Supplemental Information Report on Status Review Report And Draft Management Report For 82 Coral Candidate Species

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Southeast and Pacific Islands Regional Offices
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
Department of Commerce

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INTRODUCTION

Background

On April 17, 2012, NMFS published a notice in the Federal Register (FR) announcing the availability of a Status Review Report (SRR) and Draft Management Report (DMR) for 82 Candidate Coral Species under the U.S. Endangered Species Act (ESA) (77 FR 22750). The FR notice also requested the following information:

(1) Relevant scientific information collected or produced since the completion of the Status Review Report or any relevant information not included in the report; and
(2) Relevant management information not included in the Draft Management Report, such as regulatory mechanisms for greenhouse gases globally, and for local threats in the 83 foreign countries and the U.S. (Florida, Hawaii, Puerto Rico, U.S. Virgin Islands, Guam, America Samoa, and Northern Mariana Islands) where the 82 coral species collectively occur.

In addition to soliciting information via the FR notice, NMFS held several public workshops and listening sessions in the Pacific Islands and Southeast Regions to gather the above-mentioned information. Last, NMFS also conducted its own search for relevant scientific literature published since the completion of the SRR; this included gathering information from the recent 2012 International Coral Reef Symposium held in Cairns, Queensland, Australia.

Methods

The information solicited in the FR notice and at the public meetings was received via oral comment, electronic mail, and mail service (e.g., US Postal Service, Federal Express, UPS, etc.). This Supplemental Information Report (SIR) provides an objective summary and reporting of the all of the information received from the public during the FRN comment period in April – July 2012, and of the scientific information that NMFS gathered since the SRR was completed in 2011. The SIR similarly summarizes management-related information relevant to the DMR that was received and gathered.

Sections 2 – 8 of this report provide the information received or gathered relevant to the SRR, and Section 9 provides the information received or gather relevant to the DMR. For cross-referencing purposes, Sections 2 – 8 of this report, and their sub-sections, are organized like the SRR, with matching section and sub-section names in the two documents. Similarly, Section 9 of this report is organized like the DMR. Further, some headings are equivalent between these two documents, and are indicated as such. Citations of the literature cited in this report are provided in the References Cited section. The full text of comments cited in the report is provided in the Endnotes section.

The information received or gathered was categorized into the relevant sections and sub-sections (i.e., scientific information into Sections 2 – 8 and their sub-sections, and management information into Section 9's sub-sections). In each section or sub-section, information received and collected on each topic was summarized, in some cases preceded by quotes from the SRR *in gray italics* to provide context for the new information. At the end of each section or sub-section, NMFS' interpretation of the new information is provided in ***bold italics***. For example, in Section 6.1.1 of this report (sub-section on *Agaricia lamarcki*), new info is provided on the depth distribution of this species, as shown below. First, to provide context, *a quote from the SRR is shown*, then the new information is summarized and cited in regular text, then NMFS' interpretation of the new information is provided in ***bold italics***:

-------------------------------------start of example from Section 6.1.1--
From the SRR:
"Depth range: Agaricia lamarcki has been reported in water depths ranging from 10 to 76 m (Carpenter et al., 2008; Ghiold and Smith, 1990) and 3 to 50 m (Humann, 1993)."

As stated above, Armstrong et al. (2010) and Armstrong and Singh (2012) found corals of the genus *Agaricia* can be found at depths of 50 to 100 m on mesophotic reefs in Puerto Rico. Schizas (2012) reports *A. larmarcki* as very common (3% cover) and healthy at 70-80 m depths off Mona Island, south-western Puerto Rico, St. Thomas, and St. Croix (USVI).

The recent data extends the known depth range and refines the geographic distribution for this species.
-------------------------------------end of example from Section 6.1.1--

Each section or sub-section of this report thus has up to three types of text: *contextual quotes from the SRR*, summaries of the new information which is footnoted or cited, and ***NMFS' interpretation of the new information***. However, many sections do not have all three types of text, because it was not necessary to provide all three types (e.g., context from SRR was not necessary, no interpretation was needed, etc.).

Purpose

The purpose of this report is to provide NMFS with an objective compendium of: (1) the scientific and management information received from the public during the supplemental public engagement period in April – July 2012; (2) the scientific information that NMFS gathered since the SRR was completed in 2011; and (3) the management information that NMFS gathered since completing the DMR in April 2012. The information contained within this report will aid NMFS in its decision-making process for drafting a 12-month finding on whether the petitioned actions (i.e., listing of 83 coral species as threatened or endangered under the ESA) are warranted. This report is not intended to result in changes or edits to the final SRR document.

MISCELLANEOUS COMMENTS RECEIVED

Several thousand (7,079) emails and letters (35,664) of support for listing the candidate species under the ESA were received in response to the April 17 Federal Register notice requesting additional information for reviewing the status of the 82 candidate coral species. These emails explained the value of corals reefs and detailed what the loss of corals reefs would mean for society. Additionally, several comments received expressed opposition to listing of these candidate coral species under the ESA. Opposition stemmed from several concerns, including:

- The expected cost of implementation of protections under the ESA (e.g., Section 7 consultation costs);
- The impairment of conservation efforts due to reallocation of federal funding;
- The belief that many of the threats impacting these species could be abated through existing regulatory mechanisms and conservation efforts;[i,ii]
- The belief that the ESA is not the appropriate tool for protecting these species from the threat of global climate change and greenhouse gas emissions (GHGs)[iii,iv].

A good many of the comments received during the public meetings focused on the process set in motion by NOAA's receipt of the petition to list 83 species of corals (e.g., listing any or all candidate species under the U.S. Endangered Species Act). These comments included concerns about what would happen in terms of new regulations on various reef activities should any of the 82 candidate species be listed as threatened or endangered. Some expressed their opinion that the corals of CMNI, in particular, have not reached a status of concern for protection under the ESA.[v,vi] Additionally, commenters expressed concerns about local involvement in the management and conservation of corals should any of the candidate species be listed. One commenter questioned the peer reviewers because they were not local to CNMI.[vii] Last, several commenters included suggestions for future research[viii] and management needs[ix,x,xi] for the conservation of corals, including:

- Providing a proposed critical habitat designation concurrently with any proposed listing determination;[xii]
- Expeditiously producing a comprehensive recovery plan for any species ultimately listed under the ESA;[xii]
- Considering the use of the "warranted but precluded" category for species that occur primarily in foreign waters.[xiii]

SRR EXECUTIVE SUMMARY

Statements in the Executive Summary that included climate change impacts (e.g., ocean warming and acidification) among the major threats affecting the status of the 82 candidate species received both praise and criticism from commenters. Some commenters praised and concurred with the Biological Review Team's (BRT) assessment of the threat of global climate change, including ocean warming and acidification,[xiv,xv] whereas others commented that "Climate-change computer-model projections are not empirical science" and the science of climate change is not settled.[xvi] Another commenter expressed his concern that, at a local level, Guam is neither the cause nor the source of a solution for global climate change impacts.[xvii]

Additional comments stemmed from the assessment of risk from threats to the candidate species' continued existence. One commenter expressed concern over the apparent lack of certainty concerning the extent and detail of the knowledge base used to rank each species' risk of dropping below the Critical Risk Threshold.[xviii] Others expressed their concurrence with the conclusions reached by the BRT[xix,xx]; however, one recommended not listing all of the candidate species under the ESA until resolving the uncertainty concerning taxonomy, distribution, and abundance.[xxi] Further, it was recommended by a commenter that other Pacific coral species, not included in the original petition, be considered as potential ESA-listing candidates.[xxii]

1. Introduction

From the SRR:

"This Status Review Report provides the BRT's evaluation of the status of each of the 82 candidate coral species and the risk of extinction faced by each using the best available scientific and commercial data and analyses, including the best available climate change and ocean acidification scenarios."

A couple of commenters expressed concern over NOAA's use of "best available science" for reviewing the status of the 82 candidate species. Both commenters stated that cultural traditional experience as well as local knowledge should be used and/or incorporated into the process.[xxiii,xxiv]

The SRR does not discuss whether cultural traditional experience and/or local knowledge were considered "best available scientific and commercial data".

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One commenter was unsure of the rationale used to determine the list of species assessed in the SRR. This commenter is concerned that other coral species, not reviewed in the SRR, are facing similar threats and may require protection under the ESA.[xxv]

While the SRR discusses the petition, it does not discuss why the statuses of only the petitioned coral species were reviewed.

2. General Background on Corals and Coral Reefs

During the scientific workshop in Hawaii, Coral BRT member Chuck Birkeland focused his presentation on the fact that coral species do not need coral reefs. Coral species generally have lower vulnerability and greater persistence in the face of environmental changes than coral reefs. He used several examples to show that reefs have shrunk or disappeared in the past, but corals have persisted on whatever hard substrate remained. This suggests that declining coral cover on reefs, and/or declining reef area, does not correlate necessarily with declining coral abundance (e.g., the 30% decline in reefs described in Carpenter et al. (2008) does not necessarily indicate a corresponding 30% decline in coral species).

The SRR does not discuss this relationship of coral species to reef ecosystems.

2.1 Taxonomy & Distribution

From the SRR:

"Corals in the family Fungiidae exist only as solitary polyps, but the other families exploit the ability to form complex colonies."

One commenter mentioned that a "substantial" number of species in the family *Fungiidae* are colonial, and there are a few species in other families that are solitary.[xxvi]

2.1.1 Taxonomy and morphology of scleractinian corals

No relevant information received on this topic.

2.1.2 Species delineation and uncertainty in corals

Stat et al. (2012) reviews the current literature to aid in binominal species classification and reassessment of species boundaries for the partners in the coral holobiont, which is a complex assemblage of organisms spanning a diverse taxonomic range. The authors advocate for an integrative approach that uses both molecular genetics and phenetic characters for species delineation (Stat et al. 2012).

One commenter recommended a more neutral stance on whether morphology or genetics will prove more accurate for taxonomy. The commenter believes that current genetics methodologies are early yet in their development, and morphology is still important for distinguishing between species.[xxvii]

Both this section and Section 5.2 of the SRR discuss the uncertainties and complexities associated with both genetic and morphological approaches to coral species identification.

2.1.3 Evolutionary history of coral reefs

One commenter stated "That the corals living today will go extinct within the next century is considered doubtful." The evidence the commenter provided for this statement is that during "the Holocene (past 10 ka) and especially during the past 7 ka to 6 ka, various coral species worldwide have experienced periods of local demise. All of these periods of coral demise occurred well before the Industrial Revolution and thus were not the result of human activity."[xxviii]

The SRR includes a similar analysis of past extinction events for corals, as well as their subsequent recovery.

2.2 Biology

2.2.1 Reproduction and Recruitment

Recent studies looked at population dynamics, one in an Eastern Pacific coral species and two in a Caribbean coral species. In *Pocillopora damicornis*, researchers found that gene flow is limited in the tropical eastern Pacific, particularly among regions, but even over meter scales within regions (Combosch and Vollmer 2011). In *Montastraea annularis*, researchers found differences between modeled and empirical data indicating that processes other than dispersal might dominate among northern Mesoamerican reefs (Foster et al., 2012). Further, Levitan et al. (2011) found that external cues, genetic precision, and perhaps conspecific signaling likely influence reproductive success and reproductive isolation in a density dependent manner for *M. annularis*.

2.2.2 Nutrition

No relevant information received on this topic.

2.2.3 Calcification & Reef-building

From the SRR document:
"It is also important, for the purposes of this Status Review Report, to emphasize that many corals populate nonstructural coral communities (e.g., Riegl, 1999; Semon, 2007), whereby their abundance or growth rates may be too low to accrete reef structure and/or antecedent substrates may be non-carbonate (e.g. volcanic or sandstone)."

One commenter mentioned that another reason for the lack of carbonate buildup in some coral communities (i.e., nonstructural coral communities) is storm events, which remove corals (e.g., outside bays in Hawaii; Solitary Islands, Australia).[xxix] The commenter did not provide additional references or citations.

This aspect of reef building, or lack thereof, as moderated by storm events is not discussed in the SRR.

2.2.4 Clonality & Genetics

From the SRR:
"Although scientists are increasingly applying genetic tools to understand the structure of coral populations, this line of research is still in relative infancy."

One commenter mentioned the rapid advancement of genome sequencing technologies, which has increased the available genomic information. The commenter recommended consideration of this information in the future for understanding how corals cope with different environmental conditions and perturbations.[xxx]

2.3 Ecology of Coral Reef Ecosystems

2.3.1 Ecosystem roles of coral reefs

From the SRR:
"A coral reef is a complex three-dimensional structure providing habitat, food, and shelter for numerous marine species and, as such, fostering exceptionally high biodiversity."

One commenter mentioned that coral reefs exhibit a wide range of diversity, from high to low. The commenter presents Eastern Pacific and Brazilian reefs as examples of low-diversity reefs.[xxxi]

2.3.2 Habitat requirements of corals and reefs

Recently available information supports the occurrence of several types of refugia for corals (see below). Recent studies focus on mesophotic reefs and on the hypothesis of deep refugia, as well as upwelling areas (Eiden et al. 2012, Bayraktarov et al. 2012), fluctuating environments (Oliver and Palumbi 2011), and seagrass beds (Unsworth et al. 2012). Of these, mesophotic habitats may buffer corals against some threats, including coral bleaching (Bongaerts et al. 2010, Bayraktarov et al. 2012) and disease (Brandt et al. 2012).

