggregations.

In the Indian Ocean and Pacific grouper species have also been shown to be vulnerable to fishing pressure, with several countries showing population declines and collapses.

There do, however, seem to be various successful ways of managing grouper fisheries, which could work in the Bahamas:

- A ban on fishing spawning aggregations is essential for the continual survival of the Nassau grouper population in the Bahamas. It has proved difficult to close individual spawning aggregations to fishing on a long term basis (High Cay), and the only realistic strategy is a three month closed season for grouper over the spawning period from November to February (such as for red hind in Puerto Rico and the USVI and for grouper and other species in the South Pacific).
- A system of no-take marine reserves has been shown to stabilise rather than reduce total fish catches in St. Lucia, and is part of the grouper fisheries management system in Australia.

It is absolutely vital that the Bahamas acts to protect spawning aggregations in the near future, otherwise it is likely that Nassau grouper populations in the Bahamas will collapse.

CONCH SUMMARY

Conch are vulnerable to fishing because they are slow growing and long lived. Conch reproduction fails when conch populations fall below a critical density of 50 conch per hectare. If they are fished to below this density they are likely to take a long time to recover even if fishing is stopped.

The Caribbean Fisheries Management Council define a conch population as overfished if the adult density is lower than one fifth of the natural unfished density. There is evidence that conch populations in the Bahamas are at or below this overfishing definition. Conch populations in shallow, fished areas are at only 3% of the unfished density (as shown by the Exuma Cays Land and Sea Park), so are heavily overfished. Conch in deeper areas also show the effects of fishing (since they migrate from shallow areas, and because larval supply is reduced by fishing). Deep water populations in the southern Exuma Cays are at 24% of the unfished level; close to the overfishing definition. In general, there are only a few small areas left in the Exuma Cays where conch are dense enough to reproduce.

Case studies of fisheries for conch and related species around the world show that they are indeed vulnerable to collapse, and are in serious danger of collapse in many parts of the Caribbean. Conch populations have already collapsed in Florida and Bermuda, and several years of a total moratorium has made no difference to the population size; once populations collapse they do not return quickly or easily. Two important factors that causes conch populations to collapse are i) harvesting of juveniles and ii) fishing using hookah or SCUBA.

The best management strategy for conch species seems to be a network of permanent, no-take reserves, which is put in place while the population is still relatively healthy. This strategy, along with a ban on hookah and SCUBA for fishing, has been successful in maintaining conch stocks in the Turks and Caicos Islands, despite relatively heavy fishing. It is also being tried in Belize, which has seen big increases in conch populations inside the reserves. Both countries also use their reserves extensively in tourism promotion. The report recommends that the Bahamas make the implementation of a network of marine reserves a major priority.

1 INTRODUCTION

This report focuses on two of the three main fisheries species of the Bahamas: Nassau grouper (*Epinephalus striatus*) and queen conch (*Strombus gigas*). These species have sometimes been overlooked because of the dominant economic importance of the crawfish fishery, but are nonetheless extremely important to the Bahamas, both economically, culturally and ecologically. In addition, both species have been overfished throughout their range and the Bahamian populations of both species probably constitute the majority of remaining animals **in the world**. Thus the continued health of Bahamian populations is crucial both for the Bahamian people and for the continued survival of these species.

The report addresses four key questions:

1. Can we predict from the biology of grouper and conch whether they are likely to be vulnerable to fishing pressure? See pages 7 & 8.
2. What do we know about the status of grouper and conch populations in the Bahamas? Is there any evidence that the populations are overfished and in decline? See pages 9-16.
3. What is the worldwide experience of fisheries for grouper, conch and similar species? What does this tell us about the likely future of grouper and conch populations in the Bahamas? What management actions have been tried? Which have succeeded and which have failed? See pages 18-34.
4. Given our prediction about the future of Bahamian grouper and conch populations, does the Bahamas government need to take action to ensure the long term health of grouper and conch populations? If so, what practical measures can the Bahamas take, and on what time scale? Which management measures are likely to succeed and which are likely to fail? See pages 36-41.

2 GROUPEL AND CONCH BIOLOGY AND IMPLICATIONS FOR FISHERIES MANAGEMENT

Grouper and conch have the following life history traits:

- Long life and low adult mortality (both)
- Slow growth (both)
- Several years to reach maturity (both)
- Increasing reproductive rate (both) and number of eggs per reproductive event (grouper) with age
- Aggregate to spawn (most grouper, particularly Nassau grouper)
- Change sex from female to male (most grouper, possibly Nassau grouper)
- Reproductive failure at low density (both)

It is fairly clear to see that traits such as slow growth, a high age at maturity and reproductive failure at low density make a population vulnerable to fishing, since they mean that it is difficult for a population to recover quickly from a local reduction in density caused by fishing.

It is less easy to understand that traits such as long life, low mortality and increasing reproduction with age also make populations vulnerable. The “mortality” is defined as the number of deaths in a population in a given time period. The main action of fishing is therefore to increase the rate of mortality in the population (increase the death rate). Scientists can thus divide mortality into two parts: natural mortality, which is deaths due to natural causes, and fishing mortality, which is deaths due to fishing.

In general, overfishing is likely when fishing mortality gets close to the same value as natural mortality (Coleman *et al.* 2000). In species such as grouper and conch, which have naturally low mortality, it only takes a low level of fishing mortality to be equal to the natural mortality, hence these species can support less fishing before they become overfished.

In addition, populations with low natural mortality, long life and increased reproductive output with age tend to depend on older individuals for reproduction. As mortality increases, the probability of an individual surviving to a given age declines exponentially, meaning that even small increases in fishing mortality have a large impact on life span because the number of old individuals declines much faster than the total population figure. Therefore the reproductive output declines faster than the overall population size. This is even worse if fishing targets older (larger) individuals specifically. When this is combined with a high age at maturity, it is easy to reach the situation where very few individuals even survive to reproduce. A population that contains a large proportion of immature individuals is not likely to be in good reproductive health.

Therefore, long life, low mortality, high age at maturity, slow growth and reproductive failure at low density all combine to make species with these traits vulnerable even to relatively light fishing pressure (Musick 1999). This has been recognised by the American Fisheries Society, which has published a special policy statement on the management of long-lived reef fishes such as grouper (Coleman *et al.* 2000).

It is clear that spawning aggregations make populations vulnerable for the obvious reason that they are easy targets (high densities, predictable in time and space). However, there is another factor that is probably more important in the long run. New recruits do not know the location of the spawning aggregations by instinct. Instead, they need to learn both the location of aggregations and spawning behaviour from experienced individuals in the population. Therefore if the experienced (older) individuals in the population are removed, the spawning aggregation will fail (Coleman *et al.* 1999).

Sex change from female to male late in life makes grouper species particularly vulnerable to selective fishing pressure, because the large old (male) individuals are reduced disproportionately (see above), especially when they are targeted, e.g. by spear fishermen. There are cases of exploited grouper populations where the proportion of males in the population has been reduced below 2% (McGovern *et al.* 1998) with obvious consequences for reproduction.

Conch reproduction is known to fail at low density (Stoner and Ray-Culp 2000). This means that populations have the potential to collapse abruptly, and are likely to find it difficult to recover even if all fishing is stopped.

Biologists predict and experience confirms that grouper and conch populations are easily depleted by fishing, and will find it difficult or impossible to recover from low densities.

The disappearance of key species, such as the Nassau grouper, has a serious, ongoing and unpredictable detrimental effect on coral reef ecology (Jennings and Polunin 1996).

3 STATUS OF GROUPER IN THE BAHAMAS

The sheer size of the Bahamas, and the lack of resources for data collection has made it difficult to establish the status of grouper populations. However, there are sources of data that give some indications as to the status of the population.

3.1 GROUPER SPAWNING AGGREGATIONS

The health of grouper spawning aggregations is a good indicator of the health of the population as a whole, because the depletion of spawning aggregation has very serious consequences for the reproductive output of the population.

There have been two recent studies of Nassau grouper spawning aggregations in the Bahamas: the aggregations around Long Island and the aggregation at High Cay (Andros).

3.1.1 Long Island

Scientists from North Carolina State University surveyed several spawning aggregation sites in Long Island during the 2000-2001 and 2001-2002 winter spawning period, selecting the sites by talking to local fishermen and by using aerial overflights to look for groups of fishing boats.

In 2000-1, they found only a few tens of fish (up to 70) at every spawning site during the aggregation period. In one case, it was estimated that all the fish arriving at the aggregation were caught in fish traps. The most recent survey (January 2002) covered four historic aggregation sites, and found two completely gone (no fish, although lots of traps in the water) and two very reduced with aggregations of 14 and 28 fish respectively.

The scientists also observed aberrant spawning behaviour, and surmise that spawning behaviour is being disrupted by fishing and/or that the lack of experienced fish at the aggregation means that fish are not learning appropriate spawning behaviour (Dr. David Eggleston, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, pers. comm.).

3.1.2 High Cay

Estimates of the number of grouper aggregating at High Cay vary wildly. Acoustic surveys (Ehrhardt and Deleveaux 2001) on one of the aggregations in 1999, 2000 and 2001 estimated around 10,000 fish. The acoustic survey in this case was not validated by other methods (divers or fishing surveys) so there is no proof that the signal was entirely due to grouper numbers, particularly since other fish species are often attracted to aggregations.

Estimates by divers are of the order to 100-1,000 fish for 1999-2000 (Ehrhardt and Deleveaux 2001, Ray *et al.* 2000). In 2000-2001, divers could not locate the aggregation and believe that it may not have formed at all (Dr. G. Carleton Ray, University of Virginia, *pers. comm.*). There is no survey data available for this winter, but fishing was allowed on the aggregation for the first time in three years, and catches were low (J. Birch, Small Hope Bay, Andros, *pers. comm.*). Note also that fishermen are capable of catching every fish in an aggregation (see Long Island section above), so catches do not necessarily reflect the size of

the aggregation. If diver estimates are correct, the High Cay aggregation is also showing evidence of a large decline relative to historic estimates of fish numbers (Ray *et al.* 2000).

3.2 GROUPEL STOCK ASSESSMENT

The Department of Fisheries have collaborated on a grouper stock assessment (Ehrhardt and Deleveaux 2001), which concluded that grouper are not overfished in the Bahamas. Unfortunately, there are a number of problems with this approach as applied to Nassau grouper and in the data used for the calculations, and a series of distinguished scientists have disagreed with the conclusions (Dr. David Eggleston, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University; Dr. Mark Hixon, Department of Zoology, Oregon State University; Dr. G. Carleton Ray, Department of Environmental Sciences, University of Virginia; Dr. Y. Sadovy, Department of Ecology and Biodiversity, University of Hong Kong; Dr. C. Dahlgren, Science Director, Caribbean Marine Research Centre, *pers. comm.*).

