conservation feature

Rapid Decline of Nassau Grouper Spawning Aggregations in Belize: Fishery Management and Conservation Needs

ABSTRACT

The Nassau grouper (Epinephelus striatus) and other reef fishes aggregate in large numbers at specific locations and times to spawn. In Belize, as in the rest of the Caribbean, about one-third of the grouper spawning aggregations have disappeared due to overfishing. One of the last spawning aggregations still viable in Belize has decreased from 15,000 to fewer than 3,000 Nassau groupers in the last 25 years, a decline of more than 80%. The spawning aggregation was still open to fishing in January 2001, with a fishing quota of 900 groupers, which represented about 30% of the aggregation. The actual catch was at least 300 groupers. Fisheries models predict that, if fishing continues, the spawning aggregation will disappear by 2013, and the fishery will be abandoned by 2009 at the latest. Unsustainable fishing will eliminate the spawning aggregations in Belize, with subsequent negative effects on the grouper populations in the region. Since most of the spawning aggregations in Belize have now been fished out, it is necessary to protect the remaining spawning aggregations by closing these sites to fishing. A fishery closure would reduce income to some fishers, but a simple economic analysis of the fishery, and of an ecotourism alternative, shows that groupers are worth approximately 20 times more alive than when fished.

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Many species of groupers (Family Serranidae) and other reef fishes aggregate in large numbers at specific locations, seasons, and moon phases in order to spawn (e.g., Johannes 1978; Domeier and Colin 1997). In many countries, fishers know the locations and times of these spawning events, thus making the aggregations prime fishery targets. Unfortunately, fishery management strategies in most countries have not accounted for the concentrated nature of grouper spawning events. Heavy fishing pressure on spawning aggregations: (1) decreases spawner abundance, (2) decreases spawner mean size, (3) changes population sex ratios (most groupers are sequential hermaphrodites, being first females and then becoming males), and eventually, (4) results in the disappearance of aggregations (Russ 1991; Colin 1992, 1996; Coleman et al. 2000). This is of great concern to fishery managers, as Coleman et al. (1996) showed that species that aggregate to spawn are susceptible to local extinctions from fishing. In the Caribbean Sea, heavy fishing pressure has caused grouper aggregations to disappear in the Virgin Islands, Mexico, Belize, Puerto Rico, Cayman Islands, Florida, and the Dominican Republic, along with the fisheries they supported (Sadovy 1994b; Aguilar-Perera and Aguilar-Davila 1996; Sadovy and Eklund 1999). In addition, marked declines in aggregation size have been noted elsewhere in the region (Colin 1992; Carter et al. 1994; Sadovy and Eklund 1999). Besides the obvious ecological impacts, there are serious economic impacts on local communities when fish populations disappear.

The Nassau grouper (*Epinephelus striatus*), historically one of the more commercially important food fishes inhabiting Caribbean coral reefs (Munro 1983; Carter et al. 1994), once formed spawning aggregations throughout the Caribbean, each of which contained up to 100,000 individuals (Smith 1972). Roughly one-third of these aggregations have been eliminated by fishing (Sadovy and Eklund 1999). Most of these aggregations disappeared before any management actions were undertaken. The Nassau grouper population has been so overfished that it is fully protected in the United States, is a candidate for the U.S. Endangered Species List (Sadovy and Eklund 1999), and is listed as threatened by the American Fisheries Society (Musick et al. 2000). The only way to recover former abundances of Nassau groupers in the Caribbean Sea is to ensure the viability of the remaining spawning aggregations, so that the larvae produced at these aggregations can replenish areas where groupers have declined.

The Nassau grouper in Belize

The Nassau grouper was once the second most commonly caught fish in Belize (Carter et al. 1994). Although fishing persisted year round, the most intensive fishing occurred for about six weeks during the time of the full moon in December and January, on localized Nassau grouper spawning aggregations (Carter 1986, 1989). At least nine Nassau grouper spawning sites were known to occur along the Belize barrier reef and offshore reefs (Carter et al. 1994; Heyman 2001; Paz and Grimshaw 2001). One of the spawning sites, Cay Glory, had been fished since the 1920s, and provided a catch rate of up to 1,200–1,800 Nassau groupers per boat per spawning season during the 1960s (Craig 1969). In 2001, fishers caught only 9 Nassau groupers out of an aggregation of 21 groupers at the same site (Paz and Grimshaw 2001).