One commenter cautions “against relying on the assumption that mesophotic habitats will reduce extinction risk” and presents several studies indicating that “mesophotic reefs are subject to a large number of threats” and they “may not provide a reliable source of propagules for shallow reef areas following disturbance”.[xxxii] The commenter states that mesophotic reefs “are subject to a wide range of negative effects from (a) ocean acidification, especially since deeper waters have lower levels of carbonate saturation; (b) warm-water bleaching (which has been documented to 60 meters), although the effects of bleaching are more pronounced in shallow water; (c) cold-water bleaching; (d) sea-level rise which “has the potential to push deep reefs below the euphotic zone”; (e) indirect effects of storms including debris avalanches and sedimentation; (f) diseases which typically affect corals across their depth range (i.e., black band, dark spots, white syndrome, and yellow blotch disease have been reported on mesophotic reefs); (g) nutrient enrichment; (h) toxins such as herbicides and pesticides; (i) sedimentation; and (j) invasive species (Bongaerts, Ridgway, Sampayo, & Hoegh-Guldberg, 2010; Lesser & Slattery, 2011).”[xxxiii] In terms of reproductive connectivity between shallow and mesophotic reefs, the commenter cites Bongaerts et al. (2010), Slattery et al. (2011), van Oppen et al. (2011) to show that connectivity between reefs varies and the potential for mesophotic reefs to provide propagules for shallow reef areas following disturbance is limited.xxxiv Further, there is some evidence that mesophotic corals (even of the same species) harbor different Symbodinium communities than shallow water counterparts (Schizas et al. 2012). These sentiments concerning deep water refugia are echoed by another commenter who stated that “the protective role of upwelling is very limited geographically (Chollett et al., 2012; Karnauskas & Cohen, 2012), and that upwelling areas do not always offer corals protection from thermal stress (Chollett et al. 2012).”[xxxv]

This section, Section 3.3.7, and some of the individual species accounts in Sections 6 and 7 of the SRR discuss mesophotic reefs as refugia.

2.3.3 Global habitat condition

No relevant information was received on this topic.

2.3.4 Phase shifts

Commenters provided a number of references, reports, and information related to phase shifts in coral communities. Newer information (studies published in 2011 or later) focuses on microbial and chemical interactions between reef organisms, which may contribute to changes in reef community composition and to increased susceptibility of corals to disease and mortality (Barott et al. 2012, Morrow et al. 2011, Rasher et al. 2011). Additionally, myriad factors contribute to changes in reef community composition, including but not limited to: local and regional-scale influences (Colvard and Edmunds 2011, Lowe et al. 2011, Schute et al. 2010); fishing pressure on herbivorous fish stocks (Fenner 2012); herbivory patterns;

and reef species dominance, competition, and diversity (Hoey and Bellwood 2011, Norström 2009, ONMS 2011, Vargas-Ángel 2009). Fenner (2012) pointed out that the most pervasive phase shift on coral reefs worldwide was the shift from reefs with abundant large fish to those with few.

2.3.5 Resilience of corals and coral reefs

One commenter provided more recent information about the resiliency of Caribbean reefs compared to that of Indo-Pacific reefs (Roff and Mumby 2012). The commenter also stated that this study (Roff and Mumby 2012) supported the idea that African dust contributes to algal growth, to red tides caused by algal blooms, and to decreased resiliency of Caribbean coral reefs.[xxxvi]

The literature cited in this section is for reports published since 2011. The literature indicates regional differences in reef recovery and resilience – reefs in one region may not exhibit the same resilience as a similarly structured reef in another region (Graham et al. 2011, Roff and Mumby 2012). Geographically isolated areas may experience slower recovery following environmental perturbations (Ceccarelli et al. 2011, Graham et al. 2011). The literature also underscores the importance of connectivity at the regional scale (Huntington et al. 2011) and between nearshore and offshore reef environments (Adam et al. 2011, Graham et al. 2011, van Oppen et al. 2011).

These studies discuss regional differences in resilience, the influence of geographic isolation, or the importance of connectivity for enhancing reef resilience. These differences imply that "resilience" is not static or predictable, but rather a dynamic characteristic of reef communities and coral species dependent on a suite of environmental and geographical conditions. The exact combination of factors needed to optimize and/or predict resilience in reef communities is not yet known.

2.4 Status & Recent Ecological History of Caribbean Reefs

One commenter provided extensive information on the geologic history of Florida and Caribbean reefs[xxxvii,xxxviii,xxxix]. This commenter also included a discussion of previous declines in coral cover over geologic time,[xl] emphasizing that corals underwent precipitous declines without human influence.[xli, xlii]

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From the SRR:

"Massive, Caribbean-wide mortality events, apparently from disease conditions, of both the keystone grazing urchin Diadema antillarum (Lessios, 1988) and the dominant branching coral species Acropora palmata and Acropora cervicornis (Aronson and Precht, 2001) spread throughout the Caribbean and precipitated widespread and radical changes in reef community structure (see Section 2.3.4 above on phase shifts)."

In reference to above-mentioned mortality of *D. antillarum* and *A. palmata*, one commenter provided a link to serial photographs that show the demise of corals from 1960 to the present. The commenter states that coral mortality culminated in 1983-84, which coincides with mortality of *D. antillarum* and with the emergence of the soil fungus *Aspergillus sydowii*.[xliii]

2.5 Contrast between Caribbean & Indo-Pacific [Also relevant to Draft Mgt Report/DMR: 1.1 CURRENT RANGES]

One commenter remarked that Table 2.5.1 omits the Brazilian coral reef zone, which has uniquely low species diversity.[xliv]

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From the SRR:

"… there is a striking gradient in diversity in the Pacific, declining from west to east. For example, the Coral Triangle hosts 581 species, 81 genera, and 16 families of reef-building scleractinians (Veron, 2000), while French Polynesia (Society, Tuamotus, Australs and Gambier Archipelagoes) hosts 163 species, 38 genera and 13 families and the far eastern Pacific (Easter Island, Fanning Island, Galapagos, Malpelo, Clipperton, Cocos, Revillagigedo, and the coast from Mexico to Ecuador) hosts 49 species, 12 genera, and 7 families (Glynn et al., 2007)."

One commenter stated that in addition to latitudinal gradients, there are longitudinal gradients in diversity in the Pacific.[xlv]

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A reference provided by a commenter (Roff and Mumby 2012) indicates that theories about resilience developed from research conducted on Caribbean coral reefs may not transfer to the Indo-Pacific. Indo-Pacific reefs may be more resilient than Caribbean reefs because of several differing factors in community composition and regional geography (See Endnote xxxvi). Another commenter corroborated this sentiment, stating that the recent literature and the discussions of resilience at the 2012 International Coral Reef Symposium (ICRS) emphasize and confirm the notion that Caribbean reefs are at higher risk than their Pacific counterparts because of reduced resiliency.[xlvi] Further, recently published studies provide the following information:

- Broad-scale Caribbean reef degradation likely began earlier than in the Indo-Pacific;
- Algal proliferation/growth rates are generally higher on Caribbean reefs and impair coral recovery (Roff and Mumby 2012);
- There is greater coral cover on mesophotic reefs in the Indo-Pacific than in the Caribbean; and
- There is greater resilience to algal phase shifts on mesophotic reefs in the Indo-Pacific than in the Caribbean.

This information emphasizes the contrasts between Caribbean and Indo-Pacific reefs. This information also emphasizes the greater degradation of reefs and greater impact of threats on degraded reefs in the Caribbean compared with the Indo-Pacific. Based on this information, coral resilience in the Caribbean is likely lower than in the Indo-Pacific; however, as discussed above in Section 2.3.5, resilience can vary widely at the local, regional, and global levels.

2.6 Status and Recent Ecological History of Eastern Pacific Reefs

Two recent studies looked at patterns in and causes for extinction in Eastern Pacific reefs (Toth et al. 2012, Polidoro et al. 2012). The El Niño-Southern Oscillation played a role in extinction events and it is likely that ENSO will contribute to another regional collapse of coral reef growth (Toth et al. 2012), particularly in coral species with life history traits that decrease the likelihood of their resilience to various regional and site-specific threats (e.g., overfishing, habitat loss) (Polidoro et al. 2012).

3 Threats to Coral Species [Also relevant to Draft Mgt Report/DMR: 1.2.1]

Two commenters remarked on the generic link between the threats discussed in Section 3 and their impact on specific coral species. Both commenters implied that more specificity in the supporting science is needed to determine the exact impact of general threats, particularly climate change, on each candidate species.[xlvii, xlviii]

The SRR assesses the impact of each threat on each candidate species in the individual species accounts of Sections 6 and 7. The limitations of the assessment approach are explained in Section 5.7.

3.1 Human Population

From the SRR:

"However, the relationship may not be strictly multiplicative as described in the IPAT equation, and quantifying terms like "affluence" or "technology" in a common currency have proven to be challenging."

One commenter stated that Cinner et al. (2009) include an example of Kuznet's hypothesis, which adds to the discussion of the relationship between affluence and conservation not being "strictly multiplicative." Kuznet's hypothesis postulates that damage to the environment increases with initial economic development, then decreases.[xlix]

The SRR does not include a reference to Cinner et al. (2009).

3.1.1 Human Population

No relevant information received on this topic.

3.1.2 Consumption status and trends

No relevant information received on this topic.

3.2 Global Climate Change and Large-Scale Threats [Also relevant to Draft Mgt Report/DMR: 1.2.1.1]

A significant amount of information concerning Global Climate Change has been published since completion of the SRR. This report attempts to categorize that information by impact (e.g., ocean warming, ocean acidification, etc.). The SRR relied on climate projections provided in the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) completed in 2007 but also acknowledged that the information therein was already outdated by the time the SRR was written. Climate projections in the AR4 were based on a now 12-year old Special Report on Emissions Scenarios (SRES; IPCC 2000). IPCC AR4 will be updated by IPCC AR5 in 2013 and climate projections in AR5 will be based on a new set of four scenarios (the Representative Concentration Pathways or RCPs; Moss et al. 2010; van Vuuren et al. 2011). While the SRES scenarios cover only non-mitigation scenarios, the new RCPs span a large range of stabilization, mitigation and non- mitigation pathways. Figure 1 illustrates the previous set of emissions scenarios (SRES) used in the IPCC AR4 and the new set of RCPs to be used in the IPCC AR5.

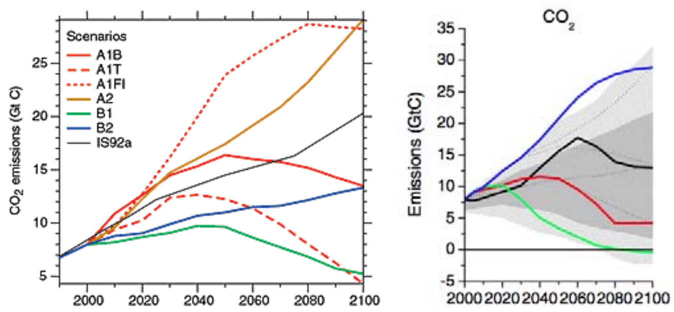


Figure 1. IPCC AR4 Emissions scenarios based on SRES (left) vs. New RPCs for IPCC AR5 (right).

The CMIP3 model intercomparison that was used in AR4 to determine potential climate futures based on the input scenarios also has been replaced with the fifth phase of the Coupled Model Intercomparison Project, CMIP5. A different set of input scenarios used as boundary conditions for updated models from various modeling centers around the world will produce new projections of potential future climate states that will be summarized in AR5. Because both the input scenarios and the models will be different, direct comparisons of the results between AR4 and AR5 is more challenging. Rogelj et al. (2012) provided probabilistic climate projections of both SRES scenarios and RCPs in a single consistent framework and find that, while the resulting range of temperature estimates for RCPs is larger than the range of the SRES scenarios, global mean temperature projections by the end of the twenty-first century for the RCPs are very similar to those of their closest SRES counterparts (see Figure 2 below). Of note is that the four RCPs chosen for AR5 are based on research published during 2006-2008 so they, too, are now several years old. However, the important message from the CMIP5 analyses to date is that projections of global mean temperatures, and presumably those of tropical oceans where corals live, are unlikely to change dramatically in AR5 and that the largest differences in future temperatures will be determined by human actions to increase or decrease greenhouse gas levels in the atmosphere.

