Greenback Parrotfish (*Scarus trispinosus*)

Status Review Report

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Executive Summary

On July 15, 2013, NMFS received a petition to list 81 species of marine organisms as endangered or threatened species under the Endangered Species Act (ESA). If an ESA petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). NMFS determined that for 27 of the 81 species, including the greenback parrotfish, the petition had sufficient merit for consideration and that a status review was warranted (79 FR 10104, February 24, 2014). This document is the ESA status review report for the greenback parrotfish, *Scarus trispinosus*.

Greenback parrotfish are endemic to Brazil and range from Manuel Luiz Reefs off the northern Brazilian coast to Santa Catarina on the southeastern Brazilian coast. A major part of their range is the Abrolhos reef complex, encompassing an area of approximately 6,000 km^2 on the inner and middle continental shelf of the Abrolhos Bank. Greenback parrotfish are habitat "generalists" and have been recorded dwelling in coral reefs, algal reefs, seagrass beds and rocky reefs, at depths ranging from 1 m to at least 30 m. The greenback parrotfish is one of the largest parrotfish species with maximum sizes reported around 90 cm. Species in the genus *Scarus* typically exhibit the following reproductive characteristics: protogynous (female first) hermaphroditism, breeding territories, harems, and external fertilization. Large "terminal phase" male parrotfish establish feeding territories which both attract females and are grazed continuously over a period of time. Greenback parrotfish are classified as detritivores (or sometimes roving herbivores) and only occasionally graze on live coral.

The following demographic risk factors were considered in the extinction risk analysis: abundance; growth rate/productivity; spatial structure/connectivity; and diversity. These demographic risk factors reflect concepts that are well founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. According to Section 4 of the ESA, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered as a result of any (or a combination) of the following factors: (A) destruction or modification of habitat, (B) overutilization, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or man-made factors. Specific threats to the greenback parrotfish from each of these five factors were considered. Due to the lack of information regarding threats and the species' life history and ecology, significant uncertainties exist surrounding the levels of risk posed by these threats and demographic factors. Because information on the greenback parrotfish is sparse and often non-quantitative, qualitative risk categories were used to characterize the threats and demographic risk factors. Scientific conclusions about the overall risk of extinction were based on the likelihood and contribution of each particular factor, synergies among contributing factors, and the cumulative impact of all demographic risks and threats on the species. The relatively long life span of this species (estimated at 23 years) means threats can have long-lasting impacts. I defined foreseeable future for the greenback parrotfish extinction risk analysis as approximately 40 years.

The likelihood that each particular demographic factor and threat contributes significantly to the greenback parrotfish extinction risk is presented in the table below. The term "significantly" is used here as it is generally defined – i.e., in a sufficiently great or important way as to be worthy of attention. Ratings are based on a five item scale: Very low = very unlikely; Low = unlikely; Moderate = somewhat likely; High = likely; and Very high = very likely.

Extinction Risk Factor	Likelihood that particular factor contributes significantly to the greenback parrotfish risk of extinction
Demographic Factor	
Abundance	Low
Growth rate/productivity	Low
Spatial structure/connectivity	Very low
Diversity	Very low
ESA Section 4(a)(1) Threat	
Present or threatened destruction, modification, or curtailment of habitat or range	Low
Overutilization by artisanal and commercial fisheries	Moderate
Competition, disease, or predation	Very low
Other natural or man-made factors	Very low
Evaluation of adequacy of existing regulatory mechanisms	Moderate

A recent quantitative assessment of the greenback parrotfish fishery on Abrolhos Bank indicates a very high level of exploitation of this species. The lack of a catch record time series or baseline information prevented a traditional assessment of the status of this species that would ideally be available for an extinction risk analysis. Instead, a Productivity and Susceptibility Analysis (PSA), designed for data deficient and small scale fisheries, placed the greenback parrotfish in the zone of high potential risk of overfishing. Despite study limitations, other research suggests that fishing pressure has reduced the abundance of greenback parrotfish, and in some localities the reduction has been significant. Due to uncertainties and limitations associated with the available data, it is difficult to quantitatively assess the magnitude of the decline in abundance caused by fishing, or to project the magnitude of future impacts of fishing on greenback parrotfish abundance or species survival. With regard to the threat of overutilization by artisanal and commercial fisheries I conclude that this factor is somewhat likely to contribute significantly to the greenback parrotfish extinction risk both now and in the foreseeable future. Traditional fishing regulations designed to limit catch and effort of reef fishes are either non-existent or poorly enforced throughout most of the greenback parrotfish range. Systemic problems associated with the enforcement of no-take marine reserves also contribute to the inadequacy of existing regulatory mechanisms to address the threat to greenback parrotfish from fishing. I conclude that the inadequacy of existing regulatory mechanisms is somewhat likely to contribute significantly to the greenback parrotfish extinction risk both now and in the foreseeable future.

Although scientific studies indicate that some portion of habitat used by greenback parrotfish has been degraded, the available information does not support a conclusion that habitat associated changes contribute to the extinction risk of this species in a significant way. Therefore, I conclude that it is unlikely that the threat of "destruction, modification, or curtailment of habitat or range" contributes significantly to greenback parrotfish extinction risk either now or in the foreseeable future. Based on the sparse information pertaining to the threats "competition, disease, or predation" and "other natural or man-made factors", I conclude that it is highly unlikely that these threats contribute significantly to greenback parrotfish extinction risk either now or in the foreseeable future.

All of the demographic factors evaluated were categorized as either unlikely or very unlikely to contribute significantly to the current extinction risk. Although available information on this species is limited, there are no indications that this species is currently at risk of extinction based on demographic viability criteria. Information on relative abundance and mean density from UVC surveys suggest that greenback parrotfish are still a commonly occurring species on many Brazilian reefs and represent a relatively large proportion of the total fish biomass on some reefs.

After considering the cumulative evidence from all the information available, I conclude that the **greenback parrotfish currently faces a low risk of extinction throughout its range**. This determination is based, in part, on the conclusion that demographic factors related to abundance and productivity are not likely to contribute to the current extinction risk. However, considering the future threat of overutilization from artisanal and commercial fishing and the inadequacy of existing regulatory mechanisms, it is likely that abundance of this species will decrease in the future. As a protogynous hermaphroditic species, greenback parrotfish may be more susceptible to fishing methods that selectively target the largest individuals in the population. Continued selective removal of terminal males, individuals undergoing sexual transition, and the largest females at high rates will result in decreased productivity and likely increase the risk of extinction over time. In addition, as one of the largest parrotfish species with relatively late maturation, greenback parrotfish may more vulnerable to overexploitation than smaller, faster maturing parrotfish species. Although not possible to accurately quantify, at least qualitatively, the overall risk of greenback parrotfish extinction in the foreseeable future is likely greater than the current risk of extinction. Therefore, I conclude that the **greenback parrotfish risk of extinction in the foreseeable future is between low and moderate**. That is, the risk of extinction in the foreseeable future is greater than low but less than moderate.

Table of Contents

Background

On July 15, 2013, NMFS received a petition from WildEarth Guardians to list 81 species of marine organisms as endangered or threatened species under the Endangered Species Act (ESA). The greenback parrotfish was one of the 81 species included in this petition. Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). NMFS determined that for 27 of the 81 species, including the greenback parrotfish, the petition had sufficient merit for consideration and that a status review was warranted (79 FR 10104, February 24, 2014; http://www.nmfs.noaa.gov/pr/species/petition81.htm for the Federal Register notices). This document is the ESA status review report for the greenback parrotfish, *Scarus trispinosus*.

The ESA requires that listing determinations should be made on the basis of the best scientific and commercial information available, after taking into consideration any efforts by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect the species (16 U.S.C. §1533(b)). In order to compile the best available information on this species, I conducted an extensive literature search and contacted several researchers for reprints of relevant papers, unpublished papers, and gray literature I could not otherwise obtain. As announced in the 90-day finding, NMFS also solicited the public for relevant data and information on this species from February 24, 2014, through April 25, 2014. Relevant information submitted by the public and extracted from my literature search is incorporated into this status review. After compiling the best available information through January 7, 2015, I completed a thorough review of the biology, population status and future outlook for the greenback parrotfish. This document reports the findings of the scientific review as well as the conclusions regarding the extinction risk of the greenback parrotfish as a candidate for listing under the ESA. These conclusions are subject to revision should important new information arise in the future.

Life History and Ecology

Taxonomy and Distinctive Characteristics

Scarus trispinosus (Valenciennes 1840) is a member of a group of shallow water fishes (parrotfishes in the family Scaridae) that are closely associated with coral reefs (Bellwood, 1994; Randall et al., 1997). Parrotfishes are distributed circumtropically and originated during the Miocene-Oligocene (14-35 million years ago) in the tropical Tethys Sea (Bellwood, 2001). Differentiation occurred prior to and after closure of the Tethys Sea and was promoted by an increasing number of habitat associations and feeding modes. Early parrotfishes were browsers inhabiting seagrass beds and shifted to feeding as scrapers and excavators inhabiting rocky and coral reef habitats (Bellwood, 1994; Streelman et al., 2002). Parrotfishes are considered a monophyletic group, and are often classified as a subfamily or tribe (Scarinae) of the wrasse family (Labridae). Currently, there are 100 species of parrotfish (family Scaridae) in 10 genera (Parenti and Randall, 2011; Rocha et al., 2012).

Parrotfishes are distinguished from other labroid fishes based upon their unique dentition (dental plates derived from fusion of teeth), loss of predorsal bones, lack of a true stomach, and extended length of intestine (Randall, 2005). Morphological features or meristic values for separating parrotfish genera or identifying species are often lacking (Bellwood, 2001). Most identifications therefore must rely on color patterns, which typically change with different life stages and after death. The greenback parrotfish, *Scarus trispinosus*, has six predorsal scales, two scales on the third cheek row, and roughly homogeneously-colored scales on the flanks (Moura et al., 2001). Juvenile *S. trispinosus* are similarly colored to the adults, but bear a yellowish area on the nape (Moura et al., 2001). Common names for *Scarus trispinosus* found in the literature include greenbeak parrotfish, greenlip parrotfish, and blue parrotfish; I will use greenback parrotfish. Records from Brazil of the midnight parrotfish (*Scarus coelestinus*) were likely misidentified greenback parrotfish (Rocha et al., 2012).

Range, Distribution and Habitat Use

Greenback parrotfish are endemic to Brazil and range from Manuel Luiz Reefs some 86 km off the northern Brazilian coast to Santa Catarina on the southeastern Brazilian coast (Figure 1) (Moura et al., 2001; Ferreira et al., 2010). Greenback parrotfish are widely distributed in reef environments throughout their range (Bender et al., 2012). Brazilian coral reefs are the southernmost reefs in the western Atlantic Ocean (Kikuchi et al., 2003). Reef environments occur along at least a third of the roughly 8,000 km Brazilian coastline, with coral reefs in the north (latitude $0^{o}52'$N to 19^{o}S) and rocky reefs in the south (20^{o}S to 28^{o}S) (Floeter et al., 2007). The main known reef areas off the Brazilian coast are shown in Figure 2 (Castro and Pires, 2001). The most northern coral reefs (Manuel Luiz and Banco do Alvaro) cover 99 km^2 and are located far from shore (up to 86km) and 180 km from the nearest large settlement (Castro and Pires, 2001). There is evidence of reefs in the 1,000 km stretch between Parcel do Manuel Luiz and the Cape of São Roque but this area has received less scientific study than other parts of the Brazilian coast. Near the Cape of São Roque, in an area extending 100 km, there are a few isolated reefs located several miles from shore (Castro and Pires, 2001). The reefs off of Brazil's oceanic islands are located far offshore (266 km for Atol das Rocas and 416 km for Fernando de Noronha). The area known as "Reefs Coast" is a 600 km stretch of coast in northeastern Brazil that contains shallow coastal reefs (Castro and Pires, 2001). Due to the proximity of large cities and ease of access, these reefs include some of the most heavily impacted areas in terms of human activity on the Brazilian coast (Castro and Pires, 2001). The State of Bahia ('BA' on Figure 2) has reefs along more than 900 km of its shoreline (Leão, 1996). This area contains a diverse mix of reef types including shallow bank reefs, fringing reefs, and isolated offshore banks (Leão, 1996). This area includes the Itacolomis Reefs (Figure 2 - sector 4) described as large, roundish reef structures, separated from each other by irregular canals located in an area varying from a few hundred meters to approximately 10 km from the shoreline (Leão, 1996). The Abrolhos reef complex (Figure 2 - sector 5) located on a widening section of the continental shelf (up to 200 km) in southern Bahia is considered the largest and richest coral reef system in the South Atlantic (Francini-Filho et al., 2008). This reef complex encompasses an area of approximately 6,000 km^2 on the inner and middle continental shelf of the Abrolhos Bank (Kikuchi et al., 2003). There are several reef structures in Abrolhos, of varying morphologies including fringing reefs, isolated columns 15 to >25 m tall known as "chapeirões," and offshore bank reefs (Leão, 1996). In 2008, researchers from Conservation International (CI), and the Federal Universities of Espírito Santo and Bahia announced the discovery of new deep reef structures (60 to 220 feet) on Abrolhos Bank which have been less exploited due to their depth and relative inaccessibility (pers. comm. Rodrigo de Moura and Guilherme Dutra, Conservation International Brazil). South of Abrolhos, in Espirito Santo and Rio de Janeiro states, only small isolated coral communities are found and corallines are rare south of Cape Frio due to shifting oceanographical conditions which brings up much colder waters (Castro and Pires, 2001). The southeastern area includes the nearshore reefs of Arraial do Cabo which cover about 1,000 m^2 in Rio de Janeiro state (Floeter et al., 2006).

Figure 1. Range map of greenback parrotfish (*Scarus trispinosus*) (source: Padovani-Ferreira et al. 2012).

