ENDANGERED SPECIES ACT
STATUS REVIEW REPORT OF 3 SPECIES OF FOREIGN CORALS

Cantharellus noumeae
Siderastrea glynni
Tubastraea floreana


Charlie Veron ©


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Executive Summary

This status review report was conducted in response to a petition received from WildEarth Guardians on July 15, 2013 to list 81 marine species as endangered or threatened under the Endangered Species Act (ESA). Twenty-three of the petitioned species were corals. NMFS evaluated the petition to determine whether the petitioner provided substantial information as required by the ESA to list these species. In A *Federal Register* notice on October 25, 2013 (78 FR 63941), NMFS determined that the petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted for three species (*Cantharellus noumeae, Siderastrea glynni*, and *Tubastraea floreana*) and, subsequently, NMFS initiated a status review of those species. This status review report considers the status and extinction risk to those three species.

Cantharellus noumeae is a fungiid or mushroom coral that was the first described species of its genus in 1984. The species may be solitary or colonial; colonies consist of a few contorted polyps. *Cantharellus noumeae* currently occurs only in a restricted area on fringing reefs in New Caledonia with uncertain presence on New Guinea. There is no species-specific population or trend information available for this species. The species is likely affected by climate change to some degree, the effects of large-scale mining and development in New Caledonia, inadequate regulatory enforcement, and a low productivity life history. Extinction risk for this species is moderately high.

Siderastrea glynni is a non-reef forming species that was described in 1994. It occurs in spherical colonies that are 70 to 100 mm in diameter. The only known specimens were brought into captivity in 1997 when they began suffering from the environmental conditions of a severe El Niño. Nine colonies currently exist in captivity. Recent genetic work has shown that *S. glynni* is genetically very similar to the Caribbean species *S. siderea*. The study could not differentiate between two possible explanations of their status: (1) that *S. siderea* and *S. glynni* are the same species and that *S. glynni* may have recently passed through or been carried across the Panama Canal to the Pacific Ocean side, or (2) the alternate possibility that *S. glynni* evolved from *S. siderea*, likely about 2 to 2.3 million years ago during a period of high sea level when the Isthmus of Panama may have been breached, allowing inter-basin transfer of species' ancestors. Here I err on the side of caution by concluding that *S. glynni* is a valid and unique species until future studies can resolve the uncertainty about its status. The species is threatened by its small population size. Should this species ever be restored to the wild, it faces considerable habitat degradation threats from coastal development, oil production, eutrophication and other pollution, and increased transportation activities in the Panama City area, the Gulf of Panama, and the enlarged Panama Canal. Climate change and disease would also likely be threats to the species. Extinction risk for this species is high.

Tubastraea floreana was first described in 1982. It is an azooxanthellate species, which means it lacks the symbiotic photosynthetic zooxanthellae that most scleractinian corals have. It is endemic to a few sites on a number of islands in the Galapagos Islands. Prior to the 1982-83 El Niño this species was known from six sites on four islands in the Galapagos. Since the 1982-83

El Niño, specimens have only been observed at two sites. At one of these two sites the species has not been seen since 2001, leaving only a single confirmed site with living specimens. El Niño, climate change, development, small population size, and inadequate regulatory enforcement are likely threats to the species. Extinction risk for this species is high.

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INTRODUCTION

Scope and Intent of the Present Document

On July 15, 2013, the National Marine Fisheries Service (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) and to designate critical habitat. NMFS evaluated the information in the petition to determine whether the petitioner provided "substantial information" as required by the ESA to list a species.

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 decided that the petition presented substantial scientific information that listing may be warranted and that a status review was necessary for three species (*Cantharellus noumeae, Siderastrea glynni*, and *Tubastraea floreana*; 78 FR 63941, 25 October 2013). Experts and members of the public were requested to submit information to NMFS to assist in the status review process from October 25 through December 24, 2013. We received information from 3 parties in response to our request for information in the 90-day finding. One commenter supported the petition finding and listing of the corals, but did not provide any substantive scientific or commercial information. The Department of Interior Bureau of Ocean Energy Management (BOEM) noted that none of the three species overlapped with areas where BOEM or the Bureau of Safety and Environmental Enforcement have jurisdiction or issue permits. The petitioner provided comments supportive of listing the three species including comments on the threats of mining, urbanization, cyclones and climate change. They also provided 4 scientific papers, 2 news stories, and 2 webpages cited in their comments. This information was incorporated in the status review as appropriate.

This document is the status review report in response to the petition and 90-day finding. The ESA stipulates that listing determinations be made on the basis of the best scientific and commercial information available. I undertook a scientific review of the biology, population status and future outlook for these three species. This document reports the findings of the scientific review as well as analysis and conclusions regarding the biological status of the species as potential candidates for listing under the ESA. These conclusions are subject to revision should important new information arise in the future. Within each topical section there is a discussion for each of the three species in turn. Where available, I provide citation to review articles that provide even more extensive citations for each topic. Data and information were reviewed through 6 February, 2014.

Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, three key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?

Under the ESA a species is defined to include taxonomic species as well as “any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.”

2) If the petitioned entity is a “species”, is the "species" threatened or endangered?

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Neither NMFS nor the FWS have developed any formal policy guidance about how to interpret the definitions of threatened or endangered species in the ESA. NMFS considers a variety of information in evaluating the level of risk faced by a species in deciding whether the species is threatened or endangered. Important considerations include 1) absolute numbers of the species and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) any trends in abundance; 4) natural and human influenced factors that affect survival and abundance; 5) possible threats to genetic integrity; and 6) recent events (e.g., a bleaching event or a change in management or habitat use) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations.

NMFS is required by law (ESA Sec. 4(a)(1)) to determine whether one or more of the following factors is/are responsible for the species' threatened or endangered status:

The present or threatened
(A) destruction, modification or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;
(C) disease or predation;
(D) inadequacy of existing regulatory mechanisms; or
(E) other natural or human factors affecting its continued existence.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific and commercial information available regarding its current status, after taking into consideration conservation measures that are being made that may help the species. Because of these key statutory, regulatory and policy requirements, this status review must carefully consider the above topics.