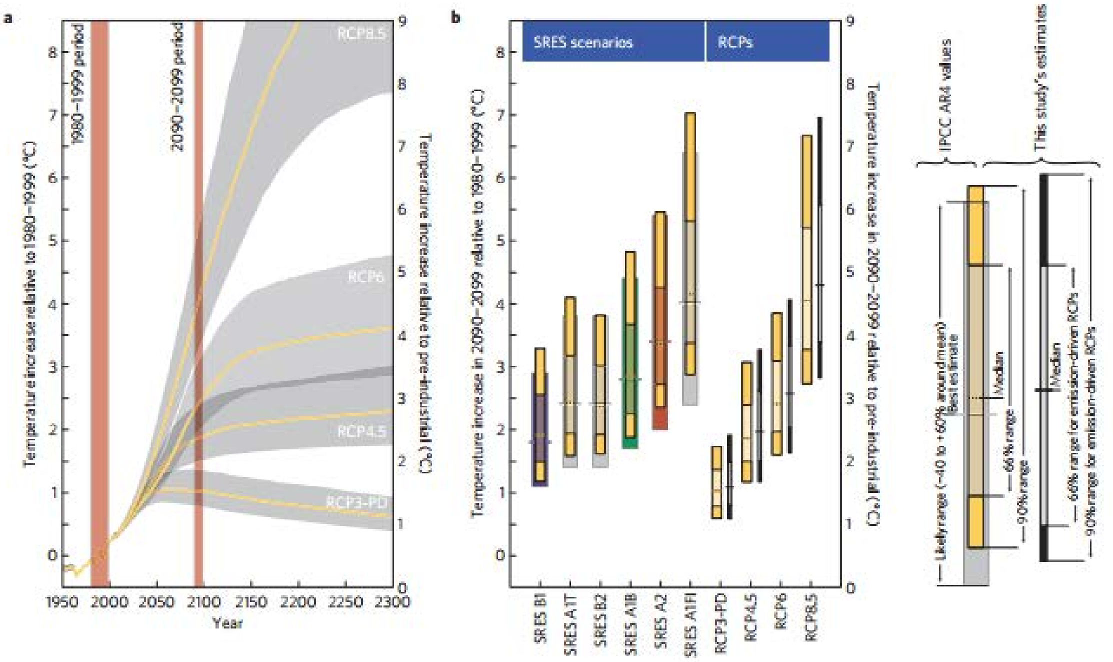


Figure 3 | Temperature projections for SRES scenarios and RCPs. a, Time-evolving temperature distributions (66% range) for the four concentration-driven RCPs computed with this study's representative ECS distribution and a model set-up representing closely the climate system uncertainty estimates of the AR4 (grey areas). Median paths are drawn in yellow. Red shaded areas indicate time periods referred to in **b**. **b**, Ranges of estimated average temperature increase between 2090 and 2099 for SRES scenarios and RCPs respectively. Note that results are given both relative to 1980–1999 (left scale) and relative to pre-industrial (right scale). Yellow and thin black ranges indicate results of this study; other ranges show the AR4 estimates (see legend at right-hand side). Colour-coding of AR4 ranges is chosen to be consistent with the AR4 (see Figure SPM.5 in ref. 1). For RCPs, yellow ranges show concentration-driven results, whereas black ranges show emission-driven results.

Figure 2. From Rogelj et al. (2012).

Additionally, recent publications examine coral reef ecosystems and the effects of global climate change. The first is a chapter in a recently published encyclopedia that reviews the scientific literature on the subject from a geologic, versus an ecologic, standpoint (Lough 2011). Lough et al. (2011) relies on IPCC AR4 and cites many of the references included in the SRR to summarize the impacts of climate change on coral reef communities. Bellard et al. (2012) reviewed the impacts of climate change on biodiversity at a global level and found large variability although the majority of models indicate alarming consequences for biodiversity, including corals. Hoegh-Guldberg (2011) discusses the response of coral reefs to increasing atmospheric CO_2 concentration while Hare et al. (2011) confirm that loss of coral reefs is one of four identified impacts likely to result from dangerous climate change. As a regional example, based on evidence of historic collapse over the last 2500 years, Toth et al. (2012) conclude that global climate change is probably driving eastern Pacific reefs toward another regional collapse.

The SRR concluded that “the threat posed by the most optimistic scenarios of emissions in the 21st century and even the threat posed by committed warming and other climatic changes represent a plausible extinction risk to the 82 candidate coral species.”

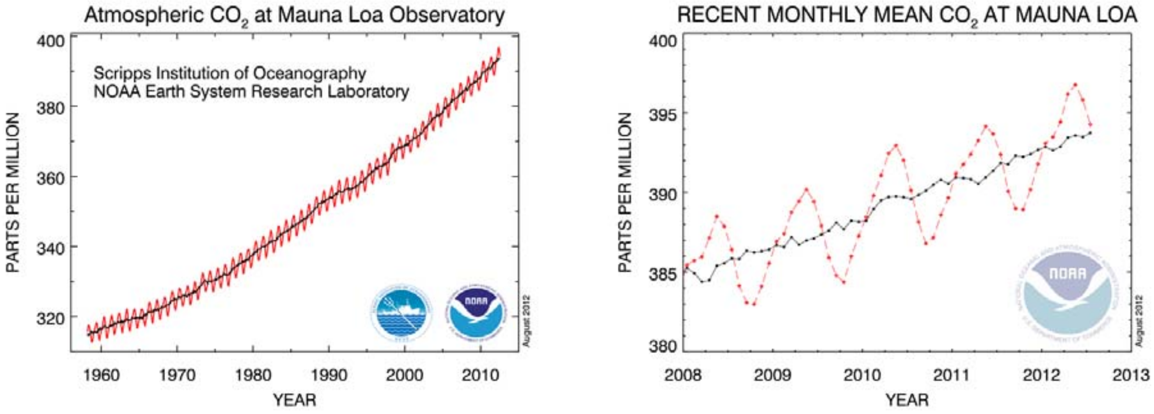
At a broad scale, one commenter questioned the efficacy of listing of corals as threatened or endangered. The commenter stated that acroporids and other reef dwellers began their demise before global warming and rising CO_2 levels, and a 1974 CIA report predicts a lowering of global temperature.[l]

One commenter expressed concerns about listing any of the candidate coral species as threatened or endangered under the ESA because of the difficulties associated with addressing global threats such as ocean warming and acidification. The commenter added that there is a great deal of uncertainty regarding the long-term impacts of thermal stress and acidification on coral species. The commenter felt listing of these species under the ESA will achieve no conservation benefit because of the difficulty of developing effective conservation measures to address global climate change[li].

The commenter does not dispute that global climate change is a threat to corals, and instead questions the effectiveness of the ESA in addressing this threat, should any of the 82 candidate coral species be listed. The commenter provided notes from a presentation at the recent 2012 International Coral Reef Symposium, which catalogues SST warming trends over time and across latitudinal gradients[lii].

3.2.1 Atmospheric CO_2 and emissions trends

The SRR used IPCC’s 4th Assessment Report (IPCC AR4 2007) as the basis for climate change projections affecting the 82 candidate corals, as it was the best available information. Specifically, the Biological Review Team (BRT) discussed increasing trends in atmospheric CO_2 concentration and increasing rates of human-induced CO_2 emissions noting that both are accelerating and currently exceed rates observed at any time during the past 720,000 to 800,000 years, with the acknowledgement that the results of AR4 were already outdated as described above. The most recent estimate (as of July 2012) of atmospheric CO_2 from the Mauna Loa Observatory is 394.29 ppm (Tans and Keeling 2012; Figures 3 and 4). Additionally, despite reductions in CO_2 emissions by the European Union (3%), the U.S. (2%) and Japan (2%), global CO_2 emissions rose by 3% in 2011 over 2010 driven by large increases in developing countries like China and India (Olivier et al. 2012).



Figures 3 and 4. From Tans and Keeling (2012).

One commenter stated that global GHG emissions are tracking the worst IPCC AR4 emissions scenario, adding that atmospheric CO_2 emissions have risen rapidly since 2000. The commenter stated that in order to preserve a likely chance of limiting overall temperature increases to 1.5° or 2°C above pre-industrial levels, recent scientific assessments have found that global emissions must peak within the next several years, decline very sharply thereafter, reach zero net emissions by mid-century, and become net-negative after 2050 (i.e. where more carbon is removed from the atmosphere than is produced)[liii].

This comment is based primarily on references published before 2011 and on the SRES scenarios used in IPCC AR4. However, current emissions continue to track the highest emission levels from the new representative concentration pathways.

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Recent studies indicate that despite uncertainties regarding specific impacts, climate changes are occurring at a quicker pace than previously estimated and predicted (Blunden and Arndt 2012, Meissner et al. 2012, NOAA 2012, Yamamoto et al. 2012).

3.2.2 Ocean Warming

Information available since the completion of the SRR shows that global temperatures continue to increase and temperature patterns differ regionally. La Niña conditions in 2011 contributed to a cooler year than 2010; however the global surface temperature in 2011 was above the 1981-2010 base period average and compared with other La Niña years was still unusually warm (Blunden and Arndt 2012). Information from NOAA's Climate Data Center indicates that the July 2011-June 2012 12-month period surpassed the June 2011-May 2012 period as the warmest consecutive 12-months that the contiguous U.S. has experienced (NOAA 2012) and 2012 is currently on track to be the warmest year ever in the U.S. Regarding future projections, as mentioned previously, Rogelj et al. (2012) find that, while the resulting range of temperature estimates for the new RCPs to be used in IPCC AR5 is larger than the range of the SRES scenarios (from IPCC AR4), global mean temperature projections by the end of the twenty-first century for the RCPs are very similar to those of their closest SRES counterparts. Arora et al. (2011) examined results from a single model (2nd generation Canadian earth system model; CanESM2) to project future warming under three of the new RCPs and found simulated warming of 2.3°C over the time period 1850-2100 in the lowest RCP emissions scenario (RCP2.6) and up to 4.9°C in the highest (RCP8.5). These are even higher than temperature increases reported in IPCC AR4 and used in the SRR, mostly reflecting the inclusion of a pathway in the RCPs with greater greenhouse gas concentrations than those found in the SRES worst-case scenario.

Gleckler et al. (2012) observed strong evidence for human-induced ocean warming (Gleckler et al. 2012), and Toth et al. (2012) asserts that ENSO-induced warming caused Eastern Pacific reefs to disappear in the past (see also Section 2.6). Levitus et al. (2012) reported the world ocean heat content for the 0 to 700 m depth layer has increased by 0.18°C between 1955 and 2010. Over an even longer timescale, Roemmich et al. (2012) report a spatial mean warming at the ocean surface of 0.59°C between the 1870s and 2010, noting regional variability. Selig et al. (2012) assert that MPAs are a good conservation tool but are not sufficient to mitigate coral loss from thermal stress and, therefore, must be supplemented by policies to reduce activities that cause climate change. They also quantified the relationship between thermal stress and coral loss, which builds on the science – based on Donner (2009) – linking ocean warming projections under different IPCC social scenarios with the frequency and spatial extent of bleaching covered in the SRR. Burrows et al. (2011) found that areas of high marine biodiversity often have greater velocities of climate change and seasonal shifts despite slower warming in the ocean than on land. Using a climate model of intermediate complexity, Meissner et al. (2012) investigated three of the new RCPs and their impact on sea surface temperature as a coral stressor. They found that regardless of the concentration pathway, more than 97% of reefs in the study would experience severe thermal stress by 2050. All of these support the SRR determination that ocean warming has been and will continue to be one of the most important threats driving coral species extinction.

During the recent public information-gathering period, one commenter pointed to evidence of "patchiness" in ocean warming observed in shallow, tropical seas over the last 25 years (Selig et al. 2010). The commenter stated that the spatio-temporal variability in ocean warming patterns should be included and emphasized in the SRR because these patterns may influence how the threat of ocean warming affects coral species' survival.[liv,lv] Further, another commenter stated that there is potential for this patchiness to provide refugia from thermal stresses, but only if the temperature patches are spatially and temporally consistent[lvi].

One commenter summarized several studies published since the completion of the SRR, including two mentioned above: Levitus et al. (2012) and Gleckler et al. (2012). In addition to these references, the commenter summarized studies by Buddemeier et al. (2012), Carilli et al. (2012), Castillo et al. (2012), Chollett et al. (2012), Hoegh-Guldberg et al. (2012), and Karnauskas et al. (2012)[lvii]. According to the commenter, Chollett et al. (2012) found that most warming in the Caribbean has been due to increases in summer rather than winter temperatures; that warming has been faster in winter in the Loop Current area and the southeastern Caribbean, narrowing the amplitude of annual temperature ranges; and that waters off Florida, Cuba and the Bahamas had a tendency towards cooling in winter, increasing the amplitude of annual temperature ranges. The commenter cited Carilli et al. (2012), Castillo et al. (2012), and Guest et al. (2012) to assert that that the susceptibility and response of corals to heat stress may be related to their level of exposure to temperature variability, where corals in regions that experience more variable temperatures may be more resistant to thermal stress than those in less variable environments. Further, the commenter cites Hoegh-Guldberg (2012) to emphasize that the ability of corals to maintain resistance to bleaching under the rapid ocean warming and acidification that is occurring is extremely unlikely. Lastly, the commenter cites the predictions of Buddemeier et al. (2011), which show that under the SRES B1, A1B, and A1FI emissions scenarios, coral cover on most Caribbean reefs is projected to drop below 5% by the year 2035.

One commenter included notes from a presentation at the 2012 ICRS, which reported that cloud cover might mitigate severe increases in SST, thereby minimizing the impacts of bleaching on corals[lviii].

