Extinction Susceptibility of Reef Fishes in Spawning Aggregations

TERRY J. DONALDSON

University of Guam Marine Laboratory, UOG Station, Mangilao, Guam 96923 USA

ABSTRACT

A number of reef fish, particularly large-bodied, slow-growing and late-maturing species, form aggregations for the purpose of courtship and spawning. Many of these same species have life history traits that render them susceptible to extinction. Factors that contribute to this susceptibility are either intrinsic and extrinsic. Intrinsic factors characteristics such as large body size, long life, slow growth and late sexual maturity, mating systems and behavior patterns that are susceptible to exploitation, Allee effects, specialized habitat or microhabitat requirements, limited dispersal potential, limited recruitment potential, limited geographical distributions or endemism, broad geographic distributions but low abundances locally, or disjunct distributions. Extrinsic factors include characteristics such as over-exploitation, or natural and anthropogenic effects that result in habitat degradation or loss. Data on resident and transient reef fish spawning aggregation species were analysed with the IUCN/SSC's Susceptibility Matrix to detect species that possess one or more of life history characteristics that render them susceptible to localized extinctions as a consequence of extrinsic factors. The analysis indicated that many transient aggregating fishes, such as groupers and snappers, and resident aggregating species, such as wrasses, parrotfishes, and surgeonfishes, all taken in reef fisheries, are especially susceptible because of over-exploitation. While this outcome is known generally for representatives of each of these taxa, the method used here provides a more rapid and quantitative means of assessing extinction susceptibility for a wide range of species.

KEY WORDS: extinction susceptibility, reef fishes, spawning aggregations

Susceptibilidad de Extinción de los Peces de Arrecife Durante las Agregaciones de Desove

Un número de peces arrecífales, particularmente de cuerpo grande, de crecimiento lento y con maduración tardía forman agregaciones con el propósito de cortegearze y desovar. Muchas de estas mismas especies tienen rasgos en su historia de vida que los hacen susceptibles a la extinción. Los factores que contribuyen a esta susceptibilidad son cualquiera intrínsicos y extrínsicos. Los factores intrínsicos de tales como tamaño grande del cuerpo, larga vida, maduración lenta y maduración sexual tardía, sistemas de acoplamiento y patrones del comportamiento que son susceptibles a la explotación, los efectos de Allee, los requisitos especializados del hábitat o del microhábitat, potencial, limitado de dispersión, un potencial limitado del reclutamiento, limitada distribuciones geográficas o endemismo, amplias distribuciones geográficas pero con baja abundancia localmente, o las distribuciones disjuntas. Los factores extrínsicos incluyen características tales como sobre-explotación, o los efectos naturales y antropogénicos que dan lugar a la degradación o a la pérdida del hábitat. Los datos sobre especies arrecífales residentes y transitorias que forman agregaciones de desove fueron analizados con la matriz de susceptibilidad del IUCN/SSC's para detectar las especies que poseen una o más de las características de la historia de vida que las hacen susceptible a las extinciones locales como consecuencia de factores extrínsicos. El análisis indicó que muchos de los peces transeúntes que se agregan, tales como meros y pargos, y los peces residentes que se agregan, como los loros, y cirujanos, son especialmente susceptible a la extinción debido a la sobre-explotación. Mientras que este resultado es conocido para varios de las especies representantes de cada uno de estos taxa, el método usado aquí proporciona medios más rápidos y más cuantitativos de determinar la susceptibilidad de la extinción para una amplia gama de la especie.

PALABRAS CLAVES: extinción, IUCN lista roja, paces de arrecife, agregaciones de desove.