Summary of the Listing Petition

The petition claims that the species are in decline, referencing the International Union for Conservation of Nature (IUCN) Red-List classifications which have assessed *Cantharellus noumeae* as "Endangered" and the other two species as "Critically Endangered". The petition identifies similar core threats for all three species: global climate change affecting temperature and bleaching events, ocean acidification, and disease; human population growth, development, and resulting pollution; and the inadequacy of regulatory mechanisms. A few species are noted as having additional threats including mining causing sedimentation and habitat degradation (C*. noumeae*), pollution from agriculture and industry (C*. noumeae*), human recreation and tourism activities (C*. noumeae*), and rarity and low genetic variability (*S. glynni*). The petition claims that listing of these species would provide much needed protections, including greater awareness, funding, trade protections, and would allow for assistance programs under Section 8 of the ESA.

LIFE HISTORY AND ECOLOGY

Taxonomy and Distinctive Characteristics

The coral species considered herein are all marine invertebrates in the phylum Cnidaria. The phylum is called Cnidaria because member species use cnidae (capsules containing stinging nematocysts) for prey capture and defense. All are tropical, shallow water, scleractinian ("stony") corals that secrete a calcium carbonate skeleton. Two of the three have the typical stony coral symbiosis with zooxanthellae algae that reside in gastrodermal cells of the coral tissue. All are non-reef building corals that live in small colonies or as solitary individuals.

Cantharellus noumeae (Figure 1) is a fungiid or mushroom coral that was the first described species of its genus in 1984 (Hoeksema and Best, 1984). It received its own new genus name because, unlike most other fungiid corals, it is stalked and not free-living as an adult. Other species in the genus have since been discovered and named, so the genus is no longer monotypic. The genus name comes from the scientific name of chanterelle mushrooms, which this species resembles. Polyps are relatively small for a fungiid coral and range from 25 to 65 mm in diameter (Hoeksema and Best, 1984). The polyps are cup-shaped when fully developed and have wavy margins (AIMS, 2013a). The primary septa are thin. The species may be solitary or colonial; colonies consist of a few contorted polyps. Their typical color is mottled brown.

Figure 1. *Cantharellus noumeae*. Charlie Veron ©

Siderastrea glynni (Figure 2) was described in 1994 (Budd and Guzmán, 1994). It occurs in non-reef forming spherical colonies that are 70 to 100 mm in diameter (AIMS, 2013b). They have polygonal corallites that are 2.5 to 3.5 mm in diameter (Budd and Guzmán, 1994). The species is a light reddish-brown in color and occur on coarse sand-rubble substrates. Recent genetic work by Forsman et al. (2005) has shown that *S. glynni* is genetically very similar to the Caribbean species *S. siderea*. Their study could not differentiate between two possible explanations of their evolution: (1) that *S. siderea* and *S. glynni* are the same species and that *S. glynni* may have recently passed through or been carried across the Panama Canal to the Pacific Ocean side, or (2) the alternate possibility that *S. glynni* evolved from *S. siderea*, likely about 2 to 2.3 million years ago during a period of high sea level when the Isthmus of Panama may have been breached, allowing inter-basin transfer of species' ancestors. Here I err on the side of caution by concluding that *S. glynni* is a valid and unique species until more precise genetic studies can resolve the uncertainty about its status.


Figure 2. *Siderastrea glynni*. Juan Mate ©

Tubastraea floreana (Figure 3) was first described by Wells (1982). It is an azooxanthellate species, which means it lacks the symbiotic photosynthetic zooxanthellae that most scleractinians have. It has a bright pink color while alive, but turns deep red-black when dead out of water. Corallites in the species are closely spaced (Cairns, 1991) and about 4-6 mm in size (Wells, 1983).

Figure 3. ***Tubastraea floreana*****. Paul Humann ©**

Based on the information presented in the petition, along with the information available from a literature review, I find that each of the three species constitutes a valid “species” eligible for listing under the ESA as each is a valid taxonomic species.

Range and Habitat Use

All of the species considered in this status review occur in the Pacific and/or Indian oceans. None occurs in the Exclusive Economic Zone of the United States or territorials seas under jurisdiction of the United States.

Cantharellus noumeae was thought to occur only in a restricted area of less than 225 km^2 on reefs in sheltered bays in New Caledonia on the southern tip of the main island of Grand Terre (Hoeksema et al., 2008). Recent research by the French Institut de recherche pour le Développement (IRD) has found that the species also occurs on fringing reefs a bit farther up the southeast coast at Noumea and at Balabaio in the northeastern part of New Caledonia (www.lagplon.ird.nc; Gilbert, personal communication). It is found in waters 10 to 35m deep close to soft sediment habitats that are in sheltered bays and lagoons (Hoeksema and Best, 1984). An erroneous report of the species in the Philippines by Licuanan and Capili (2004) was actually a misidentification of *Lithophyllon undulatum* (Hoeksema, 2009; Hoeksema, personal communication) and other misidentifications with *Fungia fungites* are known (Gittenberger et al., 2011). Another researcher has records of it in western, northern and eastern parts of the island of New Guinea that includes Papua New Guinea and West Papua, Indonesia with details likely to be published on a new website (http://coralsoftheworld.com; Charlie Veron, personal communication). There are also reports of it from Papua New Guinea in the IUCN assessment , but they question the validity of this record (Hoeksema et al., 2008). The IUCN assessment and the researcher whose published record is in question (Doug Fenner) suggest further confirmation is necessary (Hoeksema et al., 2008; Fenner, personal communication). Fossil records from the Miocene (over 5 million years ago) indicate that this species was at one time found as far west as East Kalimantan, on the island of Borneo, Indonesia (Hoeksema, 1989; Hoeksema, 1993).