This decline in abundance is not unique to Cay Glory. A survey in January 2001 showed that only 2 out of the 9 traditional spawning sites had more than 150 Nassau groupers; the rest of the sites have now been fished out (Heyman 2001; Paz and Grimshaw 2001). The impacts of the fishery on spawning aggregations may not be limited to Nassau groupers, because other species of groupers and other reef fishes have been observed spawning simultaneously at the same sites in Belize and elsewhere (Colin 1992; Carter and Perrine 1994; Sadovy 1994a).

Despite the collapse of grouper populations in Belize, spawning aggregations throughout the country were still open to fishing during the spawning event of January 2001. Until recently, the lack of quantitative data on grouper stocks has impeded fishery management action to prevent the continued disappearance of the spawning aggregations. However, presently the Belize Fisheries Department, in collaboration with local fishers and local and international conservation organizations, is considering how to properly manage the grouper spawning aggregations to ensure their long-term viability.

Data on 1999–2001 monitored grouper spawning abundance at Glover's Reef, Belize, are presented. Additionally, we present data on the Nassau grouper fishery catch and economic yield, and models to predict the impacts of the fishery on the spawning aggregation. We provide biological and economic evidence for the need to close spawning aggregations to fishing to ensure the conservation of grouper populations in Belize.

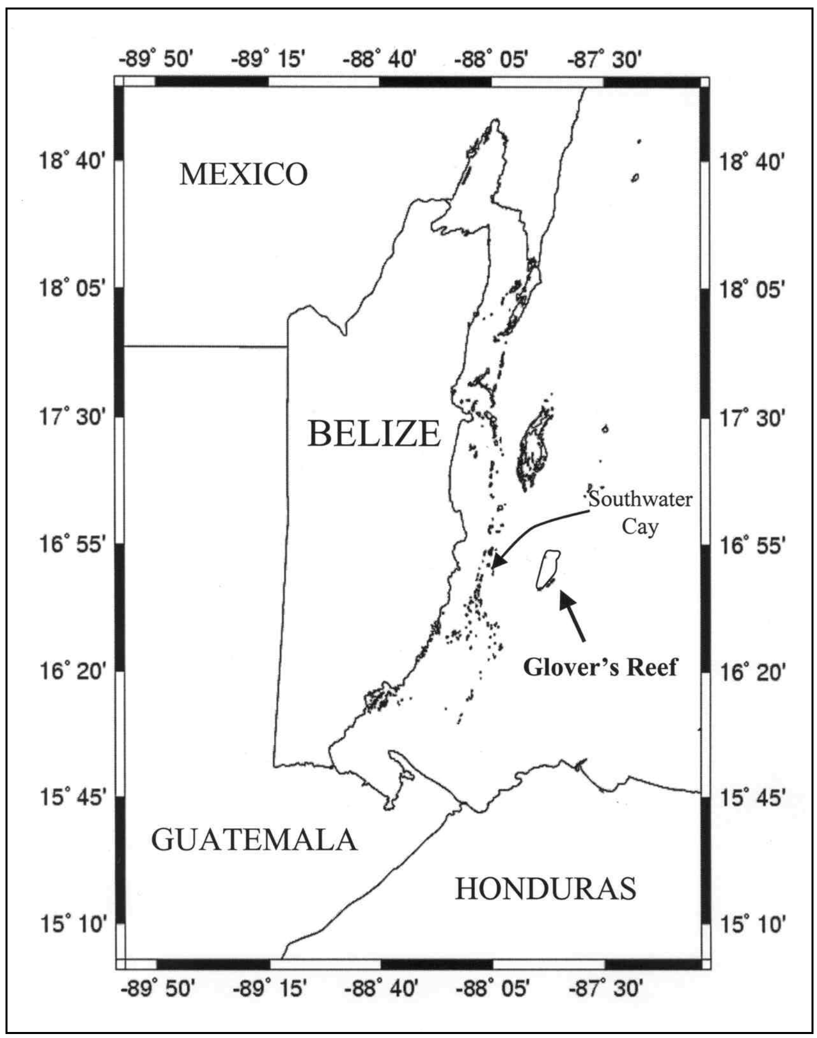
The Glover's Reef Nassau grouper spawning aggregation