While we do not really want to go into the technical arguments here some problems are as follows:

- The size and age structure of the population was assessed from landings by fishermen. However, landings rarely represent the true size structure of the population, because many fishing techniques, such as spearfishing, specifically target the largest fish. This means that landings have a higher proportion of large, old fish in them than the natural population. The large number of old fish in the sample is interpreted in the report as demonstrating that there are more old large fish uncaught in the wild which leads the report to underestimate fishing mortality (death rate due to fishing).
- The report used landings data from the Department of Fisheries statistics to estimate the total number of fish caught. However, this data is incomplete, since the Department does not have the resources to collect data in many of the islands. Nor does the Department's figures take into account the fish caught for home consumption, by sportsmen or by poachers. Therefore this also leads the report to underestimate the fishing mortality.
- Grouper in the Bahamas are likely to be several populations (groups that interbreed) rather than one big population, therefore total landings data across a large area of the Bahamas does not give the necessary information to estimate fishing mortality for each population.
- The mathematical techniques used in the report estimate mortality from all sources (fishing and natural causes). Therefore, the report has to use an estimate of natural mortality from the scientific literature to subtract from the estimate of total mortality to get fishing mortality. However, natural mortality is very difficult to measure and these estimates may not be correct.

In general, the conclusions of the report are very sensitive to the various sources of bias listed above, as shown in figure 1. The figure shows the data used to estimate mortality from 1998. Figure 1(A) shows the original data used, which concludes that the death rate from fishing only about half the death rate from natural causes (i.e. the population is not overfished). Figure 1(B) shows the same data but including two extra data points which were left out of the original analysis (it is not explained why). This concludes that the death rate from fishing is higher than the death rate from natural causes (i.e. the population is overfished).

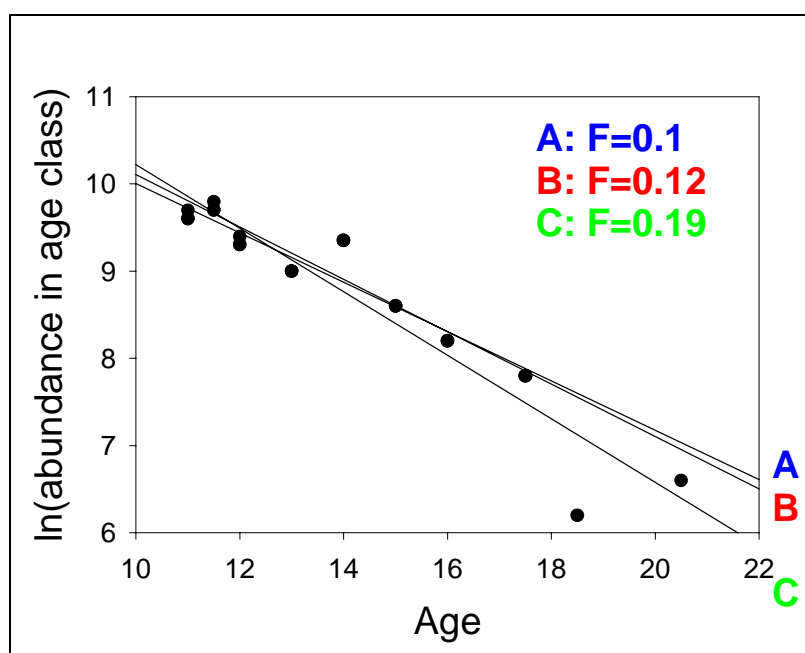
In Figure 1(C), the number of grouper in the three lowest age classes is increased by 10%. This is an attempt to test the sensitivity of the estimates of fishing mortality to the bias in the landings data. The small change in the data results in a 20% change in the estimate of fishing mortality.

Therefore the techniques used in the report are sensitive to biases in the data, and the conclusions of the report are not very reliable.

Figure 1: Nassau grouper abundance in age class vs. age in years.

The y-axis is plotted on a natural log scale (ln). This is done so that the relationship will be a straight line. The slope is an estimate of the total mortality. The fishing mortality (F) = $Z - 0.18$ (estimate of natural mortality). Regression slope A: data adapted from Ehrhardt and Deleveaux (2001). Regression slope B: Nassau grouper abundance in age class in lowest three data points increased by 10% to assess impact of bias in data. Regression slope C: data adapted from Ehrhardt and Deleveaux (2001), including two data from highest age classes excluded from original analysis.

The take home message from this figure is that the data used in the stock assessment can give several different estimates of fishing mortality, some of which (A,B) suggest that grouper are not overfished, some of which (C) suggest that they are. Therefore the conclusions of the stock assessment (that grouper stocks in the Bahamas are not overfished) are not justified.



3.3 GROUPE IN THE EXUMA CAYS LAND AND SEA PARK

Comparisons between fished and unfished areas can potentially tell us something about the impact of fishing on populations. This requires the assumption that conditions in the two areas are the same, i.e. that protection from fishing, rather than habitat, current patterns or some other factor is the cause of the difference. There are no significant differences in the proportion of different habitats between the Park and the Exuma Cays north and south of the Park (Chiappone and Sullivan-Sealey 2000). There may be differences in current patterns (hence larval supply) between the Park and the southern Exuma Cays (Stockhausen, Lipcius and Hickey 2000), but a broad comparison of the Park and close-by areas should still be valid.

Mean Nassau grouper biomass per unit area is about three times greater in the Park than to the north and south, and 35% of individuals in the park are sexually mature, compared to about 8% further north and 14% further south (Chiappone and Sullivan-Sealey 2000). The population has clearly been affected by fishing, even in this area, the Exuma Cays, which can probably be considered lightly fished relative to some areas of the Bahamas. See figure 2.

Figure 2: Nassau grouper density from four sites around Exuma Sound, June 2000 (data from Lipcius and Stockhausen unpublished).

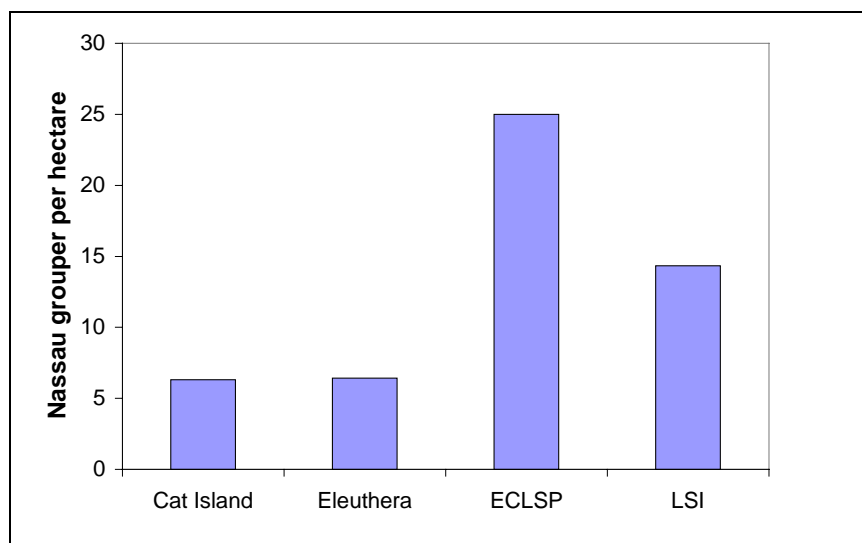
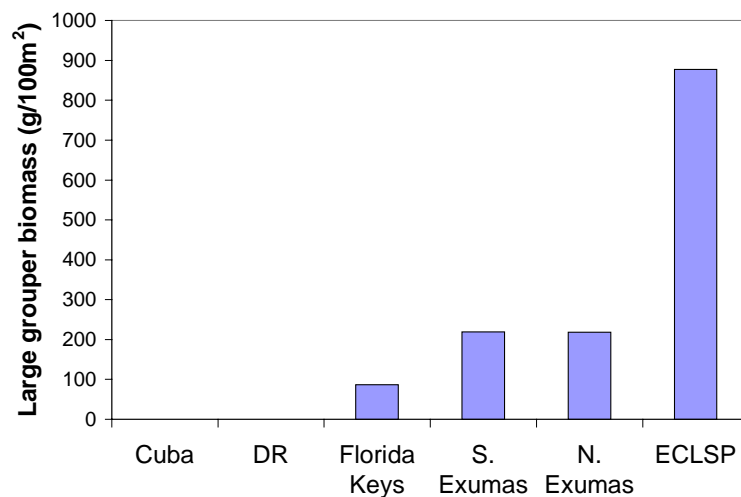


Figure 3 puts the difference between fished and unfished areas in the Bahamas in the context of the wider Caribbean. Note that the fished areas of the Bahamas have similar grouper numbers to the Florida Keys, where the Nassau grouper is classified as an endangered species and are protected from fishing.

Figure 3: Total grouper biomass (grams per 100m²) in the Caribbean, the Florida Keys and the Bahamas (data from Chiappone *et al.* 1998).



4 STATUS OF CONCH IN THE BAHAMAS

As with grouper, data on conch populations in the Bahamas is hard to collect and it is easy to plead that there is not enough evidence to be sure that conch are over exploited. However, again, there are some data sources that give indications as to the health of Bahamian conch populations.

4.1 CONCH STOCK ASSESSMENT

The Department of Fisheries sponsored conch stock assessment (Ehrhardt and Deleveaux 1999) suffers from many of the same problems as the grouper stock assessment. For example, the estimate of fishing mortality depends on the estimate of natural mortality (because fishing mortality = total mortality – natural mortality).

The report estimates that in natural conch populations 12-23% of adult conch survive one year. However, many scientists think this is inaccurate, and a figure of 30-35% survival for adult conch is probably more accurate (e.g. see Appeldoorn 1987). Estimates of survival from experiments are likely to be low because in experiments it is difficult to separate conch which have died from conch which have moved away from the study area or lost their experimental tag.

If we apply more realistic value of natural mortality to the stock assessment, we get estimates of fishing mortality that range from about half natural mortality to equal to adult mortality. Fishing mortality should be lower than natural mortality, so again even without taking into account problems with the method, it is hard to judge from this analysis whether the population is over-exploited or not.