The range of *S. glynni* is from a small area of the Pacific Ocean near the small island of Uraba in Panama Bay, a few kilometers from the opening of the Panama Canal (Guzmán and Edgar 2008). All of Uraba Island and part of the adjacent Taboga Island constitute a wildlife refuge, mainly for migratory and nesting birds. Identified colonies of *S. glynni* were reported to be unattached and occur "along the upper sand-coral rubble reef slope at a depth of 7 to 8.5 meters" (Budd and Guzmán 1994). All the islands around the site, as well as other islands to the south, were searched several times without finding any additional colonies (Fenner, 2001).

Tubastraea floreana is endemic to a few sites on some of the Galapagos islands. It is mostly found in cryptic habitats including the ceilings of caves and on ledges and rock overhangs (Hickman et al. 2007). It is reported to occur at depths of 2 to 46 m (Hickman et al., 2007).

Reproduction, Feeding and Growth

Scleractinian corals have diverse reproductive strategies including both asexual and sexual modes of reproduction (see Brainard et al. 2011). Individual reproductive modes for these three species have not been studied. *Cantharellus noumeae* may be a sequential sex-changing species like other members of its family. With sexual reproduction, embryonic development culminates with the formation of larvae called planulae that are planktonically dispersed over periods of hours to weeks or months. Because coral larvae are relatively poor swimmers, their dispersal distance will largely depend on the duration of the pelagic phase and the speed and direction of water currents transporting the larvae (Scheltema, 1986). Settlement can be stimulated by a variety of chemical and acoustic cues (Brainard et al., 2011). Once larvae are able to settle on appropriate hard substrate, energy is diverted to growth and maintenance. In asexual reproduction, colony pieces or fragments are dislodged to establish new colonies.

Because of their relationship with symbiotic zooxanthellae, *C. noumeae* and *S. glynni* need to live in shallow water to be exposed to light the symbiotic algae use to photosynthetically fix carbon. Carbon fixed by zooxanthellae can provide up to 100% of the daily caloric needs for maintenance of the host coral (Muscatine et al., 1981). The host coral however still requires additional calories and key nutrients from other sources in order to be able to have sufficient energy to grow and reproduce (Falkowski et al., 1984). All three species can also feed on zooplankton, which *T. floreana* must rely on since it lacks zooxanthellae. Other *Tubastraea* species are invasive and productive (Riul et al., 2013) so *T. floreana* may also be moderately productive. According to Figueroa (2009) no comprehensive study had been done of zooplankton in the Galapagos before his work, so there is no information on population trends in plankton food sources there. Because of its larger polyp size, *C. noumeae* likely feeds on relatively larger planktonic organisms.

There is no species-specific information on the growth of any of these species.

DISTRIBUTION AND ABUNDANCE

The petitioners use 2004 ocean-basin wide estimates of reef habitat that has already been destroyed or is "likely to be destroyed within 20 years" (Wilkinson, 2004) as proxies for likely trends in population size for the petitioned species. This may be problematic for a number of reasons: the habitat loss data are broad geographic estimates that do not necessarily reflect the actual range of the petitioned species; it is unclear on what basis and using what data Wilkinson (2004) was able to estimate future habitat loss; and not all species respond the same way to the threats underlying the assumed habitat loss (see discussion below). Moreover, even if true, the estimated population declines based on these expected habitat losses do not exceed the levels of population loss in actively and sustainably managed fishery species and thus are not necessarily severe enough to warrant consideration as meeting the requirements for ESA listing in and of themselves. These population decline estimates do not constitute information sufficient to suggest the extinction risk for any of these species is significant. I discuss the available species-specific information on population status and trends below.

Cantharellus noumeae

There is no species-specific population or trend information available for this species according to the IUCN assessment (Hoeksema et al., 2008) or in any literature I could find. Antoine Gilbert (a researcher in New Caledonia, personal communication) confirmed the lack of species-specific studies in New Caledonia. The current and continuing presence of the species in New Caledonia was confirmed by Hoeksema (personal observation) in 2012 and in one murky location in Prony Bay on the southern tip of Grand Terre in 2013 (Bruckner, personal communication). In addition, Antoine Gilbert (personal communication) notes that from surveys he has done over the past four years, the species is "uncommon and usually found in fringing reefs where sedimentation is quite intense." He also noted that the species is "usually found in low density, [but] it was observed in relative[ly] high density on the slope of artificial shores (embankment) in the biggest (commercial and industrial) harbour of New Caledonia: la Grande Rade." I found no information on abundance or trends on New Guinea. Its presence at one site in Milne Bay (Fenner, 2003) is uncertain; Veron may have information from New Guinea on his website soon (see above).

Siderastrea glynni

Only five colonies of *S. glynni* have ever been found. All were found by Budd and Guzmán (1994) when they discovered the species in 1992. All five colonies occurred within a small area of less than 10 m^2 with each colony within 1 m of another (Budd and Guzmán, 1994). Each colony was no more than 20 cm^2 in size. One colony was sacrificed in order to provide material for the species description. During the 1997-98 El Niño, the four surviving colonies started to deteriorate, displaying signs of bleaching and tissue loss. Due to their unhealthy state, the four colonies were moved to Smithsonian Tropical Research Institute (STRI) aquaria in Panama City where they remain to this day (Guzmán and Edgar, 2008; Guzmán, personal communication). According to Guzmán (personal communication) the colonies were fragmented to increase the number of specimens, but their growth rate has been very slow and some fragments did not survive. From the original colonies only one survives with less than 4 cm^2 of living tissue. Nine of the fragmented colonies also survive in the lab and all are less than 9cm^2 in area (Guzmán, personal communication). No known colonies exist in the wild, however, there is a possibility that it still exists elsewhere in the wild and is yet undiscovered (Guzmán and Edgar, 2008). There are no plans to re-introduce the species as existing colonies are too small to survive, though three of the fragments are being considered for cryopreservation, further reducing the population size (Guzmán, personal communication).