Glover's Reef (16º 44' N, 87º 48' W) is the southernmost of the three atolls off the coast of Belize (Figure 1). The atoll is located about 30 km east of the Belize barrier reef. Glover's Reef is an elongate rectangular atoll about 32 km long and 12 km wide (384 km^2). The spawning site, which is located approximately 1 km off the reef crest and outside a large channel through the reef crest, is located at 25–45 m depth, at the northeastern portion of the atoll. We studied the grouper spawning aggregation at Glover's Reef during the spawning events of December 1999, January 2000, and January 2001. The dates of the full moon, after which spawning took place, occurred on 22 December 1999, 21 January 2000, and 9 January 2001, respectively.

Our initial surveys of Glover's Reef indicated that groupers were distributed in three main habitats: coral ridges, coral shelf , and in the water column. The coral ridges occurred in parallel formation and, together with sand bars, made up a spur and groove system at depths between 25 and 30 m. The shelf edge occurred immediately below the spur and groove system at 30 to 50 m depths, and consisted of a flat area with extensive coral cover. The spawning site encompassed approximately 13 distinct coral ridges within this spur and groove system.

To estimate abundance of spawning groupers within these habitats, we conducted daily (as weather permitted) underwater visual censuses by scuba diving (a total of 22 days in December 1999–January 2000, and 12 days in January 2001, starting before spawning and before the beginning of the fishery). Our census protocol consisted of stratified sampling conducted by three divers. Underwater visibility varied between 35 and 50 m. Grouper counts on every coral ridge in the spur and groove system were carried out by swimming along all ridges in the spawning site and counting all groupers. Each diver surveyed different coral ridges independently. Grouper counts on the shelf edge were carried out using contiguous 75 x 20 m belt transects, which covered the shelf area within the spawning site (approx. 1.5 ha) between 30 and 50 m in depth. There was a variable number (1–3) of large grouper schools in the aggregation, and counts of groupers in the water column were carried out for each grouper school by each diver

Figure 1. Map of Belize showing the location of Glover's Reef.



separately, and later averaged. To evaluate our estimates of school size, schools were videotaped using a digital video camera (Sony DCR-TRV900™) in an underwater housing (Gates Underwater Diego Housing™), and our underwater estimates for each particular school evaluated with counts of the videotaped school made on a monitor screen.

The multispecies spawning aggregation had four species of large groupers: the Nassau grouper, the black grouper (*Mycteroperca bonaci*), the tiger grouper (*M. tigris*), and the yellowfin grouper (*M. venenosa*). More than 20 other species of other reef fishes spawned at the same site, including smaller groupers (Serranidae, *E. guttatus*, *E. cruentatus*), triggerfish (Balistidae), parrotfish (Scaridae), porgies (Sparidae), and others. The most abundant grouper species at the spawning site during the winter of 1999–2000 was the Nassau grouper, with an estimated maximum abundance of 3,100 individuals in December 1999, followed by the tiger grouper (250 individuals), yellowfin grouper (200 individuals), and black grouper (140 individuals) (Figures 2 and 3). Although maximum abundance of all species occurred almost simultaneously in 1999–2000, they showed different patterns of arrival and departure times, peak abundance dates, and presence/absence on each spawning event (Figures 2 and 3). Groupers were almost absent from the spawning site before the full moon, but their abundance increased by an order of magnitude within three days after the full moon. In January 2000, this sudden increase took place in a single day. In January 2001 peak abundance of groupers decreased to 2,700 Nassau groupers, 25 tiger groupers, 4 yellowfin groupers, and 10 black groupers. Nassau groupers spawned at dusk (between 20 minutes before sunset to 30 minutes after sunset). In every spawning event we observed Nassau groupers frequently spawning in large schools of up to 2,500 individuals. We observed only one spawning rush of black groupers, which occurred a few minutes after sunset. The actual spawn of tiger groupers and yellowfin groupers was not observed, although they exhibited spawning coloration and behavior (Deloach and Humann 1999).