Specific areas where greenback parrotfish are known to occur based on either underwater visual census (UVC) surveys or fishery dependent information include: Tamandare reef complex, located in the "Reefs Coast" area (Feitosa and Ferreira, 2014); sub-regions of Litoral Norte, Salvador, and Baixo Sul off Bahia State (Costa Nunes et al., 2012); Rio Grande do Norte region (Cunha et al., 2012); Sapatas Reef and Cabeço dos Cangulos Reef off Paraíba in northeastern Brazil (Honório et al., 2010; Honório, 2011); Franceses Island off the central coast of Brazil (Pinheiro et al., 2010); Arraial do Cabo in the southeastern part of its range (Ferreira et al., 2001); Laje de Santos Marine State Park on the southeastern coast off São Paulo state (Luiz et al., 2008); and throughout the Abrolhos Bank reef complex. Greenback parrotfish have been

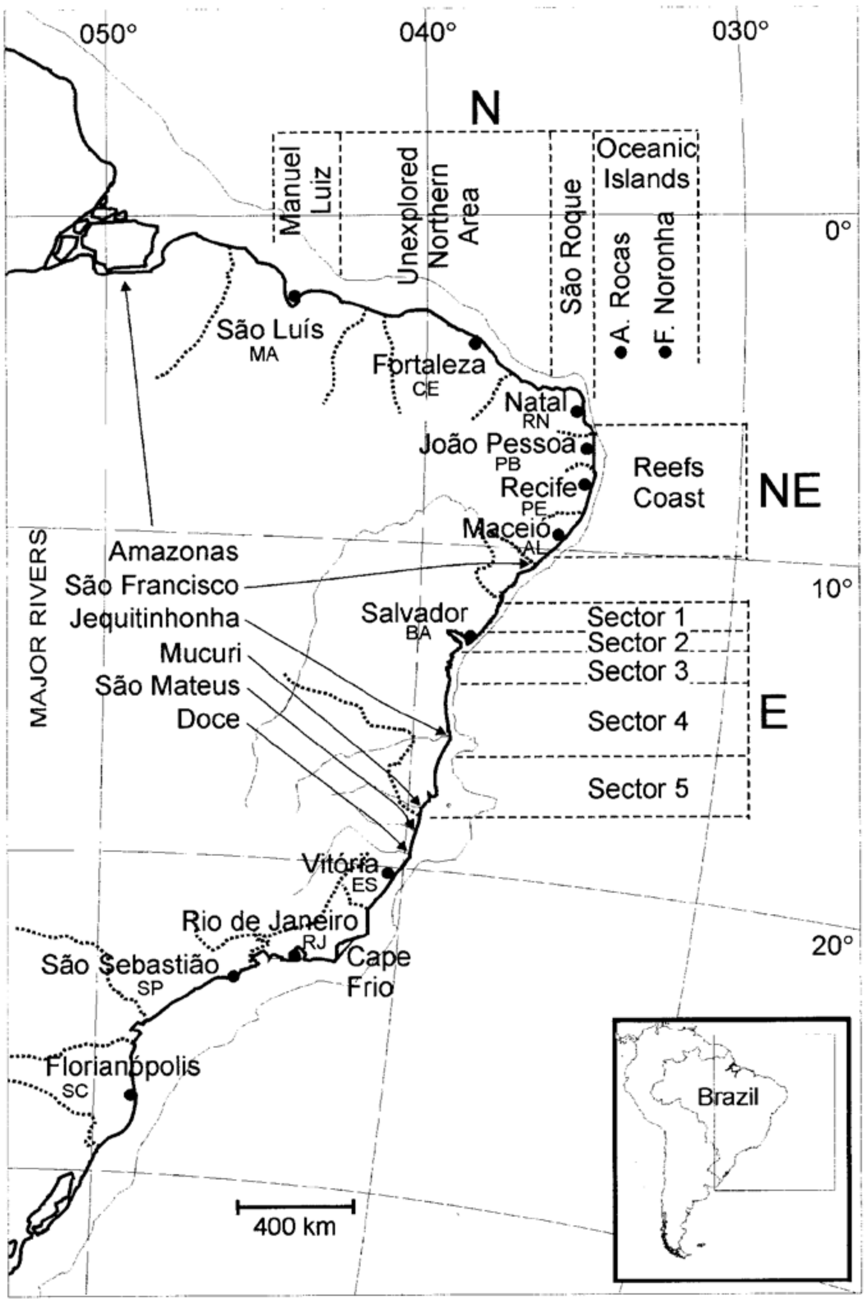

Figure 2. Map of the Brazilian coast, indicating the main known reef areas (within dotted lines): MA = Maranhão State; CE = Ceará State; RN = Rio Grande do Norte State; PB = Paraíba State; PE = Pernambuco State; AL = Alagoas State; BA = Bahia State; ES = Espírito Santo State; RJ = Rio de Janeiro State; SP = São Paulo State; SC = Santa Catarina State. Dotted lines indicate State borders (copied from Castro and Pires, 2001).

recorded at diverse reef habitats within the Abrolhos reef complex including Itacolomis Reef (Francini- Filho and Moura, 2008); Abrolhos National Marine Park (Francini-Filho and Moura, 2008; Kikucki et al. 2012); Popa Verde Reefs; Paredes Reefs; Southern Abrolhos Reefs

(Ferreira, 2005); offshore chapeirões; and on the fringing reef off Santa Bárbara Island (Kikucki et al., 2012). Given the geographic range and variety of reef habitat types where they have been found, it can be inferred that their distribution includes most reef environments off the Brazilian coastline. Notable exceptions where greenback parrotfish are not found include the Brazilian oceanic islands of St. Peter and St. Paul, Fernando de Noronha, Rocas Atoll, Trinidad, and Martin Vaz (Freitas, 2014b).

The majority of parrotfishes inhabit coral reefs, but many can also be found in a variety of other habitats including subtidal rock and rocky reefs, submerged seagrass, and macroalgal and kelp beds (Comeros-Raynal, 2012). There is little evidence that scarids have strict habitat requirements (Feitosa and Ferreira, 2014). Instead, they appear to be habitat "generalists" and their biomass is weakly related to the cover of particular reef feeding substrata (Gust, 2002). Comeros-Raynal (2012) categorized 51 *Scarus* species into one of three habitat-use categories: 1) exclusively coral reef dependent, 2) primarily found on coral reefs, and 3) coral reef and mixed habitat. The greenback parrotfish was one of 22 species categorized as "coral reef and mixed habitat." They have been recorded dwelling in coral reefs, algal reefs, seagrass beds and rocky reefs, at depths ranging from 1 m to at least 30 m (Moura et al., 2001).

Cover type may impact juvenile parrotfish densities depending on the level of protection and shelter provided (Feitosa and Ferreira, 2014). In a study of the endemic Brazilian red-eye parrotfish (*Sparisoma axillare*), Feitosa and Ferreira (2014) found that smaller individuals (<5 cm) preferred to inhabit macroalgal beds and the reef flat, whereas juveniles larger than 5 cm were more abundant in the back and fore reefs. Mumby et al. (2004) found that juvenile rainbow parrotfish (*Scarus guacamaia*) have a strong functional dependency on mangroves, and mangrove removal has contributed to the local extirpation of this species in parts of the Caribbean. However, habitat dependency or preferences of juvenile greenback parrotfish have not been studied.

Growth and Reproduction

The greenback parrotfish is one of the largest parrotfish species with maximum sizes reported around 90 cm (Previero, 2014a). Previero (2014a) conducted the first study of age and growth in greenback parrotfish. Otoliths were sampled from artisanal fisheries on Abrolhos Bank for 358 fish ranging from 13.5 cm to 86.0 cm. The following von Bertalanffy growth parameters were estimated for greenback parrotfish: $L_\infty = 84.48$ cm, $K = 0.17$ and $t_0 = 1.09$. No significant differences were found in these estimated growth parameters between males and females. Previero (2014a) estimated a maximum life span for this species of 23 years. Greenback parrotfish size at first maturity (i.e., 50% mature) has been estimated at 39.1 cm TL, with 100% maturity achieved at 48.0 cm TL (Freitas et al., 2012). Based on a similar "sister" species *Scarus guacamaia*, a generation length (i.e., the age at which half of total reproductive output is achieved by an individual) of 7 to 10 years has been inferred for the greenback parrotfish (Padovani-Ferreira et al., 2012).

Parrotfish typically exhibit the following reproductive characteristics: sexual change, divergent sexual dimorphism, breeding territories, and harems (Streelman et al., 2002). Territories of larger male parrotfish have been shown to contain more females, suggesting that male size is an important factor in reproductive success (Hawkins and Roberts, 2003). Fertilization occurs externally in parrotfishes and there is no parental care (Hawkins and Roberts, 2003). Although parrotfish are usually identified as protogynous hermaphrodites (Choat and Robertson, 1975; Choat and Randall, 1986), evidence of gonochromism has been reported for three species within the parrotfish family (Hamilton et al., 2007). In protogynous hermaphroditic parrotfish species females will always turn into males if they live long enough, but they cannot change sex before they are sexually mature (Robertson and Warner, 1978).

In a study of the Solomon Island population of green humphead parrotfish (*B. muricatum*), Hamilton et al. (2007) noted that presence of an ex-ovarian lumen in the testis cannot be used as conclusive evidence of hermaphroditism. Histological evidence of an immature male, the absence of a female biased sex ratio, and high frequencies of small males around the size that females mature, all suggested that *B. muricatum* is essentially gonochoristic with high incidences of anatomical but non-functional hermaphroditism (Hamilton et al., 2007). Freitas et al. (2012) studied reproduction of greenback parrotfish on Abrolhos Bank. From 2006-2013 they sampled a total of 1,182 fish, of which they collected gonads and prepared histological sections for 304. Results showed a strong female biased sex ratio (282 females; 22 males), the distribution of males only in the largest size classes, and histological evidence of sexual change from female to male. Freitas et al. (2012) did not find histological evidence of an immature male, nor did they find a high frequency of small males around the size that females mature. Based on this study they concluded that the greenback parrotfish is a protogynous hermaphrodite.

Some parrotfish species exhibit “diandry,” which refers to the existence of two distinct types of males (primary and secondary) in protogynous hermaphrodites (Reinboth, 1967; Streelman et al., 2002). Primary (or initial) phase males are those that are born as male without a prior existence of a female phase (Hoar, 1983). Secondary males are derived from sex changed females and possess lobate testicular tissue protruding into the former ovarian cavity in a manner comparable to the ovarian lamellae. Based on the available scientific information I could not determine if greenback parrotfish are diandrous. Freitas et al. (2012) reported that none of the greenback parrotfish males (n=22) in their study were smaller than the estimated size at first maturity. Although this finding suggests that greenback parrotfish are monandric (i.e., males only produced through sexual transition) and not diandrous, additional studies are needed to confirm this trait.

Freitas et al. (2013) used a methodological approach developed by the Society for the Conservation of Reef Fish Aggregations (Colin et al., 2003) to study spawning aggregations of Brazilian reef fish on Abrolhos Bank. This approach used a combination of fishery independent biological surveys and semi-structured personal interviews with fishermen. They found that the spawning season for greenback parrotfish occurs roughly from December through March.

Feeding and Trophic Role

Most parrotfish species are considered “generalists” in feeding behavior **–** they can rely on food types other than algae, such as detritus, crustaceans, sponges, gorgonians and dead or live coral

(Feitosa and Ferreira, 2014). Parrotfishes typically undergo a shift from omnivorous feeding to feeding on plant materials, which occurs during growth from around 1.0 to 3.0 cm TL (Bellwood, 1986). Greenback parrotfish are classified as either detritivores or roving herbivores and not obligate corallivores (as some other reef fish), since only a small percent of their diet comes from feeding on live coral (Comeros-Raynal, 2012). Francini-Filho et al. (2008c) found that greenback parrotfish allocated 0.8% of their bites to live corals compared to the reef parrotfish which allocated 8.1% in the same study area. Greenback parrotfish were observed feeding on *Orbicella cavernosa* most frequently (n = 11), followed by *Favia gravida* (n = 3), *Siderastrea* spp. (n = 2), *Mussismilia hartti* (n = 1) and *Porites astreoides* (n = 1). The mean size of greenback parrotfish engaging in coral predation was 29.6 cm TL (Francini-Filho et al., 2008c). Individuals < 20 cm TL were occasionally recorded grazing over live coral, but never left a distinct scrape and apparently removed only a thin layer of mucus and cyanobacteria over the coral tissue (Francini-Filho et al., 2008c).

Parrotfish species differ markedly in terms of jaw morphology, foraging activity and extent of substratum excavation, and are typically divided into three functional groups: browsers, scrapers and excavators. Browsers use their discrete teeth to remove food from the substrata without scarring it. Scrapers make shallow bites, leaving only a scrape marked by dislodged algae. Excavators remove large pieces of the substratum while feeding, leaving prominent scars (Bellwood & Choat, 1990; Streelman et al., 2002). Large excavating members of the parrotfish fauna may play another important functional role of facilitating bioerosion on coral reefs (Bellwood et al., 2003). Juvenile parrotfishes are typically scrapers (Bellwood and Choat, 1990), and their excavating potential may be related to body size (Bruggemann et al., 1996). Greenback parrotfish can be categorized as either scrapers or excavators depending on body size (Francini-Filho et al., 2008c). In a study by Francini-Filho et al. (2008c), larger individuals fed at lower rates and left larger scars than smaller individuals, performing a more intense bioerosion activity. Larger males will establish feeding territories, which attract females and are grazed continuously over a period of time (Francini-Filho et al., 2008c).

Ferreira and Goncalves (2006) found that greenback parrotfish on the Abrolhos Archipelago spent much of the daytime foraging over the extensive crustose coralline algae flats which form a large portion of the Abrolhos reef framework. They also observed daily movements by greenback parrotfish among different habitats around the islands (e.g. coral reefs, rocky reefs, seaweed and seagrass beds and crustose coralline flats) to take advantage of different food resources available. The foraging plasticity of greenback parrotfish, acting either as scraper, excavator, or browser, suggests that this species has the capacity to exercise some level of selectivity over their primary food, and are thus adapted to foraging in different modes. Feitosa and Ferreira (2014) found that once a given reef becomes algal-dominated parrotfish can alter food selection and interspecific interactions depending on the resulting algal community.

Abundance and Population Structure

There are no historical or current abundance estimates for greenback parrotfish. Several studies have reported mean densities of greenback parrotfish over time at specific reef locations. Francini-Filho and Moura (2008b) monitored reef fish assemblages from 2001-2005 in four areas on Abrolhos Bank: 1) no-take reserve of Timbebas Reef (i.e., “no-take old”), 2) multiple-use zone of Itacolomis Reef, 3) no-take reserve of Itacolomis Reef (i.e., “no-take new”), and 4) open-access coastal reefs. Samples were obtained annually from between three and seven sites within each area from January through March. Two habitats were sampled within each site: pinnacle tops (2–6m depth) and walls (3–15m depth). Between 15 and 20 samples were obtained per habitat per site per year, totaling 2,820 samples during the entire 5-year study period. Fish counts were made using a nested stationary UVC technique adapted from Bohnsack and Bannerot (1986). Results showed a statistically significant increase in greenback parrotfish mean biomass from 2001 to 2002 on the Itacolomis Reef multiple-use zone (Figure 3). This increase was followed by a statistically significant decrease in greenback parrotfish mean biomass in this same area from 2002 to 2003. Based on overlapping 95% confidence intervals, mean biomass on the Itacolomis Reef multiple-use zone recorded for the years 2001, 2003, 2004, and 2005 were not statistically different from each other. For the Itacolomis no-take reserve (i.e. no-take new), mean biomass of greenback parrotfish was significantly greater in 2002 and 2003 compared to 2001. Although mean biomass on the Itacolomis no-take reserve was lower in 2004 and 2005 compared to 2002 and 2003, these differences were not statistically significant. No statistically significant differences were found in mean biomass of greenback parrotfish between any of the five years at the other two study areas (i.e., Timbebas Reef “no-take old” and open access reefs). These results do not indicate a declining trend in greenback parrotfish abundance. Only one out of four study areas (Itacolomis multiple-use) showed a statistically significant decline in mean biomass from one year to the next, and mean biomass for four out of the five years were not statistically different from one another in this area.

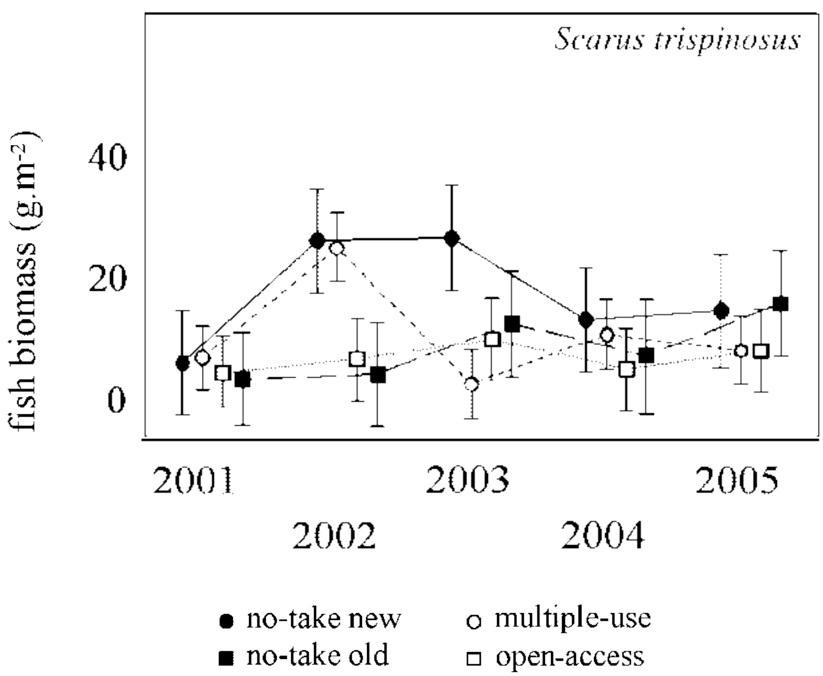

Figure 3. Biomass (mean +/- 95% confidence limits) of greenback parrotfish in four areas over 5 years (copied from Francini-Filho and Moura, 2008b).