Tubastraea floreana

According to Hickman et al. (2007), prior to the 1982-83 ENSO this species was known from six sites on four islands in the Galapagos. Since the 1982-83 ENSO, specimens have only been observed at two sites. At one of these two sites the species has not been seen since 2001, leaving only a single confirmed site with living specimens (Hickman et al., 2007). Recent reports indicate the species is still present in at least one site (Stuart Banks, personal communication). I could find no other published information on distribution or abundance for this species.

ANALYSIS OF THE ESA SECTION 4(A)(1) FACTORS

Issues Common to All Petitioned Species

As noted above, NMFS is required to assess whether these candidate species are threatened or endangered because of one or a combination of the following five threats: (A) destruction, modification or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; or (E) other natural or human factors affecting its continued existence. The status review conducted in 2011 by NOAA and Federal government biologists for a separate petition to list 83 species of corals under the ESA includes a thorough and detailed discussion of ESA Section 4(A)(1) threats to coral reefs generally (Brainard et al., 2011). That document and its discussion are incorporated herein by reference and highlighted as appropriate. Brainard et al. (2011) concluded that the most significant generalized threats to corals were ocean warming, disease, and ocean acidification. Additional new information published or received subsequent to the publication of Brainard et al. (2011) and relevant to this petition is discussed and highlighted below. A general discussion of information on the ESA Section 4(A)(1) factors relevant to all species considered in this report occurs first, followed by sections with species-specific threat information for each of the three species.

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

Climate change and its effects on coral habitat, especially through coral bleaching and ocean acidification, is the major threat cited by the petitioners and will be considered in this section. These effects are caused by the rapid increase in atmospheric concentrations of greenhouse gases that are in turn increasing the radiative forcing of the global climate system and altering ocean carbonate chemistry. Since submission of the petition and publication of Brainard et al. (2011), the United Nations Intergovernmental Panel on Climate Change (IPCC) has released the first part of the fifth global assessment report (the physical science portion) in 2013 (IPCC, 2013). This report provides increased certainty regarding the role of human sources in causing global climate change and showed with high confidence that ocean warming accounts for over 90% of the energy accumulated in the global climate system between 1971 and 2010. The report concluded that about 30% of the emitted anthropogenic CO_2 has been absorbed in the oceans. The Working Group #2 report on effects of the current estimates of global climate change will not be published until mid-2014, so the fourth assessment report discussion of effects is still the most recent IPCC information in this area and is discussed fully in Brainard et al. (2011).

Coral bleaching occurs when the photosynthetic zooxanthellae symbionts of corals are damaged by light at higher than normal temperatures. The resulting damage leads to the expulsion of these important organisms from the coral host, depriving the host of the nutrients and energy provided by the zooxanthellae. While corals can survive mild to moderate bleaching, repeated, severe, or prolonged bleaching can lead to colony mortality. Bleaching events have been increasing both in intensity and geographic extent due to worldwide anthropogenic climate change (Hoegh-Guldberg, 2006; Eakin et al., 2009). Certain genera and growth forms, particularly branched species, are more sensitive to bleaching than others (Wooldridge, 2013). Many corals are physiologically optimized to their local long-term seasonal variations in temperatures and an increase of only 1 – 2 °C above the normal local seasonal maximum can induce bleaching (Brainard et al., 2011; Logan et al., 2013). The United States National Oceanic and Atmospheric Administration (NOAA) Coral Reef Watch satellite bleaching database shows that the range of all three species occurs in areas that frequently have bleaching alerts, with alerts being more frequent and severe in the range of *S. glynni* and *T. floreana*, than for *C. noumeae*. Species-specific information is discussed below.

Ocean acidification threatens to slow or halt coral growth and reef building entirely if the pH of the ocean becomes too low for corals to form their calcite skeletons, but tolerance appears to vary by species for those that have been studied (see Brainard et al., 2011). In addition, bioerosion of reefs is likely to accelerate as coral skeletons become more fragile as a result of the effects of acidification, but here again, generalizations about the extent of the effects are highly species specific. Since the petitioned species are not reef-building, this effect is likely to be less significant for them.

Sea-level is also likely to rise as a result of climate change, but effects on corals are highly uncertain owing to uncertainty in both the likely rate and extent of sea-level rise as well as the ability of corals generally (or the petitioned species specifically) to keep pace with the rise in sea level (Brainard et al., 2011).

While climate change effects are likely to be serious for many corals, Brainard et al. (2011) show that adaptation and acclimatization of corals to increased ocean temperatures are possible, that there is intra-genus and inter-species variation in susceptibility to bleaching, ocean acidification, and sedimentation, that at least some species have already expanded their range in response to climate change, and that not all species are seriously affected by ocean acidification. In addition, a more recent paper by Logan et al. (2013) examined the potential for coral adaptation and acclimatization to climate change and found that these processes reduced the frequency of mass bleaching events in the future. Their modeling results suggest some adaptation or acclimatization may even have already occurred. A study by Wooldridge (2014) provides support that a suite of morphological and physiological traits relate to bleaching vulnerability. These include symbionts type, metabolic rate, colony tissue thickness, skeletal growth form, mucus production rates, fluorescent pigment concentrations, and heterotrophic feeding capacity. According to Wooldridge, these traits tend to correlate with the ends of the dichotomy of branching and plate corals with thin tissue layers vs. massive and encrusting corals with thick tissue layers. The species under consideration here are not necessarily the most vulnerable based on those traits (see below). Therefore, while climate change is considered a potential threat to these candidate corals, the likelihood and magnitude of threats from climate change are largely species-specific and must be examined on that basis to fully assess extinction risk.

The petitioners and Brainard et al. (2011) emphasize the underlying ultimate causal factor for these anthropogenic threats is human population growth and affluence.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes
Harvest of corals is a highly species-specific endeavor dependent on the type of coral and the potential uses for an individual species; no generalizations about this threat are possible in this section and all discussion is deferred to the species-specific discussion section below.

Competition, Disease or Predation
Coral disease has been linked to the effects of climate change (see Brainard et al., 2011), especially indirectly as a synergistic effect as climate change and other threats potentially increase stress on corals, making them more susceptible to disease. Coral diseases also appear to be increasing worldwide (Roessig et al., 2004). Nevertheless, susceptibility of coral species to disease is highly species-specific and no generalizations can be made here; all further discussion is deferred to the species-specific section below.