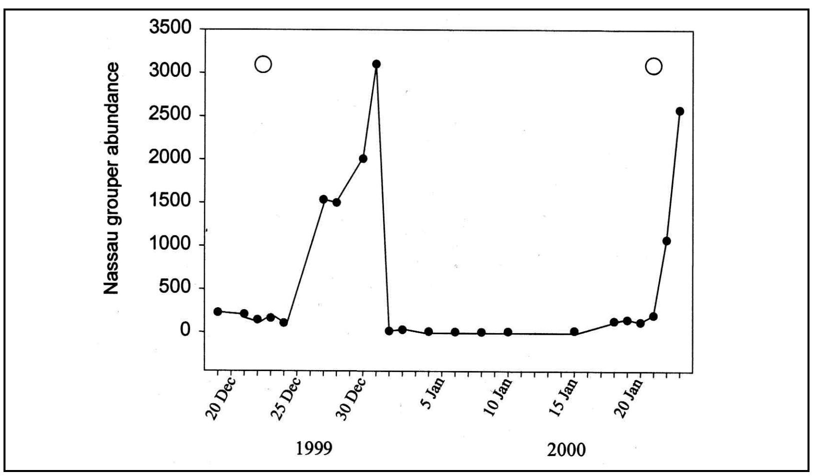
There are very few baseline data on the size of grouper spawning aggregations in the Caribbean. D. Wesby, a staff member of the Wildlife Conservation Society's Glover's Reef Marine Research Station, dived at the Glover's Reef spawning site in 1975 and estimated a total of 15,000 Nassau groupers at the aggregation (D. Wesby, pers. comm.). This estimate suggests that aggregation size decreased by approximately 80% in the last 25 years. We assume that this Nassau grouper spawning aggregation size is a historical minimum.

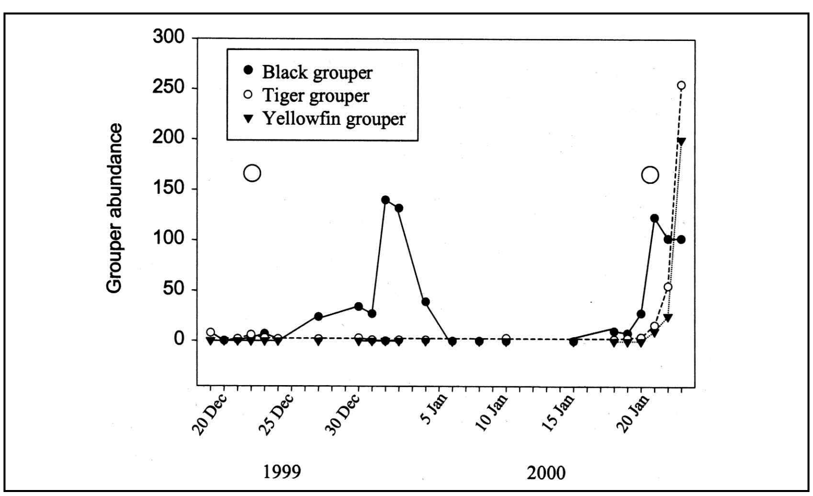
The fishery

The grouper spawning aggregation at Glover's Reef has been fished since the 1970s by fishers from Dangriga, and after the mid 1980s by fishers from Hopkins (D. Wesby, pers. comm.). The aggregation was closed to fishing for some years in the 1990s but was opened to fishing in the winter 1998–1999, although strong northern winds prevented most fishing (T. Bright, Wildlife Conservation Society, pers. comm.). The aggregation was open to fishing again in December 1999 and January 2001, exclusively to fishers from the village of Hopkins. However, the aggregation was closed to fishing in January 2000. Fishing quotas were determined on a yearly basis. There is also a grouper fishery operating outside the spawning season throughout the atoll, using mainly spearguns.