While it is impossible to be certain of the natural mortality figures of a given population of conch at varying depths over their expected life span, it is possible to get an accurate figure of the conch per hectare at any given time and to count the actual number of undersized discarded shells. Thus the natural density figures quoted below are sound, as are the figures highlighted in the report under reference, which show that many of the animals taken in the fishery are juveniles (34-87% depending on location).

4.2 CONCH IN THE EXUMA CAYS LAND AND SEA PARK

Since conch are not particularly mobile, at least as adults, the relative density of conch inside and outside areas protected from fishing can be very informative about the impact of fishing on the unprotected population (again given the same assumptions as are laid out in the grouper section).

4.2.1 Overfishing definition

The Conch Fisheries Management Plan for Puerto Rico and the USVI in 1996 (CFMC 1996) fit several different fisheries models to conch data, and concluded that a queen conch population could be considered overfished when the *density of adult conch reached 20% (one fifth) of the unfisher level*. This is a useful definition in that it is relatively simple to determine and takes into account the potential for reproductive failure at low density. We can use this definition in looking at differences in adult conch density inside and outside the Exuma Cays Land and Sea Park – if densities outside the park are less than one fifth those inside the park, that is a good indication that the unprotected populations are overfished.

4.2.2 Applying the definition to the Exuma Cays

Researchers have compared the densities of conch in the Exuma Land and Sea Park (ECLSP) where conching is prohibited, with the densities of conch around Lee Stocking Island (LSI) in the southern Exumas. Mean adult densities in the Park in 1994-5 were 50.2 conch per hectare (shallower than 5m) and 111 per hectare (deeper than 5m). Mean adult densities around Lee Stocking Island were 1.67 per hectare (shallower than 5m) and 41.2 per hectare (deeper than 5m) (Stoner and Ray 1996). See figure 4.

It is interesting that there are more conch deeper than 5m in the Park than around LSI, even though fishing takes place mainly in areas less than 5m deep. There are several possible explanations for this (not mutually exclusive):

- 1) Fishermen are now fishing in deeper water than previously due to the depletion of conch in shallow water. Not much information is available about this in the southern Exuma Cays, although the author has been told that fishermen are conching in deeper water than they used to in some areas (e.g. southern Eleuthera, Cat Island).
- 2) Conch in deep areas have come from shallower areas and have been subject to fishing earlier in their life. This is likely since juvenile aggregations are almost all in shallow areas.
- 3) Conch reproduction is low in fished areas and hence these areas do not get as much larval supply. This is also likely since
 - a) studies of conch larval transport have concluded that populations on this scale, i.e. in an area as large as the Park (456 km², 175 square miles) are largely self-recruiting, i.e. the larvae are retained in the area where they were spawned (Glazer 2001),
 - b) **mean adult density at all depths at LSI is below the critical density for reproductive failure, meaning that reproduction is confined to a few high density areas** (Stoner and Ray-Culp 2000, author *pers. obs.*). Comparisons of early stage larvae show summer densities of 174-198 per m³ in the Park compared to 8-14 per m³ at LSI (Stoner and Ray 1996). **The fact that there are 14-20 times more larvae in the park than outside reflects the potential of protected areas in conch conservation.**
- 4) The final possibility is that there are naturally more conch in the northern Exuma Cays than the southern Exuma Cays, so deep water populations reflect unfished population levels. This is less likely, since a survey of ancient conch middens showed similar numbers per km of shelf edge (22.8 at Norman's Cay in the northern Exumas, 11.9 and 15.7 around Great Guana Cay in the central Exumas, 32.4 around LSI), indicating that ancient populations were comparable (Stoner *et al.* 1998).

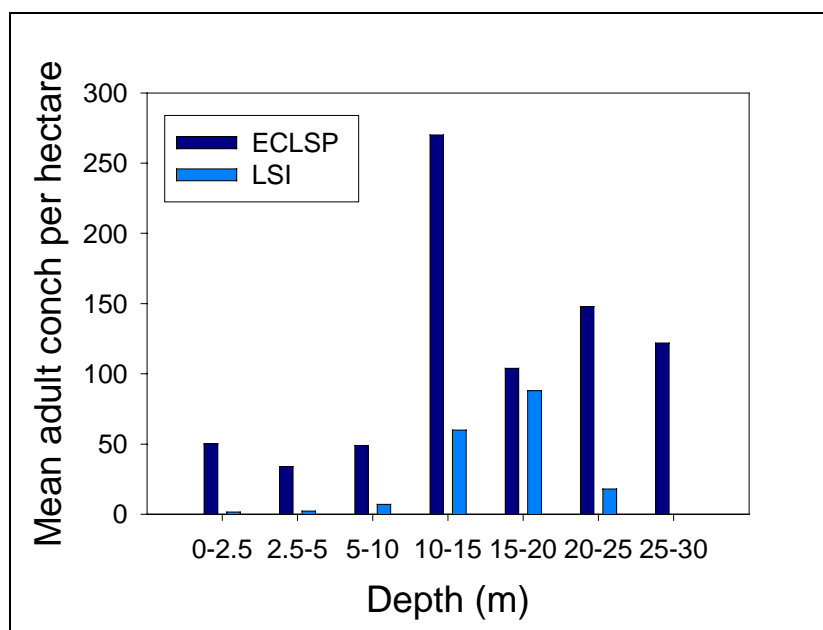
Therefore, it is likely that the reduction in conch in deeper areas at LSI compared to the Park is also due to fishing, through two mechanisms; 1) conch in deep waters have arrived there from shallow waters where they were subject to fishing and 2) fished populations produce fewer larvae than unfished populations.

If we accept this assumption, we can calculate the depletion in adult conch density in the Exuma Cays due to fishing, by comparing densities at LSI with those in the Park. Deep populations at LSI are 24% as dense as those in the Park, while shallow populations are 3% as dense.

The definition of an overfished population is one with an adult population density of less than 20% of unfished levels (CFMC 1996). Therefore we have to conclude that deep water conch in the southern Exuma Cays are approaching overfished, while those in shallow water are already extremely overfished.

If we do not accept the above, and instead make the more optimistic assumption that deep water populations at LSI reflect “natural” levels, we can normalise the LSI shallow water population accordingly¹. Under this assumption, the shallow water population at LSI is still 13% of the posited unfished density, and therefore still easily defined as overfished.

Figure 4: Adult conch density (mean number of adult conch per hectare) inside the Exuma Cays Land and Sea Park and at Lee Stocking Island in the southern Exuma Cays. Data from Stoner and Ray 1996.



¹ This is done by multiplying the bank population density by the ratio of Park shelf density to LSI shelf density, to remove the difference attributed to natural differences in density.

5 CONCLUSIONS: WHAT IS THE STATUS OF GROUPER AND CONCH IN THE BAHAMAS?

Animal populations are naturally variable and difficult to study, and even in the best circumstances (a small, easily defined area, lots of data and lots of funds) it is extremely difficult to “prove” that a population is in decline. Given the huge area and limited resources of the Bahamas, the only proof of overexploitation of a marine species that is likely is when the population reaches complete collapse. At this point the question become rather academic. Therefore, the best approach is to assess the balance of probabilities and take timely action to avoid the risk of collapse.

It any case, it is clear from above that the data collected by the Department of Fisheries and by several scientific studies provide evidence that there is cause for concern about both grouper and conch populations in the Bahamas.

5.1 GROUPER

- Recent surveys at Long Island indicate that all the known spawning aggregations around the island have collapsed or are near to collapse
- The High Cay spawning aggregation also seems to be in decline.
- Comparisons from inside and outside the Exuma Cays Land and Sea Park clearly show the effect of fishing on Nassau grouper populations in the Exuma Cays.

There is therefore definitely cause for concern about the status of grouper populations in the Bahamas. The decline in all the spawning aggregations that have been studied is particularly worrying, since we will see from the case studies that this has been the main cause of population collapse in many countries.

5.2 CONCH

Comparisons of conch populations in fished and unfished areas in the Exuma Cays provide evidence that shallow water populations in most of the Bahamas are heavily overfished, while deep water populations are reaching the point of overfishing.

5.3 CONCLUSION

The conclusion has to be that Bahamian Nassau grouper and conch populations are at serious risk unless action is taken now.

6 GROUPER FISHERIES: WORLDWIDE CASE STUDIES

This and the following section presents a series of case studies on fisheries for grouper, conch and similar species from various parts of the world. The objective is to assess:

- Whether the prediction of vulnerability to fishing pressure is borne out
- The management strategies that have been successful and those that have not

The case studies have not been selected by the author to make a particular point; rather they are a representative sample of the information available.

For grouper case studies, we look first at Nassau grouper in the Caribbean region, then other grouper fisheries in the Indian Ocean and Pacific.

6.1 NASSAU GROUPER IN THE CARIBBEAN REGION

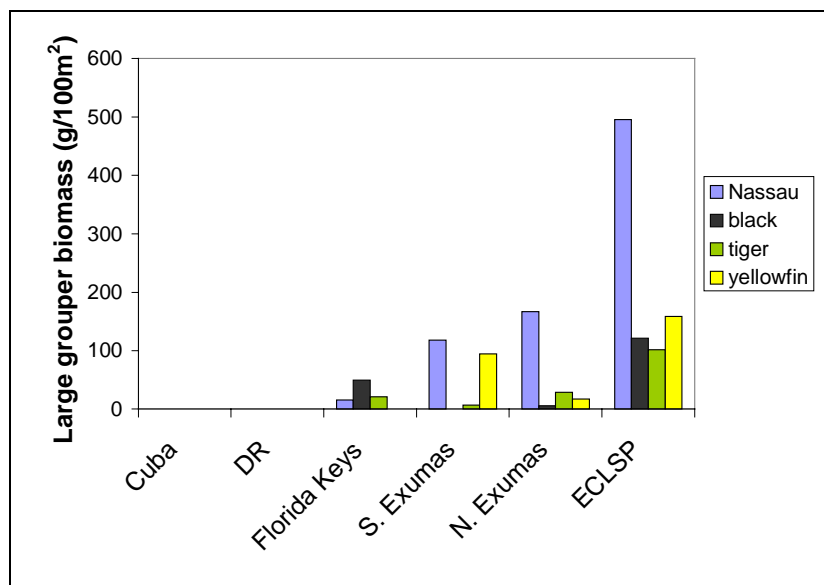
The overfishing and decline of grouper, particularly the larger species (Nassau, black, tiger, yellowfin etc.) has been well documented throughout the Caribbean. Nassau grouper have been particularly hard hit and have all but disappeared from reefs in many countries (Puerto Rico, the Dominican Republic, much of Cuba, Jamaica, the US Virgin Islands and many other parts of the lesser Antilles, Sadovy 1993, Sadovy 1995, Sadovy and Ecklund 1999). They are now listed by IUCN as endangered and are a protected species in US federal waters.