INTRODUCTION

The traditional view that the sea is an inexhaustible source of marine organisms for which extinction is impossible has been challenged by observations that chronicle recent extinctions, either globally or locally, among diverse taxa (Carlton et al. 1999, Roberts and Hawkins1999, Dulvy et al. 2003). Marine fishes are no exception and, when combined with freshwater fishes, comprise one of the most threatened groups of vertebrates (Baillie et al. 2004). Principal threats to marine fishes include exploitation, habitat loss, pollution and invasive species (Reynolds et al. 2005). Yet, data describing their conservation status is limited to less than 5% of all known species, many of which are commercial (Reynolds et al. 2005), and these are assessed largely for management purposes rather than for conservation (Reynolds 2003). Of those commercially-exploited species assessed there have been population declines from known historical levels of up to 83% over the last three decades (Hutchings and Reynolds 2004). Ironically, the risk of extinction for commercially-exploited species is often perceived to be quite low because, compared to terrestrial organisms, their large geographical ranges and high fecundity are supposed to contribute towards greater resilience in the face of exploitation (Dulvy et al. 2003, Reynolds et al. 2005). Recent studies (McKinney 1998, 1999, Jennings et al. 1999, Reynolds and Mace 1999, Reynolds et

al 2001, Dulvy and Reynolds 2002, Dulvy et al. 2003, Reynolds 2003, Reynolds et al. 2005), indicate otherwise in that a number of life history characteristics of marine fishes contribute towards extinction susceptibility, vulnerability and, ultimately, risk.

A number of factors predispose species to the risk of extinction (Purvis et al. 2000, Purvis et al. 2005). Extinction susceptibility and vulnerability are dependent upon the interaction of intrinsic and extrinsic factors (Purvis et al. 2005, Reynolds and Jennings 2000, Reynolds et al. 2005, Hudson unpubl. ms.). Life history traits, or intrinsic factors, that render marine fishes susceptible or vulnerable to extinction include large body size at maturity, late age of maturity, slow growth, long generation time and greater longevity, low natural mortality, low fecundity, low intrinsic rate of population increase, and Allee effects at reproduction (Dye et al. 1994, Roberts and Hawkins 1999, Petersen and Levitan 2001, Dulvy et al. 2003, Reynolds et al. 2005). Of these, large body size and late maturity appear to predict best vulnerability of species under exploitation (Reynolds et al. 2005). Spawning site specificity, poor dispersal, specialized feeding or breeding habitats, diadromy-related bottlenecks, and small or restricted range sizes all contribute towards susceptibility and vulnerability (Dye et al. 1994, Roberts and Hawkins 1999, Dulvy et al 2003, Hudson unpubl. ms). Extrinsic factors, mainly from exploitation and habitat effects, also come into play.

One ecological correlate of considerable importance to fishes is spawning site specificity, particularly the location and formation of spawning aggregations (Vincent and Sadovy 1998, Roberts and Hawkins 1999, Reynolds and Jennings 2000, Rowe and Hutchings 2003). Fish spawning aggregations occur when certain reef fish species aggregate in large numbers at specific times and places for the purpose of reproduction. These places, fish spawning aggregation sites (FSAS), can persist for many years (Domeier and Colin 1997). Fishes that utilize spawning aggregation sites form either transient or resident spawning aggregations (Domeier and Colin 1997). Transient aggregations are formed by species that migrate periodically from relatively distant home ranges to specific sites where they persist for days or weeks during a spawning cycle before returning home. Resident spawning aggregations are formed by species that travel relatively short distances to court and spawn over a matter of minutes or hours during a spawning cycle before leaving the aggregation site. Numerous hypotheses have been proposed to account for the occurrence of spawning aggregations at FSAS, but it is likely that multiple benefits are involved that are specific to each species (Domeier and Colin 1997, Claydon 2004). The predictable nature of spawning aggregations in time and space makes them extremely vulnerable to fishing (Johannes and Reipen 1995, Johannes 1997, Rhodes and Sadovy 2002, Sadovy and Vincent 2002, Sadovy et al. 2003, Sadovy and Domeier 2005). Because of fishing with little or no management constraints, a substantial number of aggregations, and hence species populations, have been severely depleted or become extinct locally with consequences felt regionally (e.g. Colin 1992, Sala et al 2001, Sadovy 2004, Sadovy and Domeier 2005).