The effects of ocean warming depend on exposure of the species to the threat, which varies spatially and temporally. Spatially, exposure of colonies of a species to ocean warming varies greatly across its range, depending on colony location (e.g., latitude, depth, bathymetry, habitat type, etc.), and physical processes that affect seawater temperature and its effects on coral colonies (e.g., winds, currents, upwelling shading, tides, etc.). Colony location can moderate exposure of colonies of the species to ocean warming by latitude or depth, because colonies in higher latitudes and/or deeper areas are usually less affected by warming events. Also, some locations are blocked from warm currents by bathymetric features (e.g., shelf in Okinawa, Nadaoka et al. 2001) and some habitat types reduce the effects of warm water, such as highly-fluctuating environments (Oliver and Palumbi 2011). Physical processes can moderate exposure of colonies of the species to ocean warming in many ways, including processes that increase mixing (e.g., wind, currents, tides), reduce seawater temperature (e.g., upwelling, runoff), or increase shading (e.g. turbidity, cloud cover). For example, warming events in Hawaii in 1996 and 2002 resulted in variable levels of coral bleaching because colony exposure was strongly affected by winds, cloud cover, complex bathymetry, waves, and inshore currents (Jokiel and Brown 2004). Temporally, exposure of colonies of a species to ocean warming will likely vary annually and decadally, while gradually increasing over time, because: (1) numerous annual and decadal processes that affect seawater temperatures will continue to occur in the future (e.g., inter-decadal variability in seawater temperatures and upwelling related to El-Niño Southern Oscillation); and (2) ocean warming is predicted to substantially worsen in the near future.

3.2.2.1 Coral Bleaching

Literature published in 2011 or later addresses species variability in thermotolerance. The literature underscores the multitude of factors contributing to coral response to thermal stress, including taxa, geographic location, biomass, previous exposure, frequency, intensity, and duration of thermal stress events, gene expression, and symbiotic relationships. However, the variable thermotolerance may have an upper limit as found by Riegl et al. (2011) and reported by one commenter[lix].

This section compiles and summarizes the information collected according to the following categories:

General Bleaching Information
Bleaching Models
Rate/Frequency of Bleaching
Adaptation and Acclimatization to Bleaching
Community Reshuffling
Taxa
Biomass, Size, and Morphology
Previous Exposure and Variability
Location
Symbionts
Gene Expression
Physiology

General Bleaching Information

A couple of oral comments from public meetings in Guam requesting: (1) inclusion of important science concerning bleaching events in 1998, 2009, and 2010;[lx] and (2) better descriptions of diseases caused by coral bleaching and global warming.[lxi] The first comment did not cite or include the referenced studies which were missed in the SRR, so they should be provided during the public comment period. One commenter referenced a study that presents evidence that bleaching in *Oculina patagonica* is not caused by bacteria; however, the commenter did not provide a citation[lxii].

Putnam et al. (2011) showed that short-duration fluctuations between ecologically relevant high and low temperatures result in decreases of *Symbiodinium* density in *Pocillopora meandrina* and *Porites rus* equivalent to decreases observed during exposure of these corals to constant high temperatures. Sridhar et al. (2012) analyzed the basic and major parameters/factors that generally affect mass coral bleaching such as water quality, sea surface temperatures (SST), hotspots, sea surface height anomaly (SSHA), heat content, and photosynthetically active radiation (PAR) data to determine the reason for the mass coral bleaching that occurred only the Gulf of Mannar, and not Kadamat Island in the North Indian Ocean. The results reveal that a PAR of 47 Einstein/m^2/day with a minimum SST of 30°C is significant for mass coral bleaching in the tropical regions.

These two studies show that, in some conditions, fluctuations in temperatures can be as detrimental to coral species as long-duration high temperatures.

Models

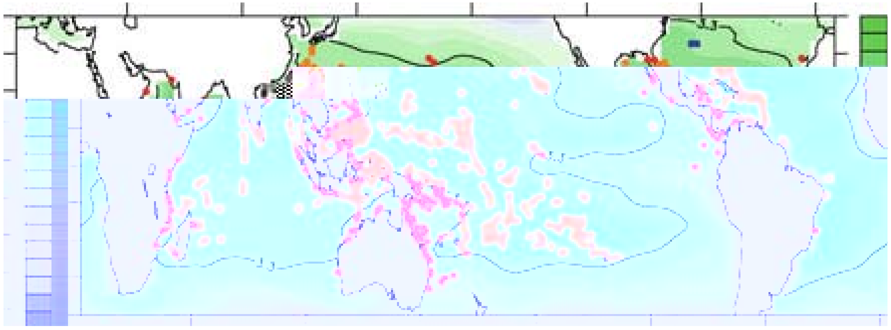
From the SRR:

"Models have provided us with important perspectives on the consequences of future warming on corals."

Recently available models included one showing the importance of considering the the potential for changes in thermal stress thresholds in predicting Degree Heating Month estimates (DHMs) and bleaching hotspots (Teneva et al. 2012), and one reviewing the accuracy of existing coral bleaching models (van Hooidonk and Huber 2012).[lxiii] Taken together, these studies indicate that species thermotolerances and seasonality of temperature fluctuations must be appropriately incorporated into prediction models to improve output accuracy. A recent study in the Caribbean incorporated projected thermotolerance via symbiont shifting into their model, which resulted in a 30-year delay in coral cover falling below 5% (Buddemeier et al. 2011). Models consistently underestimated future bleaching events when they understated seasonal cycles at reef locations (van Hooidonk and Huber 2012). Hoeke et al. (2011) quantitatively illustrated that a large decline in coral cover is highly likely in the 21st Century; however there are significant spatial and temporal variances in outcomes, even under a single climate change scenario. Further, Teneva et al. (2012) indicates that future adaptations of coral species to thermal stress may influence where and when future coral bleaching events occur. Pandolfi et al (2011) underscore this assertion that predicting future responses to increased ocean temperature depends on several factors not currently taken into consideration.

Finally, recent simulations by Meissner et al. (2012) using RCP 4.5 and 8.5 scenarios show that regardless of the concentration pathway, virtually every reef considered in this study (97%) would experience severe thermal stress by year 2050 (see Figure 4). Further, a recent review of current estimates of global climate change impacts on biodiversity of organisms shows that current estimates of biodiversity change are highly variable, depending on the method, taxonomic group, biodiversity loss metrics, spatial scales, and time periods considered; however, the majority of models indicate alarming consequences for biodiversity, with the worst-case scenarios leading to extinction rates that would qualify as the sixth mass extinction in the history of the earth (Bellard et al. 2012).

RCP 3PD year 2100



RCP 8.5 year 2100

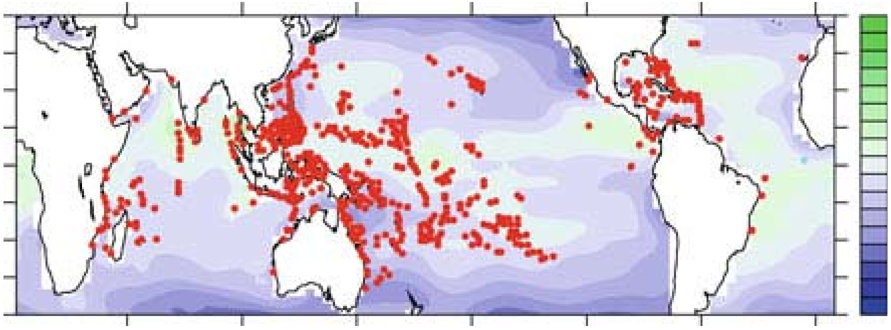


Figure 4. Reefs in blue have a less-than-10% probability of experiencing a severe bleaching event (DHW 8) and live in areas with annual mean open ocean seawater aragonite saturation above 3.3. Orange reefs are thermally stressed experiencing a severe bleaching event at least once every 10 years. Light blue reefs are chemically stressed (annual mean seawater aragonite saturation below 3.3), and reefs in red are both thermally and chemically stressed (from Meissner et al. 2012).

These studies underscore the thematic elements of species adaptation and species-specific responses to environmental condition seen in the comments and information submitted during the public information-gathering period. Further, the studies identify regional scale variation in projected impact.

Rate/Frequency

From the SRR:

"A comparison of the recent and accelerating thermal stress events with the slow recovery rate of most reefs (Baker et al., 2008), suggests that this critical frequency may have already been exceeded."

One commenter recommends the inclusion of Sheppard (2003) as a citation for the second part of this statement in the SRR.[lxiv]

From the SRR:

"This is a troubling statistic for the three species of Caribbean Montastraea that are candidates for protection under the U.S. Endangered Species Act as the Caribbean has been hit by six such events since 1985, a return frequency of less than 5 years (Eakin et al., 2010)."

Recent research looks at whether corals have the capacity to acclimate to temperature increases depending on coral mortality rates and frequency of bleaching events. Brown and Cossins (2011) conducted a literature review to assess whether the magnitude of coral acclimation through phenotypic adaptations (e.g., heat-hardening, longer-term acclimatization responses or even trans-generational epigenetic effects) can keep up with the predicted increases in sea temperatures over the period of global warming. Brown and Cossins conclude while many studies discuss the potential for acclimatization in tropical reef corals and how it may, or may not, be significant in the context of the world's changing climate, remarkably little is known about the potential for and extent of acclimatization in corals, and the complex physiology and behavior underlying the phenomenon. While the exact response of corals to global climate change is uncertain, Hoegh-Guldberg (2011) asserts it is highly unlikely that coral-dominated reef systems will be present in future oceans at the current rate of warming and acidification of the world's tropical oceans. Last, based on the available scientific literature, Hoegh-Guldberg (2012) expects the current (and largely unprecedented) rate and scale of environmental change is exceeding the capacity of coral reef ecosystems to maintain their contribution to human well being through evolutionary and ecological processes. Using modeling data, Buddemeier et al. (2011) predicted that if future mortality rates are equivalent to those observed during the Caribbean bleaching event in 2005, coral cover on most Caribbean reefs would drop below 5% by the year 2035. For a scenario where corals gain an additional 1-1.5˚C of heat tolerance through a shift in the algae that live in the coral tissue, coral cover above 5% is prolonged until 2065.

While there is uncertainty concerning the ability of corals to acclimate to global climate change, there is no evidence from recent research and modeling data that corals will be able to keep pace with the current rate of environmental changes expected by the end of the century.

Adaptation and Acclimatization

From the SRR:

"…bleaching did not select for more temperature tolerant genotypes (see below and Baker et al., 2004; Maynard et al., 2008). For many coral species to survive anticipated ocean warming, corals and their zooxanthellae will likely need to undergo significant adaptation and/or acclimation (Baskett et al., 2009a; Baskett et al., 2009b; Donner, 2009)."

The SRR briefly mentions adaptation and acclimation of corals in response to ocean warming. As discussed above under "Rate/Frequency," currently little is known concerning the potential for an extent of acclimatization in corals (Brown and Cossins 2011). In a review of recovery following bleaching events, van Woesik et al. (2011) determined species most likely to withstand bleaching impacts and persist were "(1) thermally tolerant, locally persistent colonies, (2) remnant survivors that rapidly regrew, and (3) regionally persistent colonies that recruited."

One commenter remarked that there seem to be "lots of potential mechanisms for adaptation, but the jury is still out on all of them in terms of providing reasonable expectation of lowered extinction risk." Further, the commenter noted that studies that document an "altered bleaching response" (e.g., Guest et al. 2012) score bleaching at a generic level with no notation of overall species abundance; therefore, the commenter asserts "it is quite possible that this 'altered response' is not manifest by a single species, but represents to some degree a shift in the species being observed[lxv]".

Based on surveys documenting the spatial and temporal variations in coral taxa responses between two locations in South East Asia during the 2010 bleaching event, Guest et al. (2012) found that bleaching was much less severe at locations that bleached during 1998 and that displayed greater historical temperature variability and lower rates of warming. Further, two taxa typically highly susceptible to bleaching (*Acropora* and *Pocillopora*) were among the least susceptible where their populations bleached previously during the 1998 event, suggesting adaptation or acclimatization to thermal stress (Guest et al. 2012). Carilli et al. (2012) also suggest that coral reefs in locations with more frequent warm events may be more resilient to future warming. Baker (2012) further suggests coral resilience to global change stressors is likely to be not only site specific, but taxon specific and influenced by neighboring organisms.

In addition to host coral adaptation to thermal stress, Howells et al. (2011) demonstrated that shuffling of *Symbiodinium* types could contribute to adaptation to local differences in thermal climate. Howells et al. (2011) suggest this adaptation shapes the fitness of coral hosts because of observed bleaching and tissue death when juvenile corals associated with *Symbiodinium* from cooler reef environments were exposed to 32°C; juvenile corals associated with *Symbiodinium* from warmer reefs grew rapidly under the same thermal conditions. Oliver and Palumbi (2011) also suggest that coral-algal symbioses often conform to particular temperature environments through changes in the identity of the algal symbiont as determined by sequenced rDNA samples from the *Symbiodinium* communities of nine reef-building corals across two thermally distinct lagoon pools. Silverstein et al. (2011) examined identity and diversity of *Symbiodinium* spp. in reef corals by surveying along a latitudinal gradient in Western Australia. When Silverstein et al. (2011) compared symbiont distributions with sea surface temperature data, they found that the putatively thermotolerant *Symbiodinium* ITS-2 type D1a was more frequently detected in 'chronically warm' tropical sites than at 'chronically cool' temperate sites, while clade B symbiont types showed the reverse pattern. In addition to latitudinal differences in *Symbiodinium* spp., van Oppen et al. (2011) examined symbiont specificity in the brooding coral *Seriatopora hystrix* across a depth profile in both northwest (Scott Reef) and northeast Australia (Yonge Reef). Strong genetic structuring over depth was observed in both regions based on the microsatellite loci; however, Yonge Reef exhibited an additional partitioning of mtDNA lineages (associated with specific symbiont ITS2 types), whereas Scott Reef was dominated by a single mtDNA lineage (with no apparent host-symbiont specificity).