Greenback parrotfish were found to be relatively abundant in monthly underwater visual census (UVC) counts conducted at Arraial do Cabo (Rio de Janeiro State) during 1992 but entirely absent from census counts conducted in 2002 at the same location (Figure 4) (Floeter et al., 2007). Arraial do Cabo is a relatively small (1,000 m^2) marine extractive reserve with heavy exploitation due to its proximity to a traditional fishing village and general lack of enforcement of fishing regulations (Floeter et al., 2006; Bender et al., 2014). Bender et al. (2014) compiled a more contiguous time series of observed greenback parrotfish mean densities at Arraial do Cabo. UVC surveys were conducted using a technique adapted from Bohnsack and Bannerot (1986) during 9 out of 23 years from 1992 to 2012. Greenback parrotfish mean density declined from 1992 to 1995 and the species was not seen during all 7 subsequent UVC surveys from 1997 through 2012 (Figure 5, black bars). The UVC surveys, combined with interviews with local fishermen, suggest that the greenback parrotfish was once abundant at Arraial do Cabo and are now thought to be locally extirpated from this area (Floeter et al., 2007; Bender et al., 2014).

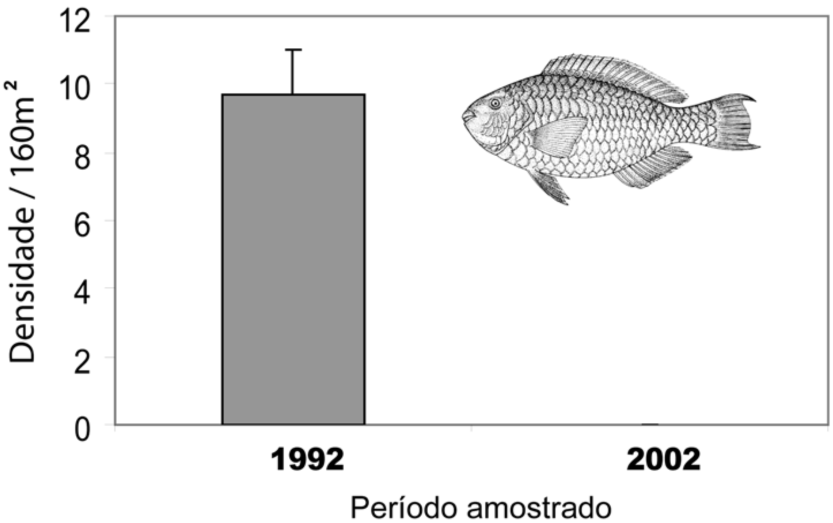

Figure 4. Mean density (and SE) of *Scarus trispinosus* at Ponta da Fortaleza - Arraial do Cabo, through monthly visual census (n = 5) conducted in 1992 and 2002 (from Floeter et al., 2007).

Previero (2014b) reported average densities of greenback parrotfish by size class from 2001-2009 based on UVC surveys conducted at the following Abrolhos Bank sites: Abrolhos Archipelago; Itacolomis Reef; Parcel dos Abrolhos; Parcel das Paredes; and Timbebas Reef (Table 1). Average densities fluctuate considerably during this time series with no strong trends detected for any of the size classes (note: variances were not available for evaluation of statistical significance between years). For the largest size class (40-100 cm) that would be most targeted by fishing, the years 2006-2009 represent four out of the five largest mean densities of greenback parrotfish in the nine year time series.

Ferreira (2005) conducted a baseline study of reef fish abundance at six different sites within the Abrolhos Reef complex in 2005. Relative fish abundance was estimated using the Bohnsack and

Bannerot (1986) UVC technique replicated for each site. The family Scaridae was the most abundant fishery target family, constituting 30% to 57% of all fishes observed across six different Abrolhos reef sites. The most abundant scarids observed in this study were *Sparisoma axillare*, *Scarus trispinosus* (greenback parrotfish), and *Sparisoma amplum*. The mean density of greenback parrotfish ranged from 0.80 (Southern Reefs) to 6.04 (Timbebas Reefs) fish per 100 m^2 across the six sites. The relative abundance of greenback parrotfish among all fishery targeted species ranged from 3.05% (Southern Reefs) to 15.25% (Timbebas Reefs) (Ferreira, 2005). Francini-Filho and Moura (2008b) found that greenback parrotfish accounted for 28.3% of the total fish biomass across a diverse range of Brazilian reefs surveyed from 2001-2005. On the Itacolomis Reef alone, greenback parrotfish accounted for 37.4% of the total fish biomass and 45.6% of the total target fish biomass (Francini-Filho and Moura, 2008a). Kikucki et al. (2012) conducted a rapid assessment of fish communities in the Abrolhos National Marine Park in three offshore chapeirões and at eight sites in the fringing reef off Santa Bárbara Island. Average mean density recorded for greenback parrotfish was 11.8 individuals per 100 m^2 and this species was ranked 8th in mean density among all species recorded. These studies indicate that the greenback parrotfish is not only the most abundant parrotfish species on Abrolhos Bank (Francini-Filho and Moura, 2008b) but is also one of the dominant reef species overall in terms of fish biomass at some sites within the Abrolhos complex.

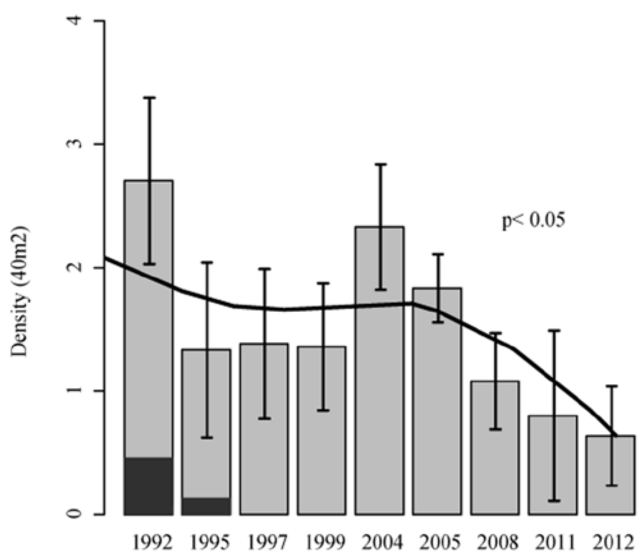

Figure 5. Mean densities (and SE) of Scarinae species in Arraial do Cabo from underwater visual census. Black portion of bars correspond to the contribution of greenback parrotfish to densities (from Bender et al., 2014).

Table 1. Average density of *Scarus trispinosus* (grams per m^2) at Abrolhos Bank sampling points by visual census between 2001 and 2009, by size class (copied from Previero, 2014b).

Size Class cm	2001	2002	2003	2004	2005	2006	2007	2008	2009
0-2	0.00	0.00	0.00	0.08	0.16	0.08	0.00	0.40	0.00
2-10	3.50	7.64	7.40	9.31	4.70	5.97	6.53	4.77	13.21
10-20	1.75	2.19	3.48	2.61	3.36	3.08	2.35	1.37	2.88
20-30	2.45	3.38	3.12	2.21	3.72	3.50	2.07	1.81	2.17
30-40	1.61	2.79	1.39	1.71	2.51	3.42	2.01	1.49	1.99
40-100	0.90	3.34	1.95	1.71	2.07	2.83	3.18	2.79	2.41

Two studies reported mean densities of greenback parrotfish on northeastern Brazilian reefs. Medeiros et al. (2007) used a stationary UVC technique adapted from Bohnsack and Bannerot (1986) to evaluate reef fish assemblage structure on two shallow reefs (maximum depth 6 m) located 1.5 km off the coast of João Pessoa, Paraíba state. A total of 60 censuses were done at randomly chosen locations between April and October of 2006. Greenback parrotfish densities were lower on the recreationally exploited reefs (0.15 fish per 100 m^2) than on unexploited reefs (0.85 fish per 100 m^2). In this study, greenback parrotfish accounted for only 0.04% of all fish recorded on the exploited reefs and 0.56% of all fish recorded on the unexploited reefs. Feitosa and Ferreira (2014) studied reef fish distribution on the shallow, fringing reef complex at Tamandare (northeastern coast) between December 2010 and May 2012. Reef fish abundances were estimated based on a UVC belt-transect technique modified from Brock (1954). Four visually different habitats were selected for sampling: macroalgal beds; back reef; reef flat; and fore reef. Greenback parrotfish were only observed on the fore reef where the mean density was 2.0 fish (SE +/- 0.55) per 100 m^2.

Assessment of Extinction Risk

Approach

I considered demographic risks to the greenback parrotfish, similar to approaches described by Wainwright and Kope (1999) and McElhany et al. (2000). In this approach, the collective condition of individual populations is considered at the species level according to four demographic viability risk criteria: abundance; growth rate/productivity; spatial structure/connectivity; and diversity. According to Section 4(a)(1) of the ESA, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered as a result of any (or a combination) of the following factors: (A) destruction or modification of habitat, (B) overutilization, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or man-made factors. Specific threats to the greenback parrotfish from any of these five factors were considered. All of the available scientific and commercial information is presented here, and an assessment is made regarding the likelihood that each particular demographic factor or threat is contributing, on its own or in combination, to the risk of extinction of the greenback parrotfish population. Due to the lack of information regarding threats and the species' life history and ecology, significant uncertainties exist surrounding the levels of risk posed by these demographic factors and threats. Because information on the greenback parrotfish is sparse and often non-quantitative, I used the following qualitative risk category five item scale to characterize the likelihood that a particular demographic viability criteria or threat contributes significantly to the species' risk of extinction:

- Very low – it is very unlikely that the particular threat or demographic factor contributes significantly to the risk of extinction
- Low - it is unlikely that the particular threat or demographic factor contributes significantly to the risk of extinction
- Moderate - it is somewhat likely that the particular threat or demographic factor contributes significantly to the risk of extinction
- High - it is likely that the particular threat or demographic factor contributes significantly to the risk of extinction
- Very high - it is very likely that the particular threat or demographic factor contributes significantly to the risk of extinction

(Note: The term "significantly" is used here as it is generally defined – i.e., in a sufficiently great or important way as to be worthy of attention).

Scientific conclusions about the overall risk of extinction faced by the greenback parrotfish under present conditions and in the foreseeable future are based on my evaluation of the species' demographic risks and Section 4(a)(1) threat factors. Assessment of overall extinction risk considered the likelihood and contribution of each particular factor, synergies among contributing factors, and the cumulative impact of all demographic risks and threats on the species. I do not make recommendations as to whether the greenback parrotfish should be listed as threatened or endangered. I used the following 5-item qualitative scale for assessment of overall extinction risk:

- No or very low risk - it is very unlikely that this species is at risk of extinction due to threats or trends in abundance, productivity, spatial structure, or diversity.
- Low risk - it is unlikely that this species is at risk of extinction due to trends in abundance, productivity, spatial structure or diversity; however, threats may alter those trends but not by enough to cause the species to be influenced by stochastic or depensatory processes.
- Moderate risk - the species exhibits a trajectory indicating that it is approaching a level of abundance, productivity, spatial structure, and or/diversity that places its persistence in question. A species may be at moderate risk of extinction due to declining trends in abundance, productivity, spatial structure, or diversity and/or threats that inhibit the reversal of these trends.
- High risk - the species is at or near a level of abundance, productivity, spatial structure, and or/diversity that places its persistence in question. It faces clear threats that are likely to create such demographic risks and inhibit their reversal.
- Very high risk - the species is strongly influenced by stochastic or depensatory processes resulting from threats and demographic risks that jeopardize its existence.

The term “foreseeable future” in the ESA’s definition of “threatened” is defined as the timeframe over which threats can be reliably predicted to impact the biological status of the greenback parrotfish. In considering an appropriate “foreseeable future” timeframe, I considered both the life history of the greenback parrotfish and whether I could project the impact of the particular threat. The relatively long life span of this species (estimated at 23 years by Previero, 2014a) means threats can have long-lasting impacts. I defined foreseeable future for the greenback parrotfish extinction risk analysis as approximately 40 years. Determination of the ESA listing status of each species is a decision that includes the findings and conclusions in this report as well as consideration of existing conservation efforts, the certainty of implementation and effectiveness of those conservation efforts not yet implemented or not yet shown to be effective, as well as other management considerations.

Analysis of Demographic Risk Factors

The approach of considering demographic viability criteria to help frame the evaluation of extinction risk is widely used in NMFS status reviews (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). These viability criteria reflect concepts that are well founded in conservation biology and that individually and collectively provide strong indicators of extinction risk.

Abundance

Population abundance is an important determinant of risk, both by itself and in relation to other factors (McElhany et al., 2000). Small populations are subject to a host of risks intrinsic to their low abundances, while large populations can exhibit a greater degree of resilience (McElhany et al., 2000). Although there are no population abundance estimates for this species, mean densities and relative abundance of greenback parrotfish have been recorded by several researchers using UVC techniques (see “Life History and Ecology: Abundance and Population Structure” above for more details). Results indicate that the greenback parrotfish is not only the most abundant species of parrotfish on Abrolhos Bank but is also one of the dominant reef species overall in terms of fish biomass at some sites within this reef complex (Ferreira, 2005; Francini-Filho and Moura, 2008b; Kikucki et al. 2012). Based on limited data, mean densities and relative abundance of greenback parrotfish reported from studies on northeastern Brazilian reefs were generally lower that those reported on Abrolhos reefs (Medeiros et al., 2007; Feitosa and Ferreira, 2014). It is unclear whether differences in greenback parrotfish mean densities across study sites are due primarily to different levels of fishery exploitation or to the natural distribution of this species.

Time series datasets for detecting trends in greenback parrotfish abundance over time are limited. Three studies (Francini-Filho and Moura, 2008b; Bender et al., 2014; Previero, 2014b) reported mean densities at particular reef sites over multiple years (see “Life History and Ecology: Abundance and Population Structure” above for more details). Only one of these studies indicated a declining trend in greenback parrotfish abundance over time (Bender et al., 2014). UVC surveys, combined with interviews with local fishermen, suggest that the greenback parrotfish was once abundant at Arraial do Cabo (Rio de Janeiro state) and are now thought to be locally extirpated from this area (Floeter et al., 2007; Bender et al., 2014). Arraial do Cabo is a relatively small (1,000 m^2) marine extractive reserve with heavy exploitation due to its proximity to a traditional fishing village and general lack of enforcement of fishing regulations (Floeter et al., 2006; Bender et al., 2014).

Studies indicating a declining trend in greenback parrotfish abundance over time are lacking. Increased fishing pressure on this species in the past two decades has likely reduced overall abundance (Previero, 2014b), but available data are insufficient to quantitatively assess the magnitude of this decline. Despite the likely negative impact of fishing on abundance, mean densities recorded for greenback parrotfish are very high when compared to mean densities recorded for similar sized species in the north-western tropical Atlantic (Debrot et al., 2007). In parts of their range greenback parrotfish are still a commonly occurring species and represent a large proportion of the total fish biomass on some reefs. UVC time series data indicate that greenback parrotfish have been locally extirpated from a relatively small reef near the southern range of this species (Rio de Janeiro state). However, the impact of this localized decline on the greenback parrotfish population as a whole may be small. Based on the available scientific and commercial information, I conclude that it is unlikely that demographic factors related to abundance contribute significantly to the current extinction risk of this species: Risk Category - Low.