Spawning aggregations are an example of a reproductive bottleneck that, in the face of exploitation or other negative impacts, has at least two major consequences that ultimately could lead to localized extinction because of Allee effects. The first is the skewing of sex ratios at increasingly low densities that reduce average reproductive

Table 1. Intrinsic and extrinsic factors contributing towards extinction susceptibility in spawning aggregation reef fishes (modified from Hudson, unpublished ms. and Donaldson et al. in prep.)

Type	Factor	Abbreviation
Intrinsic	Large body size (> 35 cm TL)	IF-1
	Late maturity	IF-2
	Long-life span (> 10 years)	IF-3
	Low intrinsic fecundity	IF-4
	Low dispersal capability	IF-5
	Long generation time	IF-6
	Low intrinsic rate of population growth, r	IF-7
	Specialized breeding (spawning aggregation formation, FSAS)	IF-8
	Migratory bottleneck (amphidromy, catadromy)	IF-9
	Limited range size (< 50,000 sq km)	IF-10
Extrinsic A	Over-exploitation (adults and, for culture or aquaria, juveniles)	EF-1
Extrinsic B	Habitat-destruction (effects upon adults or recruiting larvae)	EF-2

success within a population (Petersen and Levitan 2001). The second is the inability to initiate courtship and spawning among aggregating species because of low population densities. A number of species may lack sufficient plasticity to adapt to the levels of behavioral stimuli available at very low population densities and thus may forego reproductive opportunities. The corresponding cumulative effects would result in even lower population densities over time and the eventual loss of the spawning aggregation because of dysfunction. Some aggregating species are able to adapt to lower population densities, however, by shifting to an alternative mating system (e.g. Donaldson 1990, Samoilys 1997, Domeier et al. 2002). In addition, and owing in part to their large body sizes, many species in spawning aggregations demonstrate relatively high levels of catchability and are thus amongst the first to be over-exploited, even in subsistence fisheries (Jennings et al. 1999, Donaldson 2003).

The IUCN Red List of Threatened and Endangered Species classifies species that are at high risk of global extinction (Baille et al. 2004). Outputs from this classification are used typically to determine the conservation status of a given species, to measure trends in extinction risk, and to set priorities for conservation (Baille et al. 2004). Determining the conservation status of an estimated 15,500 marine fish species is a daunting one, with less than 4% assessed thus far. Even the assessment of the proportion of those species that form spawning aggregations is no simple task. A lack of quantitative data on the population status of most species limits the ability to assess species reliably with Red List criteria. One means of circumventing this obstacle is the utilization of simple methods that estimate a species' susceptibility to or risk of extinction. Two models have been proposed recently to make these estimations (Purvis et al. 2005, Hudson unpublished ms.). Both rely upon intrinsic and extrinsic factors. The IUCN SSC Susceptibility Matrix (Hudson unpublished ms.) estimates extinction susceptibility by construction of a matrix of intrinsic (life history) and extrinsic (ecological, exploitation and habitat loss) factors. Species scoring the greatest number of factors are most susceptible and have priority for marine conservation efforts. Recently, this model was validated in double-blind tests of 53 randomly-selected elasmobranch species (Donaldson et al. in prep. A) and it is being applied currently in an analysis of several families of Indo-Pacific reef and insular freshwater fish species (Donaldson et al. in prep. B). The second model (Purvis et al. 2005) estimates extinction risk by summing susceptibility (intrinsic attributes), threat (human impacts), and an interaction term (susceptibility x threat). Here, intrinsic effects likely have little effect alone, given that background rates of extinction are very low compared to current rates, and so species are at risk largely from anthropogenic effects. Thus, correlations between intrinsic attributes and extinction risk reflect the influence of the interaction term (Purvis et al. 2005). This model has been used to assess

terrestrial mammals (Purvis et al. 2005) also being used to assess Indo-Pacific reef and insular freshwater fish species (Donaldson et al. in prep. B).