Lastly, McCowan et al. (2012) investigated whether there is a relationship between coral morphology and bleaching susceptibility. Overall, patterns of bleaching susceptibility were significantly different among coral growth forms, whereby a much higher proportion of branching, tabular, and submassive corals bleached compared to encrusting, massive, and free-living corals; however, differences in bleaching susceptibility and mortality were not consistent among growth forms within families (McCowan et al. 2012).

These studies provide evidence that sub-lethal bleaching can be beneficial by fostering adaptation, environmental variability fosters adaptation, and greater potential exists for symbiont shuffling and adaptation than previously realized. Related to this are observations of contrasting bleaching patterns on the same reefs after the 1998, 2005, and 2010 bleaching events that suggest adaptive responses in many taxa.

Community Reshuffling

As discussed above, van Woesik et al. (2011) reviewed recovery of various coral taxa on a Pacific reef following bleaching events and found that although species richness had recovered after 10 years, reef composition had changed with reduced abundance of pocilloporids and acroporids. Similar work in Florida found that coral mortality has reduced variations among communities on the Florida reef tract, resulting in a homogeneous community composition along the entire region (Burman et al. 2012). Burt et al. (2011) also observed a shift in coral community composition following the severe bleaching of the late 1990s in the southern Arabian Gulf where bleaching-resistant taxa now dominate instead of *Acropora* spp.

Taxa

From the SRR:

The SRR identified differing responses by taxa to thermal stress and species that have shown increased susceptibility to bleaching.

Recent research identified differing responses among taxa to the same thermal stress. Kongjandtre et al. (2012) and Vargas-Angel et al. (2011) found the genera *Acropora* and *Pocillopora* to be the most affected by bleaching. Faxneld et al. (2011) showed that the response of corals to elevated seawater temperature varies with species and environmental background history. As discussed previously, van Woesik et al. (2011) found that species displaying the following traits were mostly likely to persist in the face of rising temperatures: (1) thermally tolerant, locally persistent colonies; (2) remnant survivors that rapidly regrew; and (3) regionally persistent colonies that recruited.

Biomass, Size, Morphology

Several recent studies show that various colony metrics affect response to elevated temperature. Bleaching response is positively correlated with colony size (Vargas-Angel et al. 2011, van Woesik et al. 2011). Thornhill et al. (2011) found that individuals with lower tissue biomass had increased susceptibility to mortality after bleaching than higher biomass individuals of the same species. Last, morphology might have an effect on bleaching response and subsequent mortality that varies between growth forms and among growth forms within families (McCowan et al. 2012).

Exposure and Variability

One recent study found that previous chronic exposure (Faxneld et al. 2011) did not increase particular species' thermotolerance. Another found several species in the Florida Keys experienced mass mortality from an extreme cold event (Lirman et al. 2011) even though the region had experienced high temperature bleaching events previously. Alternatively, one commenter and several other recent studies suggest that previous exposure to bleaching conditions or high temperature variability yield corals that are more thermotolerant to subsequent bleaching conditions either from adaptation or acclimatization (Palumbi et al 2012; Armoza-Zyuloni et al 2011; Oliver and Palumbi 2011; Donner 2011; van Woesik et al 2011; Carilli et al 2012; Guest 2012; Castillo et al 2012).

Location

Several recent studies identify varying bleaching responses in different geographic locations, different locations within a region, and in different habitats within a single reef (Obura and Mangubhai 2011, Krug et al 2012, Bauman et al 2011). Further, Miller et al. (2011) found, in contrast to the common convention, deep reefs in the remote, uninhabited island of Navassa were more affected by bleaching than shallow reefs.

Symbionts

Commenters[lxvi,lxvii, lxviii] and several recent studies identified the role of symbionts in potential adaptation or acclimatization of the holobiont to increased temperatures via regulating symbiont densities, mitigating photoinhibition, or shuffling clades (Silverstein et al 2011, Hennige et al. 2011, Baker 2012, Oliver and Palumbi 2011).

In a study measuring the physiological effects of low-temperature stress on three common reef-building corals (i.e., *Montastraea faveolata, Porites astreoides,* and *Siderastrea siderea*), Kemp et al. (2011) found species-specific physiological responses indicating different coral and/or *Symbiodinium* cold tolerances. After pre-conditioning scleractinian corals to higher temperatures for 10 days, Bellantuono et al. (2012) demonstrated that acclimatization of coral species did not result in simple changes in *Symbiodinium* or associated bacterial communities suggesting that physiological plasticity of host or symbiotic components might play a role. Leggat et al. (2011) highlighted significant variations in the stress response of individual partners in the symbiosis, and measurable changes in the expression of genes in the host well before reaching the temperature required for observable bleaching. Further, the changes in gene expression in response to higher temperatures depended on the genotype of the symbiont (Yuyama et al. 2012).

Correa and Baker (2011), Howells et al. (2011), and Tchernov et al. (2011) suggest that the highly adaptive capacity of symbionts could be co-opted by host corals, and selection of thermotolerant traits might be occurring. However, others suggest[lxix] that the amount of thermotolerance gained may not be enough to cope with predicted temperature increases (Berkelmans and van Oppen 2006, Oliver et al. 2012), or that symbiotic flexibility does not enhance holobiont resilience (Hollie et al. 2012). Additionally, Littman et al. (2011) suggest major shifts in microbial associates during heat stress might lead to deteriorating coral health, based on a direct comparison of metagenomic data sets from healthy versus bleached corals.

See also discussion under “Adaptation and Acclimatization to Bleaching”.

Gene Expression

One commenter provided notes from a presentation at the 12th International Coral Reef Symposium suggesting that mapping of genes that react to heat stress could help pinpoint locations resilient to ocean warming[lxx]. Leggat et al. (2011) highlight that measurable changes in the expression of genes in the host occurs well before the temperature required for observable bleaching are reached. Additionally, changes in gene expression in response to higher temperatures depend on the genotype of the symbiont (Yuyama et al. 2012), and on genetic background including qualitative differences (i.e., up-regulation in one family and down-regulation in another) (Meyer et al. 2011). Not only does the stress response of individual partners in the symbiosis (host vs. symbiont) vary significantly (Leggat et al. 2011), gene expression patterns in *Symbiodinium* appear to be independently regulated, apart from the host (Rosic et al. 2011). Voolstra et al. (2011) highlight several genes that may be responsible for thermal adaptation, and summarize that “at the moment we have next to no information about the evolutionary mechanisms that brought about morphological, ecological, and physiological diversity of corals.”

Physiology

A recent study suggests that a coral’s ability to curb cell death (apoptosis) may be the most important trait affecting a coral’s thermotolerance and survival (Kvitt et al. 2011). Pernice et al. (2011) also suggest that regulation of apoptotic mediators may mitigate sudden environmental changes such as thermal stress. Further, the “evolvability of the underlying genetic networks and proteins” may indicate a coral’s ability to adapt to environmental changes (Voolstra et al. 2011).

From the SRR:

“Most of the scientific literature about coral bleaching recognizes temperature as a primary driver of bleaching, but it is also recognized that other factors play important roles.”

Maina et al. (2011) combined global spatial gradients of coral exposure to radiation stress factors (temperature, UV light and doldrums), stress-reinforcing factors (sedimentation and eutrophication), and stress-reducing factors (temperature variability and tidal amplitude) to produce a global map of coral exposure and identify areas where exposure depends on factors that can be locally managed. They found high spatial variability of the relative exposures of corals to radiation and reinforcing stressors, with radiation stress being dominant.

3.2.2.2 Potential Impacts on Disease and Reproduction

Several studies published since the completion of the SRR show that warming ocean temperatures affects coral reproduction and coral health. Schnitzler et al. (2012) observed impaired symbiosis establishment and survivorship in coral larvae at elevated temperatures and Webster et al. (2011) observed reductions in the ability of crustose coralline algae to induce coral larval metamorphosis. Further, Yuyama et al. (2011) observed genetic expression differences in endosymbiotic algae at higher temperatures, which affected thermal stress tolerance of host corals. Littman et al. (2011) and Vidal-Dupiol et al. (2011) both show increased bacterial virulence at higher temperatures, supporting the conclusion that thermal stress may lead to deteriorating coral health. Lastly, Burt et al. (2011) observed limited recovery in *Acropora* spp., indicating that severe bleaching can have long-term impacts.

From the SRR:
"The latter is especially important as analyses of global warming patterns indicate that low temperatures during winter months are increasing more rapidly than high temperatures during summer months (IPCC, 2007c)."

The SRR briefly mentioned the impact of cold-water events on corals. Several recent studies indicate that cold-water events can be just as detrimental to corals as warm water events. Lirman et al. (2011) documented the widespread coral mortality as well as reduced resistance/resilience patterns in coral reef communities on the Florida Reef Tract following the cold-water anomaly of January 2010. Kemp et al. (2011) also observed reduced physiological function in Symbiodinium after exposure to cold temperatures and a return to normal water temperatures. Putnam and Edmunds (2011) concluded "short transgressions to ecologically relevant high and low temperatures can elicit a potentially detrimental response equivalent to that occurring upon exposure to a constant high temperature." Further, Roth et al. (2012) indicate that differences in cold and warm water events are dependent on duration with short-term cold temperature being more detrimental than short-term warm temperature; and long-term cold temperature being less detrimental than long-term elevated temperature.

One commenter provided additional references to support their discussion of increasing cold temperature events around the world due to climate change.[lxxi] This commenter also provided a discussion of two of the references above (Kemp et al. 2011 and Roth et al. 2012) as evidence of the impact of cold-water events on corals.[lxxii]

This information indicates that extreme fluctuations in temperature, both hot and cold, have severe impacts on the health and resilience of corals.

3.2.2.3 Changes to water column stratification (less mixing, less nutrients)

No relevant information received for this topic.

3.2.2.4 Potential for range shift and biogeographic expansion

No relevant information received for this topic.

3.2.3 Ocean Acidification

One commenter, while supportive of the conclusions presented in the SRR for the effects of ocean acidification on corals, stated that the SRR discussion is "brief and tends to understate the risks of ocean acidification as a threat to corals."[lxxiii] Ocean acidification is an area of ocean and climate sciences that generates a significantly increasing amount of new data each year. Since the completion of the SRR a number of studies have been produced. As discussed in the SRR, "there is considerable temporal…and spatial variation…over a broad range of time (diel to decadal) and space (reef to globe) scales" in CO_2 levels in the surface waters of the ocean. One commenter cited Hoffman et al. (2011) to support this statement, and to highlight that some marine organisms are already experiencing pH regimes not predicted to occur until 2100.[lxxiv] Other commenters echoed the idea of looking to areas with already low pH waters for predicting what might happen under reduced aragonite saturation regimes. Crook et al. (2012) looked at coral growing near a naturally-occurring groundwater discharge in Mexico and observed that areas near the spring with naturally low pH generally showed reduced coral species size, cover, and diversity.[lxxv, lxxvi] Another commenter mentioned a similar instance in the Indo-Pacific where an area that is naturally low in pH due to volcanic carbon dioxide seeps exhibited reduced coral diversity, recruitment, and abundances of structurally complex framework builders, as well as shifts in competitive interactions between taxa (Fabricius et al. 2011)[lxxvii]. Additionally, notes from a recent presentation by Jury and Toonen (2012) at the International Coral Reef Symposium (ICRS) provided by a commenter describe strong coral growth occurring in an area that experiences both elevated summertime temperature (1-3 °C) and elevated pCO_2 (~100 µatm)[lxxviii].

Based on observations in areas with naturally low pH, the effects of increasing ocean acidification may include potential reductions in coral size, cover, diversity, and structural complexity under decreased saturation regimes.

The effects of ocean acidification depend on exposure of the species to the threat, which varies spatially and temporally. Spatially, while CO_2 levels in the surface waters of the ocean are generally in equilibrium with the lower atmosphere, there is considerable variability in seawater pH across reef-building coral habitats, and thus high spatial variability in exposure of colonies of a species to ocean acidification. The spatial variability in seawater pH occurs from within-reef to global scales, driven by numerous physical and biological characteristics and processes, including at least seawater temperature, proximity to terrigenous runoff and seeps, proximity to sources of oceanic CO_2, salinity, nutrients, photosynthesis, and respiration. CO_2 absorption is higher in colder water, causing lower pH in colder water. Terrigenous runoff causes decreases in salinity and increases nutrients, both of which can raise pH (Gagliano et al. 2010). Local sources of oceanic CO_2 like upwelling and volcanic seeps lower pH (Fabricius et al. 2011). Photosynthesis in algae and seagrass beds draws down CO_2, thereby raising pH (Anthony et al. 2011). These are just some of the sources of spatial variability in pH, which results in high spatial variability in ocean acidification across the ranges of the 82 species. Temporally, high variability over diurnal to decadal time-scales is produced by numerous processes, including diurnal cycles of photosynthesis and respiration, seasonal variability in seawater temperatures, and decadal cycles in upwelling. Temporal variability in pH can be very high diurnally in highly-fluctuating or semi-enclosed habitats such as reef flats and back-reef pools, due to high photosynthesis during the day (pH goes up) and high respiration during the night (pH goes down). In fact, pH fluctuations during one 24-hr period in such reef-building coral habitats can exceed the magnitude of change expected by 2100 in open ocean subtropical and tropical waters (Shaw et al. 2012). As with temporal variability in exposure to ocean warming, temporal variability in exposure to ocean acidification is a combination of high variability over short time-scales together with long, slow directional change. While exposure of the 82 coral species to ocean acidification varies greatly both spatially and temporally, exposure is expected to increase for all species across their ranges in the near future.