Growth Rate / Productivity

Productivity (i.e., population growth rate) is a measure of how well a population is performing in the habitats that it occupies during its life cycle (McElhany et al., 2000). Productivity and related parameters are integrated indicators of how a population, or a species, responds to its environment (McElhany et al., 2000).

In general, parrotfish display indeterminate growth, achieve moderate longevities, and have typical growth curves in which size increases gradually throughout life (Kobayashi et al., 2011). Greenback parrotfish generation length, based on a similar “sister” species *Scarus guacamaia*, is estimated around 7 to 10 years (Padovani-Ferreira et al., 2012). The following von Bertalanffy growth parameters were estimated from greenback parrotfish sampled from the Abrolhos Bank artisanal fishery landings between 2010 and 2011: $L\infty$ = 84.48 cm, K (growth rate) = 0.17 and t_0 = 1.09 (Previero 2014a). Although no significant differences were found in estimated growth parameters between males and females in this study (Previero, 2014a), as a protogynous species, the greenback parrotfish likely displays sex-specific growth patterns. In a study of several parrotfish species from Australia’s Great Barrier Reef, Choat et al. (1996) found that transition to the terminal male phase was associated with enhanced growth resulting in terminal males that were consistently larger than females for a given age class.

In protogynous hermaphrodites, such as the greenback parrotfish, the largest individuals are, in order, terminal males, individuals undergoing sexual transition, and the largest females next in line for sexual transition. Selective removal of these groups at high rates can lead to decreased productivity of a population. As the relative numbers of terminal males fall, females may have difficulty finding a terminal male to spawn with even if some remain (Hawkins and Roberts, 2003). If sex change is governed by social (exogenous) mechanisms, then transition would be expected to occur earlier in the life cycle when larger individuals are selectively removed by fishing (Armsworth, 2001; Hawkins and Roberts, 2003). This would cause the mean size and age of females to decrease for protogynous species and could result in a reduction in egg production (Armsworth, 2001). Sexual transition takes time and energy, including energy expended on social interactions and competition among females vying for dominance. Since removal of terminal males by fishing will result in more sexual transitions, overall population fitness may be negatively impacted.

Previero (2014b) assessed greenback parrotfish productivity using an index designed for data deficient and small scale fisheries (from Hobday et al., 2007). Productivity was measured based on the following seven attributes: average age at maturity, average maximum age, fecundity, average size at maturity, average maximum size, reproductive strategy, and trophic level. Each attribute was given a score from 1 (high productivity) to 3 (low productivity). Data for this analysis were obtained from greenback parrotfish sampled from Abrolhos Bank artisanal fishery landings from 2010 to 2011. Productivity scores for greenback parrotfish ranged from 1 to 2 with a mean score across all seven attributes of 1.71. This overall score reflects a species with average productivity.

In summary, while protogynous hermaphrodites may be particularly susceptible to the effects of fishing on productivity loss, information indicating a significant decline in greenback parrotfish productivity are lacking. I conclude that it is unlikely that demographic factors related to growth rate/productivity contribute significantly to the current extinction risk of this species: Risk Category - Low.

Spatial Structure / Connectivity

Spatial structure is composed of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al., 2000). A population's spatial structure depends fundamentally on habitat quality and spatial configuration, and the dynamics and dispersal characteristics of individuals in the population. There is very limited information in the literature on the spatial structure, configuration or dispersal characteristics of the greenback parrotfish. Greenback parrotfish range from the northern Brazilian coast to the southeastern Brazilian coast and are widely distributed throughout their range (Bender et al., 2012). There is little evidence of fragmentation in the greenback parrotfish population. Although greenback parrotfish disappeared from UVC counts at Arraial do Cabo reef after 1995, there is not enough information to determine if this is due to population fragmentation or other factors. Even if this does represent fragmentation, the impact on greenback parrotfish survival may be minimal considering the extremely small size of Arraial do Cabo reef compared to the much larger Abrolhos reefs where greenback parrotfish are still relatively abundant.

Based on findings of significantly greater biomass of target reef fish (including large herbivores) on deep reefs compared to shallower coastal reefs, Francini-Filho and Moura (2008b) suggest that regional-scale movements of exploited reef fish from deeper (i.e., "source") to shallower (i.e., "sink") areas may occur on Abrolhos Bank. More studies are needed to fully understand the scale and patterns of greenback parrotfish movement, and to better estimate not only the rates of fish spillover from no-take reserves, but also the rates of "spill-in" from neighboring habitats. Research has shown that no-take reserves can impact fish movement patterns and the flow of biomass on a reef (Gell and Roberts, 2003; Francini-Filho and Moura, 2008a). Marine reserve theory predicts that fishes will tend to move from inside reserves, where fish abundance is expected to be higher due to protection, to outside reserves, where fish abundance is expected to be lower due to fishing pressure. Francini-Filho and Moura (2008a) found some evidence of a "spillover effect" on greenback parrotfish on Abrolhos Reefs (i.e. higher biomass both inside the reserve and in unprotected sites closer to its boundary). However, "spillover effects" are thought to operate over small spatial scales, generally from tens to a few hundred meters, depending on species' mobility and habitat connectivity (Gell and Roberts, 2003). Afonso et al. (2008) found that for the parrotfish *Sparisoma cretense* in the Azore Islands, haremic adults displayed very high site fidelity with minimal dispersion from established male territories that could last for several years. In general, adult migration and connectivity may be less important for the survival of species with haremic, territorial mating systems and strong site fidelity.

Compared to the limited spatial scale of "spillover effects" from no-take reserves, "recruitment effects" – i.e., the net export of pelagic eggs and larvae - typically operate more diffusely and over broader spatial scales, generally tens of kilometers, depending on the dispersal capability of the pelagic larvae and patterns of ocean currents (Gell and Roberts, 2003). Scaridae generally exhibit broad dispersal capabilities. Their ability to recruit to a variety of habitats through pelagic larval dispersal may improve spatial connectivity among local reef populations, although there are no specific studies on greenback parrotfish spawning behavior or larval dispersal to verify this.

Based on the available information I find no evidence to suggest that current spatial structure and connectivity of the greenback parrotfish population pose an extinction risk to this species. I conclude that it is very unlikely that demographic factors related to spatial structure/connectivity contribute significantly to the current extinction risk of this species: Risk Category – Very low.

Diversity

Diversity is important for species and population viability because diversity (1) allows a species to use a wider array of environments, (2) protects a species against short-term spatial and temporal changes in the environment, and (3) provides the raw genetic material for surviving long-term environmental changes (McElhany et al., 2000). The loss of diversity can increase a species' extinction risk by decreasing a species' capability of responding to episodic or changing environmental conditions.

Greenback parrotfish are one of several reef species that are endemic to Brazil. Moura and Sazima (2000) found that endemism levels within Brazilian reef fish families are closely associated with restricted dispersal capabilities (demersal spawners, viviparous species, and fishes exhibiting parental care) but noted that scarids were exceptions to this finding. This family exhibited both high levels of endemism (40-50%) and broad dispersal capabilities. The authors postulate that faster mutation rates in this labroid lineage may account for their high endemism levels.

In the first cytogenetic study of scarids, Sena and Molina (2007) analyzed the gray parrotfish (*Sparisoma axillare*) and the greenback parrotfish (*Scarus trispinosus*) (Note: The authors originally referred to greenback parrotfish as *Scarus coelestinus* in this paper but corrected this to *Scarus trispinosus* in a subsequent erratum). The greenback parrotfish karyotype had a diploid number of 48 chromosomes, typical for marine teleosts.

Based on the sparse information available, I find no evidence to suggest that diversity within the greenback parrotfish population poses an extinction risk to this species. I conclude that it is very unlikely that demographic factors related to diversity contribute significantly to the current extinction risk of this species: Risk Category – Very low.

Analysis of ESA Section 4(a)(1) Factors

The following provides information and analysis on each of the five ESA Section 4(a)(1) threat factors as they relate to the current status of greenback parrotfish.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Certain changes are likely to occur in the world's oceans due to long-term (on the order of centuries) changes in global mean temperature and possible anthropogenic impacts that could pose potential future threats to greenback parrotfish habitats. The principal changes anticipated by the year 2100 are summarized as follows: 1) ocean temperature will increase 0.5 - 2.5°C (IPCC, 2013), 2) sea level will rise 0.5 -1.4m (Rahmstorf, 2007), and 3) ocean acidity will increase with pH falling 0.3–0.4 pH units due to increasing atmospheric and oceanic CO2 (Doney et al., 2009). The adverse effects of global coral loss and habitat degradation (including declines in species abundance and diversity, reduced physiological condition, decreased settlement, change in community structure, etc.) on species dependent upon coral reefs for food and habitat have been well documented (Comeros-Raynal et al., 2012). Comeros-Raynal et al. (2012) noted that coral reef area loss and decline was present within almost all the 179 parrotfish and surgeonfish (Acanthuridae) species' ranges they assessed. Within the Southern Tropical American Region, which includes Brazil, Columbia, Costa Rica, Panama, and Venezuela, an estimated 13% of coral reef habitat was categorized as "destroyed" and another 40% as "critically declining" (Wilkinson, 2008). "Destroyed" was defined as reefs with greater than 90% coral cover loss over at least the past 15 to 20 years that are unlikely to recover, while "critically declining" was defined as reefs with between 50–90% coral cover loss and are likely to join the total coral loss category within 10 to 20 years (Wilkinson, 2008).

In 2008, as part of the International Coral Reef Initiative, coral reef experts worldwide were asked to assess the threat status of reefs in their regions due to human pressures and global climate change (Wilkinson, 2008). For purposes of this assessment, reefs were categorized into one of three groups: 1) Not threatened - reef at very low risk of decline in the short term (5-10 years); 2) Threatened – proportion of potential reefs under high risk of decline in the mid-long term (> 10 years); 3) Critical - proportion of reefs under high risk of decline in the short term (5-

10 years). In the Atlantic Eastern Brazil Region experts classified 40% of the reefs as "Not Threatened," 50% as "Threatened," and 10% as "Critical" (Wilkinson, 2008).

A monitoring program was initiated by the Brazilian government (Ministry of Environment and Instituto Recifes Costeiros) in 2002 to track the health and sustainability of the nation's coral reef ecosystems. The Brazilian National Coral Reef Monitoring Program, which includes all major reef areas in Brazil, conducts annual surveys at 90 different sites within 12 reef systems (Wilkinson, 2008). Areas monitored include reefs ranging in protection levels (e.g. fully protected, limited access, multi-use MPAs, and open access). Program areas of investigation include coral and fish diversity, latitudinal differences in species abundances, and evaluating impacts of different management strategies along the Brazilian coast.

The Brazilian monitoring program used Reef Check (www.reefcheck.org) compatible methodology to monitor 8 localities between 2003-2008: 5 in Northeastern Brazil (Atol das Rocas, Fernando de Noronha island, Maracajaú, Tamandaré and Maragogi); and 3 in Eastern Brazil (Itaparica, Porto Seguro and Abrolhos) (Wilkinson, 2008). Results showed that due to chronic land based stresses the nearshore, shallow reefs, less than 1 km from the coast, were in poor condition, with less than 5% mean coral cover, while reefs further than 5 km from the coast, or deeper than 6 m, showed an increase in algal cover but also some local coral recovery (Wilkinson, 2008). Mild coral bleaching was observed in 2003 and 2005 along the 2000 km coast. Anthropogenic threats to Brazil's coastal zone include industrial pollution, urban development, agricultural runoff, and shrimp farming (Diegues, 1998; Leão and Dominguez, 2000; Cordell, 2006).

Francini-Filho and Moura (2008b) surveyed unprotected deeper reefs (25–35 m) on the Abrolhos Bank from 2003 to 2005 that were composed of scattered drowned reefs surrounded by extensive flat plains covered by rhodoliths of calcareous algae and macroalgae. They found that these deeper reefs contained up to 30 times greater biomass of target fish than shallow coastal areas, and biomass on deeper reefs was significantly greater across three trophic categories of fish.

The Corumbau Marine Extractive Reserve was the first reserve of its kind in Brazil specifically designed to protect coral reefs (Cordell, 2006). The Itacolomis reefs, the largest reef complex within this reserve, have a rich coral fauna as well as relatively high cover, particularly of *Orbicella cavernosa*, *M. brazilensis*, and *Siderastrea stellata*, which are biologically representative of the range of Abrolhos corals (Cordell, 2006). Biological surveys of species diversity, coralline cover, and condition of colonies, carried out before and after the creation of the reserve in 2000 indicated that the Itacolomis reefs were still in a good state of conservation as of 2006 (Conservation International – Brazil, 2000; Conservation International – Brazil, 2006).

Atlantic and Gulf Rapid Reef Assessment (AGRRA; www.agrra.org) monitoring methods have been used at five Eastern Brazilian reefs since 1999: Todos os Santos Bay, Tinharé/Boipeba, Cabralia, Itacolomis and Abrolhos). Monitoring via the AGRRA methodology showed that reefs less than 5 km from the coast were in poor condition with a mean of less than 4% coral cover, and more than 40% cover of macroalgae (Wilkinson, 2008). The poor condition of nearshore reefs was attributed to damage from sewage pollution, increased sedimentation and low water turbidity, as well as damage by tourists and over-exploitation (Wilkinson 2008). Reefs more than 5 km offshore and in no-take reserves had more than 10% coral cover and less than 10% algal cover (Wilkinson, 2008). Coral cover has declined since 2003 at Itacolomis and the Abrolhos area, from a maximum of 21% prior to 2003, to a maximum of 16% in 2008 (Wilkinson, 2008).

Coral reef area loss and decline is widespread globally, including many reef areas along the Brazilian coastline. However, there is considerable variation in the reliance of different species on coral reefs based on species' feeding and habitat preferences - i.e., some species spend the majority of their life stages on coral reef habitat while others primarily utilize seagrass beds, mangroves, algal beds, and rocky reefs. There is little evidence in the scientific literature of scarids having strict habitat requirements (Feitosa and Ferreira, 2014). Instead, they appear to be habitat "generalists" and their biomass is weakly related to the cover of particular reef feeding substrata (Gust, 2002). Less than half of all parrotfishes and surgeonfishes (78 species or 44%) exclusively inhabit coral reef habitats, and the majority of these (72 species) are listed by IUCN as Least Concern, indicating that information on habitat loss alone was not enough to definitively estimate significant species population decline at a global level (Comeros-Raynal et al., 2012). For parrotfishes and surgeonfishes, species classified as "mixed habitat" (i.e., species that are neither exclusively found on coral reefs nor even primarily found on coral reefs) by Comeros-Raynal et al. (2012) the threat related to coral reef loss and decline should be less of a concern. Similarly, the greenback parrotfish is considered a "mixed habitat" species, found on rocky reefs, algal beds, seagrass beds, and coral reefs (Comeros-Raynal et al., 2012; Freitas et al., 2012), that feeds mainly on detritus and algae and only occasionally grazes on live coral (Francini-Filho et al. 2008c). Although the IUCN uses different criteria and standards for Red List Assessments, it is noteworthy that "habitat loss" was not indicated as a major threat to the greenback parrotfish in this process (only "fisheries" were identified as a major threat) (Comeros-Raynal et al., 2012).

Impacts of ocean acidification to coral abundance and/or diversity are arguably significant; however, the direct linkages between ocean acidification and greenback parrotfish extinction risk remain tenuous. As discussed above, the ability of greenback parrotfish to occupy multiple habitat types should make this species less vulnerable to climate change and ocean acidification compared to other reef species that are more dependent on coral for food and shelter. Similarly, there is no evidence directly linking increased ocean temperatures or sea level rise with greenback parrotfish survival.