Inadequacy of Existing Regulatory Mechanisms
All of the species considered in this petition were listed in Appendix II of the Convention on International Trade in Endangered Species (CITES) in 1989 when all scleractinian corals were listed. The 1989 listing rationale for including all scleractinians when only some were in trade was because of identification difficulties where non-traded species resemble species in trade. According to Article II of CITES, species listed on Appendix II are those that are "not necessarily now threatened with extinction but may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival." Based on the CITES definitions and standards for listing species on Appendix II, the species' actual listing on Appendix II is not itself an inherent indication that these species may now warrant threatened or endangered status under the ESA. The significance of any threat of international trade would depend on the amount of international trade relative to the population size of the species, as well as any other factors related to the trade, such as habitat damage caused in the collecting process, or synergistic effects of other threats.

Because each of the species considered herein exists in small ranges that do not overlap with each other and they are not otherwise managed or regulated under any other common international regimes, additional discussion of this factor is left for the species-specific entries for this section.

Other Natural or Manmade Factors Affecting Continued Existence
There is no information on other threats that affect all of the species considered herein.

Synergistic effects
Recent research has shown that synergistic interactions among threats often lead to higher extinction risk than predicted based on the individual threats (Brook et al., 2008). "Like interactions within species assemblages, synergies among stressors form self-reinforcing mechanisms that hasten the dynamics of extinction. Ongoing habitat destruction and

fragmentation are the primary drivers of contemporary extinctions, particularly in the tropical realm, but synergistic interactions with hunting, fire, invasive species and climate change are being revealed with increasing frequency" (Brook et al., 2008). "[H]abitat loss can cause some extinctions directly by removing all individuals over a short period of time, but it can also be indirectly responsible for lagged extinctions by facilitating invasions, improving hunter access, eliminating prey, altering biophysical conditions and increasing inbreeding depression. Together, these interacting and self-reinforcing systematic and stochastic processes play a dominant role in driving the dynamics of population trajectories as extinction is approached" (Brook et al., 2008). Similar synergistic effects are likely in marine ecosystems as well. For example, climate change may indirectly magnify disease as discussed above as well as coastal pollution and other problems. Because of water circulation and oceanic volume changes, estuarine and coastal systems are predicted to experience "increased eutrophication, hypoxia, and anoxia" (Roessig et al., 2004). For most of these coral species it is possible that the interactive effects of the numerous threats identified herein are having multiplicative effects on extinction risk. In particular, habitat loss, climate change, and decreased water quality may interact in ways to multiplicatively increase the extinction risk of these species, especially so as populations reach such small sizes where Allee effects, genetic drift, and disasters can dominate population dynamics. Nevertheless, the effects of these interactions are likely to be highly species-specific and dependent on each species' underlying sensitivity to the individual threats and their interactions, so that even broad generalizations about synergistic effects are not possible.

Cantharellus noumeae

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

Cantharellus noumeae is exposed to deforestation, urbanization and mining activity that causes sedimentation and water pollution throughout its range in New Caledonia (Hoeksema et al., 2008; David et al., 2010; McKenna et al., 2011). The mining activity is a result of nickel and smaller amounts of other metal mining (cobalt and chromium especially) on land throughout the main island of Grand Terre (McKenna et al., 2011; Hoeksema, personal communication). The economy of New Caledonia is based mainly on nickel mining and the associated metallurgy processing industry as the main island of Grand Terre holds 25% of the world's known nickel deposits (McKenna et al., 2011). Nickel mining started there in the 1870s. Currently most mining is done by open-cast strip mining, which has caused deforestation and increased erosion and runoff of sediments leading to varying degrees of sedimentation and light attenuation throughout the lagoon of Grand Terre, including in areas in and adjacent to the species range (Ouillon et al., 2010). Labrosse et al. (2000) estimate that 300 million cubic meters of soil has been displaced since the beginning of mining activities. Douillet et al. (2001) modeled sediment transport in areas in and adjacent to the species range. Mines are located across the country, including the large new Goro complex which includes mines, processing facilities and a port (Figure 4). The complex began production in late 2010 and is very near the most abundant population of *C. noumeae*. The Goro processing plant, along with another new one further north on the island, will triple the country's metal processing capacity by 2024 (David et al., 2010). The Goro complex has already had three incidents affecting the environment related to spill and releases of sulfuric acid solutions used in the processing of the nickel ore (Sulfuric Acid on the Web, 2013). Runoff of heavy metals from the mining operations has greatly increased concentrations of those metals in the marine environment (Fichez et al., 2010). Nickel has been shown to affect fertilization success of four reef coral species in the families Acroporidae and Faviidae (Reichelt-Brushett and Harrison, 2005) and to affect settlement and cause mortality of larvae in the coral *Pocillopora damicornis* (Goh, 1991), but there was no correlation of meiofauna communities with metal concentrations in New Caledonia's south-west lagoon (Dalto et al., 2006). Gilbert (personal communication) reports that *C. noumeae* occurs in areas of high sedimentation (Figure 5) and in the largest harbor, so may be tolerant to environmental stressors like sedimentation. The species may have the ability to actively remove sediments as has been shown in other fungiid corals (Bongaerts et al., 2012). Mitigation measures for mining operations are required by legislation and include reef monitoring requirements (UNESCO, 2011; Gilbert, personal communication), but this monitoring is not at the species level (Gilbert, personal communication). It is unclear how effective the mitigation measures are as sedimentation and pollution remain concerns (David et al., 2010).

Figure 4. Part of the Goro complex mine in southeast Grand Terre, New Caledonia. Mining-technology.com.