According to one commenter, the SRR "fails to examine the magnitude of the changes in ocean chemistry", which are "an order of magnitude faster than what occurred 55 million years ago during the Paleocene-Eocene Thermal Maximum" (Honisch et al. 2012, Zeebe 2012). Further, this commenter cited Friedrich et al. (2012) to state the current "anthropogenic ocean acidification exceeds the trend in natural variability, up to 30 times in some regions. The commenter cites the following predictive modeling studies to support the assertion that current and expected changes in ocean chemistry are unprecedented[lxxix,lxxx]. Joos et al. (2011) predicts that up to 75 percent of the ocean volume could become undersaturated with respect to aragonite, and Meissner et al. (2012) found that even under the most optimistic scenario, 98 percent of reefs would be stressed by ocean acidification by 2050. Meissner et al. (2012) also noted that in all simulations, changes in surface seawater aragonite saturation lead changes in temperatures, so the damage from acidification will influence coral reefs while the climate system continues to warm. Further, the commenter cites the following studies that report more recent in situ observations of declining saturation states. Feely et al. (2012) observed decreasing aragonite and calcite saturation states of surface seawater in the Pacific and Atlantic during cruise surveys and Dore et al. (2012) reported 20 years of decreasing surface water pH at Station ALOHA in the North Pacific[lxxxi].

While the SRR discusses projected changes in aragonite saturation, it does not include a comparison of current or predicted saturation conditions with historical changes in saturation.

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Additional modeling results presented by one commenter shows the following impacts to coral communities under decreased saturation conditions[lxxxii]:

- By the end of the century, Hoeke et al. (2011) predicted total loss of scleractinian coral at some sites in Hawaii under the middle-of-the-road greenhouse gas emissions scenario; Hoeke et al. (2011) believe this to be an underestimate.
- Using scenarios at 600 and 900 ppm CO_2, Anthony et al. (2011) modeled the interaction between coral cover and macroalgae and predicted a more than 50% decrease in coral cover.

While the SRR discusses discrete effects on corals likely to result from increasing ocean acidification (e.g., reproductive, calcification, and erosion effects), there does not seem to be a discussion of the likelihood for reduced coral cover due to ocean acidification. The modeling data available since the completion of the SRR (see above) uses GHG emissions scenarios from the IPCC AR4, which presents a broader suite of conditions than just aragonite saturation conditions in seawater.

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In addition to the references provided by the commenter above, a significant amount of published data on ocean acidification has become available since the completion of the SRR.

Ballantyne et al. (2012) estimated changes in global carbon uptake over the last 50 years and found it unlikely that land and ocean carbon sinks had decreased on a global scale. Lenton et al. (2009), however, found that the combination of ozone depletion and increasing greenhouse gases in the atmosphere enhance ventilation accelerating ocean acidification but reducing the CO_2 uptake of the Southern Ocean. Andersson and Mackenzie (2012) emphasize that high pCO_2 in some areas is linked to biological processes, that estimates of $CaCO_3$ budgets are currently based on measuring the net of gross calcification and dissolution, and that any potential negative effects on organisms from ocean acidification are not likely to be buffered by the dissolution of metastable carbonate mineral phases. Additional effects on corals and reef communities identified by information available since completion of the SRR include:

- Anthony et al. (2011) predicts that the threshold at which herbivore overfishing (reduced grazing) leads to a coral-algal phase shift was lowered by the combination of both acidification and warming.
- Observed differences in growth rate and photosynthetic capacity among four different *Symbiodinium* phylotypes (Brading et al. 2011);
- Potential for coral (Acropora) reefs to become increasingly susceptible to seaweed proliferation under ocean acidification conditions (Diaz-Pulido et al. 2011);
- The likelihood that CO_2 stabilization levels below 350 ppm are needed to assure long-term viability of coral reefs, and these levels are not attainable under existing international agreements on GHG emissions (Hare et al. 2011);
- Increased skeletal weights of coral polyps under lower pH with an apparent saturation plateau above pH 7.77 (Inoue et al. 2011);
- Observed increases in bacteria associated with diseased and stressed corals maintained at lower pH, as well as increased anti-bacterial activity (Meron et al. 2011);
- The uniquely adapted corals of the Persian Gulf may, within the next three centuries, be threatened by a chronic habitat shortage brought about by the dissolution of the lithified seabed on which they rely for colonization. This will occur due to modifications in the chemical composition of the Gulf waters due to climate change (Purkis et al. 2011); and
- Veron (2011) summarizes contributions to predict impacts of acidification on corals and concludes that reefs will be severely affected by acidification by mid-century and they will be reduced to ecologically collapsed carbonate platforms by century's end; "synergistic impacts will lead to progressive reduction in species diversity correlated with habitat loss and widespread extinctions in most metazoan phyla."

The information demonstrates that ocean acidification is likely having a greater impact on corals and reef communities by affecting community composition and dynamics (Anthony et al. 2011, Diaz-Pulido et al. 2011), exacerbating the effects of disease (Meron et al. 2011) and other stressors (e.g., temperature) (Anthony et al. 2011), contributing to habitat loss (Purkis et al. 2011), and affecting symbiotic function (Brading et al. 2011).

One last study, by Form and Riebesell (2012), found that cold-water coral *(Lophelia pertusa)* acclimation to seawater acidification did not increase metabolic rates.

3.2.3.1 Reduced Calcification

As discussed in the SRR, one of the major expected effects on coral of increased ocean acidity is a reduced ability of corals to calcify. One commenter pointed to Andersson et al. (2011) as a supplement to the information presented in Table 3.2.2 of the SRR[lxxxiii]. Andersson et al. (2011) demonstrate in their review that the response of corals to ocean acidification is overwhelmingly negative with both *in situ* and laboratory studies indicating that many coral species have difficulty with calcification and growth under increased acidity. Some species are more susceptible to these effects than others. An example of resilience to these conditions provided by another commenter who cited McCulloch et al. (2012), is some corals up-regulate their pH, allowing them to increase calcification at higher temperatures and low pH conditions with little energetic cost[lxxxiv]. It should be noted that this ability is not ubiquitous across coral species, however (McCulloch et al. 2012). Additionally, this commenter supported their assertion that the response of corals to ocean acidification is not well-understood[lxxxv] by citing Cooper et al. (2012), who could not detect a widespread pattern of consistent decline in calcification rates of massive *Porites* during the 20th century on reefs spanning an 11 degrees latitudinal range in the southeast Indian Ocean off Western Australia. Cooper et al. (2012) suggest that recent changes in coral calcification are responses to temperature rather than ocean acidification.

Additional studies submitted by a commenter included the following conclusions:

- Predicted declines in community calcification by 55% by the end of the century based on increasing GHG emissions and observed calcification rates and other parameters (Shaw et al. 2012)[lxxto2_1⍰1⍰Tf⍰0⍰Tc⍰0.984⍰0⍰Td⍰<000e⍰0.

The other commenter, while supportive of the conclusions in the SRR concerning ocean acidification, questioned the lack of rationale supporting why the SRR "discounts scientific reports that have shown that effects of ocean acidification on corals have already been observed." The commenter provides several references supporting the assertion that declining aragonite saturations already are affecting corals in the Caribbean (Bates et al. 2010, Gledhill et al. 2008) and in the Pacific where reduced calcification is being observed (Cooper et al. 2008, De'ath et al. 2009).

As mentioned previously, the SRR discusses the variability of the data for calcification rates in separate species, as well as the difficulty of applying the existing data to the threats analysis for individual species. Additionally, the SRR discusses that ocean acidification is one of many factors affecting coral status.

Additional information published since the completion of the SRR includes the following:

- Allemand et al. (2011) reviewed the present state of knowledge concerning coral calcification and presented a list of key issues to be resolved in order to understand the intimate mechanisms of calcification of corals.
- Ocean acidification is having impacts not only on the calcification of corals, but also on coralline algae. Diaz-Pulido et al. (2012) demonstrated that *Porolithon onkodes* is particularly sensitive to ocean acidification under warm conditions, suggesting that previous experiments focused on ocean acidification alone have underestimated the impact of future conditions on coralline algae.
- Edmunds et al. (2011) showed that massive *Porites* spp. has the capacity to resist the effects on calcification of 1 month exposure to 81.5 Pa pCO_2 through heterotrophy and changes in biomass.
- Erez et al. (2011) used the relations between aragonite saturation (Ω_{arag}) and community calcification to predict that coral reefs globally may start to dissolve when atmospheric CO_2 doubles.
- Endosymbiont photosynthetic dysfunction may enhance the decrease of coral calcification in future acidified ocean conditions. Calcification and fluorescence yield among colonies clearly differed, showing that the response to acidified seawater is highly variable among colonies in natural coral populations (Iguchi et al. 2012).
- The lowered calcification rate observed in corals under increasing conditions of ocean acidification may be attributed to higher [H(+)] in the seawater with consequent decrease in the efflux of H(+) through the boundary layer (Jokiel et al. 2011).
- Kleypas et al. (2011) estimated an overall 15% decrease in coral calcification since preindustrial times, and the results show that the upstream-downstream patterns of carbonate chemistry were affected by the spatial patterns of benthic community structure. Changes in the ratio of photosynthesis to calcification can thus partially compensate for ocean acidification, at least on shallow reef flats. With no change in benthic community structure, however, ocean acidification depressed net calcification of the reef flat consistent with findings of previous studies.
- Rodolpho-Metalpa et al. (2011) showed that tissues and external organic layers play a major role in protecting shells and skeletons from corrosive seawater, limiting dissolution and allowing organisms to calcify. Their combined field and laboratory results demonstrate that the adverse effects of global warming are exacerbated when high temperatures coincide with acidification.
- Shi et al. (2012) discussed the response relationship of coral calcification to atmospheric CO_2 and sea surface temperature (SST) that shows calcification on the Meiji Reef responded nonlinearly to SST. Here, increasing atmospheric CO_2 had a negligible effect on coral growth in the past century; however, rising SST improved coral growth in the early and middle 20th century, and restricted coral growth in the recent 20 years.

In general, these demonstrate the detrimental effect of ocean acidification – in conjunction with high seawater temperatures – on coral calcification. There is also data comparing the effect of ocean acidification in different coral taxa, and the effect of benthic community changes on the resilience of corals facing increased ocean acidity.

3.2.3.2 Increased erosion

Recent studies have shown an increase in bioerosion of coral skeletons and reef frameworks under acidified conditions. Tribbolet et al. (2009) found an increase in erosion by euendolithic and epilithic algae growing on coral blocks in acidified water. More importantly, Wisshak et al. (2012) found that boring sponges, the largest source of internal erosion of coral skeletons and reef frameworks, significantly increased their chemical dissolution of calcium carbonate under acidified conditions.

These two papers indicate that not only does acidification slow reef construction but it also accelerates deconstruction.

3.2.3.3 Effects on reproduction (fertilization, settlement, recruitment, juvenile growth)

One commenter provided a summary of impacts to certain life history phases for corals from ocean acidification. This summary cited a couple of studies already summarized in the SRR (e.g., Albright et al. 2010; Nakamura et al. 2010), and offered up several additional references[xcv]. Albright and Langdon (2011) demonstrated the acidified seawater reduced larval settlement and post-settlement growth. They found that ocean acidification primarily affects settlement via indirect pathways, whereby acidified seawater alters the substrate community composition, limiting the availability of settlement cues. Doropoulos et al. (2012) suggest that ocean acidification may reduce coral population recovery by reducing coral settlement rates, disrupting larval settlement behavior, and reducing the availability of the most desirable coralline algal species for successful coral recruitment.

Additional information published since the completion of the SRR includes the following conclusions:

- Results from Anlauf et al. (2011) indicate that in future scenarios of increased temperature and oceanic acidity coral planulae will be able to disperse and settle successfully but primary polyp growth may be hampered.
- Clode et al. (2011) found that skeletons of new coral recruits share the same aragonitic mineralogy as those of their mature counterparts. Therefore it is expected that skeletogenesis in both larval and mature growth stages of scleractinian corals will be similarly affected by ocean acidification and predicted environmental changes.

These studies show that ocean acidification is negatively affecting reproduction in corals by disrupting larval settlement, post-settlement growth, and algal-larval interactions. As pointed out by one commenter, "general dysfunction of signaling and sensing may be one of the most overarching effects of ocean acidification[xcvi]."

The SRR discussed the uncertainty of the effect of ocean acidification. Recent information shows that the threat of ocean acidification is more severe than previously thought, particularly when considered in conjunction thermal stress on corals.