The purpose of this paper is to illustrate qualitatively and by example the susceptibility to extinction of selected reef fishes that form, or may form, spawning aggregations by an assessment utilizing the IUCN SSC Susceptibility Matrix (Hudson unpublished ms). Those taxa considered here include Micronesian genera of the Serranidae (subfamily Epinephelinae: *Epinephelus* and *Plectropomus*; groupers and coral trouts), Lutjanidae (*Lutjanus* and *Macolor* spp; snappers), Labridae (Tribe Chelinini: *Cheilinus undulatus*; humphead wrasse; subfamily Scarinae: *Bolbometopon*, *Calotomus*, *Cetoscarus, Chlorurus*, *Hipposcarus*, *Leptoscarus* and *Scarus* spp; parrotfishes), Acanthuridae (*Acanthurus*, *Ctenochaetus* and *Naso*; surgeonfishes and tangs), and two members of the Balistidae (*Pseudobalistes* spp; triggerfishes) that, unlike the other taxa, spawn in nests rather than pelagically. The Epinephelinae, Lutjanidae, and Balistidae are transient aggregating fishes while the Labridae (*Chelinus undulatus* and Scarinae) and Acanthuridae are resident spawning aggregation fishes. A more complete and detailed analysis of susceptibility of these and other spawning aggregation fishes, at the species level, in comparison with taxa that do not form spawning aggregations, will appear elsewhere (Donaldson in prep. a).

MATERIALS AND METHODS

The IUCN SSC Susceptibility Matrix (Hudson unpubl. MS) scores a taxon as $1 =$ yes, $0 =$ no, or $0 =$ unknown with respect to its currently understood level of susceptibility to two categories of factors, intrinsic and extrinsic (Table 1). Thus,

$$\text{Extinction Susceptibility} = \text{Intrinsic factor} + \text{Extrinsic factor A} + \text{Extrinsic factor B.}$$

Ideally, only one "yes" answer is required per category of factors for a positive listing of susceptibility for each taxon assessed respectively, where total scores could range from 0 (no factors apply) to 3 (one point for each factor category) (Hudson unpublished ms, Donaldson et al. in prep. A). This method obscures those factors that apply most within a category, however, and so each intrinsic factor with a score of 50% or greater was included in the final tally, only. Thus, possible scores were: intrinsic (10 factors), extrinsic A (one factor, exploitation), and extrinsic B (one factor, habitat destruction). A total score of 12 was possible for the sum of all three categories. Decisions were based upon data from the literature, but mainly from the Society for the Conservation of Reef Fishes Data Base (SCRFA 2006), FISHBASE (Froese and Pauly 2006), Allen (1985), Manooch (1987), Ralston (1987), Randall and Heemstra (1991), Russ et al. (1996), Randall et al. (1997), Myers (1999), Donaldson and Sadovy (2001), Choat and

Robertson (2002), Randall (2002), Martinez-Andrade (2003), Donaldson and Dulvy (2004), Dulvy and Polunin (2004), Randall (2005), and Donaldson et al. (in prep. B). Sample sizes for each taxon (number of species per genus) assessed are as follows: *Epinephelus* (n = 24), *Plectropomus* (n = 4), *Lutjanus* (n = 15), *Macolor* (n = 2), *Chelinus* (n = 1), *Bolbometopon* (n = 1), *Calotomus* (n = 2), *Cetoscarus* (n = 1), *Chlorurus* (n = 6), *Hipposcarus* (n = 1), *Leptoscarus* (n = 1), *Scarus* (n = 23), *Acanthurus* (n = 21), *Ctenochaetus* (n = 6), *Naso* (n = 12), and *Pseudobalistes* (n = 2). A checklist of species and their scoring by genus in the matrix is available as a spreadsheet from the author.