Anthropogenic eutrophication occurs in the range of the species near the capital of Noumea and is attributed mostly to inadequately treated sewage (Fichez et al., 2010), although 19 aquaculture farms on the west coast, and island-wide agriculture, may also play a role (David et al., 2010). Storm events and flooding have also recently occurred in the range of the species (EMR 2013), and there is concern that climate change may make such events more frequent in New Caledonia (Gilbert, personal communication).

Figure 2: *Cantharellus noumeae* settled on hard substratum of the slope of artificial embankment in la Grande Rade harbor, New Caledonia. Antoine Gilbert ©

The biggest threats to New Guinea's coral reef resources include sedimentation and pollution from inland sources (e.g., forest clearance, sewage, and erosion) and climate change (Burke et al., 2011; PNG, 2009; PNG, 2012) as well as dynamite fishing (PNG, 2012).

Despite the frequency of bleaching alerts, heat-related bleaching is apparently not a significant current threat in the species range in New Caledonia as water temperatures there are relatively low (Hoeksema, personal communication) and the ReefBase coral bleaching database only reports low bleaching severity as the worst past events to ever occur there. I have found no species-specific information on the susceptibility of this species to bleaching or ocean acidification nor does its growth form suggest it is among the most susceptible species (Wooldridge, 2014).

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes
There is no known harvesting of the species (Hoeksema, personal communication) and general fishing pressure is low in New Caledonia, except for sea cucumbers (David et al., 2010). Overfishing generally is threat in Papua New Guinea (Cinner and McClanahan, 2006; Burke et al., 2011; PNG, 2012), but there is no evidence of harvest of *C. noumeae*. The CITES trade database reports no trade in this species, and under 50 specimens of unidentified *Cantharellus* spp., from 1975-2012. Gilbert (personal communication) reports the species "is not attractive for the aquarium trade." The above information is insufficient to suggest international trade is a threat for this species.

Competition, Disease or Predation
The prevalence and the number of identified coral diseases are limited in New Caledonia compared to other pacific regions (Tribollet et al., 2011) and there is no information on diseases of *C. noumeae*. *Acanthaster planci* (crown-of-thorns starfish) does not appear to be major cause of coral mortality in New Caledonia (Adjeroud, 2012) but several remote reefs surveyed during the Global Reef Expedition in November 2013 on the outer-slope of Guilbert's atolls showed evidence of past outbreaks (LOF, 2013). I was not able to find any species-specific information regarding competition.

Inadequacy of Existing Regulatory Mechanisms
Since the Organic Law (No. 99–209 on March 19th 1999), New Caledonia has been recognized as an ''Overseas Country" of France. This status gives New Caledonia extensive autonomy with regard to France, in particular the national laws in force within Metropolitan France are no longer applicable and New Caledonia now manages the ocean resources of its Exclusive Economic Zone. The territorial sea and the maritime public domain (coastal terrestrial and nearshore aquatic zone originating under French colonial law) depend on management from the three provinces (David et al., 2010). Collection of live corals (and other marine resources) is restricted in the two provinces of New Caledonia where *C. noumeae* occurs to scientists and licensed fishers who can only collect for a domestic market.

An important management feature in New Caledonia is the strong customary tenure and practices of the Kanak (native Melanesian) people. The Kanak were involved in developing the management framework for resources in the country in partnership with the French, New Caledonian and provincial governments. Approximately 50% of the main island and all the offshore islands are held in customary tenure through local Kanak chiefs and villages; whereas individual land ownership is most prevalent around the capital, Noumea, and on the west coast of Grand Terre.

The range of the species is included in the United Nations Education, Scientific and Cultural Organization (UNESCO) World Heritage Site designation for the "Lagoons of New Caledonia" site, specifically within the South Grand Lagoon area. The World Heritage Site implementation is supported by specific legislation on fisheries, land and water use planning, urban development and mining (Morris and Mackay, 2008). A wide monitoring program of the heritage Site all around New Caledonia was created (Andréfouët 2008), but this also suffers from a lack of sampling at a species level (Gilbert, personal communication). In 2011 the World Heritage Committee of UNESCO (the organizing body for World Heritage Sites) issued Decision 35Com 7B.22, which expressed concern regarding permits granted to the mining company GEOVIC to explore for cobalt in mineral sands in areas adjacent to the site and near to the range of this species. The committee requested that New Caledonia submit Environmental Impact Assessments for the proposed exploration and possible exploitation of cobalt sands to the World Heritage Centre. I have no evidence this has occurred. The New Caledonian Mining Code prescribes mitigation measures to mitigate the impacts of mining activities (see above), and abandoned mines are being restored using indigenous plant species (UNESCO, 2011). Thirteen Marine Protected Areas are designated in about 2% of the lagoon (Wantiez et al., 2007; David et al., 2010).

In Papua New Guinea there is a variety of legislation to protect biodiversity and habitat, including a mandate to ensure marine resource sustainability, and a plan of action directed at coral reef conservation (PNG, 2009). However, as noted above, threats remain. Resources and capacity may not be adequate to ensure full implementation of these laws and plans (PNG, 2009; PNG, 2012).

While the above laws and protected area designations provide a great deal of protection for resources in the area in principal, in practice illegal activities could threaten *C. noumeae*. Moreover, it is not clear that the threat from habitat modification, destruction and pollution is adequately addressed or mitigated by existing regulatory mechanisms.

Other Natural or Manmade Factors Affecting Continued Existence

The range of the species in New Caledonia is exposed to eight tropical storms per year on average (David et al., 2010). Specific effects of storms on this species are not documented, but the petitioner submitted an undated webpage that claims Cyclone Erica destroyed between 10 and 80% of live coral in New Caledonia in 2003 (EDGE, Undated; Guillemot et al., 2010). I was not able to find any other species-specific information available regarding this threat category.

Synergistic effects

No species-specific information on synergistic effects among the threats is known.

Siderastrea glynni

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

Should this species ever be restored to the wild, it faces considerable habitat degradation threats from coastal development, oil production, sedimentation, eutrophication and other pollution, and increased transportation activities in the Panama City area, the Gulf of Panama, and the enlarged Panama Canal, which is due to open in 2016 (Mate, 2003; Guzmán and Edgar, 2008). Almost continuous dredging and release of oil-based compounds (bunker oil, diesel, gasoline, etc.) that are spilled from nearby port facilities and commercial vessels anchored near the species' natural range are other reasons why it was decided to transfer and then keep them in captivity (Guzman, personal communication).