60-80 Nassau grouper spawning aggregations have been documented in the Caribbean and Bermuda, of which about one third have been exploited to extinction and no longer form at their original site (Sadovy and Ecklund 1999). There is anecdotal evidence of more than 31 aggregations in the Bahamas. Few of these are fully documented.

Figure 5 shows the effect of fishing on large grouper species in the northern Caribbean. There is a big contrast between grouper biomass in fished and unfished areas (Chiappone *et al.* 1998).

Hence the general pattern of grouper abundance in the Caribbean bears out predictions that groupers, and particularly Nassau grouper, are vulnerable to fishing, and there is a clear impact even of light fishing on grouper abundance (e.g. in the Exuma Cays). There is a lot of data available on grouper populations and fisheries in the region but here we focus on a few illustrative case studies.

Figure 5: Biomass of large grouper on a gradient of northern Caribbean reefs from heavily to lightly fished. Cuba and the Dominican Republic are heavily fished, Florida and the Exuma Cays are moderately fished and the Exuma Cays Land and Sea Park is a protected area. Data adapted from Chiappone *et al.* 1998.



6.1.1 Puerto Rico and the US Virgin Islands

Nassau grouper were always fished in Puerto Rico², but the scale of the fishery increased in the 1970s along with increases in population size, tourism and technology. Between 1977 to 1989 there was a six fold decline in the weight of all grouper landings, with an even steeper decline for large grouper species (Sadovy 1995). The maximum age of grouper in the US Virgin Islands is now about 9 years, compared to 29 in the Cayman Islands, which is closer to natural levels. Grouper aged 9 are barely sexually mature (Sadovy and Eklund 1999).

Nassau grouper spawning aggregations were heavily fished, and all the known Nassau grouper spawning aggregations from the region (several in Puerto Rico, one in St. Croix, one in St. Thomas) have disappeared (Sadovy and Eklund 1999). Nassau grouper is now very rarely seen, and the collapse of the spawning aggregations may explain why it seems to have declined more than any other species when it was once one of the most abundant (Beets and Hixon 1994).

The most common grouper species in landings is now the red hind (*Epinephelus guttatus*). Three red hind spawning aggregations are known from Puerto Rico and two from the US Virgin Islands. All are strictly protected, with a complete ban on all fishing (and in one case anchoring) within a 1.5 mile radius of the aggregation from December 1 to February 28³.

² “The Nassau grouper is a common and very important food-fish, reaching a weight of 50 pounds or more.” (Evermann B.W. 1900: *Fishes and Fisheries of Porto Rico*. US Commission of Fish and Fisheries, Washington DC)

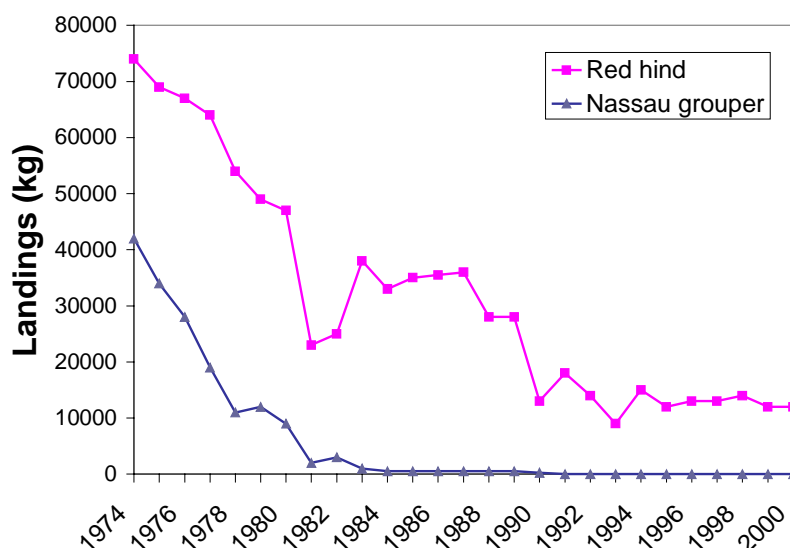
³ See <http://www.caribbeanfmc.com>

6.1.2 Bermuda

Bermuda is of interest to the Bahamas since its situation away from sources of larvae from other populations is somewhat comparable to some of the more remote Bahamian islands (e.g. Mayaguana, San Salvador).

Bermuda was the first country in the Caribbean region to protect grouper spawning aggregations, passing a law in 1974 to protect two known aggregations of red hind. There were also aggregations of Nassau grouper close to the red hind sites, but these aggregations were not protected. The Nassau grouper population declined 95% between 1975 and 1981. Despite a fish trap ban in 1990, Nassau grouper is now a protected species which is commercially extinct in Bermuda. There is still a fishery for red hind, although at a reduced level (Luckhurst 2001). See figure 6.

Figure 6: Nassau grouper and red hind landings in Bermuda, 1974-2000. Data from Luckhurst 2001



6.1.3 The Cayman Islands

In the Cayman Islands, fishing is permitted on Nassau grouper spawning aggregations by locals, with hook and line only. The government has been monitoring Nassau grouper catches from aggregations since 1987, when there were a total of 5 aggregations between the three Cayman Islands, four on the islands' shelves and one on an offshore bank. All the aggregations have recorded a steady decline in numbers and size of fish caught. Two aggregations now yield very low catches, while one has completely disappeared.

One aggregation moved about half a mile, leading to it being unfished for 8 years until it was rediscovered in the mid 1990s. This aggregation initially yielded high catches, which are now declining. In 2000, a new aggregation was discovered (bringing the number of aggregations back up to 5). It was estimated to contain 6-7,000 fish, however in the first year of fishing (2000-2001) 2,000 fish were taken and in December 2001 and January 2002 1,600 fish were taken, with more fishing expected on the February full moon. Therefore it is likely that this new aggregation is also being rapidly depleted.

In an attempt to reduce fishing pressure on the aggregations, legislation is under discussion which would i) close spawning aggregations every second year, ii) allow only 12 per boats per day in open years (Phillippe Bush, Department of the Environment, Grand Cayman, BWI, *pers. comm.*).

6.1.4 Quintana Roo, Mexico

Seven Nassau grouper spawning aggregations are known off the coast of Quintana Roo, but only three are exploited because the others are deep and either remote or a long way offshore. One aggregation has been targeted heavily because it is unusually shallow; between 6m and 16m (probably because of a strong outlet current from a blue hole?). Historically, the catch from each aggregation event (there are two or three per year) has been about 14 tonnes, but catches have been gradually declining since the 1970s as fishing effort has increased and spearguns were introduced.

In December 1988, the catch was about 4 tonnes (about 8,800 lbs), a historic low, from a total aggregation size of about 1,000 fish. This implies that a significant proportion of the aggregating fish were caught (40%, assuming a mean weight of 10kg or 22lbs). In December 1989 the aggregation contained fewer fish and was of shorter duration. The fish behaved unusually, with spawning apparently disrupted. The catch from this aggregation was about 50kg – only a few fish (Aguilar-Perera 1995). Observations of this aggregation seem to bear out predictions that fishing can disrupt spawning behaviour as well as reduce numbers at aggregations.

6.1.5 St. Lucia

Grouper and other reef fish fisheries in St. Lucia show similar patterns of overexploitation to those in the rest of the southern Caribbean. In 1995, the Government created a network of 5 no-take marine reserves which incorporate about 35% of the coral reef fishing grounds around the island, in an attempt to rehabilitate grouper and other reef fish populations.

Biomass increased rapidly in and around the reserves, with grouper about three times as dense in the protected areas, and about twice as dense in fished areas. However, fishermen initially suffered because they had a smaller area available for fishing; in the first year of the reserve, 75% of fishermen said that they had to increase their time spent fishing to catch as many fish as before. However, 5 years after the reserve network was put in place, catch per unit effort for fishermen has increased, catches were constant and 57% of fishermen who expressed an opinion said that fishing had improved because of the reserve (68% of younger fishermen) (Roberts *et al.* 2001).

6.2 AUSTRALIA

There is a commercial and recreational fishery for reef fish along the Great Barrier Reef in northeast Australia. Both fisheries use hook and line and both have landings of 3-4,000 tonnes a year, of which 35-40% are grouper (coral trout *Plectropomus maculatus*). This species does not form spawning aggregations, making it less vulnerable to fishing pressure than most grouper species.

The management system for reef fish is complicated. Under Australia's decentralised federal system, the authority in charge is the state of Queensland. It regulates the commercial fishery through limited entry (a limited number of licence holders) and limits on gear (number of lines and hooks per boat, size of boats).

However, the Great Barrier Reef is a National Park (and a World Heritage Site) and the park is managed by the Great Barrier Reef Marine Park Authority. They have instituted a complicated system of zoning within the park, with zones as follows:

- General Use A: Open to all use except commercial spearfishing and spearfishing with hookah or scuba (both of which are banned everywhere in the park).
- General Use B: As above, no trawling or commercial shipping.
- Marine National Park A: Recreational fishing only. No spearfishing. No collecting.
- Marine National Park B: No fishing.
- Scientific Research Zone: No entry except scientists.
- Preservation Zone: No entry.

Hence, aside from the specific fisheries management regulations from the state, there is also a network of protected areas which are closed to fishing, which are administered separately. Currently no-take areas (Marine National Park B, Scientific Research and Preservation Zones) represents about 4.5% of the total area of the marine park, or approximately 17,400 km². The Marine Park Authority have decided that this is not sufficient to protect the park, and its species, and is in the process of designating a whole series of additional no-take areas (the Representative Areas Programme). By contrast, the shallow banks of the Bahamas total 30,000 sq: miles, the ECLSP is 175 sq: miles or 0.58% of the total. That is only 13% of the 4.5% protection that the Australians now consider "not sufficient".

In addition to this, the Marine Park Authority has the right to close individual reefs to fishing if it feels they are being overexploited or damaged. (The Bahamas Department of Fisheries has similar powers which it used to close the High Cay aggregation to fishing for short periods in 1999, 2000 and 2001.)

The Great Barrier Reef, like the Bahamas, is a vast area (~350,000 km²) so that it is difficult to generalise about the status of grouper populations. There is evidence of localised overfishing: closed reefs reopened to fishing have showed large drops in grouper numbers (75% in 18 months, 57% in 3 months, 78% in one year), and fishermen move around in response to local depletion of stocks. However, more general comparisons of fished and unfished reefs tend not to show a difference in grouper numbers, although fished reefs consistently have grouper of a smaller average size. Data from logbooks (compulsory for all commercial fishermen) show no trends in catch or catch per unit effort, indicating that overall grouper populations are benefiting from the zoning system in place, have stabilised and are not being overfished⁴.