We monitored the fishery at the spawning aggregation in December 1999 and January 2001. In 1999 we counted, measured, weighed, and sexed groupers caught at the aggregation. We also conducted interviews with fishers to learn about the natural history and the temporal trends of the fishery. Fishers came

Figure 2. Temporal abundance estimates of the Nassau grouper spawning aggregation at Glover's Reef during the 1999-2000 winter spawning events. Full moons are indicated.
Figure 3. Temporal abundance estimates of black, tiger, and yellowfin groupers at the spawning aggregation at Glover's Reef during the 1999-2000 winter spawning events. Full moons are indicated.





from Hopkins in skiffs with outboard motors, and spent about 10 days in huts built above a sandflat inside the lagoon, close to the reef crest, one mile south of the northeast channel of Glover's Reef. They usually fished twice daily, once in the morning, starting between 09:00 and 10:00, and again in the afternoon, from 13:00 to 16:00. No fishing was conducted at dusk. Fishers used hand lines baited with small yellowtail snapper (*Ocyurus chrysurus*), grunts (*Haemulon* spp.), and smaller groupers (such as the red hind *E. guttatus*). The catch was filleted in the fishing camp, and head, tail, and bones were discarded. Fillets and roe were kept in ice chests, and transported to the mainland for sale within a few days.

Six boats with a total of 24 fishers (4 fishers per boat) from the village of Hopkins arrived at the Glover's Reef spawning site on 20 December 1999. The fishing quota established the year before was 1,360 kg catch per fisher (approximately 300 Nassau groupers per capita) (T. Bright, pers. comm.). Lack of knowledge of previous aggregation size and dynamics in addition to the extremely low number of fish observed in the underwater surveys before the arrival of the large grouper school prompted the Belize Fisheries Department to close the fishery three days after it started. However, the closure was not enforced and fishing continued until 31 December 1999, with a reported catch of 219 Nassau groupers and 4 black groupers. Our discussions with fishers indicated that the total catch was actually closer to 300 groupers. Assuming the total catch was 200–300 groupers, catch per unit effort (CPUE) in 1999 ranged from 0.8–1.1 groupers per fisher per day.

The spawning aggregation was open to fishing again in January 2001. The established quota was 900 Nassau groupers, which represented about 30% of the aggregation. Four boats and 14 fishers from Hopkins fished the aggregation from 8 to 14 January 2001. The reported catch was 302 Nassau groupers, with a CPUE of 3.1 groupers per fisher per day. Interviews with fishers suggest that the catch was higher than reported.

Fishery modeling and economic analysis

We asked the question, "What will be the impact on the spawning aggregation of continued fishing at the current rate?" We used a simple discrete-time model to assess the impacts. Nassau groupers aggregate to spawn during a single season (although in two spawning events), and are fished mostly during that season. We used a Schaefer model

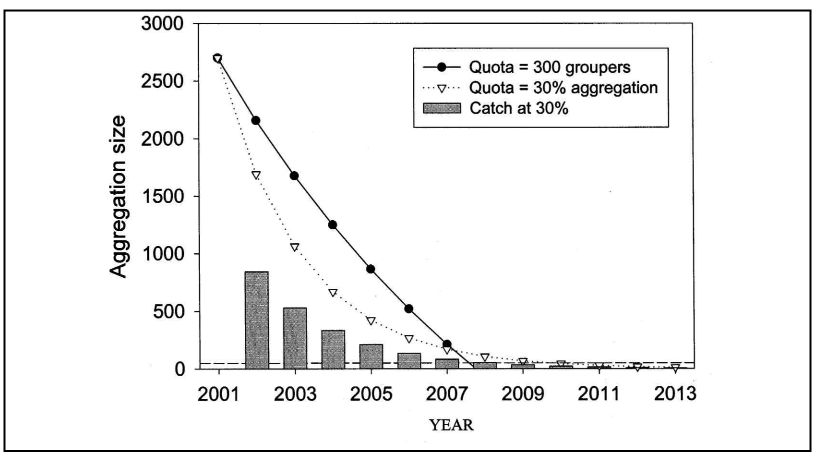
$$N_{t+1} = N_t + rN_t\left(1 - \frac{N_t}{K}\right) - C_t$$

where N is number of groupers at time t, r is intrinsic rate of population growth, K is carrying capacity, and C_t is the catch. Population growth is likely to be r = 0.05 / year at low grouper abundances (Froese and Pauly 2001). We assume that K = 15,000 which is the only previous, although anecdotal, information for Glover's Reef. This number is, however, consistent with Carter's (1989) estimates of aggregation sizes in excess of 15,000 Nassau groupers at other sites in Belize. However, the maximum size of the aggregation could have been larger. Total catch equals the catch at the spawning aggregation plus the catch during the rest of the year. The catch at the spawning aggregation may vary as a function of the fishing quota. We simulated two different scenarios, one where the quota and actual catch are 30% of the aggregation (such as the quota in January 2001), and another where the catch is 300 groupers per year (as realized in 1999 and 2001).

