Aggregations as a Proxy for Changes in Abundance in a Threatened Reef Fish, the Nassau Grouper, *Epinephelus striatus*

Las Agregaciones como un Proxy para los Cambios en la Abundancia en un Pez de Arrecife Amenazado, el Mero Cherna, *Epinephelus striatus*

Agrégations comme un Proxy pour les Changements dans l'Abondance dans un Poisson de Récif Menacé, le Mérou *Epinephelus striatus*

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EXTENDED ABSTRACT

Assessing the conservation status of poorly documented, biologically vulnerable commercial fish species can become a downward spiral. As fish numbers decline, information may become more scarce or difficult to obtain and the species harder to assess. For commercially important species, as populations decline and commercial value wanes (assuming value and rarity are not inversely related), they drop in government priorities and become only of conservation attention and concern. Even if of some concern and protected from fishing, there may be little follow-up data collected to determine the effectiveness of that protection, or governments might even want to obscure data on a species that might be undergoing further declines. For several reasons, then, information can become ever sparser as a species declines. Information may continue to be available from non-fishery studies or regional underwater census programmes (such as the volunteer reef survey project: http://www.REEF.org/vfsp), but declining numbers do tend, overall, to make data more challenging to collect. A case of 'out of sight increasingly means out of mind'.

The best known and most widely used protocol for the assessment of conservation status in animals and plants globally is the International Union for Conservation of Nature (IUCN) Red List which applies one to several among 5 available 'criteria' (A-E) to assign species to a conservation category. To apply the criteria to commercially important fishes the most commonly used criterion is changes (past and projected) in population numbers over time (Criterion A). The necessary information ideally comes from fishery-dependent and fishery-independent sources and an understanding of the fishery and its practices. Data can be in the form of abundance estimates or proxies for these (usually this is catch per unit of effort for exploited species), and all available data are assembled and assessed to determine population trends, past and projected. Attempts are made to gather such datasets from as much of the geographic range as possible, for a global assessment, and from both grey and published sources. In addition, assessment can include well-documented anecdotal evidence and information such as from fisher interviews, or can consider trends over time regarding habitat that is particularly important to the species at different life history phases. In the latter case the implication would be that serious loss of the habitat is a potential threat to the species and can be used as a proxy for the species.

Criteria other than "A" could potentially be applied to assess commercial fishes like the Nassau grouper. For example Criterion "E", though little used for fishes, involves virtual population analyses and could be useful for those species for which fishery stock assessments have been completed (http://www.iucnredlist.org/static/categories_criteria_3_1). Under Criterion "D", which addresses species with populations that are very small or restricted, a species would be vulnerable if either D1 (population size was estimated to number fewer than 1,000 mature individuals), or D2 (population had a very restricted area of occupancy -- typically less than 20 km^{2} -- or number of locations -- typically five or fewer -- such that it is prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, apply. In the latter case (D2) this could apply to key parts of life history, which, in the case of the Nassau grouper, could be the spawning aggregations because these are very important to the persistence of the species (as far as we know).

The Nassau grouper (*Epinephelus striatus*) is widely distributed in the Caribbean in reef habitat. It is of high commercial interest and was once one of the most important groupers in the insular Caribbean (Hill and Sadovy de Mitcheson 2013). It is also, overall, the best studied of all groupers. However, due to overexploitation, particularly uncontrolled targeting of its spawning aggregations, estimated declines over 3 generation lengths (the IUCN time-frame for Red List assessments applies to changes that have occurred in the species either in the last 10 years or over 3 generations, whichever is the longest) placed it in the threatened category of the Red List in 2003. Declines have been serious and are ongoing since that time and management scant or ineffective (Hill and Sadovy de Mitcheson 2013).

According to IUCN guidelines, Red List assessments must be done at least once every 10 years, and the species has just been reevaluated. Today, its numbers appeared to be healthiest (i.e. most stable or abundant) only where it is now or has been little exploited (e.g. Turks and Caicos) or where it has been well-protected (Cayman Islands). Elsewhere, there is little recovery and ongoing declines, despite protection in a few places. A recent and welcome development was the addition of this species to Annex III of the Specially Protected Areas and Wildlife in the Wider Caribbean Region (SPAW) protocol (2017) the signatories of which are most countries in the species' range state, with the notable exception of Mexico, and which address regional rather than national level protective measures. Also, in 2016, the U.S. National Marine Fisheries Service published its final rule to list the Nassau grouper as threatened under the Endangered Species Act. However, much better enforcement of existing management measures is clearly needed to allow the species to recover and to stem further declines. Overall, and if nothing changes, it is highly likely that the global population will continue to decline over the foreseeable future. And information on the condition of the species is becoming sparser.