⁴ More information on coral trout, the management of the Great Barrier Reef area and the Representative Areas Programme is available at the GBRMPA website (<http://www.gbrmpa.gov.au>) and the Australian Institute of Marine Science website (<http://www.aims.gov.au>).

6.3 THE LIVE FISH TRADE IN SOUTHEAST ASIA

It is a local tradition in places such as Hong Kong and Singapore to keep fish alive until just before cooking, hence live fish have a high market price (between US\$30 and US\$100 per kilo for live grouper, depending on species). Imports of live fish to Hong Kong grew from about 2,000 tonnes in the late 1980s to about 15,000 tonnes in the mid 1990s, although they may have declined recently due to the Asian economic crisis. Grouper species make up about two thirds of this trade by number (more by weight), and 30 species are commonly found in live fish markets in Hong Kong.

As local waters around Hong Kong and South China have become depleted, the live fish trade has fanned out around the region, and Hong Kong now imports live fish from throughout Southeast Asia, the Maldives, Australia and the South Pacific. A study of the development of the trade in the Maldives is given below. In general, the trade has been devastating to grouper stocks throughout the region, because the high market value means that fishing can still be economically feasible even when fish become rare and catch per unit effort is low. Particular problems have come from targeting spawning aggregations and from fishing with cyanide, which kills many other fish species and damages coral and other reef organisms.

Table 1 shows the consequences of the live fish trade in various countries (Lee and Sadovy 1998).

Table 1: Impact of the live fish trade in various countries in Southeast Asia and the Indo-Pacific.

Hong Kong and Southern China	Stocks depleted by overfishing
Papua New Guinea	Stocks depleted by overfishing
Palau	Spawning aggregations devastated; return to traditional management techniques.
Maldives	Stocks rapidly depleted by overfishing; socio-economic impacts, baitfish fishery for traditional tuna fishery damaged.
Philippines, Indonesia	Stocks depleted by overfishing. Cyanide fishing has caused damage to reef communities.

6.4 THE MALDIVES

Grouper and other large reef fish were not traditionally fished in the Maldives, where native fisheries have always concentrated on tuna. The only reef fish fishery was for bait, and concentrated on small fish which naturally formed large schools.

In the mid 1990s overfishing in Southeast Asia meant that the live fish trade needed to look for new fishing locations, and started to target the Maldives. The islands posed enormous logistic difficulties for flying out live fish since they are remote with a sparse population and little infrastructure. However the very high market price of live fish in Singapore and Hong Kong meant that the fishery could still be profitable. Fish were captured alive in traps, kept in temporary cages and then flown out in barrels of seawater.

The fishery sprang up on most of the atolls in the Maldives and was briefly very profitable; the government suggested it would be the “new tourism”. Unfortunately, by 1999 grouper had all but disappeared from the reefs around inhabited atolls. All the cage owners have since gone bankrupt.

Aside from financial boom and bust, the fishery has had two other effects on the Maldivian economy. Firstly, it has affected dive tourism (the majority of tourists visiting the Maldives go to scuba dive). Secondly it turned out that the small reef fish gathered in large schools to escape the grouper. Now the grouper are gone, the bait fish that the tuna fishermen want no longer need to school and are much harder to catch (MacAlister Elliott and Partners, unpublished information).

6.5 SOUTH PACIFIC GROUPEL SPAWNING AGGREGATION FISHERIES

The live fish trade reached the South Pacific in the early 1990s and targeted the spawning aggregations which form in reef cuts (up to 50 species, particularly grouper species, may aggregate in the same place at various times). As in Southeast Asia, the fishery was devastating to local stock. However, it has had the effect of making communities in places such as Palau (Micronesia) rediscover traditional beliefs which controlled or forbade the exploitation of these aggregations (Johannes 1981), with regulations and fishing bans created by traditional chiefs according to perceptions of the number of fish in the aggregation and the status of the population. The reintroduction of traditional management has stabilised the fishery, although without the large short-term profits that come from the uncontrolled live fish trade.

7 CONCH FISHERIES: WORLDWIDE CASE STUDIES

In this section, we look at the conch fishery in several countries (those for which most data is available). We look at both traditional and non-traditional indicators of population health, and the effect of various different approaches to management.

Queen conch are the only member of their family (Strombidae) for which there is a major fishery. To get a worldwide view, we also take some case studies from two other groups, abalone and top shells. Abalone (*Haliotis* spp.) share with conch the key traits of long life, long age to maturity and reproductive failure at low density, and they are also fished in a similar way (by diving, with or without compressed air). Top shells (*Trochus niloticus*) are a tropical Indo-Pacific species which also fished by diving or collecting from shallow reefs.

7.1 CONCH IN THE CARIBBEAN REGION

There has been general concern throughout the Caribbean for the status of queen conch stocks, reflected in the listing of queen conch in CITES Appendix II in 1992. Table 2 shows the average density in conch per hectare for various Caribbean countries, including the Bahamas. Only the offshore Pedro Bank in Jamaica and the Exuma Cays Land and Sea Park has average densities greater than the threshold for reproduction (50 conch per hectare, Stoner and Ray-Culp 2000), although there may be smaller patches of higher density in other areas. Densities of adult conch in most of the Bahamas, as well as the Puerto Rico, the US Virgin Islands, the Florida Keys, Bermuda and Belize are all low enough that widespread reproductive failure is likely. These examples are discussed below.

Table 2: Average densities of queen conch in the Caribbean (conch per hectare). Note that local densities below 50 conch per hectare seem to result in reproductive failure (Stoner and Ray-Culp 2000). Data from Caribbean Fisheries Management Council (CFMC) 2001.

Location	Year surveyed	Density
Bahamas: Little Bahama Bank	1983	28.5
Great Bahama Bank	1983	20.8
Exuma Cays Land and Sea Park: shallow	1994	53.6
Exuma Cays Land and Sea Park: deep	1994	96
Pedro Bank, Jamaica: 0-10m	1994	89.1
10-20m	1994	144
20-30m	1994	277
US Virgin Islands: St. Croix	1981	7.6
St. Thomas / St. John	1996	22.6
Florida Keys	1990	1.54
Bermuda	1989	2.9
Belize	1996	14.9
Puerto Rico	1985-6	8.11
Puerto Rico: West coast	1995-6	9.2
East coast	1996	7.46

7.1.1 Puerto Rico and the US Virgin Islands

The queen conch fishery in Puerto Rico and the USVI has shown strong signs of overfishing (CFMC 1996, 2001):

- In the early 1990s, the adult conch density in Puerto Rican waters was about 9% of unfished levels (the definition of an overfished population is one at 20% of unfished levels).
- Landings in Puerto Rico in 1992 were less than a quarter those of the early 1980s (see figure 7). Landings from St. Croix in 1991-2 were less than half those in 1981-2.

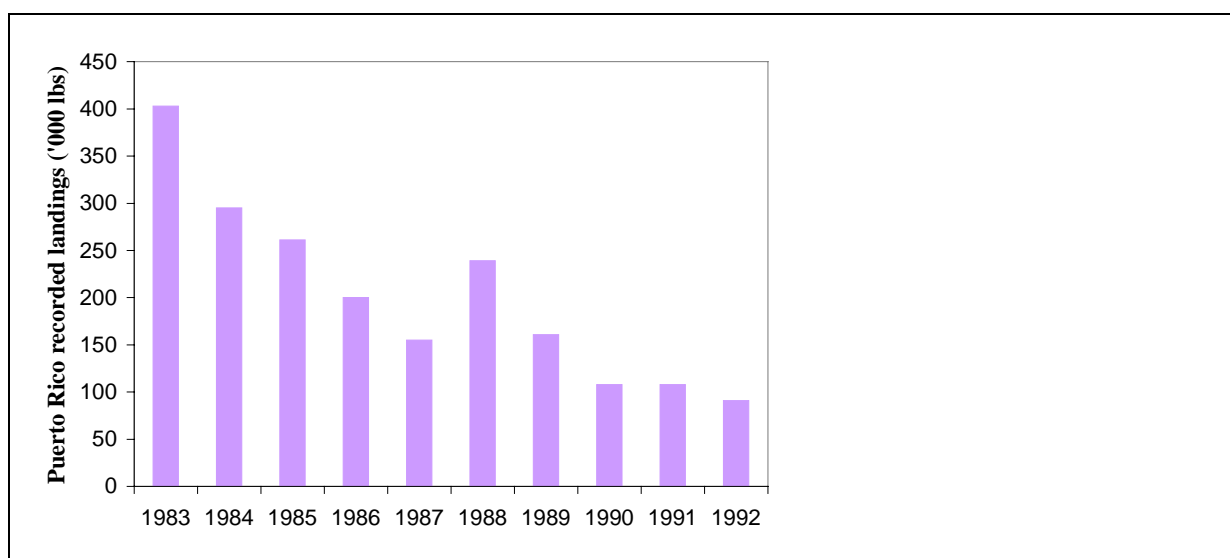
- In the USVI in 1998, 74% of conch landed were smaller than the legal length and 94% were smaller than the legal lip thickness.
- Estimates of mortality from fishing were more than twice as high as estimates of natural mortality. An adult conch in Puerto Rico had only a 19% chance of surviving one year, as opposed to the natural level of 60% or more.
- In 1992-3, Puerto Rico imported \$1.5 million worth of conch meat, so the fishery was not meeting local demand.

Thus the population was certainly overfished, which is unsurprising given that until 1996 there were no fisheries regulations whatsoever. In particular, the use of compressed air (scuba and hookah) were common in the fishery throughout the 1980s and 90s, meaning that the population was exploited throughout its depth range.

All conch fishing was banned around St. Thomas and St. John in early 1988. Populations rebounded and the fishery was reopened in January 1993 without any restrictions, whereupon populations were reduced to pre-closure levels almost immediately.

In 1996, a series of regulations were put in place in federal waters (more than 9 nautical miles offshore). This includes a closed season in summer, a minimum size, bag limits and a ban on hookah, but not scuba. However, the population has continued to decline, and the Caribbean Fisheries Management Council now recommends a ban on taking conch from federal waters. St. Thomas and St. John are also considering a moratorium on conch fishing in their state waters (CFMC 2001).

Figure 7: Recording queen conch landings from Puerto Rico, 1983-1992. Data from CFMC 1996.