In conclusion, there is adequate evidence that some portion of habitat used by greenback parrotfish has already been modified and degraded, and this trend will likely continue into the future. However, studies indicating that habitat associated changes are contributing significantly to the extinction risk of this species are lacking. Therefore, based on the available scientific and commercial information, I conclude that it is unlikely that the threat of destruction, modification, or curtailment of greenback parrotfish habitat or range contributes significantly to the extinction risk of this species either now or the foreseeable future: Risk Category - Low.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Several studies suggest that overutilization of fish populations is leading to significant changes in the community structure and balance of Brazilian reef ecosystems (Costa et al., 2003; Gasparini et al., 2005; Ferreira and Maida, 2006; Previero, 2014b). Artisanal and commercial fisheries appear to be affecting the population size and size structure of fish populations (Ferreira and Gonçalves, 1999; Ferreira, 2005; Gasparini et al., 2005; Previero, 2014b). An estimated 20,000 fishermen currently use the natural resources of Brazil's Abrolhos Region as their main source of income (Dutra et al., 2011). Their activity is predominantly artisanal, performed with small and medium-sized boats. Small-scale artisanal fisheries account for an estimated 70% of total fish landings on the eastern Brazilian coast (Cordell, 2006), where coral reefs are concentrated (Lea˜o et al., 2003). In Brazil, as in many other tropical countries, artisanal fisheries are typically embedded in mixed land and sea-based economies, having both commercial, semi-commercial, and subsistence components (Cordell, 2006). A growing number of larger and industrial fishing boats have moved to this region in the last few years, increasing the pressure on target species and competing with artisanal fishing (Francini-Filho and Moura, 2008b; Dutra et al., 2011).

As populations of top oceanic predators collapse due to overfishing, other large-bodied species at lower trophic levels become new targets (Bender et al., 2014). This is part of a global phenomenon described by Pauly et al. (1998) as "fishing down the food web." In tropical regions, the scarcity of top reef predators may explain the relatively recent increased exploitation of large herbivorous fishes, especially parrotfishes, as food (Ferreira and Goncalves, 1999; Debrot et al., 2007). Parrotfish populations are being overexploited on coral reefs around the world as abundance of more traditional target reef species (i.e., snappers, groupers) declines (Hughes, 1994; Ferreira and Goncalves, 1999; Mumby, 2006). Parrotfishes may be highly susceptible to harvest in general due to their conspicuous nature, relatively shallow depth distributions, small home ranges, and vulnerability at night (Taylor et al., 2014). Overfishing of parrotfishes is considered by some to be one of the most important coral reef conservation issues globally (Hughes, 1994; Mumby, 2006; Jackson et al., 2014). Although no parrotfish species global extinctions are reported in the literature, there have been local-scale extirpations reported in subsistence and artisanal fisheries (Dulvy et al., 2003). Local populations of rainbow parrotfish (*Scarus guacamaia*) have disappeared from parts of the Caribbean (Mumby et al., 2004) and bumphead parrotfish (*Bolbometopon muricatum*) have not been sighted since 1999 on some Pacific Islands (Dulvy et al., 2003). Ferreira et al. (2005) reported the extirpation of an endemic Brazilian population of rainbow parrotfish (*S. aff. guacamaia*) due primarily to spearfishing. However, there is some debate in the literature over the historical occurrence of this species in Brazil which is based largely on evidence from museum specimens and anecdotal accounts (Choat et al., 2012b).

Greenback parrotfish were not considered a traditional fishery resource by most fishermen in Brazil as recently as 20 years ago (Francini-Filho and Moura, 2008b). Although fishermen from some localities have reported landing greenback parrotfish as far back as the late 1970's (Bender et al. 2014; Previero, 2014b), the importance of this species to Brazil's artisanal fisheries has increased greatly only in the past few decades. Since about the mid-1990's parrotfish have increasingly contributed to fishery yields in Brazil as other traditional resources such as snappers (lutjanids), groupers and sea basses (serranids) are becoming more scarce (Costa et al., 2005; Previero, 2014b). Being the largest of all Brazilian parrotfishes, the greenback was the first herbivorous-detritivorous reef fish targeted by spearfishermen (Bender et al., 2014). Other large-bodied parrotfishes of the genus *Sparisoma* have also been targeted in more recent years (Bender et al., 2014). The exploitation of these resources was rapidly taken up by small boat fishing fleets that previously targeted other species. Some boats now exclusively target these non-traditional reef fishes, whereas others target them only during periods of low productivity or during closed seasons of higher priority target species (Cunha et al., 2012). Greenback parrotfish are now considered an important fishery resource that is sold to regional markets in nearby large cities (e.g., Vitoria and Porto Seguro) and even to overseas markets (Francini-Filho and Moura, 2008b; Cunha et al., 2012; Previero, 2014b). The recent exportation of parrotfish and other non-traditional reef fishes has created a demand for species that were not previously the main targets of artisanal fisheries in Brazil (Cunha et al., 2012). Primary fishing methods used in Brazil to capture parrotfish are spearfishing and seine nets (Ferreira, 2005; Araujo and Previero, 2013).

Quantitative data on fishery activities in Brazil are limited by the insufficient number of individuals collecting data, a lack of commitment on the part of industry to provide information, and the absence of an integral institutional policy aimed at the generation of national fishery statistics (IBAMA, 2008). Up until 1989 the Brazilian Institute of Geography and Statistics published fishery statistics with data on national production by species and fishing mode for all states in the country. Beginning in 1990, the collection of these data was interrupted due to financial and operational problems (IBAMA, 2008). The lack of precise information impedes any reasonable assessment of the economic, social, and environmental impacts caused by the removal of reef fish for human consumption (Cunha et al., 2012). Although some landings information can be derived from market transactions, these economic sources often lack the data specificity (e.g., species level identification, sizes, gender, gear used, and precise fishing location) needed to assess and manage fish populations. In some cases, very little of the catch, particularly artisanal production, passes through the marketplace at all (Cordell, 2006). Landings records from spearfishing in particular are critically lacking despite the increased popularity of this fishing method in the past two decades (Costa Nunes et al., 2012). It is difficult to determine the impact of fishing activities on Brazilian reefs due to the lack of basic data such as catch, effort (overall and directed), size, and gear type (Ferreira, 2005).

Previero (2014b) conducted the first quantitative assessment of the greenback parrotfish fishery on Abrolhos Bank. Fishery dependent data were collected over 13 months between 2010 and 2011 from the main fishing ports that exploit reef fish on Abrolhos Bank: Caravelas; Prado; Corumbau Marine Extractive Reserve (RESEX); and Alcobaca. Greenback parrotfish account for the largest landings weight among all parrotfish species at these ports (Araujo and Previero, 2013). This study evaluated the effects of fishing on the population based on landings volume, catch per unit effort (CPUE), length frequencies, population age structure, and estimated fishing mortality and survival rates. The Alcobaca fleet was characterized by relatively large vessels (some over 12 m) equipped with freezer space for the preservation of fish over long periods. These vessels targeted parrotfish on more distant fishing grounds (depths up to 40 meters) on

Abrolhos Bank and Royal Charlotte Bank during extended fishing trips (average duration 11.7 days). By comparison, fishermen from Caravelas mainly took day trips targeting greenback parrotfish closer to shore (depths up to 25 meters) and from smaller vessels than used in Alcobaca. Prado fishing vessels also traveled longer distances, but greenback parrotfish were considered a less important target species by fishermen at this port (compared to either Alcobaca or Caravelas) and landings were considerably lower as a result. Figure 6 shows the distribution of fishing spots reported by fishermen from the ports of Alcobaça, Caravelas, and Prado. Alcobaca fishermen caught greenback parrotfish only with harpoons, often with air compressors to increase bottom time at greater depths, while Caravelas fishermen indicated they used a combination of harpoons and nets.

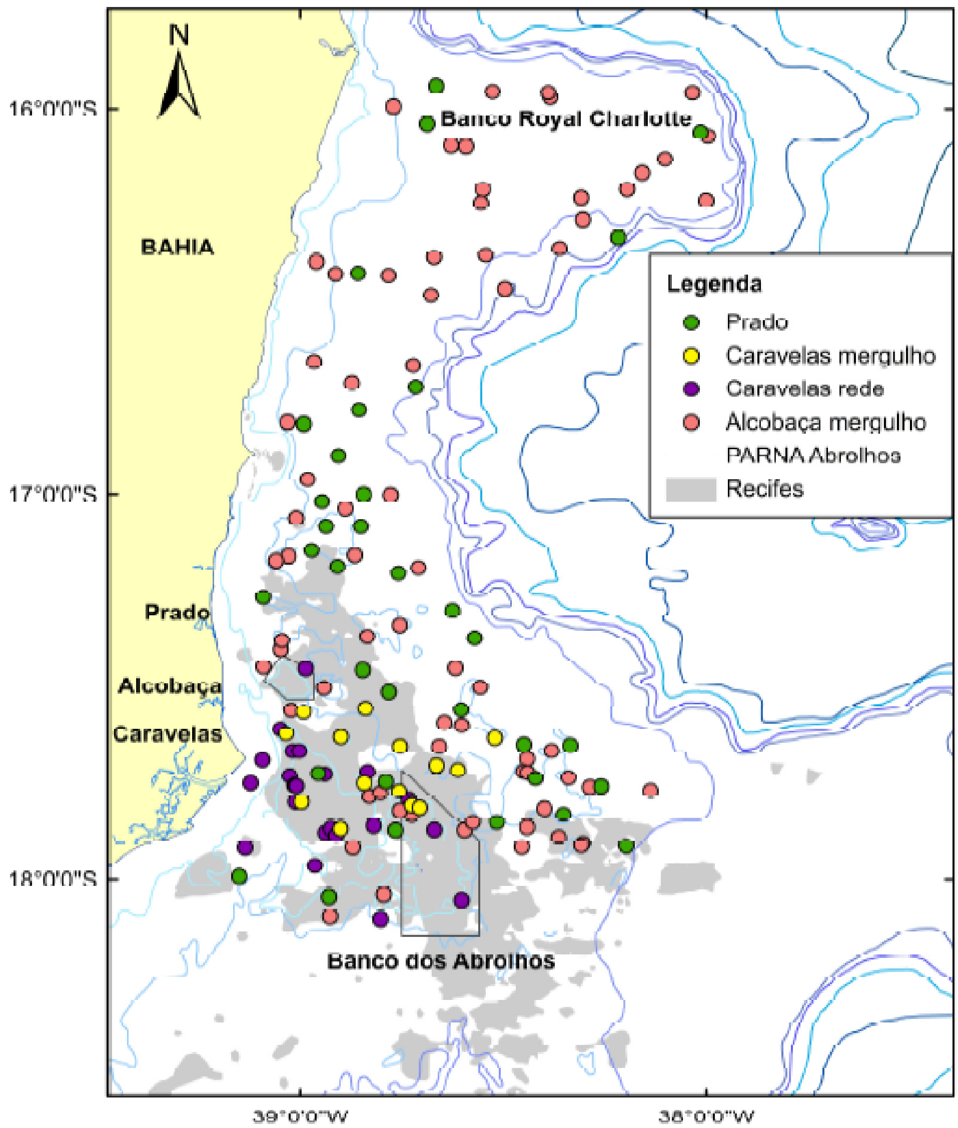

Figure 6. Distribution of fishing spots reported by fishermen from the ports of Alcobaça, Caravelas, and Prado. Note: Recifes = reefs (from Previero, 2014b).

Greenback parrotfish landings ranged in size from 28 cm to 91 cm TL and the fishery was dominated by 8 and 9 year-old fish. The oldest fish sampled was 11 years old – considerably younger than the estimated maximum life span of 23 years for this species (Previero, 2014a). In Alcobaca port, significantly larger specimens were landed from more distant fishing locations compared to Caravelas port, which had smaller fish caught on shallower, near-shore reefs (Figure 7) (Previero, 2014b). Length frequency data suggest that a relatively large portion of the greenback parrotfish landings, particularly from the near-shore Caravelas fleet, were fish that had not yet reached maturity (Freitas et al., 2012; Previero, 2014b). Total landings of greenback parrotfish recorded for 13 months at Caravelas was 24.80 metric tons (average 1.90 tons per month). Total landings for 7 months of monitoring at the RESEX and Alcobaca were 1.93 and 9.21 metric tons, respectively (average 0.27 tons per month at RESEX and 1.31 tons per month at Alcobaca). The CPUE for Caravelas ranged from 0.911 to 1.92 kg per fisherman/hour/day and for the RESEX from 0.65 to 1.25 kg per fisherman/hour/day. Previero (2014b) combined greenback parrotfish landings and length frequency data with an age and growth assessment (Previero, 2014a) to arrive at the following estimated fishery parameters: fishing mortality = 0.68; natural mortality = 0.19; total mortality = 0.87; and survival rate = 0.42.

The potential vulnerability of the greenback parrotfish population to fishery exploitation was evaluated by Previero (2014b) using a Productivity and Susceptibility Analysis (PSA) index designed for data deficient and small scale fisheries (Hobday et al., 2007). The PSA is a semi-quantitative approach based on the assumption that the risk to a species will depend on two characteristics: (1) the species productivity, which will determine the rate at which the population can sustain fishing pressure or recover from depletion due to the fishery; and (2) the susceptibility of the population to fishing activities (Hobday et al., 2007). The following greenback parrotfish productivity attributes were used: average age at maturity, average maximum age, fecundity, average size at maturity, average maximum size, reproductive strategy, and trophic level (Freitas et al., 2012; Previero, 2014a). Four susceptibility attributes were evaluated: 1) Availability - overlap of fishing effort with the species' distribution 2) Encounterability - the likelihood that the species will encounter fishing gear that is deployed within its geographic range, 3) Selectivity - the potential of the gear to capture or retain the species and the desirability (value) of the fishery, and 4) Post Capture Mortality - the condition and subsequent survival of a species that is captured and released (or discarded) (Hobday et al., 2007). Susceptibility attributes were derived from sampling data obtained at major ports and from interviews with fishermen and other fisheries stakeholders (e.g., fish processors, dealers, fishmongers, and representatives of environmental institutions and government agencies). The productivity and susceptibility rankings determine the relative vulnerability and are each given a score: 1 to 3 for high to low productivity, respectively; and 1 to 3 for low to high susceptibility, respectively. The average productivity score of greenback parrotfish on Abrolhos Bank across seven different attributes was 1.71 and the average susceptibility score across four attributes was 3.00. Related to susceptibility, Freitas et al. (2013) found that the greenback parrotfish spawning season (December-March) is overlapped by the months (September-March) when fishermen indicated this species was easiest to catch. This combination of very high susceptibility and average productivity places the greenback parrotfish in the zone of "high potential risk" of overfishing (Figure 8). The PSA results, in combination with an estimated high fishing mortality, strongly suggest that greenback parrotfish are heavily exploited by artisanal fishing on Abrolhos Bank (Previero, 2014b).

Taylor et al. (2014) studied relationships between life history traits and response to fishing exploitation in 12 parrotfish species from Guam. They found age at female maturity was the best predictor of vulnerability to overexploitation, but that length-based traits, particularly maximum length, were also good predictors. In general, late maturing and large bodied parrotfish species were significantly more vulnerable to overexploitation. The 12 parrotfish species in this study were all considerably smaller (i.e., mean maximum lengths ranging from 22.6 cm to 40.9 cm) than the greenback parrotfish which can reach lengths of 80-90 cm. Mean age at female maturity (50% mature) for the 12 Guam species ranged from 1.1 to 3.7 years (Taylor et al., 2014). By comparison, Freitas et al. (2012) estimated greenback parrotfish size at first maturity (50% mature) at 39.1 cm which corresponds to a 4 to 5 year-old fish (Previero, 2014b). Although Taylor et al. (2014) did not include greenback parrotfish, results suggest that as one of the largest parrotfish species with relatively late maturation the greenback parrotfish may more vulnerable to overexploitation than smaller, faster maturing parrotfish species.