"During the 1997-98 ENSO event, the four known colonies of *S. glynni* began to deteriorate, displaying bleaching and tissue loss" (Guzmán and Edgar, 2008). This suggests this species is vulnerable to increased ocean temperatures, though there is no specific research on this point. Carricart-Ganivet et al. (2013) however found that the closely related species. *S. siderea* has a massive-type growth strategy which, based on the work of Wooldridge (2014) discussed above, would not suggest high-susceptibility to bleaching. As discussed above, the area is subject to a high frequency of bleaching warnings. I have also found no species-specific information on the susceptibility of this species to ocean acidification.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

I was not able to find any species-specific information regarding this threat, though Mate (2003) reports that extraction of live rock coral occurred in the range of. *S. glynni* prior to 1992. With such low numbers of reported specimens, interest in them could be large should the species be reintroduced into the wild.

Competition, Disease or Predation

Large outbreaks of *Acanthaster planci* have not occurred in Panama and the species has not been found at all in Panama Bay where *S. glynni* occurred (Mate, 2003). I was not able to find any species-specific information regarding this threat category. Black-band, dark spot and white plague diseases in the Caribbean occur on the closely related species *S. siderea* (Sekar et al., 2008; Brandt and McManus, 2009; Cardenas et al., 2012), suggesting *S. glynni* may be susceptible to similar coral diseases.

Inadequacy of Existing Regulatory Mechanisms

A national law in Panama prohibits coral extraction or mining (Guzman, 2003). The site is adjacent to the Bay of Panama, which is designated an internationally important wetland under the Ramsar Convention and contains extensive mangrove beds that are critical nursery grounds for many marine species. The Bay is a protected Wildlife Refuge under Panamanian law. However, developers seek to open the area for tourism and Panamanian authorities have requested a reduction of the Ramsar area of the Bay (AIDA, 2013). The island of Taboga near the location where this species occurred in the wild is a protected area.

I was not able to find any other species-specific information on this threat. Therefore, it is not clear that regulatory mechanisms would be adequate to protect this species should it be reintroduced into the wild or found in additional locations.

Other Natural or Manmade Factors Affecting Continued Existence

Because this species derives from such a small number of colonies, it is susceptible to all of the problems of species with low genetic diversity and population size.

Synergistic effects

No species-specific information on synergistic effects among the threats is known.

Tubastraea floreana

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

"Despite a lack of information on the thermal tolerances of *Tubastraea floreana*, the dramatic reduction in its distribution immediately after the 1982-83 [ENSO] event suggests that this mortality resulted from the event" (Hickman et al., 2007). This is true despite the fact that this species is azooxanthellate, suggesting that other mechanisms besides loss of calorie subsidy from symbionts are involved. Edgar et al. (2010) document a series of drastic ecosystem changes in the Galapagos pre- vs post-1982-83 ENSO event that includes dramatic declines in dissolved nutrients and phytoplankton productivity leading to declines across the food chain and resulting heavily grazed reefs with crustose coralline algae ('urchin barrens') replacing former macroalgal and coral habitats. A total of 95–99% of reef coral cover was lost from the Galapagos between 1983 and 1985 (Edgar et al., 2010). All known coral reefs based on calcareous frameworks died and subsequently disintegrated to rubble and sand (Glynn, 1994). These changes led to large decreases in biodiversity. The urchin *Eucidaris galapagensis* now appears to be present in sufficient numbers to prevent re-establishment of coral and macroalgal habitat, thereby facilitating a regime shift in local benthic habitats (Edgar et al., 2010). Moreover, the Galapagos Islands sit near the center of the most intense El Niño events in the region (Glynn and Ault, 2000) and are regularly included in bleaching threat warnings issued by NOAA (see above). Therefore, future ENSO events and inhibition of recruitment are likely to remain threats to this species.

I have found no species-specific information on the susceptibility of this species to ocean acidification.

Land-based concerns have been raised about the increasing impacts of tourism and population growth on the islands, but the population is still only around 25,000 people and marine impacts at this stage appear relatively minor (Gonzalez et al., 2008).

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The CITES trade database reports that between 1975 and 2012 there were two trades of this species, both from Indonesia to the United States, with 15 specimens imported to the U.S. in 1998 and 5 in 2010. The United States Fish and Wildlife Service (FWS) examined their records for these transactions and found them to be recorded erroneously for the 2010 trade which the original documents only list as *Tubastraea spp*. and not specifically *T. floreana*. Records for the 1998 trade no longer exist, but FWS believes those are also likely in error given that Indonesia is not near the known range of this species (Mark Albert, personal communication).

Fishing is highly regulated in the Galapagos Marine Reserve that contains the range for this species (see below). However illegal fishing became a large problem in the early 1990s and continued through the early 2000s as the reserve did not have the capacity to patrol and enforce fishing regulations in the vast area that contained many relatively undisturbed species of interest that had not been previously heavily exploited. Many fisherman from mainland Ecuador moved to the Galapagos in the latter decades of the 20th century, resulting in permanently increased fishing pressure in the area (the population size of the Galapagos increased from 9700 in 1990 to over 25,000 today). In addition, longline vessels and other illegal fishers from outside Ecuador regularly enter the reserve to fish. International aid provided needed training, equipment and resources to improve the situation in the last decade, but the problem remains, albeit at some lower level. Current threats from illegal fishing are mostly directed towards sea cucumbers, lobsters, pelagic fishes and sharks (Toral-Granda, 2008; Carr et al., 2013; Galapagos Conservancy, 2013). There is no information on harvesting of reef corals.

Competition, Disease or Predation
I was not able to find any species-specific information on this threat.