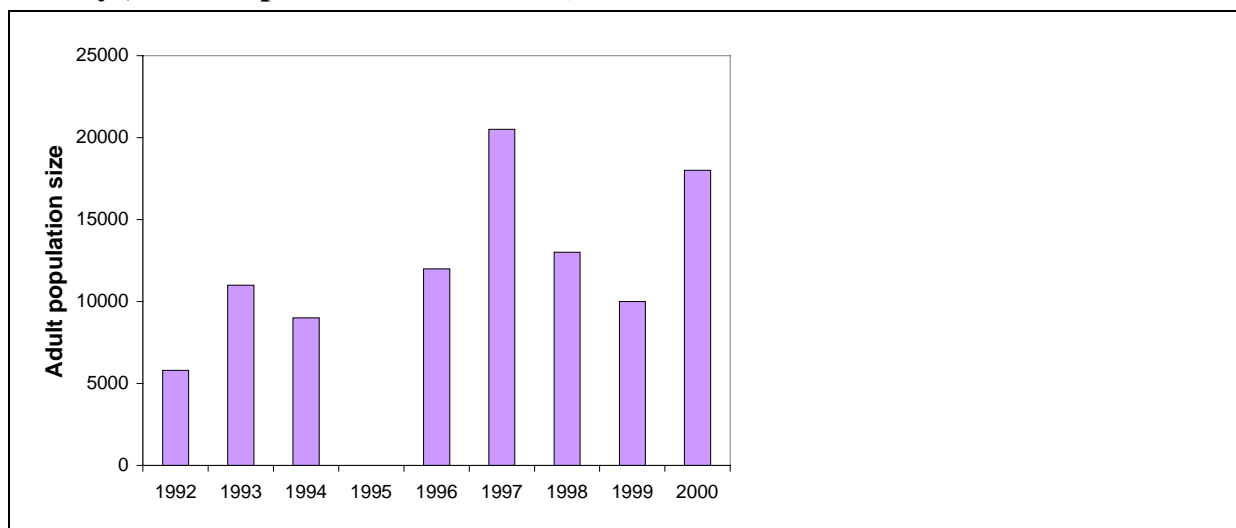


7.1.2 Florida Keys

The queen conch fishery in the Florida Keys started in the early 20th century, mainly for the tourist curio market. A decline in the population size caused concern from the early 1960s. A series of measures (size and bag limits) failed to prevent further rapid decline in the population and in 1985 conch fishing was banned in Florida state waters, with the ban extended to adjacent federal waters the following year.

Conch populations did not change much as a result of the moratorium, and in 1992 the population was estimated at 5,800 adults along the entire 180km of shallow reef tract (Glazer 2001), so seven years after complete closure of the fishery the situation was probably worse rather than better. Since then there has been little sign of recovery; apparently because of very low reproduction associated with low density (Glazer 2001). Figure 8 shows estimates of adult population size from 1992-2000.

Figure 8: Estimated adult conch population size, Florida, 1992-2000 (from towed diver surveys, data adapted from Glazer 2001).



7.1.3 Bermuda

Queen conch in Bermuda were so depleted by fishing during the 1960s and 70s that all conch fishing was banned in 1978. In 1988, 10 years after closing the fishery, 73 hectares of conch habitat down to 20 metres were surveyed, turning up 39 adult conch and no juveniles (Berg *et al.* 1992). It is hard to find any information on the current status of the population, but queen conch are rarely seen by divers in Bermuda (Jo Pitt, Bermuda Biological Research Station, *pers. comm.*) and are still protected, implying that there has been little, if any, recovery.

Bermuda is a rather special case. Bermuda conch were found to be genetically differentiated from the Caribbean (Berg *et al.* 1992), implying that the population was self-sustaining and received little external larval input, as would be expected from its isolated position. Therefore, if the population reached the threshold for collapse it would be unlikely to recover in the short term. The populations around some of the more isolated Bahamian islands, such as San Salvador and Mayaguana, might be in a similar situation.

7.1.4 Turks and Caicos Islands

The Turks and Caicos Islands (TCI) are a similar environment to the Bahamas, with broad shallow banks providing extensive conch habitat. They are also lightly populated, but don't have the same volume of tourism as the Bahamas. The Turks and Caicos Islands have the benefit (from the fisheries management point of view) of being a British Overseas Territory and hence the recipient of technical assistance and funding from the British Government for fisheries monitoring and management. The conch fishery has therefore been fairly well monitored since its inception in the late 1960s. Fishing has always been by free diving only.

The extensive oversight of the fishery didn't prevent heavy exploitation becoming a concern, such that in 1979 the country included queen conch in a set of stamps showing endangered species! Minimum size and meat weight limits were imposed. In 1988, the Government established 33 marine protected areas, some of which are no-take (no fishing or collecting allowed).

Despite the size and weight limit, adult conch in protected areas are 4.5 to 9 times denser than in the same habitat type in fished areas (Tewfik and Béné 2000), implying that the population in fished areas are 'overfished' by the Caribbean Fisheries Management Council definition (overfished if adult density is less than one fifth of the unfished density). However, as of 1995, there was no decline in catch per boat day, implying that conch are still relatively easy to find (Medley and Ninnes 1999).

No spillover effect (emigration of adults to fished areas) has been seen from the reserves, however fishing effort is high at the reserve boundaries, so it would be difficult to tell directly from surveys (Tewfik and Béné 2000). It is possible that the animals in the reserves are maintaining the population outside the reserve through larval transport. This would explain why the fishery seems relatively healthy despite the depleted spawning stock biomass in fished areas. These 33 Marine Protected Areas established fourteen years ago just south of the Bahamas seem to be working.

7.1.5 Belize

Belize has huge areas of reef, much of which is quite remote, and a low population density. Nonetheless, the effect of overfishing on conch populations is visible. Conch have disappeared from some areas and are significantly less dense in others. (Nassau grouper landings are also down 60% since the 1960s.) (Carter *et al.* 1995).

Belize has started to approach fisheries management in a slightly different way from other Caribbean countries. The government is aware that it does not have the funds or the knowledge to manage its marine resources, particularly in the face of rapidly increasing coastal development and tourism. They are therefore using two strategies:

1. Management has been devolved from central government to local groups; specifically fishermen's cooperatives, NGOs, town councils and tour guide associations, although the Department of Fisheries still plays an important role in decision making.
2. The main focus of management is on creating no-take reserves. This has been popular with many communities because of the major importance of dive tourism: more than 50% of the tourists visiting Belize come to scuba dive.

There is not enough information available on conch (or grouper) populations in Belize to say whether these management strategies have worked on a country-wide level – probably results are patchy since there is a problem of enforcement in many of the reserves. However, anecdotal evidence suggests that conch populations have increased rapidly, at least inside the reserve areas.

7.2 ABALONE

Abalone are also gastropods, although quite distantly related to queen conch. However, they make an interesting comparison in that they also require a critical density of adults for reproduction to be successful (Shepherd and Brown 1993), so they potentially have a similar vulnerability to fishing pressure and similar management issues. They require a completely different environment to conch; a rocky bottom and cold, nutrient-rich water. The most important abalone fisheries are the west coast of North America, Australia, New Zealand and South Africa.

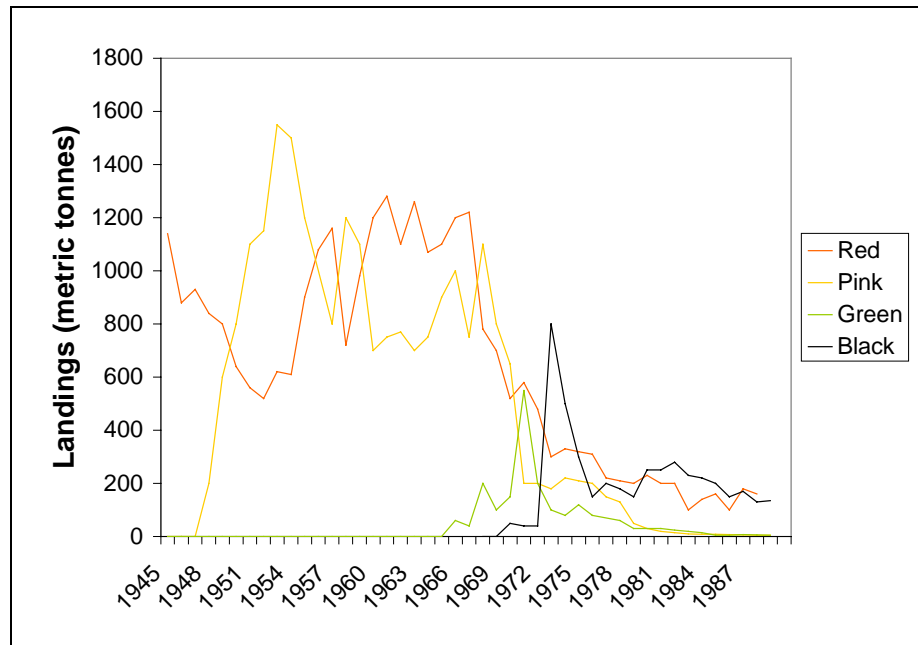
7.2.1 North America

There are a series of abalone species along the west coast of North America from Mexico to Alaska, most of which are heavily fished and all of which show a picture of initial stability followed by abrupt and precipitous population decline, as predicted by the observation of reproductive failure at low density.

Figure 9 shows abalone landings from California: after the abrupt decline of the preferred species, red abalone (*Haliotis rufescens*) in the late 1960s, there is a pattern of serial depletion of the other species, first pink (*H. corrugata*), then green (*H. fulgens*) and finally black (*H. cracherodii*). Size limits, a recreational bag limit and limited entry introduced in the 1970s did not stop the population declines. A similar pattern of rapid expansion followed by abrupt collapse and failure to recover is seen in the Washington State / British Columbia / Alaska fishery for northern abalone (*H. kamtschatkana*) and the Mexican fishery (a mix of three species) (Shepherd *et al.* 1992).

Figure 9: Landings of 4 species of abalone in California, 1945-1989

red line=red abalone (*Haliotis rufescens*), yellow line=pink abalone (*H. corrugata*), green line=green abalone (*H. fulgens*) and black line=black abalone (*H. cracherodii*). Note the serial collapse of populations of each species in order of their value to the fishery (red, pink, green, black).



7.2.2 Australia, New Zealand and South Africa

The Australian abalone fishery initially followed the same pattern as in North American, with the development of the fishery from the mid 1960s and an abrupt decline in landings and catch per unit effort in the early 1970s. As in California, a size limit and recreational bag limit (1973), limited entry and a larger size limit (1980) and a reduction in the number of licences (1980s) were imposed but failed to stabilise the fishery.