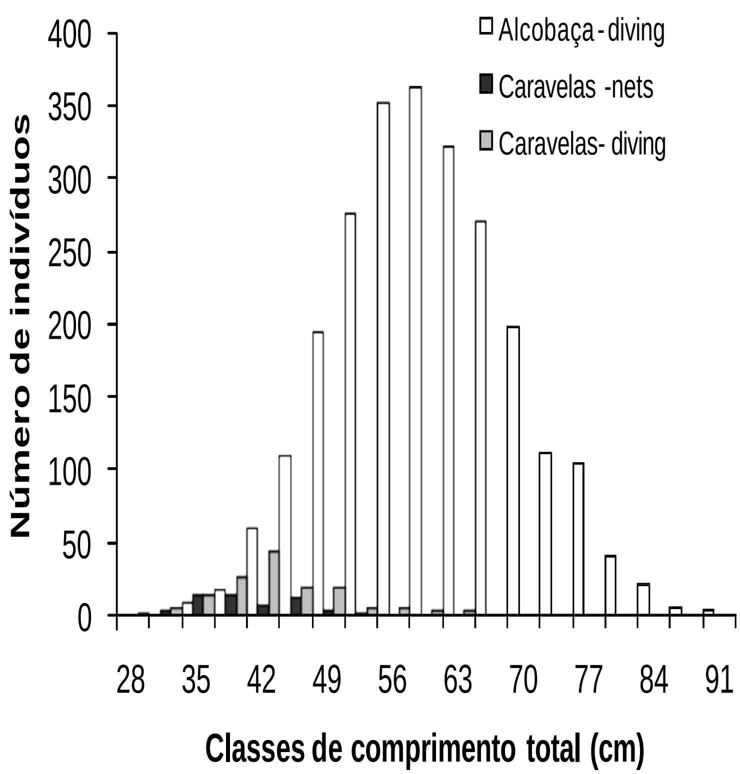

Figure 7. Length frequency measurements obtained for *Scarus trispinosus* between August 2010 and September 2013 from Caravelas and Alcobaça ports in Brazil (from Previero, 2014b).

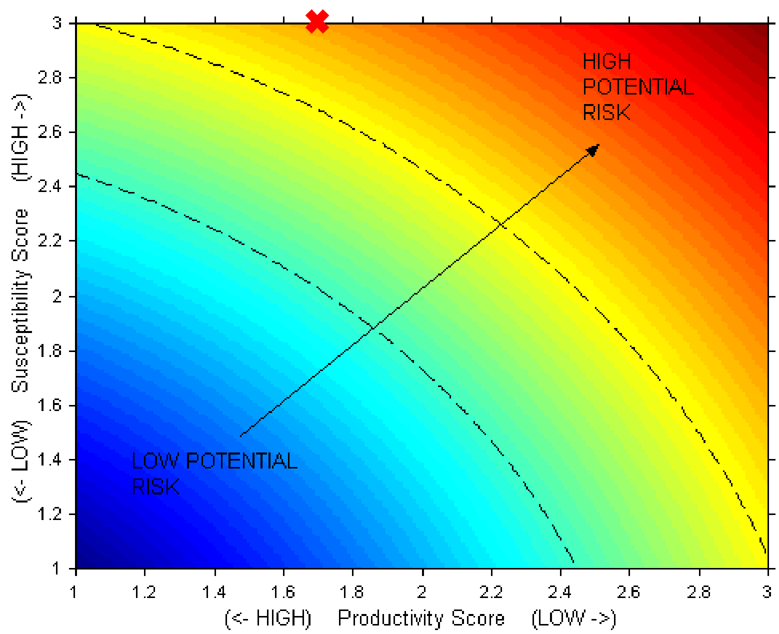

Figure 8. The axes on which risk to the ecological unit is plotted. The x-axis includes attributes that influence the productivity of a unit, or its ability to recover after impact from fishing. The y-axis includes attributes that influence the susceptibility of the unit to impacts from fishing. The contour lines divide regions of equal risk and group units of similar risk levels (from Hobday et al., 2007). Greenback parrotfish risk denoted on figure by red "X" (susceptibility = 3.0, productivity = 1.71).

Cunha et al. (2012) estimated the tonnage of reef fish exported by firms in the Brazilian state of Rio Grande do Norte, using export certificates issued by the Ministry of Agriculture, Livestock and Provisions. In the period studied (1998-2006), a total of 3,335 tons from 7,377 lots were exported. Most of the production was air-shipped fresh to importers in the United States. The family Lutjanidae represented the greatest weight exported (36.77%), followed by Scaridae (21.06% and 702,000 kg). Species level data were not available for parrotfish as all Scaridae were declared on export certificates as *Sparisoma* sp. Limited sampling of the catch identified three genera and seven species of parrotfish: *Scarus trispinosus*, *Scarus zelindae*, *Sparisoma amplum*, *Sparisoma. axillare*, *Sparisoma frondosum*, *Sparisoma radians* and *Nicholsina usta*. While parrotfish accounted for a relatively large percentage of the reef fish landings in this region, since this study did not attempt to estimate parrotfish exports by species, the precise contribution of greenback parrotfish to these landings remains unknown. The authors did note that during sampling two species (*Sparisoma axillare* and *Sparisoma frondosum*) dominated the Scaridae landings (Cunha et al., 2012), suggesting that, unlike the Abrolhos fishery, greenback parrotfish are not a major contributor to the landings in Rio Grande do Norte.

Greenback parrotfish are also targeted by recreational spearfishermen in Brazil (Costa Nunes et al., 2012). Spearfishing was introduced in the region as a recreational activity in the late 1940's (Costa Nunes et al., 2012). The Brazilian Association of Spearfishing (Associação Brasileira de Caça Submarina-ABCS), founded in 1951 in Rio de Janeiro, held several championships and afterwards the sport spread throughout the country. In the early 1960s, Americo Santarelli created a diving equipment company, and since then spearfishing equipment became more accessible to divers, thus popularizing the sport (Santarelli, 1983; Colassanti, 2009). Costa Nunes et al. (2012) analyzed photographs taken by recreational spearfishing clubs in Bahia State from 2006-2008 in an attempt to quantify the composition of fish landings. They found that the greenback parrotfish was the most common herbivore (68 captured) and 6th most commonly captured species overall.

Several studies have linked localized declines of greenback parrotfish populations to increased fishing effort by comparing abundances at the same location over time or at different locations subjected to varying levels of targeted fishing pressure (Floeter et al., 2007; Pinheiro et al., 2010; Costa Nunes et al., 2012; Bender et al., 2014). As previously discussed (see "Abundance and Population Structure" section of this report; Figures 4 and 5), UVC data indicate that greenback parrotfish were once abundant at Arraial do Cabo and are now considered locally extirpated due primarily to spearfishing (Floeter et al., 2007; Bender et al., 2014). Arraial do Cabo was declared a Marine Extractive Reserve (MER) in 1997 – the first of its kind in Brazil – a collaboratively managed marine protected area where only local fishermen are allowed to exploit resources (Bender et al., 2014). However, while there are some fishing regulations, enforcement is poor or non-existent, resulting in a typical overexploitation scenario (Bender et al., 2014).

In addition to compiling information from UVC and from fisheries landings, Bender et al. (2014) conducted personal interviews with 214 artisanal fishermen from the Arraial do Cabo area. One of the study objectives was to use fishermen's Local Ecological Knowledge (LEK) to obtain past estimates of relative abundance and population trends for exploited fish species. The spearfishing questionnaire included questions about four endemic parrotfishes (including greenback) to explore the possible fishing impacts at lower trophic levels. For each species, divers were asked to recall the largest individual they ever caught (in kilograms), their best day's spearfishing catch (number of fish speared), and the year in which these catches were made. Survey results strongly suggest that both the size of the largest greenback parrotfish captured (Figure 9, left graph) and the maximum number landed (i.e., best day's catches) (Figure 9, right graph) had decreased through time.

Pinheiro et al. (2010) studied the relationships between reef fish frequency of capture (rarely, occasionally, or regularly), intensity at which species are targeted by fisheries (highly targeted, average, non-targeted), and UVC counts off Franceses island (central coast of Brazil) between 2005 and 2006. Greenback parrotfish were one of 19 species classified as both "highly targeted" (by spearfishing) and "rarely caught." In general, "highly targeted" species showed extremely low density in the UVC counts, although specific data on greenback parrotfish from UVC counts were not available. The authors conclude that, overall, results indicate that the reef fish community off Franceses island is already overexploited, with a low density of highly targeted species and a high predominance of non-target species both in natural environments and in fishery landings. Similarly, Feitosa and Ferreira (2014) attributed low observed abundance of greenback parrotfish outside of no-take areas on Tamandare reefs (northeastern coast of Brazil) to heavy fishing pressure in this region.

Medeiros et al. (2007) studied the effects of recreational activities (i.e., snorkeling, SCUBA, and fish feeding) on a tropical shallow reef off the northeastern coast of Brazil by comparing its fish assemblage structure to a nearby similar control reef where tourism does not occur. Greenback parrotfish were found to be less abundant on the recreationally exploited reef compared to the control reef (0.15 versus 0.85 individuals per $100m^2$), although the relative abundance of this species was very low on both reefs (0.04% versus 0.56% of all fish individuals recorded) and results were based on very small sample sizes of fish observed.

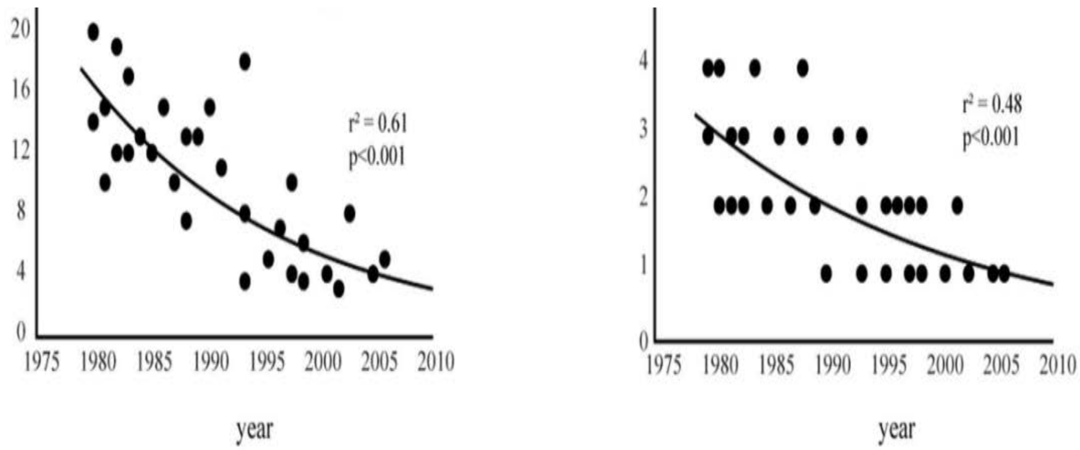

Figure 9. Largest greenback parrotfish individual (graph on left; in kg) and greatest catch (graph on right; number of fish) that Arraial do Cabo spearfishermen remembered landing (from Bender et al., 2014).

Spearfishing is a highly size selective, efficient gear - fishermen target individual fish, typically the largest, most valuable individuals. For protogynous hermaphrodites the largest individuals are (in order) terminal males, individuals undergoing sexual transition, and the largest females. As discussed above in more detail (see "Growth Rate/Productivity" section), selective removal of these large individuals can lead to decreased productivity at the population level. Thus, protogynous hermaphrodites, such as the greenback parrotfish, may be particularly susceptible to over-fishing (Hawkins and Roberts, 2003; Francis, 1992). With continued heavy exploitation from fishing it is plausible that the proportion of male greenback parrotfish could fall below some critical threshold needed for successful reproduction in some localities. More information is needed to adequately assess the impact continued overfishing will have on greenback parrotfish sex ratio, spawning success, and productivity.

Hawkins and Roberts (2003) studied parrotfishes on reefs around six Caribbean islands from 1994-2001 to test predictions that fishing will (1) decrease population densities; (2) have a greater impact on larger species compared to small; (3) reduce the average size of parrotfish; (4) limit the availability of terminal phase males, and (5) cause species to change sex at smaller sizes. Biomass of larger parrotfish species declined as fishing intensified, and smaller species came to constitute a greater proportion of the total assemblage. In the most heavily fished islands, adults of two of the largest species, *Sparisoma viride* and *Scarus vetula* were virtually absent. Fishing pressure reduced the size of fish in all species, and decreased the proportion of terminal males in four out of five species (Hawkins and Roberts, 2003). The data suggested that on the most heavily fished reefs, as fractions of terminal males fall, females have more difficulty finding a terminal male to spawn with.

Assessing the magnitude of the threat of fishing to greenback parrotfish survival is difficult for two reasons: 1) The directed fishery for greenback parrotfish, and one of the primary fishing methods used to capture them (spearfishing), are both relatively new in Brazil, and 2) Long-term fisheries data that are typically needed to determine exploitation levels (e.g. landings, fishing effort, length frequencies, age and growth) are lacking in Brazil. Only one study (Previero, 2014b) combined fisheries landings data, length data, and an age-growth analysis to quantitatively assess catch rates and mortality/survival rates for this species. This study strongly suggests that greenback parrotfish are heavily exploited throughout much of the Abrolhos Bank region, overfishing is likely occurring, and in the absence of sustainable fishery management controls and adequate enforcement, overfishing will likely continue into the future. However, this quantitative assessment of the impact of fishing on greenback parrotfish is based on fisheries data collected over only a 13 month period. The lack of a catch record time series or baseline information for this species prevents traditional assessments of the state of exploitation of this species or the magnitude of the population decline (Previero, 2014b).

Several other studies (cited above) estimated relative abundances using a variety of methods (i.e., export certificates, UVC counts, fishermen's traditional ecological knowledge, and old photographs) and relied on qualitative assessments of fishing effort (e.g., highly targeted, average targeted, not targeted; fully protected, partially protected, not protected) to demonstrate the impact of fishing on reef fish populations. In general, these studies suggest that abundance of greenback parrotfish was lower at sites where fishing pressure was high. Interpretation of the results should consider data limitations found in some of these studies. These include small sample sizes for comparison of species level abundance estimates, lack of specificity in measuring targeted effort or illegal fishing activity, temporally limited data, and confounding variables that could not be controlled for in space (across reefs) or over time (across years).

Artisanal and commercial fishing pressure on greenback parrotfish will likely increase in the future as the country's coastal population grows and more traditional target species become less available due to overfishing. As easily accessible nearshore and shallow reefs become more depleted, fishing effort will likely shift to currently less utilized, more remote, and deeper reefs. This is already evident in landings for the fishing port of Alcobaca, where a fleet of larger, freezer equipped vessels return from long duration trips (up to several weeks) specifically targeting large greenback parrotfish on offshore reefs (Previero, 2014b). This level of fishing capacity and sophistication suggests that, over time, greenback parrotfish may become over-exploited throughout their range, including more remote areas that were at one time considered inaccessible to local fishermen. This is supported by the PSA results which rated greenback parrotfish as "highly susceptible" to overfishing on all four susceptibility criteria: availability, encounterability, selectivity, and post capture mortality (Previero, 2014b). It is likely that greenback parrotfish are being overfished (Previero, 2014b) and that overfishing will continue into the future unless additional regulatory mechanisms are implemented and adequately enforced. While eliminating overfishing is necessary for sustainable fisheries management, in terms of extinction risk the important question is: At what level of overfishing does the population drop below some threshold such that the probability of extinction risk is unacceptable? This is a difficult question to answer for greenback parrotfish due to scientific uncertainties and data limitations.