RESULTS

The percentage of species assessed for each genus scoring positively for a Susceptibility Matrix factor is given in Table 2. Those percentages greater than or equal to 50% each had a score of 1. Five genera (*Epinephelus*, *Plectropomus*, *Cheilinus*, *Bolbometopon* and *Cetoscarus*) had the highest susceptibility to extinction scores (total score equals 6 factors in all three categories) among genera, followed by *Macolor* and *Hipposcarus* (total = 5), *Scarus*, *Naso*, and *Pseudobalistes* (total = 4), *Lutjanus*, *Calotomus* and *Chlorurus* (total = 3), and *Scarus*, *Acanthurus* and *Ctenochaetus* (total = 2). Scores are summarized in Table 3.

Overall, the most important intrinsic factors were large body size and spawning aggregation use, followed by long-life span, low intrinsic population increase, and late maturity. Low intrinsic fecundity, low dispersal potential, long generation time, and range size were not important; catadromy, as a migratory bottleneck, was important in only one lutjanid, *Lutjanus argentimaculatus*. Habitat destruction was the most important extrinsic factor in all genera, while over-exploitation was important in 11 of 16 genera.

Table 2. Percentage of species in each genus with a positive score for each Susceptibility Matrix factor. Percentages are rounded to the nearest whole number. N: number of species in genus assessed; IF: intrinsic factor; EF; extrinsic factor A (exploitation) and extrinsic factor B (habitat destruction); ST: subtotal of scores; *denotes not reported. See Table 1 for definitions of factors.

| Taxon | N | Intrinsic (IF) | | | | | | | | | | Extrinsic (EF-A) | Extrinsic (EF- B) |
		1	2	3	4	5	6	7	8	9	10	1	2
Epinephelus	24	83	100	100	0	0	0	33	54	0	0	100	100
Plectropomus	4	100	0	100	0	0	0	75	100	0	0	100	100
Lutjanus 15	47	7		100	0	0	0	7	40	7	0	100	100
Macolor 2	100	0		100	0	0	0	0	100	0	0	100	100
Cheilinus	1	100	0	100	0	0	0	100	100	0	0	100	100
Bolbometopon	1	100	0	100	0	0	0	100	100	0	0	100	100
Calatomus	2	50	0	0	0	0	0	0	0*	0	0	100	100
Cetoscarus	1	100	100	100	0	0	0	0	100	0	0	100	100
Chlorurus	6	50	0	17	0	0	0	33	100	0	0	100	100
Hipposcarus	1	100	0	0	0	0	0	100	100	0	0	100	100
Leptoscarus	1	0	0	0	0	0	0	100	100	0	0	100	100
Scarus	23	35	0	13	0	0	0	26	100	0	0	100	100
Acanthurus	22	14	0	100	0	0	0	23	41	0	0	100	100
Ctenochaetus	6	0	0	100	0	0	0	0	17	0	0	100	100
Naso	12	75	2	100	0	0	0	42	42	0	0	100	100
Pseudobalistes	2	100	0	0	0	0	0	0	100	0	0	100	100