Finally, in 1989, a system of individually transferable quotas (ITQs) was introduced, with an buy-back scheme funded by the industry which reduced the total landings. This system seems to have stabilised the fishery, albeit with annual landings about one quarter of the historical maximum. New Zealand and South Africa have similar ITQ systems and a fishery which seems to be sustainable. In Australia, research and administration of the management system is partially funded through high licence fees for abalone divers, and in New Zealand fishermen pay a “resource rent” of NZ\$126 (US\$53) per tonne in addition to a small licence fee. In South Africa control of the fishery is rather centralised, with divers employed by a small number of processing houses (Shepherd *et al.* 1992).

Temporary closed areas have also been tried in Australia, and have not been successful. Abalone numbers within the closed areas do increase, but fishermen target newly reopened areas, reducing numbers to pre-closure values almost immediately.

7.3 TOP SHELLS

The top shell (*Trochus niloticus*) fishery is not one of the traditional fisheries of the South Pacific, but developed in the 20th century as an export commodity for making buttons etc. Nonetheless, with the help of scientists and government, many South Pacific countries have managed to adapt traditional management techniques to new fisheries. In many countries there are strong traditional rights of marine tenure, and fishing grounds may belong either to a community, under a traditional chief, or to an individual family.

In Vanuatu, the Department of Fisheries has started an education programme, explaining *Trochus* biology to communities, who then take decisions on closing particular areas, or closing the fishery for a specified period. Individuals who violate bans, or outsiders fishing in a community area, can be punished, formerly by death or threats of spiritual retribution; nowadays more often by a fine. These tenure systems have been successful in maintaining successful *Trochus* fisheries in Vanuatu and the Solomon Islands (Foale 1998, Johannes 1998).

8 LESSONS FROM CASE STUDIES

This section summarises the results from the case studies above and looks at some of the general and species specific lessons that can be drawn. We discuss these conclusions further in the Bahamian context in the next section.

8.1 WHAT WENT WRONG? NEGATIVE CONCLUSIONS

1. ***Grouper and conch fisheries are indeed sensitive to fishing and can collapse quickly.*** Grouper and conch fisheries in Puerto Rico and the USVI collapsed within 2-3 decades, the live fish trade in SE Asia and the Maldives caused the collapse of grouper populations throughout the region in less than a decade, conch populations in Florida and Bermuda collapsed after 10-20 years of commercial fishing, North American abalone populations collapsed successively after only a few years of heavy fishing.
2. ***Fisheries with no management end in disaster.*** All the examples of grouper and conch fisheries with no management regime have resulted in the collapse of the fishery sooner or later. See case studies of Puerto Rico and USVI fisheries (both species), grouper live fish trade, Bermuda conch and North American abalone.
3. ***Leaving management too late ends in disaster.*** Once there is clear, incontrovertible evidence of overfishing, it is usually too late for management actions, and even drastic action such as the total closure of the fishery may not help populations to recover. See examples of Puerto Rico and USVI grouper and Florida and Bermuda conch.
4. ***Fishing grouper spawning aggregations ends in disaster.*** All available evidence is that spawning aggregations are easy to deplete and once lost do not return. Puerto Rico and the USVI have lost all their Nassau grouper spawning aggregations and with them almost every grouper. The live fish trade in the South Pacific decimated spawning aggregations within a very few years until community management was restarted. Even controlled fishing on aggregations (e.g. locals and hook and line only in the Cayman Islands) resulted in the loss of one aggregation, the likely future loss of another and the reduction and disruption of the rest. Observations of the fished aggregation in Mexico shows that spawning behaviour is also disrupted by fishing.
5. ***The introduction of technology into fisheries may end in disaster.*** Grouper aggregation have collapsed after the introduction of spearguns (e.g. Mexico). Conch fisheries where hookah and/or scuba is allowed are much more vulnerable than those where it is not (e.g. Puerto Rico vs. TCI).
6. ***Technology is not easy to get rid of once it is part of a fishery.*** Despite the perilous state of Puerto Rican conch stocks, the management body (the Caribbean Fisheries Management Council) still has not been able to ban the use of scuba in the fishery, because of political pressure. Cyanide fishing has been banned in the Philippines and Indonesia but is still extremely widespread and has become a tradition passed on through families (Lee and Sadovy 1998).

8.2 WHAT WENT RIGHT? POSITIVE CONCLUSIONS

Unfortunately the sensitivity of grouper and conch to fishing is such that it is easier to draw negative than positive conclusions from the case studies. However, there seems to be one general rule and three (not mutually exclusive) strategies for successful management that emerge:

1. **General rule: pre-emptive management.** Management actions which are put in place while the population is still in relatively good shape seem to have a much better chance of i) being accepted and ii) working. It is evidently much easier to maintain a healthy population than it is to regenerate one. Examples are conch in the TCI (compare with Florida and Bermuda) and grouper and abalone management in Australia (compare with Nassau grouper in Puerto Rico and Bermuda, North American abalone).
2. **Prevent fishing on spawning aggregations.** The South Pacific managed to stabilise grouper populations after a period of very intensive fishing by reasserting traditional rules banning fishing on spawning aggregations.
3. **Permanent no-take areas (reserves).** There are only five examples above where management seems to have been (more or less) a success and permanent no-take areas are a central part of three of them (St. Lucia, Australia grouper and TCI conch). In particular, in these examples, the closed areas seem to have acted to maintain the population despite evidence that there is heavy fishing pressure outside the closed areas. These are discussed further below.
4. **Community management.** The South Pacific traditional resource management systems are classic textbook examples of successful community management in action. Their basis is i) a decentralised system of government, with power rested in village chiefs and elders and ii) a system of marine tenure, where a community or family has fishing rights in a particular location or to a particular fishery. Neither of these are the norm in the Caribbean. Nonetheless, the example of Belize shows that it is possible to develop some kind of community management system in the Caribbean. It is a bit early to say how well it is working, but it clearly is not doing any worse than traditional centralised fisheries management.
5. **Resource intensive management.** The Southern Hemisphere abalone fisheries provide an example of successful management but at high cost; the management system (ITQs) requires a comprehensive data collection and analysis system and much administration. This is (partially) funded either by a high licence fee (Australia), a “resource rent” tax on landings (New Zealand) or directly by government (South Africa).

8.3 NO-TAKE PROTECTED AREAS

The case studies provide some instructive examples on when no-take protected areas work and when they don't.

1. ***Don't work if too late.*** The examples of Florida and Bermuda show that closed areas can be as large as you like (incorporating the entire fishery) and very strongly enforced, BUT, if the population has already crashed to very low levels, they will not bring it back. Reproductive failure at low density is an unfortunate feature of the biology of queen conch, and if the entire population reaches these levels, closed areas do no good.

However, the example of fisheries closures in St. Lucia and the USVI shows that grouper and conch populations can rebound from low densities in closed areas. In this case, the population was caught just in time, or possibly these areas are lucky in being downstream from a source of larvae from a healthier population.

2. ***Don't work if: reopened to business as usual.*** A five year conch fishing ban in St. Thomas and St. John allowed the population to rebound, such that the government then succumbed to pressure from fishermen to reopen the fishery, and they did not put any additional management measures in place. Within a year, the population was back to the same low levels that prompted the closure in the first place. This was therefore completely unsuccessful as a management measure; 5 years of hardship for fishermen resulted in at most a few months of bonanza catches and absolutely no long term gain.
3. ***May not work if: rotating different areas.*** In some areas (e.g. Georges Bank, off New England) rotating closed areas are proposed for fisheries management, whereby areas in different parts of the bank are closed at different times, allowing fishermen to exploit biomass in newly reopened areas (Murawski *et al.* 2000). However, the Australians tried and rejected this idea for the abalone fishery, finding that, like the example above, several years of closure resulted in just a few weeks or months of large catches, and no long term gain.
4. ***Do work if: pre-emptive and permanent.*** Despite heavy fishing pressure and low adult density in fished areas (meeting the overfishing definition), the TCI conch fishery seems healthy. This is almost certainly due to two things: no fishing using compressed air apparatus (SCUBA or hookahs) and a network of marine reserves, which are permanent and which contain healthy, dense adult populations. Likewise, the St. Lucia grouper fishery has improved despite an increase in fishing pressure in the fished area when the reserves were formed, due to the protection of one third of the area in no-take reserves. The grouper populations on the Great Barrier Reef in Australia seem to be stable, although they are fished in certain zones while being protected in 4.5% of the whole area.

9 WHAT CAN THE BAHAMAS DO?

There is clear evidence, (see pages 9 - 17 above, sections 3, 4 & 5) that the grouper and conch populations of the Bahamas are over-exploited. This section applies the lessons of the case studies to Bahamian circumstances, and suggests the management actions most likely to be successful in preventing the collapse of Bahamian Nassau grouper and conch populations.

9.1 PRE-EMPTIVE MANAGEMENT

The collapse of local grouper or conch populations would cause economic hardship in most areas of the Bahamas, and, as the case studies make clear, measures taken after a fishery has collapsed, even if they are draconian, are rarely successful. Appropriate management measures, put in place while the population is still relatively healthy, have a chance of maintaining the population even in the face of fairly high fishing mortality. Therefore, the time to act is now.

9.2 EDUCATION AND COMMUNITY INVOLVEMENT

It is much easier for any Government to take action, particularly action that might initially have a negative effect on some of its citizens, if people understand why it is necessary. To understand the need for fisheries management actions requires a certain basic level of education about how animal populations work and the life cycle of the species in question. Without understanding there is no support for management, and without popular support, fisheries management laws only work by top-down enforcement by the government. Given the limited resources and large area of the Bahamas, this alone is unlikely to be successful in the long run, hence education is critical to the success of management actions.

BREEF, the Department of Fisheries, the Bahamas National Trust and others have made sterling efforts towards making teachers aware of environmental and marine education and providing materials. However, the Department of Education should consider making the environment and the natural resources of the Bahamas a central part of its curriculum from an early age.

Connected to the idea of education is that of giving communities a say in the management of resources at the local level, or in the management of a local marine reserve. A two-way dialogue between communities and government is critical for the long term success of reserves.

9.3 SPAWNING AGGREGATIONS

In every case⁵ studied by the author, fishing on grouper spawning aggregations resulted in the eventual loss of the spawning aggregation. In every case studied by the author, the loss of a substantial proportion of the spawning aggregations resulted in the collapse of the population. Fishing grouper spawning aggregations is fatal to the long term viability of the population.