Inadequacy of Existing Regulatory Mechanisms
The Galápagos Marine Reserve was established in 1986 and expanded to its current size around all the islands in 1998. The reserve has a zoning plan with both limited and multiple use zones. Rules prohibit removing or disturbing any plant, animal, or remains of such, or other natural objects. *Tubastraea floreana* also occurs inside the Galapagos Island World Heritage Site (expanded to include Galapagos Marine Reserve areas in 2001) and the Galápagos Island Man and Biosphere Reserve (1984), both designations of UNESCO. The area was also designated the Galápagos Archipelago Particularly Sensitive Area in 2005. This is a designation by the International Maritime Organization (IMO) that recognizes the area as having ecological, socio-economic, or scientific attributes that make the area vulnerable to damage by international shipping activities. The IMO therefore instituted special navigation rules in the area.

Ecuador's "Ley de Gestion Ambiental" (Law of Environmental Management) establishes principles and directives for environmental management, land-use planning, zoning, sustainable use, and natural heritage conservation. Their fisheries law states that no harm may be caused to areas that are declared protected, with corals included under those protections (MCA Toolkit, 2013).

While the above laws and protected area designations provide a great deal of protection for resources in the area in principal, in practice illegal activities and incomplete and difficult enforcement as discussed above, could threaten *T. floreana*. Moreover, the threat from climate change and ENSO events is outside the scope of these protections.

Other Natural or Manmade Factors Affecting Continued Existence
Because this species has such a small number of colonies, it is susceptible to all of the problems of species with low genetic diversity and population size.

Synergistic effects
Edgar et al. (2010) suggest that the removal of large lobster and fish predators by artisanal fishing probably reduced ecosystem resilience and magnified the effects of the 1982/1983 El Niño event through a cascade of indirect effects involving an expansion of grazing sea urchins. No other species-specific information on synergistic effects among the threats was found.

ASSESSMENT OF EXTINCTION RISK

To inform the extinction risk determination I considered demographic risks to each species as described in approaches by Wainwright and Kope (1999) and McElhany et al. (2000). The approach of considering demographic risk factors to help frame the consideration of extinction risk has been used in many status reviews including Pacific salmonids, Pacific hake, walleye pollock, Pacific cod, Puget Sound rockfishes, Pacific herring, scalloped hammerhead sharks and black abalone (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). 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. These viability criteria reflect concepts that are well-founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. In addition to the demographic risk factors I considered the threat factors listed in Section 4(a)(1) of the ESA and discussed above. Based on all of the above information I describe the likely extent of extinction risk faced by each species. Because information is sparse and often non-quantitative, I use qualitative risk categories in describing the assessment of extinction risk: very low, low, moderate, moderately high, and high. For colonial corals productivity is most closely related to growth rate of colonies. I did not make recommendations as to whether the species should be listed as threatened or endangered. Rather, I drew scientific conclusions about the overall risk of extinction faced by the species under present conditions and in the foreseeable future based on an evaluation of the species' demographic risks and threats. Determination of the ESA listing status of each species is a decision that includes the above analyses as well as consideration of the certainty of implementation of future conservation efforts, the certainty of effectiveness of existing conservation efforts, as well as other management considerations.

Cantharellus noumeae
Based on its small, restricted range, likely low growth rate and genetic diversity, and potential threats from development, water pollution, possibly sedimentation at some level, and potential illegal activities that currently exist and are likely to continue to occur, mitigated by potential resilience to sedimentation threats and uncertainty regarding sensitivity to heavy metals, extinction risk for this species is moderately high.

Siderastrea glynni
Based on the lack of known populations in the wild, a small captive population in a single location, low growth rate and genetic diversity, and potential increased threats from El Niño, climate change, disease and other development and habitat degradation should it be reintroduced to Panama, extinction risk for this species is high.

Tubastraea floreana
Based on its small, restricted range, documented declines, likely low levels of genetic diversity, and threats from El Niño, climate change, development and illegal activities, mitigated by potential for moderate productivity, extinction risk for this species is high.

CONSERVATION EFFORTS

Section 4(b)(1)(A) of the ESA requires the Secretary of Commerce to take into account "* * * efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species". The ESA therefore directs us to consider all conservation efforts being made to conserve the species. The joint USFWS and NOAA Policy on Evaluation of Conservation Efforts When Making Listing Decisions ("PECE Policy", 68 FR 15100; March 28, 2003) further identifies criteria NMFS uses to determine whether formalized conservation efforts that have yet to be implemented or to show effectiveness contribute to making listing unnecessary, or to list a species as threatened rather than endangered. In determining whether a formalized conservation effort contributes to a basis for not listing a species, or for listing a species as threatened rather than endangered, NMFS must evaluate whether the conservation effort improves the status of the species under the ESA. Two factors are key in that evaluation: (1) for those efforts yet to be implemented, the certainty that the conservation effort will be implemented and (2) for those efforts that have not yet demonstrated effectiveness, the certainty that the conservation effort will be effective. The following is a review of the major conservation efforts I was able to find in a literature and web search and relevant information to assist NMFS in its evaluation. Other conservation efforts that are currently implemented and/or effective are described in the above sections and have already been considered in the extinction risk assessment above.

Cantharellus noumeae

The international Coral Triangle Initiative occurs in Indonesia and Papua New Guinea where the species may occur. This is a broad-based partnership to address crucial issues such as food security, climate change and marine biodiversity. It will likely have some success in improving conditions in that area. I was not able to find any information on conservation efforts specific to this species or their habitat in its confirmed range that are not yet implemented or effective and that would potentially alter the extinction risk for the species.

Siderastrea glynni

Dr. Hector M. Guzmán, who maintains the only surviving colonies of this species in captivity at the STRI laboratories, is planning to cryopreserve some specimens to provide an additional means to recover the species and preserve its' genetic information. The scientific effectiveness of cryopreservation effort for species recovery are largely unknown.

Tubastraea floreana

I was not able to find any information on conservation efforts specific to this species or their habitat that are not yet implemented or effective and that would potentially alter the extinction risk for the species.

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