The cumulative research indicates that greenback parrotfish are heavily exploited by fishing throughout much of its limited geographic range. In one small area (Arraial do Cabo) fishing has led to the local extirpation of this species, although the contribution of this area to the population as a whole is likely minimal. As a protogynous hermaphrodite, the greenback parrotfish may be more susceptible to fishing methods that selectively target the largest individuals in the population. Continued removal of terminal males, individuals undergoing sexual transition, and the largest females at high rates can lead to decreased productivity and increased risk of extinction over time. The lack of baseline information and a time series of fishery dependent data, combined with limitations of the available studies, make it difficult to quantitatively assess the impact of this threat on greenback parrotfish abundance. It is also difficult to determine if differences in mean densities of greenback parrotfish found at different study areas are due primarily to fishing or reflect the natural distribution of this species. Based on the information available, and taking into account the scientific uncertainty associated with this threat, I conclude that the threat of overutilization from artisanal and commercial fishing is somewhat likely to contribute significantly to the extinction risk of this species both now and in the foreseeable future: Risk Category - Moderate.

Competition, Disease or Predation

There is very little information in the published literature or otherwise on the impact of competition, disease or predation on greenback parrotfish. These subjects are data poor, but there are no serious or known concerns raised under this threat category with respect to greenback parrotfish extinction risk.

As a relatively large-bodied herbivore, older greenback parrotfish should have fewer natural predators compared to other smaller reef species. Populations of large piscivorous species (e.g., red grouper and black grouper) on Brazilian reefs that prey on greenback parrotfish have also been significantly reduced due to heavy fishing pressure (Freitas, 2014a) as part of the global phenomenon described by Pauly et al. (1998) as “fishing down the food web.” Large predators in northeastern Brazil are restricted to deeper reefs as a consequence of a long history of overfishing that has taken place in the shallow reefs of this region (Feitoza et al., 2005).

My literature search did not find any studies related to greenback parrotfish diseases. Coral reef monitoring in Brazil has shown that the Abrolhos reefs have a higher incidence of coral diseases than other reef systems, which have particularly affected the Brazilian-endemic coral, *Mussismilia braziliensis* (Wilkinson, 2008; Francini-Filho et al., 2008d). However, the impact of coral reef disease on the greenback parrotfish population has not been studied.

In a study of the endemic Brazilian red-eye parrotfish (*Sparisoma axillare*), Feitosa and Ferreira (2014) found that aggressive interactions with territorial damselfish were the primary driving factor of juvenile distribution and feeding rates. Attack rates increased with juvenile size and the lowest bite rates were observed in zones with higher densities of territorial damselfish. Still, as with predation and disease, there is no scientific evidence to suggest that competition from damselfish or other species is negatively impacting the greenback parrotfish population.

Therefore, based on the available scientific and commercial information, I conclude that it is very unlikely that the threats of competition, disease, or predation contribute significantly to the extinction risk of this species either now or the foreseeable future: Risk Category – Very low.

<u>Other Natural or Manmade Factors</u>

Although the increase in human population size is not considered to be an independent threat to greenback parrotfish species survival, it can influence the threats discussed above related to habitat degradation, fishing, and the inadequacy of existing regulatory mechanisms. With Brazil's large (203 million) and growing (1.1% per year) population (PRB, 2014), half of which lives along the coast, the demand for fish protein will likely increase in the coming years (Floeter et al., 2007). Highest population densities in Brazil are found in coastal areas, and many important fishery resources are already under threat or collapsed due to over-exploitation, failed fisheries management plans, and over-optimistic fisheries incentive policies (Abdallah and Sumaila, 2007). Preventing overexploitation of marine resources will become increasingly difficult in the absence of strong and enforceable fisheries regulatory controls. However, while population growth can be more generally linked to the concepts of coastal ecosystem health and sustainability, there is no information that can be used to link population growth to greenback parrotfish extinction risk. I conclude that it is very unlikely that the threat associated with other natural or manmade factors contributes significantly to the extinction risk of this species either now or the foreseeable future: Risk Category – Very low.

<u>Evaluation of Adequacy of Existing Regulatory Mechanisms</u>

The ESA requires an evaluation of existing regulatory mechanisms to determine whether they adequately address threats to the greenback parrotfish population. Existing regulatory mechanisms may include national, state, local, and international regulations. Below is a description and evaluation of current management measures that affect greenback parrotfish.

Fisheries Regulations

Brazil has never had a formal regulatory system for managing commercial or artisanal fisheries in its coastal waters (Cordell, 2006). For years, the only marine management practices that limited access to fishing grounds were unofficial, informal ones: local sea tenure systems based on artisanal fishers' knowledge, kinship and social networks, contracts, and a collective sense of "use rights" (Begossi, 2006; Cordell, 2006). Aside from establishing a geographically limited system of "no-take" protected areas (see MPA section below), few actions have been taken in Brazil to manage reef fisheries. Traditional fishery management controls (e.g., annual quotas, daily catch limits, limited entry, seasonal closures, and size limits) are typically not implemented either at the state or national level (Cordell, 2006; Wilkinson, 2008).

In 2002 Brazil created its first national fisheries agency—the Special Secretariat for Aquaculture and Fisheries (SEAP). This new agency was intended to have broad, national policy-setting and regulatory powers that could serve to reverse decades of coastal habitat degradation and depletion of marine resources (Cordell, 2006). In 2009 this Special Secretariat position was changed to a Ministry of Fisheries with increased budget and power, reflecting increased interest in the fisheries sector (OECD, 2011). The new ministry is responsible for monitoring, controlling, and surveilling Brazil's fisheries, activities which have all been lacking in the past (OECD, 2011). A National Fishing Monitoring Program was implemented in 2009 and a pilot-project was initiated in the Abrolhos Region to develop methodologies to obtain more accurate data on artisanal fishing and to make comparisons between areas with and without special management designations (Dutra et al., 2011).

Marine Protected Areas (MPAs)

Over the past two decades, marine resource management and conservation has focused increasingly on marine protected areas (MPAs) as a tool for managing coastal ecosystems and species (Floeter et al., 2006). No-take MPAs, in particular, are recognized as an important tool for reef fisheries management (Bohnsack, 1998; Roberts and Hawkins, 2000) as they have been shown to promote recovery of exploited populations within their boundaries as well as in adjacent areas outside the protected reserve (Gell and Roberts, 2003; Halpern, 2003; Francini-Filho and Moura, 2008a). The flow of reef fish biomass from no-take reserves may occur through two mechanisms: net emigration of juveniles and adults (spillover effect) and net export of pelagic eggs and larvae (recruitment effect) (Gell and Roberts, 2003).

Several MPAs have been established in the Abrolhos Region of Brazil. The core Abrolhos MPA network consists of four federally protected areas: 1) Abrolhos National Marine Park, 2) Corumbau Marine Extractive Reserve, 3) Canavieiras Extractive Reserve, and 4) Cassurubá Extractive Reserve. These four areas, and specific reef systems within them, vary considerably in terms of size, ecosystem type, zoning regulations, management structure, fishing pressure, and level of compliance and enforcement.

The Abrolhos National Marine Park was established by the Brazilian government in 1983 as a "no-take" protected area with limited use allowed by non-extractive activities (Cordell, 2006). Effective conservation policy was not implemented in the national park until the mid-1990s (Ferreira, 2005). The park, which covers an area of approximately 88,000 hectares, is divided into two discontinuous portions: 1) the coastal Timbebas Reef which is considered poorly enforced, and 2) the offshore reefs of Parcel dos Abrolhos and fringing reefs of the Abrolhos Archipelago which are more intensively enforced (Ferreira and Goncalves, 1999; Francini-Filho et al., 2013).

The Corumbau Marine Extractive Reserve (MERC), located in the northern portion of the Abrolhos Bank in eastern Brazil (Figure 10), was established in 2000 and covers 89,500 hectares (930 km^2) of nearshore habitats and coralline reefs (Francini-Filho et al., 2013). Extractive reserves are co-managed, multi-use protected areas in Brazil established by the initiative of local communities with support from the Federal Protected Areas Agency (ICMBio) and nongovernmental organizations (Francini-Filho and Moura, 2008a). The MERC, which was the first extractive reserve in Brazil to encompass coral reefs, includes no-take reserves embedded within the larger multi-use extractive area as a means to restore fish populations and benefit adjacent fishing grounds through spillover (Francini-Filho and Moura, 2008a). Exploitation of marine resources within the MERC is only allowed for locals with use rules (e.g., zoning and gear restrictions) defined by a deliberative council made up of more than 50% fishermen (Francini-Filho and Moura, 2008a). Handlining, spearfishing and various types of nets are allowed, while destructive fishing practices (e.g., drive-nets above reefs and collections for aquarium trade) are prohibited (Francini-Filho and Moura, 2008a). The MERC management plan, approved in November 2001, created several no-take zones, the main one (~10 km^2) covering about 20% of the largest reef complex within the MERC - Itacolomis Reef (Francini-Filho and Moura, 2008a).

The Canavieiras Extractive Reserve, located just north of the Abrolhos Region, was created in 2006 and covers an area of 100,600 hectares comprising extensive mangrove forests, coastal islands, rivers, and marine environments (Dutra et al., 2011). The Cassurubá Extractive Reserve was created in 2009 and covers an area of 100,687 hectares of terrestrial, coastal and marine habitats, including 95% of Abrolhos Bank's mangroves and estuaries.

Besides those on Abrolhos Bank, there are a few other no-take reserves with reef habitat within the greenback parrotfish range. Laje de Santos State Marine Park on the southeastern coast of Brazil (São Paulo state) is a no-take reserve consisting mainly of rocky reefs (Wilkinson, 2008; Luiz et al., 2008). Established in 1993, Laje de Santos was initially considered a "paper park" with inadequate (or non-existent) enforcement to eradicate poaching in this heavily populated region of Brazil (Luiz et al., 2008). In the past 10 years significant efforts have been made to protect the park from illegal and extractive activities (Luiz et al., 2008). Costa dos Corais, located in Northern Brazil (Pernambuco state), was established in 1997 as a sustainable multi-use MPA. This area includes coral reef habitat and is used for tourism, fisheries, and coral reef conservation (Gerhardinger et al., 2011).

Effectiveness of Regulatory Mechanisms

Several studies have evaluated the effectiveness of Brazil's MPAs in protecting and restoring populations of overexploited reef species. Francini-Filho and Moura (2008a) estimated fish biomass and body size within the Itacolomis Reef no-take zone and at unprotected sites on the reef before (2001) and after (2002–2005) initiation of protection. Greenback parrotfish was the dominant species found on the Itacolomis Reef in terms of biomass (37.4% of total biomass), and considered a major fishery resource in the study area. Biomass of this species increased significantly inside the reserve and also in unprotected reefs close (0–400m) to its boundary between 2001 and 2002, soon after the reserve establishment and banning of the parrotfish fishery from the entire MERC (Francini-Filho and Moura, 2008a). Some evidence of spillover (i.e. higher biomass both inside the reserve and in unprotected sites closer to its boundary) was also found for the greenback parrotfish. The initial greenback parrotfish biomass increase on the unprotected reefs was followed by a statistically significant decrease from 2002 to 2003 after local fishermen decided to re-open the parrotfish fishery. Greenback parrotfish biomass inside the no-take reserve also decreased starting in 2004, although this decline was not statistically significant. The authors attributed this decline to increased poaching by some local fishermen who were strongly resistant to regulatory controls despite the apparent positive effects on fish biomass in the first few years after the reserve was established (Francini-Filho pers. comm).

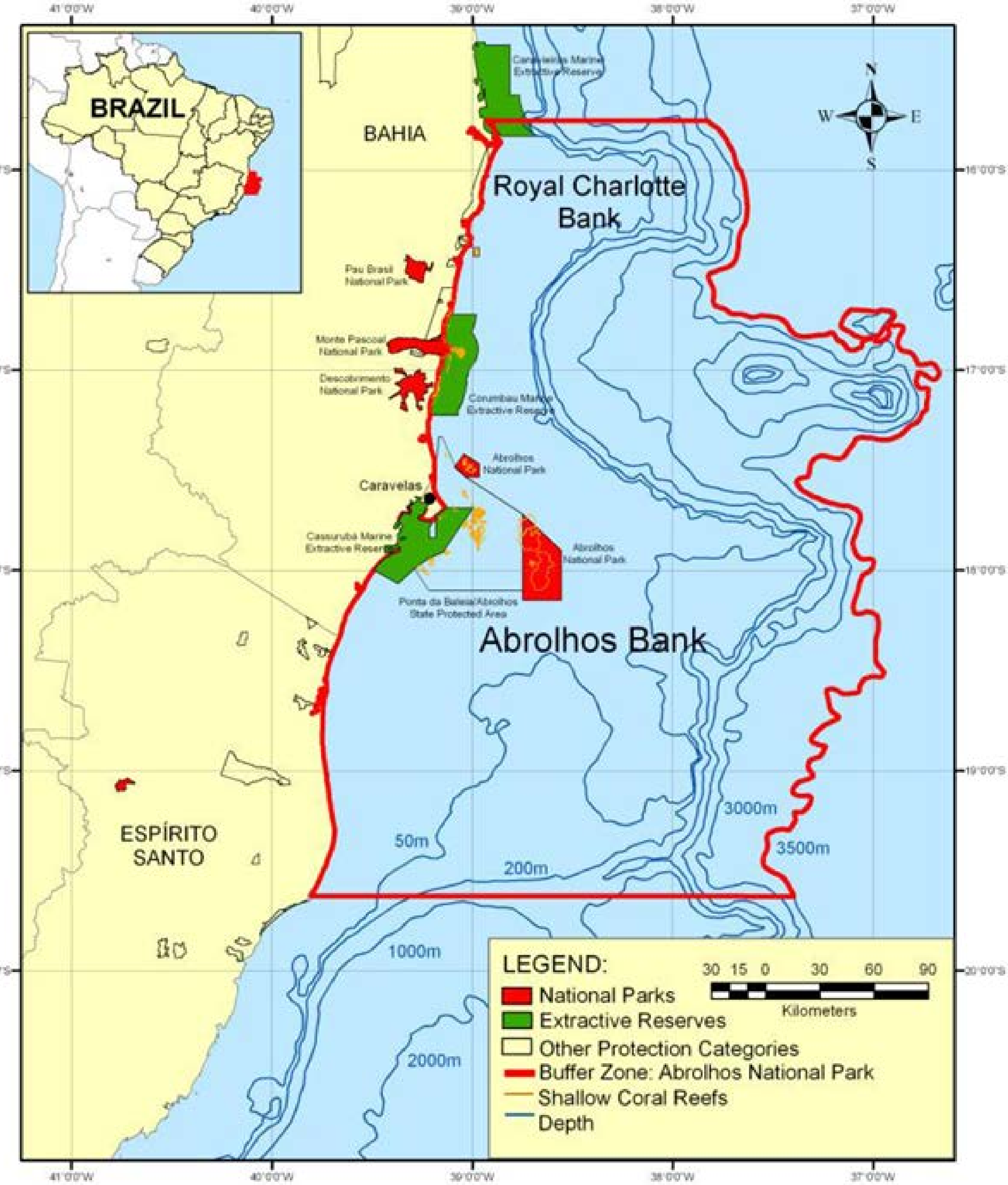

Figure 10. Distribution of Marine Protected Areas on Abrolhos Bank in Bahia State Brazil (from Cordell, 2006).

Araujo and Previero (2013) assessed evidence of potential MPA “spillover” effects in the greenback parrotfish fishery on Abrolhos Bank and Royal Charlotte. Fishermen from the municipalities of Alcobaça, Caravels, and Prado (Bahia state) were asked to mark locations on a nautical chart where they fished for greenback parrotfish. Results showed that about one-half (47%) of the 159 fishing locations were within a 15km radius of a no-take MPA and 38% were within a 10km radius. The authors suggest that fisheries operating within a 10-15 km radius of could be benefiting from “spillover” of greenback parrotfish to areas adjacent to the no-take reserve. “Spillover” effects may more spatially limited (i.e., to areas closer to the reserve boundary) for parrotfish species that are territorial and have small home ranges (Afonso et al., 2008).