Species **assessed:** *Epinephelus caeruleopunctatus, E. chlorostigma, E. coioides, E. cyanopodus, E. fasciatus, E. fuscoguttatus, E. hexagonatus, E. howlandi, E. lanceolatus, E. macrospilos, E. maculatus, E. malabaricus, E. melanostigma, E. merra, E. milliaris, E. morrhua, E. octofasciatus, E. ongus, E. polyphekadion, E. polystigma, E. retouti, E. socialis, E. spilotoceps, E. stictus, E. tauvina, Plectropomus areolatus, P. laevis, P. leopardus, P. oligacanthus, Lutjanus argentimaculatus, L. biguttatus, L. bohar, L. decussatus, L. ehrenbergi, L. fulviflamma, L. fulvus, L. gibbus, L. kasmira, L. malabaricus, L. monostigma, L. rivulatus, L. rufolineatus, L. semicinctus, L. vitta, M. macularis, M. niger, Cheilinus undulatus, Bolbometopon muricatum, Calotomus carolinus, Cal. spiniferum, Cetoscarus bicolor, Chlorurus bleekeri, C. bowersi, C. frontalis, C. japanensis, C. microrhinos, C. sordidus, Hipposcarus longiceps, Leptoscarus vaigensis, Scarus altipinnis, S. chameleon, S. dimidiatus, S. festivus, S. flavipectoralis, S. forsteni, S. frenatus, S. fuscocaudalis, S. ghobban, S. globiceps, S. hypselopterus, S. longipinnis, S. niger, S. oviceps, S. prasiognathos, S. rivulatus, S. rubrioviolaceous, S. schlegeli, S. spinus, S. tricolor, S. xanthopleura, Scarus sp., Acanthurus achilles, A. bariene, A. blochii, A. dussumieri, A. guttatus, A. japonicus, A. leucocheilus, A. leucopareius, A. lineatus, A. maculiceps, A. mata, A. nigricans, A. nigricauda, A. nigrofuscus, A. nigoris, A. nubilus, A. olivaceus, A. pyroferus, A. thompsoni, A. triostegus, A. xanthopterus, Ctenochaetus binotatus, C. cyanocheilus, C. hawaiiensis, C. marginatus, C. striatus, C. tominiensis, Naso annulatus, N. brachycentron, N. brevirostris, N. caesius, N. hexacanthus, N. lituratus, N. lopezi, N. minor, N. thynnoides, N. tuberosus, N. unicornis, N. vlamingii, Pseudobalistes flavimarginatus, Ps. fuscus.*

Table 3. Summary of Susceptibility Matrix scoring of intrinsic (life history) and extrinsic (A = exploitation; B = habitat destruction) factors. IF = intrinsic factor, EF-A = extrinsic factor A (exploitation), EF-B = extrinsic factor B (habitat destruction).

Genus	IF	EF-A	EF-B	Total
Epinephelus	4	1	1	6
Plectropomus	4	1	1	6
Bolbometopon	4	1	1	6
Cheilinus	4	1	1	6
Hipposcarus	3	1	1	5
Macolor	3	1	1	5
Leptoscarus	2	1	1	4
Naso	2	1	1	4
Pseudobalistes	2	1	1	4
Calotomus	1	1	1	3
Chlorurus	1	1	1	3
Lutjanus	1	1	1	3
Scarus	1	0	1	2
Acanthurus	1	0	1	2
Ctenochaetus	1	0	1	2

DISCUSSION

Application of the Susceptibility Matrix to a suite of Micronesian reef fishes indicates that those taxa that form spawning aggregations have a combination of intrinsic and extrinsic factors that make them susceptible to extinction. Large body size and longevity are two life history factors that appear to correlate with the use of spawning aggregations, and contribute most, along with two extrinsic factors, habitat destruction and exploitation, towards susceptibility. These same two traits are also likely the best predictors of vulnerability to fishing pressure (Reynolds et al. 2005). Large body size is correlated with rates of natural mortality, and thus affects longevity, age at maturity and reproductive effort. At low maximum rates of population increase, such as those brought about by fishing upon vulnerable species in spawning aggregations, lower reproductive output is expected (Reynolds et al. 2005) and the potential for Allee effects likely increases as the size of the aggregation is reduced (Roberts and Hawkins 1999, Petersen and Levitan 2001, Dulvy et al. 2003, Reynolds et al. 2005), particularly among those species that form transient spawning aggregations. Based upon available data and a majority scoring of 50% or greater within genera for this study, the use of spawning aggregations appeared correlated with large body size and long life in *Epinephelus*, *Plectropomus*, *Macolor*, *Cheilinus*, *Bolbometopon*, and *Cetoscarus*.