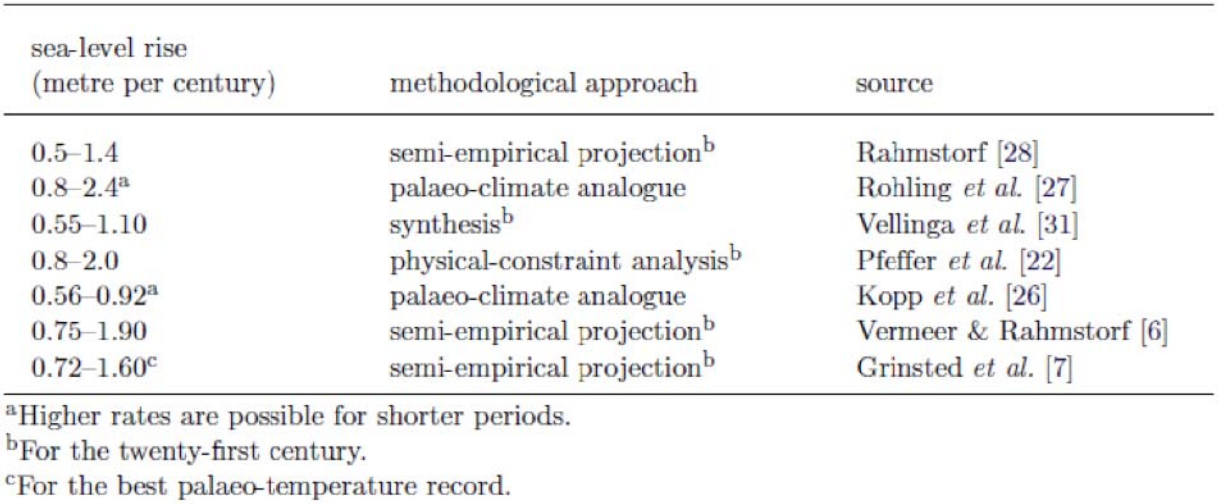
3.2.4 Sea-level rise (slow and/or rapid)

3.2.4.1 Sea level rise – processes and predictions

The SRR discussed future projections of sea level rise in the context of the IPCC AR4 but again acknowledged its limitations including that its models did not include the effects of changes in glacier or ice sheet melting or flow, which may have the largest impact on sea level rise of any component. The SRR reported that post-AR4 estimates already predicted significantly higher rates of sea level rise and the best estimates at the time of sea level rise attributed to ice melting and thermal expansion during this century were between 0.8 and 2.0m (Pfeffer et al. 2008).

Since completion of the SRR, several additional estimates have been released by various researchers, which are all consistent with the implication that the IPCC AR4 underestimated rates of sea level rise in this century. New research still based on IPCC AR4 scenarios suggests rates ranging from 0.6 – 1.9m by 2100 (Vermeer and Rahmstorf 2009; Jevrejeva et al. 2010; Grinsted et al. 2010). Jevrejeva et al. (2011) use a physically plausible sea level model constrained by observations, and forced with the four new RCP radiative forcing scenarios being used in IPCC AR5 (Moss et al. 2010). Their results project median sea level rises of 0.57 m for the lowest forcing and 1.10 m for the highest forcing by 2100. They point out that sea level will continue to rise for several centuries even after stabilization of radiative forcing with most of the rise after 2100 due to the long response time of sea level. Nicholls et al. (2011) summarized projections of sea-level rise published since the AR4 (their Table 1, below). They suggest a pragmatic range of 0.5 to 2.0 m but conclude that the upper part of this range is considered unlikely to be realized.

Table 1. Range of global sea-level rise (meters per century) according to post-AR4 research. From: Nicholls et al. (2011).



sea-level rise (metre per century)	methodological approach	source
0.5–1.4	semi-empirical projection[b]	Rahmstorf [28]
0.8–2.4[a]	palaeo-climate analogue	Rohling *et al.* [27]
0.55–1.10	synthesis[b]	Vellinga *et al.* [31]
0.8–2.0	physical-constraint analysis[b]	Pfeffer *et al.* [22]
0.56–0.92[a]	palaeo-climate analogue	Kopp *et al.* [26]
0.75–1.90	semi-empirical projection[b]	Vermeer & Rahmstorf [6]
0.72–1.60[c]	semi-empirical projection[b]	Grinsted *et al.* [7]

[a] Higher rates are possible for shorter periods.
[b] For the twenty-first century.
[c] For the best palaeo-temperature record.

The largest area of uncertainty in these predictions is the response of the large ice sheets. Mitrovica et al. (2001) attempted to elucidate the contributions of the Antarctic and Greenland ice sheets to sea level rise over the 20th century by accounting for changes in Earth's gravity field and rotation, and shoreline migration. Results indicate distinct spatial patterns in relative sea level (RSL), further supported by Mitrovica et al. (2009) and Bamber et al. (2009) whose results show an increase about 30% higher than the eustatic value around the coastlines of North America and Australasia. Bamber and Riva (2010) further estimate RSL maxima at latitudes between 20°N and 40°S across the Pacific and Indian Oceans (specifically, along coastlines of North America, Australia, and particularly vulnerable land masses in Oceania).

The effects of sea-level rise depend on exposure of the species to the threat, which varies spatially and temporally. This threat is expected to disproportionately affect shallow areas adjacent to degraded coastlines, as inundation results in higher levels of sedimentation from the newly-inundated coastlines to the shallow areas. Spatially, exposure to sea-level rise will be moderated by horizontal and vertical distances of reef-building coral habitats from inundated, degraded coastlines. Temporally, exposure to sea-level rise will increase over time as the rate of rise increases.

One commenter provided an extensive summary of projected ranges for sea level rise, citing several of the references used in the SRR, as well as additional references[xcvii].

3.2.4.2 Impacts to corals and coral reefs

One commenter asserted that growth rates of even the slowest-growing Atlantic corals are sufficient to keep pace with rising sea levels, and hurricanes are considered a likely cause for why the Florida reef tract and other areas in the Caribbean have been unable to keep pace with rising sea level over the past 6 ka[xcviii].

One commenter takes issue with the first sentence of this section in the SRR: “An increase in sea level (or increased depth via subsidence) provides accommodation space for corals living near the sea surface, which corals can potentially fill through vertical growth.” The commenter provides several references (Brown et al. 2011, Scopélitis et al. 2011, and Fenner 2012) to assert that sea level rise will result in increased coral cover on reef flats because fewer corals will die from low tide. The commenter also states that coral mortality on reef flats due to bleaching (Fenner 2012) and sediment (Field et al. 2012) impacts will likely counteract any positive benefit from sea level rise[xcix]. Another commenter corroborates this last statement by citing Field et al. (2012)[c]. Additionally, Hongo et al. (2011) assert that despite the potential for *Acropora* and *Porites* to grow at rates that keep pace with expected sea level rise, these species are likely to experience severe mortality in upcoming decades due to natural and anthropogenic stresses.

The SRR states that “[e]ven at the most rapid trajectories of sea-level rise, it is likely that many of these corals would be capable of keeping up (growing upward) if conditions were otherwise suitable for growth. However, rapid growth is likely to be hindered if the corals are stressed by other factors.”

From the SRR:
“*Hence, rapid sea-level rise may result in either loss of corals or changes in community structure and composition of corals, most likely to slower growing forms.”*

One commenter remarked that the above statement might be “true about corals on reef flats and/or lagoons, but not on reef slopes, barrier reefs, or atolls[ci].” ***The SRR states “[t]he influence of rising sea level on the 82 candidate coral species is likely to have mixed responses for the respective species depending on their depth preferences, sedimentation tolerances, growth rates, and the nearshore topography.”***

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From the SRR:
“In many areas, human response to rapid sea-level rise is likely to result in “hardening”—coastal construction designed to protect critical human infrastructure from advances of the sea into coastal communities. Under such scenarios, it is not unlikely that societies will strive to protect human development and coastal infrastructure, even if this results in the destruction or degradation of coral reefs.”

One commenter mentioned that no evidence is presented that hardening shorelines will damage coral reefs, and if there is evidence it should be presented. The commenter continues that there is potential for the hardened shoreline to serve as coral habitat with rising sea levels. The commenter has seen hardened shoreline serve as habitat for coral colonization at one location in American Samoa[cii].

The SRR states "hardening of shorelines is likely to delay the progression of coastlines;" however, no supporting references are provided. The overview of major ecological effects of increasing infrastructure to marine habitats conducted by Bulleri and Chapman (2010), which found that urban infrastructure does not function as surrogate natural rocky habitat, may address this commenter's concern.

3.2.5 Changing ocean circulation

No relevant information received for this topic.

3.2.6 Changing Storm Tracks and intensities

For effects on corals caused by hurricanes and cyclones, Mumby et al. (2011) showed that clustered storm events (i.e., high frequency storm years) have a less detrimental impact than independent random events. The data presented does not estimate the likelihood that storms will increase, decrease, cluster, or be individual and random into the future.

The following literature considered effects beyond hurricanes and tropical storms, which were discussed in the SRR. It provides evidence that precipitation is getting worse (e.g., 2011's La Niña produced more intensive precipitation) and evidence that continuous chronic stress from various threats makes corals more susceptible to damage from flooding. With a predicted intensification of extreme precipitation at the global scale (Peterson et al. 2012), there is an increased likelihood of negative impacts to corals from flood events (like the one observed in Queensland, AU; Tan et al. 2012), which deliver potentially detrimental terrestrial pollutants via flood plumes (Devlin et al. 2012).

These effects are not discussed in the SRR.

From the SRR:
"Tropical storms can bring benefits to reefs if the storms pass far enough away to not inflict damage, but close enough to cool waters through enhanced wave-induced vertical mixing and reduce bleaching risk (Manzello et al., 2007; Szmant and Miller, 2005)."

One commenter provided an additional reference that further validates this assertion from the SRR with observations from the Indian Ocean[ciii].

3.2.7 African & Asian Dust

Two commenters mentioned that "Dust could also be a source of a limiting nutrient (e.g., iron) facilitating the growth of benthic cyanobacteria or algae that, unchecked by herbivores, can outcompete corals[civ]." A citation was not provided.

The impact of nutrients, algal growth, and loss of herbivorous fishes is assessed in Section 3.3 of the SRR, which discusses local threats.

3.2.8 Changes in Insolation

No relevant information received for this topic.

3.2.9 Summary of Global Changes and their impacts

Two commenters suggested the inclusion of a 2009 reference, which summarizes the impact of global climate change on disease in coral species (Sokolow 2009).[cv] Sokolow (2009) summarizes "current research suggests that environmental factors, such as ocean warming, altered rainfall, increased storm frequency, sea level rise, altered circulation, and ocean acidification may play a role in coral disease. These climate variables likely alter coral epidemiology through effects on pathogen growth rates, transmission, virulence, and susceptibility…Current evidence is still preliminary but is increasingly suggestive that mitigating the effects of climate change may help reduce the emergence of disease and improve the health of coral reef ecosystems."

One commenter stated that the environments in which coral species, including the candidate species, are found are highly dynamic and coral species are adaptive to a wide range of environments and stressors. The commenter implies that this adaptability to a variety of environments has allowed corals species to persist throughout geologic history[cvi].

The SRR discusses the uncertainty of impacts to coral candidate species from global changes.

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Recent scientific literature suggests that complexity in the Indo-Pacific (i.e., high coral species diversity on reefs, high environmental variability across ranges of coral species) will lead to complexity in the responses at the species and community levels to numerous, simultaneous, broad threats (Hoeke et al. 2011, Pandolfi et al. 2011, Hoegh-Goldberg 2012, Hughes et al. 2012). At the species level, the complexity is likely to lead to temporal and spatial heterogeneity in the response of a given species across its range. At the community level, the complexity is likely to lead to rapid inter-disturbance recovery (Ateweberhan et al. 2011, Graham et al. 2011) and reassortment of coral species on a given reef, with more resilient species becoming more common (i.e., in the Indo-Pacific, in general, reef community structure will change, but reefs won't be replaced by algae or slime) (Hughes et al. 2012). In some predictions, models show worst-case scenarios of mass extinction events (Bellard et al. 2011). McClanahan et al. (2011) assert that reducing additional human disturbances, such as fishing and pollution, in these areas is expected to improve the chances for their persistence.

Two main themes emerged from recent publications and comments received during the public information-gathering period: (1) global climate change threats are worsening; and (2) impacts of the threats to corals are complicated and moderated by large latitudinal/longitudinal/vertical ranges, adaptive capacity, and high spatial/temporal variability in threat response (among other things). There was little new information that indicates the SRR overestimated the threats that global changes impose on the petitioned corals and, in fact, most information indicates the threats may have been underestimated.

3.3 Local Threats [Also relevant for Draft Mgt Report/DMR: 1.2.1.2]

Several commenters mentioned a variety of human activities that are having a negative impact on corals, including the following:

- Snorkeling;
- Fishing[cvii];
- Run-off;
- Federal construction projects in flood-prone areas[cviii];
- Dredging[cix];

- Military activities[cx].

These activities and their impacts on the 82 candidate corals are discussed in the SRR.

3.3.1 Land-based Sources of Pollution

One commenter recommended that NMFS evaluate the impacts of non-point source pollution on reefs, including pollutants from tires (e.g., heavy metals)[cxi].

Information published since the completion of the SRR includes a study demonstrating that *Symbiodinium* distribution correlates significantly with spatial variability in water quality, indicating changes in resident symbiont communities with changes in water quality (Cooper et al. 2011). Another study models coral community composition as a function of stressors and degradation (Melbourne-Thomas et al. 2011). The authors assert that community composition is more predictable for coral communities with a greater number of stressors and more severe degradation. These studies look at water quality in general and show that degraded water quality has an effect on the symbiotic associations of corals as well as overall reef community composition.