A recent reassessment of the Nassau grouper by the IUCN Species Survival Commission's Groupers & Wrasses Specialist Group again (as in 2003) found it to be threatened under criterion A (population decline) with an observed, estimated, inferred, or suspected population size reduction of ≥ 50% over three generations and the reduction or its causes not considered to have ceased. This listing is probably conservative because a range of information suggested that declines could be as much as 80% over several decades in Cuba, Mexico and the U.S. Ongoing declines were also noted of suspected in almost all other countries where the species is or was recently exploited and for which there is sufficient information. The largest remaining population is in the Bahamas but there this is still declining (Cheung et al. 2013). Despite serious protection in Belize numbers at aggregations remain low, possibly due to poaching. The biggest threat faced by this species continues to be the unmanaged targeting of its spawning aggregations (Hill and Sadovy de Mitcheson 2013).

However, there is a major challenge with long-lived species which are assessed some time after major declines have occurred. In the case of the Nassau grouper most major declines took place in the 1970s and 1980s. The 2003 assessment could include data from the early '70s (30 years/three generations of data could be considered for the assessment). By 2017, however, Red List assessments could only consider data from the late 1980s onwards after much of the declines had occurred. This effective 'loss' of the early fishery history in assessing long-lived species can result in a highly threatened species that still have population sizes likely to be above critical minima, even if low relative to historical levels, being down-listed to non-threatened; this is known as the 'ski jump' effect. To address this issue, the solution is to assess the taxon against all the criteria (A-E).

Given the paucity of new information for the Nassau grouper after the 2003 Red List assessment, the 'ski-jump effect' and acknowledging the importance of spawning aggregations to the species, these became part an important part of the discussion during the recent Red List re-assessment for the species. It was considered:

i) Whether the species could also be listed also under Criterion D2 (note that several criteria can be considered in each assessment and the final listing will be the most threatened category), and
ii) Whether aggregations themselves could be a proxy for abundance.

Aggregations were known to be declining both in absolute number and also in terms of numbers of fish per aggregation. In the past, aggregations were estimated to consist of 10,000 to 30,000 and up to 100,000 individuals (Lavett-Smith 1972, Olsen and LaPlace 1979, Colin et al. 1987, Fine 1990, 1992, Carter et al. 1994, Sadovy 1997). The relatively few remaining aggregations reported to exist today had greatly declined in numbers of fish gathering and contained only 100s to, rarely, 3,000 individuals (Sadovy de Mitcheson et al. 2008, Hill and Sadovy de Mitcheson 2013; www.SCRFA.org/database).

In relation to D2, a summation of the areas of remaining aggregations would have to be less than about 20 km^2 or there would need to be five or fewer locations prone to the effects of human activities or stochastic events within a very short time period in an uncertain future. While the former seems quite possible, there are insufficient data, at present, to apply this Criterion but the need to assess all known aggregations and their status was highlighted.

In relation to using Criterion A and for aggregations to be a proxy for population status, this is being tested by compiling information on all known aggregations in terms of numbers of fish and changes over time. This is a time-consuming process since much of the data are not readily available. However, in principle, aggregations are likely to be a highly appropriate proxy since their persistence may be a key indicator of the viability of the species, or its populations, rather than numbers of fish *per se*. This would certainly be a major consideration if there were thresholds of animal numbers for reproduction (i.e. depensation or Allee Effect; Sadovy de Mitcheson 2106). There are certainly indications of Allee effects in this (and other aggregating species) species from observations that smaller aggregations last longer at the spawning site, to lower courtship rates when fish numbers are low. The possibility for such behavioural effects from reduced numbers or disruption of spawning cannot be ignored and using functional aggregations as a proxy for population status could be a very meaningful measure of conservation status for this species for future assessments. It is already timely to be collecting such data and thinking about such approaches to assessing conservations status.

KEYWORDS: Conservation, proxy, population, abundance, status

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