Our models assume that Nassau groupers come back every year to the same spawning site, and that the size of the aggregation would be constant if net population growth were zero. We do not know what proportion of the spawning groupers comes back to the spawning site, or if groupers move to other aggregation sites. However, a Nassau grouper tagged in Belize moved >250 km along the Mesoamerican Barrier Reef (Carter et al. 1994). Thus the size of any spawning aggregation may fluctuate interannually because of movements of reproductive individuals. Despite these shortcomings, our simple deterministic models are optimistic, because they assume optimum reproduction, constant population growth rate, and do not take into account demographic and environmental stochasticity, and Allee effects. Estimating parameter values to include stochasticity and Allee effects in the models is difficult at this point because of the lack of data on the effects of population size on reproduction success in Nassau groupers. Nonetheless, adding these factors would likely accelerate the rate of disappearance of the spawning aggregation.

We carried out a tagging experiment in January 2001 to estimate fishing mortality outside the spawning season. We tagged 284 Nassau groupers with Floy dart tags at the spawning aggregation during 12 days. Two of the tagged fish were caught by fishers during the spawning season at the spawning site, but released immediately. We advertised a reward of US $15 per tag (hereafter all currency values are US $) in the primary fishing villages along the coast. As of 5

Figure 4. Deterministic models of the fishery at the Nassau grouper spawning aggregation on Glover's Reef. Models simulate two different scenarios, annual catch = 300 Nassau groupers, and annual catch = 30% of the aggregation (after fishing). The figure also shows an estimate of the temporal trajectory of the catch if 30% of the aggregation is fished every year. The dotted line represents 48 Nassau groupers, which is the minimum number of groupers needed to make the fishery profitable for a single commercial boat (see text for details).



August 2001, 21 tags have been returned by fishers. Twenty represented groupers caught at Glover's Reef, and one a grouper caught at Southwater Cay, on the barrier reef 30 km west of Glover's Reef (Figure 1). An extrapolation gives a total of 200 Nassau groupers (approximately 7% of the spawning groupers) caught (mainly from spearfishing) within a six month period after spawning. Fishing mortality outside the spawning season and between spawning seasons is therefore about 14% per year for 2001.

To predict when the fishery would reach economic extinction, we used economic data obtained during the interviews with fishers. Interviews at the fishing camp revealed that the operating costs (fuel, food, and supplies) for fishing the spawning aggregation were $400 per fishing boat. The average weight of Nassau groupers caught at the spawning site was approximately 4.5 kg (10 lb). A 4.5 kg grouper yields 1.5 kg (3.3 lb) of fillet and 0.36 kg (0.8 lb) of roe (the rest is discarded because there is not enough ice in the fishing camp). In 2001, 450 g (1 lb) of fish fillet sold for $3, and 450 g of roe for $5 (Hopkins fishers, pers. comm.; Paz and Grimshaw 2001). Therefore, every Nassau grouper provided revenue of $10 if only fillets were obtained, and $14 if fillets and roe were obtained. To match operating costs, every fishing boat has to catch a minimum of 48 groupers. Thus we assume that the commercial fishery will be abandoned when the spawning aggregation has fewer than 48 Nassau groupers. There is no reason for the fishery to continue if unprofitable.

Assuming an annual catch at the spawning aggregation of 300 Nassau groupers, the model predicts that fishing will eradicate the spawning aggregation by 2008 (Figure 4). Assuming that the 30% annual quota is reached and not exceeded, the model predicts that, although the aggregation will not be eliminated until 2013, the fishery will be abandoned in 2009, when the number of Nassau groupers at the spawning aggregation declines to less than 48 (Figure 4). This assumes no change in market value of the Nassau grouper, although as fish become scarce the price usually increases and the results could change.