In another study, Francini-Filho and Moura (2008b) compared fish biomass from 2001-2005 across several reef areas with different levels of protection. Their results varied depending on species considered and were sometimes confounded by year effects. For the greenback parrotfish, biomass was statistically higher within the newly established Itacolomis Reef’s no-take reserve than in any of the following areas: Itacolomis Reef multi-use area, no-take reserves within Abrolhos National Marine Park, and other open access areas. Greenback parrotfish biomass within the Abrolhos National Marine Park no-take areas was not statistically different than biomass found at either the multi-use or open access sites surveyed. This may be partially due to the lack of enforcement at Timbebas Reef no-take area (located within the national park) for many years after it was established in 1983 (Floeter et al., 2006).

Floeter et al. (2006) compared abundances of reef fishes across areas with varying levels of protection and enforcement along the Brazilian coastline (Table 2) to determine: 1) the current threat to reef fishes at different sites, and 2) the potential response of reef fish populations to different levels of regulatory protection. They found that heavily fished species, including greenback parrotfish, were significantly more abundant in areas with greater protection, while lightly fished and unfished species responded differently to protection at the different sites. Study sites with full protection (i.e., no-take areas with adequate enforcement and/or little fishing pressure) also produced significantly more large parrotfish (>21 cm) than did sites with only partial protection from fishing (Floeter et al., 2006). Ferreira (2005) found that reefs within the fully protected and enforced areas of the Abrolhos National Marine Park contained greater numbers of large-sized parrotfish compared to unprotected reefs on Abrolhos Bank. Similarly, Ferreira et al. (2001) reported a four-fold increase in the total abundance of studied species (from six families: Acanthuridae, Chaetodontidae, Holocentridae, Lutjanidae, Scaridae, and Serranidae) in protected versus fished areas on the Tamandare´ Reefs in Northeastern Brazil. Data from the Brazilian Coral Reef Monitoring Program has also shown that all trophic levels of fish were significantly more abundant on fully protected, no fishing areas, than areas in general use or lacking adequate enforcement (Wilkinson, 2008).

Table 2 – Characteristic features of the studied Brazilian reef sites (from Floeter et al., 2006).

Reef site	Distance from coast (km)	MPA area	Kinds of fisheries	Reserve status	Year of establishment	Effectiveness of the reserve
Abrolhos Reefs						
Arquipélago (P)	50	802 km^2	None	Marine National Park	1983	Full protection. enforced since 1986
Timbebas (PP)	10	110 km^2	Spearfishing, nets, hook and line	Marine National Park	1983	Not enforced[b]
Guarapari Islands						
Escalvada (PP)	11	None	Spearfishing, hook and line	None	–	Partially protected by distance
Coastal (NP)	0.5	None	Spearfishing, nets, hook and line	None	–	None
Arraial do Cabo						
Pedra Vermelha (PP)	–	500 m^2	Hook and line[a]	'Artisanal Fisheries Reserve'	1997	Not continuously enforced
Saco do Anequim (NP)	–	500 m^2	Hook and line, Spearfishing	None	–	None
Laje de Santos (P)	36	50 km^2	None	Marine State Park	1993	Full Protection. Not continuously enforced
Arvoredo Island (P)	11	178 km^2	None	Biological Reserve	1990	Full Protection. enforced

Sites are classified as protected (P), partially protected (PP), or not protected (NP).
a Mid-water fish only.
b Not enforced during the studied period. Since 2002, the Abrolhos National Park has a 45^0 vessel, a 12-people field staff including rangers, as well as an annual budget of more than US$150,000.00 that are also covering Timbebas.

The studies cited above provide ample evidence that, when fully protected and enforced, no-take reserves can have positive effects on greenback parrotfish abundance and size within the reserve boundaries, and possibly outside due to "spillover" effects. Local sea tenure systems and informal agreements, such as the short-lived ban on parrotfish harvest within the MERC (Francini-Filho and Moura, 2008a), may also provide some threat reduction, although without legal authority and regulatory backing such arrangements may be viewed as tenuous or unstable. Whether the existing system of MPAs in Brazil adequately addresses the threat to the greenback parrotfish population from fishing largely depends on the following factors: 1) the areal coverage and connectivity of no-take MPAs, 2) the relative importance of these areas to greenback parrotfish, 3) compliance and enforcement levels, 4) outside pressures or competing interests that could compromise MPA effectiveness, and 5) the legal, political and organizational systems within which the MPAs were established and operate.

For MPAs to work as a fishery management tool, fully protected (no-take) areas must be sufficiently large in area and include a variety of habitats critical to the various life history stages of the target species (Dugan and Davis, 1993). MPAs cover an estimated 3.85% of the greenback parrotfish total range (Comeros-Raynal et al., 2012). UVC data indicate that within this range, the reefs with the greatest abundance of greenback parrotfish are located within Abrolhos Bank (Ferreira, 2005; Francini-Filho and Moura, 2008a). At present, about 2% of the Abrolhos Bank is designated as a "no-take" marine reserve (Francini-Filho and Moura, 2008a). Afonso et al. (2008) found that for the parrotfish *Sparisoma cretense* in the Azore Islands, haremic adults displayed very high site fidelity with minimal dispersion from established male territories that could last for several years. This study suggests that a network of small to medium sized, well enforced no-take marine reserves can effectively protect "core" populations of reef fish (Afonso et al., 2008) and possibly serve as a buffer from extinction risk.

Magris et al. (2013) conducted a gap analysis to evaluate how well MPAs in Brazil meet conservation objectives for representation, connectivity, and replication (i.e. risk spreading). Replication of conservation features across multiple no-take areas lessens the probability that a catastrophic event or major threat within a no-take area will eliminate entire protected populations of species. Coral reef ecosystems were subdivided into four ecoregions: Eastern Brazil, Northeastern Brazil, Amazon, and Fernando de Noronha and Atoll das Rocas islands (note: greenback parrotfish are not found in the latter two ecoregions). No-take areas exceeded 20% coverage in three out of the four coral reef ecoregions, but accounted for less than 2% of coral reef areas in Northeastern Brazil. While a large portion of coral reef ecosystems in Brazil are designated as no-take, only a few of these areas are greater than 10 km^2 (Magris et al., 2013). Although details were not provided for coral reefs ecosystems specifically, Magris et al. (2013) reported that about half of all no-take areas in Brazil met their connectivity objective that the distance between adjacent no-take areas should not exceed 15 km. Pressey et al. (2014) followed up on the Magris et al. (2013) study by more finely delineating coral-reef ecosystems based on six geomorphic types (nearshore bank, bank off the coast, fringing, patch, mushroom reef, and atoll), two depth classes (deep and shallow), and two tidal zones (subtidal and intertidal), in addition to the four coral reef ecoregions (above). They found that the protection of coral reef ecosystems by no-take areas was very uneven across the 23 ecosystems delineated. Coverage ranged from 0% to 99% with a mean of 28%, with 13 of 23 ecosystems having no coverage (mostly nearshore banks and patch reefs located in the Northeastern ecoregion).

Vila-Nova et al. (2014) developed a spatial dataset that overlays Brazil's reef fish hotspots with MPA coverage and protection levels. Hotspots were identified as areas with either high species richness, endemism, or number of threatened species. Results showed a mismatch between no-take coverage and reef hotspots in the Northeast region from Paraíba state to central Bahia state. Reef fish hotspots for total richness, endemics, and targeted species were found in this region which does not have any designated no-take areas (only multi-use MPAs). The state of Espírito Santo was also identified as a hotspot for endemic, threatened and targeted reef fish species despite being the least protected region along the Brazilian coast.

Several researchers have noted the prevalence of high levels of poaching and inadequate enforcement within Brazilian "no-take" reserves (Ferreira and Goncalves, 1999; Cordell, 2006; Floeter et al., 2006; Wilkinson, 2008; Francini-Filho and Moura, 2008a; Luiz et al., 2008; Francini-Filho et al., 2013). Although these reports are based largely on anecdotal information, and quantitative data are lacking, illegal fishing activity is consistently cited as a factor that could undermine the effectiveness of "no-take" marine reserves in Brazil. In particular, easily accessible, shallow, near-shore reefs in heavily populated areas along the coast (e.g., Timbebas) appear to be more susceptible to the effects of poaching than more distant and deeper reefs. Management and enforcement of at least some Brazilian no-take areas has been reported as improving within the past decade (Luiz et al., 2008; Floeter et al., 2006).

Despite some recent environmental initiatives, there is still a high degree of pessimism concerning the effectiveness of Brazil's system of MPAs (Gerhardinger et al., 2011). Gerhardinger et al. (2011) interviewed MPA managers and high level government officials about their perceptions of the implementation of a national MPA strategy and the recent institutional changes in marine conservation agencies. Structural governance challenges identified by respondents included poor inter-institutional coordination of coastal and ocean governance; institutional crisis faced by the national marine conservation agency; poor management (or lack of cohesive management plan) within individual MPAs; problems with regional networks of MPAs; an overly bureaucratic management and administrative system; and financial shortages creating structural problems and a disconnect between MPA policy and its delivery (Gerhardinger et al., 2011). The success of a national MPA system in Brazil will depend on the capacity to overcome pervasive lack of enforcement, frequent re-structuring and re-organization of government environmental agencies, and difficulties with the practicality of implementing management plans (Wilkinson, 2008). Inter-institutional coordination with state environmental agencies is also seen as a challenge to a successful national system of MPAs (Cordell, 2006). Companies frequently take advantage of a loophole in licensing stemming from long-running federal state jurisdictional conflicts and disjunctions. State environmental agencies have considerable autonomy and latitude to issue permits for development projects without IBAMA's approval, thereby avoiding more stringent federal oversight (Cordell, 2006). As stated by Cordell (2006): "Even if the sea in Brazil were filled with a latticework or network of MPAs (closed areas) to match biological scales (geared to support connectivity) and the country could overcome tactical problems of enforcing closures, the likelihood and risks that eventually such networks would still be undercut from (uncontrolled) upstream, inland, and off-site network threats remain extraordinarily high."

As discussed above, overutilization from artisanal and commercial fishing was categorized as "somewhat likely" to contribute significantly to the extinction risk of greenback parrotfish. Given the systemic problems associated with enforcement of no-take MPAs in Brazil and the general lack of traditional fishing regulations designed to limit catch and effort of reef fishes, I conclude that the threat of inadequate existing regulatory mechanisms is also somewhat likely to contribute significantly to the extinction risk of this species both now and in the foreseeable future: Risk Category – Moderate.

Analysis of Overall Extinction Risk

The overall extinction risk to the greenback parrotfish was determined based on my qualitative assessment of the specific demographic risks factors and ESA Section 4(a)(1) threats discussed above and the interplay among those factors. As a general caveat, scientific data available to assess greenback parrotfish demographic viability criteria and threats were fairly limited in this review. A summary of categorical ratings showing the likelihood that each particular demographic factor and threat contributes significantly to the risk of greenback parrotfish extinction is shown in Table 3. These ratings were based on my analysis of the available scientific and commercial information when the report was written and could be modified as new information relevant to greenback parrotfish extinction risk is made available. The term “foreseeable future” in the ESA’s definition of “threatened” was defined as the timeframe over which threats can be reliably predicted to impact the biological status of the greenback parrotfish. I did not define a specific “foreseeable future” due to uncertainty regarding greenback parrotfish life history parameters and threats to the species. For purposes of this analysis, foreseeable future was defined as approximately 40 years.

Table 3. Summary of categorical ratings of the likelihood that each particular demographic factor and threat contributes significantly to the risk of greenback parrotfish extinction. Based on a five item scale: Very low = very unlikely; Low = unlikely; Moderate = somewhat likely; High = likely; and Very high = very likely.

Extinction Risk Factor	**Likelihood that particular factor contributes significantly to the greenback parrotfish risk of extinction**
Demographic Factor	
Abundance	Low
Growth rate/productivity	Low
Spatial structure/connectivity	Very low
Diversity	Very low
ESA Section 4(a)(1) Threat	
Present or threatened destruction, modification, or curtailment of habitat or range	Low
Overutilization by artisanal and commercial fisheries	Moderate
Competition, disease, or predation	Very low
Other natural or man-made factors	Very low
Evaluation of adequacy of existing regulatory mechanisms	Moderate

A recent quantitative assessment of the greenback parrotfish fishery on Abrolhos Bank indicates a very high level of exploitation of this species. The lack of a catch record time series or baseline information prevented a traditional assessment of the status of this species that would ideally be available for an extinction risk analysis. Instead, a Productivity and Susceptibility Analysis (PSA), designed for data deficient and small scale fisheries, placed the greenback parrotfish in the zone of “high potential risk” of overfishing. Despite study limitations, other research suggests that fishing pressure has reduced the abundance of greenback parrotfish, and in some localities the reduction has been significant. Due to uncertainties and limitations associated with the available data, it is difficult to quantitatively assess the magnitude of the decline in abundance caused by fishing, or to project the magnitude of future impacts of fishing on greenback parrotfish abundance or species survival. With regard to the threat of overutilization by artisanal and commercial fisheries, I conclude that this factor is somewhat likely to contribute significantly to the greenback parrotfish extinction risk both now and in the foreseeable future. Traditional fishing regulations designed to limit catch and effort of reef fishes are either non-existent or poorly enforced throughout most of the greenback parrotfish range. Systemic problems associated with the enforcement of no-take marine reserves also contribute to the inadequacy of existing regulatory mechanisms to address the threat to greenback parrotfish from fishing. I conclude that the inadequacy of existing regulatory mechanisms is somewhat likely to contribute significantly to the greenback parrotfish extinction risk both now and in the foreseeable future.

Although scientific studies indicate that some portion of habitat used by greenback parrotfish has been degraded, the available information does not support a conclusion that habitat associated changes contribute to the extinction risk of this species in a significant way. Therefore, I conclude that it is unlikely that the threat of "destruction, modification, or curtailment of habitat or range" contributes significantly to greenback parrotfish extinction risk either now or in the foreseeable future. Based on the sparse information pertaining to the threats "competition, disease, or predation" and "other natural or man-made factors," I conclude that it is very unlikely that these threats contribute significantly to greenback parrotfish extinction risk either now or in the foreseeable future.

All of the demographic factors evaluated were categorized as either unlikely or very unlikely to contribute significantly to the current extinction risk. Although available information on this species is limited, there are no indications that the greenback parrotfish is currently at risk of extinction based on demographic viability criteria.   Information on relative abundance and mean density from UVC surveys suggest that greenback parrotfish are still a commonly occurring species on many Brazilian reefs and represent a relatively large proportion of the total fish biomass on some reefs.

After considering the cumulative evidence from all the information available, I conclude that the **greenback parrotfish currently faces a low risk of extinction throughout its range**. This determination is based, in part, on the conclusion that demographic factors related to abundance and productivity are not likely to contribute significantly to the current extinction risk. However, considering the future threat of overutilization from artisanal and commercial fishing and the inadequacy of existing regulatory mechanisms, it is likely that abundance of this species will decrease in the future. As a protogynous hermaphroditic species, greenback parrotfish may be more susceptible to fishing methods that selectively target the largest individuals in the population. Continued selective removal of terminal males, individuals undergoing sexual transition, and the largest females at high rates will result in decreased productivity and likely increase the risk of extinction over time. In addition, as one of the largest parrotfish species with relatively late maturation, greenback parrotfish may more vulnerable to overexploitation than smaller, faster maturing parrotfish species (Taylor et al., 2014). Although not possible to accurately quantify, at least qualitatively, the overall risk of greenback parrotfish extinction in the foreseeable future is likely greater than the current risk of extinction. Therefore, I conclude that the **greenback parrotfish risk of extinction in the foreseeable future is between low and moderate**. That is, the risk of extinction in the foreseeable future is greater than low but less than moderate.

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