⁵ Including numerous cases not presented in the report in an attempt to minimise repetition.

The Bahamas has several choices as to how to go about protecting spawning aggregations, discussed below. However, the first comment to make is that education is critical to the success of this process (see above). Many Bahamians already understand that disrupting spawning is a problem, but few realise that spawning aggregations have already disappeared in the Bahamas, and that once they have disappeared they cannot reform.

In the short term, at least, there are two main options for protecting spawning aggregations:

1. *Individual closures of aggregations during the spawning period.* This has been tried at the aggregation at High Cay and worked relatively well for three years. However, the Department of Fisheries and the Defense Force do not have the resources to enforce closures of all known aggregations for each spawning period every year, even assuming that they can all be found.
2. *Closed season for grouper over the spawning period.* This is the strategy now used in Puerto Rico and the USVI by the Caribbean Fisheries Management Council for red hind, to prevent the species from following the Nassau grouper into population collapse⁶. It is easier to enforce than individual closures. Bahamians already have the example of the crawfish closed season and understand that it is to allow reproduction, and fortunately, the grouper spawning season is not at the same time.

A winter closed season for Nassau grouper will be unpopular with many in the Bahamas and may cause hardship to some. This would be alleviated to some extent by encouraging fishermen to hire out to divers and scientists monitoring the aggregations during the closed season. The resulting data will be very valuable to the Department of Fisheries. At the same time the fishermen would be acting as guardians of “their” aggregations. Alternatively, neglecting to protect the grouper while they are spawning will result in a grouper population collapse that will cause hardship to many Bahamians and will be unpopular with all.

9.4 NO-TAKE RESERVES

The case studies show that permanent no-take reserves, deployed in time and in sufficient numbers can be successful in maintaining healthy populations of both grouper and conch. These reserves must be:

- Permanent. Rotating reserves and temporary reserves don’t seem to help in the long term (Australia abalone, USVI temporary conch closure).
- Established before the population collapses (unlike Florida, Bermuda).
- Act as a network. Reserves in a network support one another, provide suitable habitat for the different species as they move within and between reserves according to the varying requirements of their life cycles, spread risk (one reserve may not be in the best place, or may be damaged) as well as spreading the burden and the benefits more equally between communities.
- Large enough to protect a thriving population as in the Exuma Land and Sea Park.

⁶ See <http://www.caribbeanfmc.com>

Given the difficulties of traditional fisheries management in the Bahamas (data collection, enforcement), a network of marine reserves set up under the above conditions is certainly the best hope for maintaining Bahamian populations of conch and grouper (if spawning aggregations are also protected).

The Bahamas might consider the example of the Australian Great Barrier Reef “representative habitat” programme, where reserve areas are designated to cover a series of important habitats across the whole country, in discussion with communities. Reserves can have uses other than for fisheries protection; TCI and Belize both use their marine reserve networks extensively in tourism marketing aimed at divers⁷.

It is also important for the Bahamas not to neglect the more remote southern and eastern parts of the country. They are lightly populated and conch and grouper populations seem to be in good condition there compared to northern and central areas. However remote eastern islands such as San Salvador and Mayaguana are particularly vulnerable if their grouper and conch populations collapse, since they are probably less accessible to larvae from other sources, and therefore the populations will recover very slowly, if at all (as in Bermuda).

Poaching is a major problem throughout the Bahamas, although particularly damaging in the south. However action taken to solve this problem will have a double benefit. As well as taking the pressure off the Bahamian fish and keeping the benefit of the fishery for Bahamian fishermen, the protected stocks will survive to breed. Then the currents that flow from south to north will carry their larvae to increase populations in the rest of the archipelago.

The best time to put in reserves is when populations are healthy (as they may still be in some southern areas) and reserves may help development by encouraging tourism.

9.5 TECHNOLOGY

From the case studies, fisheries that are technologically advanced (notably those involving spearguns, hookah and scuba) tend to cause overfishing rapidly. The Bahamas has been wise in not allowing the introduction of most of these technologies into fisheries (with the exception of hookah).

9.6 COMMUNITY MANAGEMENT

Community management systems (South Pacific) are in many ways the ideal way to manage fisheries for coastal, non-mobile species such as conch. They allow management decisions to be taken quickly and give control over the resource to the people who depend on it. Decisions can therefore balance resource conservation and local need on a very fine scale. For this kind of system to work communities need tenure rights over their fishing grounds, and the ability to exclude outsiders. They also need strong community decision-making structures, so that decisions can be taken, are abided by and violators punished.

⁷ See for example <http://www.turksandcaicostourism.com>, <http://www.belizenet.com> and <http://www.belize.com>.

In an ideal world, this kind of system would provide optimum management for many Bahamian resources, particularly conch. Community decision making systems are strengthening with the development of local government, but there is no system for community rights to fishing grounds, which makes community management difficult. However, many of the ideas are applicable in the Caribbean; they have been quite successful in Belize.

In particular, the role of the government in education could be given more priority (see above). If the Department of Fisheries were given the resources, it would be able to play a much stronger role in community education, and supporting community decision making about fisheries management. In the long run this would remove much of the burden of enforcement from the national to the local level, which is likely to be much more successful.

9.7 FUNDING FISHERIES MANAGEMENT

Almost all kinds of fisheries management require some input of resources from government. Some governments regard the cost as a subsidy to the fishery, and try to recoup funds by charging high licence fees (Australia) or resource rents (usually a tax on landings; New Zealand). However, far from collecting funds for fisheries management, the Bahamas government currently subsidises the fishery directly, since fisheries inputs can be imported tax free. The government may not wish to charge fishermen the cost of management activities, but actively subsidising entry into overexploited fisheries is not logical.

Fisheries management in the Bahamas could be better financed if the Department of Fisheries were allowed to levy realistic fees or resource rents (e.g. from the commercial crawfish fishery) and plough those funds back into fisheries management. As long as such fees go into a central government pot and are redistributed, high fees or resource rents will simply amount to a tax on fishermen for which they will gain little direct benefit. Another possibility is that additional tax income from the import of fisheries goods be directed to fisheries management, through a corresponding increase in the budget for the Department of Fisheries and the marine reserves programme. In any case, regardless of the distribution of resources within government, highly profitable businesses such as commercial crawfish fishing boats should really make a more realistic contribution to the cost of managing the resources from which they benefit; a cost that is borne by the Bahamian public as a whole. Currently, commercial fishing licences are \$15 per year in the Bahamas.

The case studies show that management techniques such as ITQs can be successful (e.g. Australia), however these are very resource intensive, requiring scientific inputs and constant enforcement. Under the current fisheries management funding system in the Bahamas this is a non starter, but the idea could be reconsidered along with the suggestions above.

9.8 SOURCES OF EXTERNAL FUNDING

There are various sources of funding available internationally for actions such as developing, establishing and managing marine reserves. Possibilities are international organisations such as Caricom, private foundations such as the Pew Foundation (which has already indicated to BREEF that they would be very interested in discussing deployment of a network of reserves with the Bahamian Government) and international NGOs such as The Nature Conservancy. All of these have supported similar activities in the region. An existing marine reserve system in the Caribbean (the Bonaire Marine Park Authority) has also expressed a willingness to BREEF in the past to providing free training for reserve staff.

There are various governmental and non-governmental organisations in the Bahamas who would be in a good position to apply for such funds (e.g. BNT, BREEF and Family Island groups), once the government has taken action to discuss reserve locations with communities and declare reserve sites. Hence once a reserve network has been declared, it is likely to be possible to find external funding for items such as building infrastructure, hiring and training staff and developing and implementing a management plan.

9.9 CONCLUSIONS: SUGGESTED ACTIONS TO BE TAKEN BY THE GOVERNMENT OF THE BAHAMAS

- Take emergency action before the 2002 breeding season (which starts in late November or early December 2002) to prevent the collapse of the Nassau grouper populations in the Bahamas. This should take the form of an annual closed season over the spawning period, from November to February inclusive. To survive the Nassau grouper needs the same seasonal protection enjoyed by crawfish, which brings great economic benefit to the Bahamas⁸.
- Review the key fisheries sector priorities of the Government of the Bahamas, with an emphasis on management, conservation and sustainability rather than on subsidies to fishermen.
- Review the way that the Department of Fisheries is funded and level of financial support and training that they receive in relation to their responsibilities. Review the contribution of profitable fishing enterprises to the cost of resource management and conservation.
- Continue the process of national and local discussion on a network of marine reserves as soon as possible. Several proposals for reserve sites are currently in circulation, but progress has been slow on all of them. Getting the first reserves in place should be a national priority. Once they are designated, non-government and international organisations will be able to raise funds for activities such as warden training and environmental education, as well as practical infrastructure such as signs, boats and moorings.

⁸ The crawfish catch documented by the Department of Fisheries was worth just under \$300 million in the five years to 2001.

- Review the position of marine environmental education in the core school syllabus. Start discussions between the Department of Fisheries, the Ministry of Education and other concerned groups such as BNT and BREEF on environmental education for children, teachers, educators and fishing communities.
- Focus discussion on conservation issues at the local level, through connections between national and local government, public meetings and national financial and technical support for local initiatives.

9.10 THE BARE MINIMUM

This final section is a run down of key priorities. Set out above are suggestions for the actions the Bahamas should take; here we present actions that we feel the Government of the Bahamas can not afford NOT to take:

- **Act now:** Grouper and conch are almost certainly overfished in the Bahamas; they need to be protected now, while populations can still recover.
- **Spawning aggregations:** Fishing on Nassau grouper spawning aggregations has got to stop, or the collapse of the Nassau grouper population of the Bahamas is inevitable. There should be a closed season on Nassau grouper from November to February. **If only one piece of management action can be taken, this should be the one.**
- **Reserve network:** A network of permanent, no-take marine reserves is the best way to protect conch populations. It will also benefit grouper (and other species such as crawfish), and may help promote tourism in the Family Islands.
- **Tax subsidies:** Government subsidies to commercial fisheries through tax free import of materials i) encourages more people to enter overexploited fisheries and ii) reduces funds available for management.
- **Sportsfishing:** Sportsfishing for conch and grouper must be made illegal. (It is illegal for tourists to take conch in the Turks and Caicos.)
- **Poaching:** Presently poachers perceive the Bahamas as a soft target. Firm action must be taken to make poaching prohibitively costly. Bahamian fishermen are more likely to support new regulations for stock preservation if they know that poachers or sports fishermen are not going to be the main beneficiaries. Fishermen could play a key role in the regulation of sports fishing and the elimination of poaching

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