What were the economic benefits of the fishery? In December 1999 and January 2001, fishers caught about 300 Nassau groupers, obtaining a gross revenue of approximately $4,200 for the spawning season. Subtracting operating costs ($400 per boat) from gross revenue leaves a net profit of $1,800 ($75 per capita) in 1999, and $2,600 ($186 per capita) in 2001. How much are Nassau groupers worth if fishing continues? The present net value of the spawning aggregation is the sum of all Nassau groupers caught at the aggregation site until the fishery is abandoned. Our models estimate a total catch from present until the fishery is abandoned of 1,712 Nassau groupers if the annual catch at the aggregation is 300 groupers, and 2,188 groupers if the annual catch is 30% of the aggregation (Table 1). This gives a net present value of less than $30,000 for the entire remaining life of the fishery.

How much are Nassau groupers worth alive? If the aggregation is not fished, the revenue from catches would be lost, thus a complete fishery closure would need to be followed by economic alternatives for the fishers during the time in which spawning takes place. Let's assume that a small group of recreational divers (e.g., 20 divers) is allowed to dive at the spawning aggregation, which occurs during four weeks every year. The current rate for diving at Glover's Reef in one of the existing resorts is $1,600 per week (two dives per day). Thereby gross revenue for taking recreational divers to the spawning site for a period of four weeks per year would be about $128,000. Let's also assume that such an ecotourism facility is operated entirely by Belizean people. After the initial fixed investment costs, annual operating costs consist of food, freshwater, electricity, fuel for filling diving tanks, and fuel for boats to transport divers to the spawning site. Assuming a total daily cost of $60 per diver per day, operating costs would be $33,600 during the four-week spawning period. Subtracting operating costs from gross revenue results in an annual net profit of $94,000 (Table 1). The number of recreational divers used here is just an arbitrary example to illustrate the economic benefits of ecotourism, although it may not represent the carrying capacity of divers at the spawning aggregation.

Secondary benefits of fishing the spawning aggregation include benefits to the consumer from eating fish (difficult to quantify), resale to restaurants, and export of consumer surplus, minus other operating costs. The secondary benefits for ecotourism will be higher, because the ecotourism industry requires more infrastructure and services, with creation of additional income and employment. Without taking into account these economic multipliers, the net profit of not fishing the spawning aggregation can be more than 20 times greater than the value of landed fish. Note that this enormous difference is created during a period of only four weeks. Adding the other economic multipliers would likely increase the nonconsumptive value of the fish.

Discussion and recommendations

Little is known about the temporal variability in size of unfished grouper spawning aggregations (Sadovy and Eklund 1999), thus it is difficult to determine the natural variability in the abundance of spawning groupers at one site. Johannes et al. (1999) found that grouper spawning aggregations in Palau varied from 37% to 61% from year to year. In Glover's Reef, our estimates of abundance carried out from December 1999 to January 2001 are within a range of 13%. Since approximately 10% of the aggregation was fished in 1999 and 2001, it is difficult to determine the sources of error in our observations. Nevertheless, our grouper estimates are similar from year to year and we believe they are reliable. In any case, an 80% decrease in abundance since 1975 appears evident. There probably is a critical number of fishes needed to form an aggregation, and a limited number of aggregation sites. The reduction of fish abundance below such critical thresholds will imperil reproduction; in other words, every aggregation that disappears is diminishing irreversibly the species' chance to replenish.