Those genera that appear to be most susceptible, and thus at a greater risk of extinction, include *Epinephelus*, *Plectropomus*, *Cheilinus*, *Bolbometopon* and *Cetoscarus*. The IUCN Red List (IUCN 2004) currently lists eight species of *Epinephelus* as near-threatened, three as vulnerable, three as endangered, and three as critically endangered. Of those species assessed with the Susceptiblity Matrix here, one species, *Epinephelus lanceolatus*, is considered endangered, and three, *E. coioides*, *E. fuscoguttatus*, and *E. polyphekadion* are considered near-threatened. All four species form spawning aggregations, have large body sizes, and are long-lived. Among species of *Plectropomus*, only *P. leopardus* appears in the Red List, as near-threatened, and this species forms spawning aggregations, has a large body size, and is long-lived, too (SCRFA 2006).

Morris et al. (2000), using a set of criteria largely different from those used in the Susceptibility Matrix or the Red List, but applying a Red List category of threat, assessed 66 species of *Epinephelus* (mainly Caribbean and Western Atlantic in distribution) and five species of *Plectropomus*. Among the *Epinephelus*, three species were deemed critically endangered, two endangered, 25 vulnerable, and 17 near-threatened. Of these, 14 species were assessed with the Susceptibility Matrix. *Epinephelus corallicola*, *E. lanceolatus*, *E. fuscoguttatus*, *E. malabaricus*, *E. polyphekadion*, were considered vulnerable, and *E. howlandi*, *E. maculatus*, *E. melanostigma* near-threatened (Morris et al. 2000). Among *Plectropomus*, three species were deemed vulnerable, one near-threatened, and one data deficient. Of these, two species, *P. areolatus* and *P. leopardus*, were assessed with the Susceptibility Matrix. The former was considered near-threatened and the latter vulnerable (Morris et al. 2000). All of these species in both genera have large body sizes, have long life spans, are vulnerable to over-exploitation because of their high level of catchability (Jennings et al. 1999), and occur in fragile or

threatened inshore habitats.

Macolor spp. are have large body sizes, long life spans, spawns in aggregations, and is vulnerable to over-fishing. Neither species in this genus is listed in the Red List. Both *Cheilinus undulatus* and *Bolbometopon muricatum* are considered highly threatened (Donaldson and Sadovy 2001, Donaldson and Dulvy 2004, Dulvy et al. 2004, Sadovy et al., 2004). The former species is listed currently as Endangered on the IUCN Red List (2004) and the latter will be shortly (Donaldson in prep. b). *Cetoscarus bicolor* is a relatively uncommon species on many reefs (Donaldson unpubl. data), is large and rather showy (Myers 1999), and is likely vulnerable to exploitation by spearing or nets. All three genera are vulnerable to habitat destruction from both natural and anthropogenic forces.

Scoring was likely biased because of incomplete data sets for spawning aggregation use by *Lutjanus, Calotomus, Scarus, Acanthurus, Ctenochaetus, Naso*, and many *Epinephelus* species. *Calotomus, Hipposcarus, Naso* and have large body sizes. *Lutjanus, Acanthurus, Ctenochaetus* and *Naso* are all long-lived. *Pseudobalistes* has both large body size and the use of spawning aggregations, but the longevity of species in this genus is unknown. All are vulnerable to both over-fishing and habitat destruction, too. For example, spawning aggregations of *Pseudobalistes flavimarginatus* at sites in the central Philippines have been eradicated by fishing pressure (unpublished data). Fisheries data for *Scarus, Acanthurus* and *Ctenochaetus* are needed because although these fishes appear to be targeted extensively, quantitative landings data by species is lacking. Susceptibility Matrix scores would likely increase at the generic level if missing data were available or if a larger suite of species were assessed. Nevertheless, this assessment illustrates that fishes that utilize spawning aggregations are also to susceptible extinction and this, coupled with other correlated life history traits, should be considered carefully in fisheries management of reef fish species.

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