If the spawning aggregation at Glover's Reef disappears, as has been the case for other spawning aggregations in Belize and throughout the Caribbean, could Nassau groupers from other locations replenish Glover's Reef? Our preliminary tracking data show that only 5% of the Nassau groupers that spawn at Glover's Reef appear to leave the atoll and swim across the 30 km of deep pelagic habitat separating Glover's Reef from the barrier reef. If most of the reproductive groupers remain at Glover's Reef, then recolonization would have to be carried out principally by larvae from other spawning aggregations. Nassau grouper larvae have a pelagic larval life of 30–45 days, thus it is possible that recruitment could come from other spawning aggregations in Belize or in neighboring countries (Shenker et al. 1993; Stevenson et al. 1998). However, since other spawning aggregations have disappeared or are declining in Belize (Heyman 2001; Paz and Grimshaw 2001) and in neighboring countries (Sadovy and Eklund 1999), the chances of recovery would be extremely low. In fact, there is no evidence of a spawning aggregation eliminated by fishing in the Caribbean ever reforming or recovering (Sadovy and Eklund 1999). The grouper spawning aggregation on Glover's Reef is at its historical minimum, harboring less than 3,000 Nassau groupers, and less than 200 black, tiger, and yellowfin groupers. This aggregation has been fished intensively since the 1970s. The conclusion of our analysis is that the current fishing activity on Glover's Reef is not sustainable. If fishing continues, the Nassau grouper spawning aggregation on Glover's Reef will be eliminated, and the fishery probably abandoned within a decade. As a consequence of our analysis, we recommend that the spawning aggregation at Glover's Reef and all other spawning aggregations in Belize be closed indefinitely to fishing year-round. Since other species of groupers, snappers and other reef fishes aggregate to spawn at the same sites, during the same season or at other times of the year, the permanent closure of the spawning sites would provide protection for many other commercially important species as well.

Our simple economic analysis indicates that the economic benefits for stakeholders of not fishing the spawning aggregations and developing an ecotourism industry are significantly larger (greater than 20 times) than the short-term benefits of fishing the aggregation. The value of the aggregation, if fished, will be realized and exhausted within a decade, because the groupers will be gone with consequent low chances of recovery. In contrast, if the groupers are left alive, they may create income repeatedly and yearly for the long term. Moreover, this shift in stakeholder activity will involve only four weeks per year; the rest of the year fishers should be able to continue fishing outside the spawning sites. Therefore, protecting the spawning aggregations can enhance the fishery outside the spawning sites in the long term because of the recovery of grouper populations, and create a huge additional net profit during short periods of time. In fact, such an ecotourism industry could support fishing communities for entire seasons. To ensure that such a tourist industry is not detrimental to conservation of spawning aggregations and the local economy, strict controls on the number of recreational divers should be established. Access to spawning sites should also be rigorously regulated and enforced, and the potential impact of divers on grouper behavior determined. We suggest that a small number of divers conduct a maximum of two dives per day, in the morning and early afternoon, and that the spawning site is not visited during late afternoon and dusk, to allow groupers to spawn without disturbance.

Moreover, we recommend that grouper fishing be prohibited during the spawning season elsewhere, and not only at the spawning site. Closing a spawning site can give the illusion of protection, but it might be ineffective. In Mexico, a Nassau grouper spawning site was closed to fishing, but fishers placed gillnets across the reef around the spawning site to catch groupers that were moving towards the aggregation (Aguilar-Perera and Aguilar Davila 1996). The question of whether prohibiting fishing for groupers throughout the country and throughout the year would help recovering grouper abundances is not trivial. Our tagging experiment at Glover's Reef indicates that spearfishers caught approximately 7% of the aggregation size on Glover's Reef in only six months. At present low grouper abundances, these catches can have significant effects on grouper populations. A total prohibition of grouper fishing would be impractical to enforce, and it might increase the black market value of the Nassau grouper with consequent effects such as increase of fishing effort. However, the use of spearguns could be prohibited as a means of reducing fishing mortality outside the spawning season. We hope that our data and recommendations will help the Belize Fisheries Department to develop sound management policies for groupers.

Table 1. Number of Nassau grouper fished (if fishing) or present at the aggregation (if ecotourism), present economic value, and annual net profit of the grouper spawning aggregation on Glover's Reef, Belize, under different scenarios: a) annual catch = 300 Nassau groupers, b) annual catch = 30% of the aggregation, and c) the aggregation is closed to fishing. Currency is US $.

	Catch = 300	Catch = 30%	Catch = 0 (Ecotourism)
Total number of Nassau groupers	1,712	2,188	Increasing
Number of years of operation	8	7	Long term
Gross present value	$24,000	$31,000	$128,000 /year
Operating costs	$3,200	$2,800	$33,600 /year
Net present value	$20,800	$28,200	$94,000 /year
Average annual net profit	$3,800	$4,000	$94,000

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