The effects of land-based sources of pollution such as sedimentation and nutrient over-enrichment depend on exposure of the species to the threat, which varies spatially and temporally. Exposure varies depending on the type of LBSP and location: For sedimentation in the Caribbean, exposure is moderated by distance of some coral habitats from areas where sedimentation is chronically or sporadically heavy (i.e., heavily populated areas), resulting in some areas of coral habitats being unaffected or very lightly affected by sedimentation. Exposure to sedimentation is more moderated in the Indo-Pacific by large distances of many coral habitats from areas where sedimentation is chronically or sporadically heavy (i.e., heavily populated areas), resulting in vast areas of coral habitats being unaffected or very lightly affected by sedimentation. Exposure to sedimentation is also moderated by depth of many habitats in both regions, but again more so in the Indo-Pacific than in the Caribbean. Deep habitats are generally less affected by sedimentation, especially in the Indo-Pacific. Temporally, exposure to sedimentation will increase as human activities that produce sedimentation increase over time, but in the Indo-Pacific will still be strongly moderated by distance.

3.3.1.2 Nutrients

From the SRR:

"Laboratory manipulations with elevated nitrogen and phosphorus have shown decreased calcification, sometimes with greater reduction in combination than either alone (Ferrier-Pages et al., 2000; Marubini and Davies, 1996). Nutrients may enhance linear extension but reduce skeletal density, making corals more prone to breakage or erosion (Koop et al., 2001; Tomascik, 1990; Tomascik and Sander, 1985)."

Dunn et al. (2012) show that increased phosphate concentrations caused increased coral growth, and a more brittle skeleton. Sawall et al. (2011), however, observed that the coral *Stylophora subseriata* seemed to exhibit a lack of metabolic stress under highly turbid nearshore conditions.

Exposure is generally higher for nutrient over-enrichment than for sedimentation because nutrients can be transported further than sediments. Spatially, as with sedimentation, exposure to nutrients is moderated by distance of some coral habitats from areas where nutrients are chronically or sporadically heavy (i.e., heavily populated areas). However, nutrient over-enrichment can result from very small human populations (Barott et al. 2012), and nutrients can be quickly transported large distances, thus distance is less of a moderating factors for nutrients than for sedimentation. Similarly, although nutrient exposure may also be moderated by depth of some habitats, nutrient impacts can reach much farther than sedimentation impacts. Temporally, exposure to nutrients will increase as human activities that produce nutrients increase over time.

3.3.1.3 Toxins and contaminants

The following information concerning toxins and contaminants in corals has been published since completion of the SRR. These studies looked at the effects of heavy metals on corals in the field and in the laboratory. As discussed in the SRR, it is difficult to tease out the specific impacts of non-point source pollution in the field, particularly when other stressors are present. Much of the data is correlative versus causative. For example, Ali et al. (2011) found that soft corals had lower concentrations of heavy metals in their tissues than hard corals, which incorporated heavy metals into their skeletons. Additionally, in areas with high concentrations of heavy metals, there was a higher percentage of dead coral cover and greater presence of soft corals (Ali et al. 2011). Hedoin et al. (2011) also observed a significant correlation between coral cover and heavy metal concentrations in sediments; as heavy metal concentrations increased, coral cover decreased.

In addition to affecting coral cover, Chen et al. (2012) found that acute exposure of the scleractinian coral, *Stylophora pistillata*, to the PCB Aroclor 1254 had the potential to alter gene expression. Further, in an effort to look at interactive effects between stressors, Negri et al. (2011a, 2011b) investigated the combined impact of changing heavy metal concentrations and changing temperatures. In one analysis, the authors show that decreasing the heavy metal concentration in seawater assists in protecting corals from a 2-3°C increase in temperature (Negri et al. 2011a). In the other analysis, Negri et al. (2011b) found that the effects of aluminum refinery wastewater and temperature on fertilization and metamorphosis was additive.

This information looks at the effects of toxins in the field (Ali et al. 2011, Hedoin et al. 2011), in the laboratory at the molecular level (Chen et al. 2011), and in combination with other stressors (i.e., temperature) (Negri et al. 2011a, 2011b).

From the SRR:
“Adult corals are usually not directly affected by herbicides (Peters et al., 1997); however, zooxanthellae have been shown to be affected at very low concentrations (ng/L) (Jones, 2005).”

A recent study by Negri et al. (2011) looked at the combined effects of temperature and herbicides on coral using a mixed model and concluded “environmentally relevant concentrations of each herbicide increased the negative effects of thermal stress on coral.” In some cases these negative effects of temperature and herbicides combined were additive, while in others these effects were synergistic. Further, reducing herbicide concentrations seemed to protect photosynthetic efficiency with increasing temperatures.

3.3.1.4 Salinity Impacts

From the SRR:
“osmoregulation”

One commenter recommended correcting this terminology by using the term “osmoconformers,” which is a more accurate description of corals. The commenter also pointed out “no corals have ever adapted to fresh water[cxii].”

3.3.2 Disease

Several publications discuss observed disease impacts and dynamics at various coral reef sites around the world and in particular coral species. Bruckner (2012) surveyed Puerto Rico, the Cayman Islands, Bonaire, and the Bahamas and documented widespread coral mortality. For the species *Montastraea annularis*, few recruits were observed and “formerly large colonies that have survived now consist of small tissue isolates that continue to shrink in size” (Bruckner 2012). Jacobson et al. (2012) identified a higher disease incidence on the south central shore of Majuro atoll than at neighboring atolls in the Marshall Islands. The incidence of disease correlates with local human population and nutrient input concentrations, and based on observations it appears as if few massive coral colonies will survive the decade (Jacobson et al. 2012). In Guam, a commenter provided a study by Myers and Raymundo (2009) who assessed 15 reefs for disease prevalence, host abundance, and community structure. The surveys revealed 6 disease states affecting 8 families of reef-building corals and highly variable prevalence between sites, ranging from 0.2 to 12.6% (Myers and Raymundo 2009). Five out of 6 of the observed disease states affected *Porites* spp. (mean prevalence within the genus: 6.14 ± 0.88%), and acroporids and pocilloporids also showed high susceptibility. In the South China Sea, surveys conducted by Shi et al. (2012) in 2008 and 2010 revealed a rapid and severe decline in coral cover, with evidence indicating that outbreaks of black-band disease are at least partially responsible for the massive coral mortality at the northern reef of Yongxing Island during 2002 to 2010. Last, Wiel et al. (2012) reported the first known occurrence of lesions similar to Porites ulcerative white spots (PUWS), brown band disease (BrB), pigmentation response (PR), and crustose coralline white syndrome (CCWS) in Japan, which significantly expands the geographic distribution of these diseases in the Indo-Pacific.

These studies indicate that the incidence of coral disease in the Indo-Pacific is expanding geographically (Shi et al. 2012, Wiel et al. 2012), that massive coral species are not recovering from disease events (Bruckner 2012, Jacobson et al. 2012), and that prevalence of disease is highly variable between sites and species (Myers and Raymundo 2009).

Other information available since the completion of the SRR includes discussion of modeling results, which suggest greater resilience to disease in mesophotic reef systems (Brandt et al. 2012) and suggest that bleaching could be a more important precursor to white syndromes (WS) outbreaks than previously anticipated (Maynard et al. 2012).

The effects of coral disease depend on exposure of the species to the threat, which varies spatially and temporally. Spatially, exposure to coral disease in the Caribbean is moderated by distance of many coral habitats and areas from the primary causes of most disease outbreaks, such as stressors resulting from sedimentation, nutrient over-enrichment, and other local threats. Exposure to coral disease in the Indo-Pacific is somewhat more moderated by distance than in the Caribbean, due to a greater proportion of reef-building coral habitats located in remote areas that are much further away from local threats. Exposure to coral disease is also moderated by depth of many habitats in both regions, but again more so in the Indo-Pacific than in the Caribbean. Deep habitats are generally less affected by disease outbreaks from stressors resulting from ocean warming, especially in the Indo-Pacific. Disease exposure in remote areas and deep habitats appears to be low but gradually increasing. Temporally, exposure to coral disease will increase as the causes of disease outbreaks (e.g., warming events) increase over time (NMFS 2012c, SIR section 3.3.2).

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Two commenters provided additional references and citations concerning correlation of disease with anthropogenic influence and cross-shelf transmission (Kaczmarksky 2006)[cxiii] and correlation of disease prevalence with fish diversity in MPAs (Raymundo et al. 2009)[cxiv]. In the Philippines, Kaczmarksky (2006) found that the high prevalence of disease near uninhabited Sumilon Island appeared to be linked to the highly diseased reefs near Dumaguete City due to transmission of disease along a cross-shelf front formed between the Tañon Strait and Bohol Sea. Raymundo et al. (2009) investigated potential links between coral disease and the trophic components of fish diversity, finding that only the density of coral-feeding chaetodontid butterflyfishes, seldom targeted by fishers, was positively associated with disease prevalence. These studies suggest potential routes of infection including physical oceanographic processes (Kaczmarksky 2006) and coral-feeding fishes (Raymundo et al. 2009).
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From the SRR:
"At least two of the 82 candidate species (Dichocoenia stokesi and Montastraea annularis complex) have experienced documented dramatic, and likely unrecoverable, declines in local populations (up to 60% in one year) from disease, either alone or in conjunction with major bleaching events (Bruckner and Hill, 2009; Miller et al., 2009; Richardson and Voss, 2005)."

Two commenters expressed doubts about the "unrecoverable" description of *Dichocoenia stokesi* and cited survey data showing this species' relative abundance in Florida (Wagner et al. 2010)[cxv]. Further these commenters cited Lirman et al. (2011) to support the statement that the species exhibits "high resistance to both warm and cold-water anomalies."

Disease and LBSP

One commenter recommended consideration of the study by Sutherland et al. (2010), which found a link between a unique bacteria strain found in human sewage with white pox lesions in *Acropora palmata*[cxvi]. In a more recent study, Sutherland et al. (2011) also suggest that *C. abbreviata* and non-host corals may function as reservoirs or vectors of the APS pathogen. Their results provide the first example of a marine "reverse zoonosis" involving the transmission of a human pathogen *(S. marcescens)* to a marine invertebrate *(A. palmata)* (Sutherland et al. 2011). Additional evidence for the impact of human populations on coral health is the study by Aeby et al. (2011), which showed strong positive associations between Porites Growth Anomalies (PGAs) and human population size. This is one of the first broad-scale studies unambiguously linking coral disease with human population size (Aeby et al. 2011). Lamb et al. (2011) observed that coral diseases were 15 times more prevalent at reefs with offshore tourism platforms than at nearby reefs without platforms; diseases affected 10 coral genera from 7 families at reefs with platforms and 4 coral genera from 3 families at reefs without platforms. This contrasts with Onton et al. (2011) who suggest that natural stressors are potential drivers of disease at Ningaloo Marine Park on the coast of Western Australia because of observed positive relationships among disease, anoxic events, and *Drupella* spp. feeding. Onton et al. (2011) saw no strong indication that human activities, measured as density of people or vessels in the water, were related to disease prevalence.

Haapkyla et al. (2011) and Kaczmarksy and Richardson (2011) investigated the relationship between water quality and coral disease prevalence. Results from Haapkyla et al. (2011) suggest that rainfall and the associated terrestrial runoff may facilitate seasonal disease outbreaks, potentially by reducing host fitness or by increasing pathogen virulence due to higher availability of nutrients and organic matter. Kaczmarksy and Richardson (2011) provide quantitative evidence linking relatively higher coral disease prevalence to an anthropogenically-impacted environment through observations of positive correlations between coral disease, nutrient levels, and organic carbon.

The SRR asks: "What is the contribution of local anthropogenic stressors (e.g., runoff or sewage) to increased coral disease impacts?" The bulk of recent research shows strong correlations between human population density and disease prevalence in corals (Aeby et al. 2011, Lamb et al. 2011), with definitive causative links identified between human sewage and coral disease (Sutherland et al. 2010, 2011). Quantitative evidence also points to higher disease prevalence in areas with reduced water quality (Haapkyla et al. 2011, Kaczmarksy and Richardson 2011).

Disease and Ocean Warming

Aeby et al. (2011b) focused on the three indicator diseases (Porites growth anomalies (PorGAs), Porites trematodiasis (PorTrm), Porites tissue loss syndrome (PorTLS)) and used statistical modeling to examine the underlying associations between disease prevalence and 14 different predictor variables (biotic and abiotic). All three diseases showed positive associations with host abundance and negative associations with thermal stress. Kimes et al. (2012), however, identified potential virulence mechanisms using whole genome sequencing of *V. coralliilyticus* ATCC (American Type Culture Collection) BAA-450 and demonstrated direct temperature regulation of numerous virulence factors using proteomic analysis and bioassays. These results provide evidence that temperature regulates multiple virulence mechanisms in *V. coralliilyticus*, independent of abundance (Kimes et al. 2012). Additionally, when Palmer et al. (2011) investigated the immunological responses within three Caribbean corals, *Montastraea faveolata*, *Stephanocoenia intersepta*, and *Porites astreoides* to the presence of thermal stress followed by exposure to pathogen-associated molecular patterns (PAMPs), they found results consistent with hypotheses that increased disease prevalence during periods of warmer water temperature is partly due to a suppression of coral immunity. Rogers et al. (2012) found a positive correlation between water temperature and disease prevalence, and not incidence, with greater disease prevalence among bleached corals than those that did not bleach.

Yakob and Mumby (2011a) assert that allowing for a more dynamic population turnover in an epizoological model of coral disease not only gives a superior fit to empirical data, but also suggests that emerging coral assemblages could be far less prone to epizootics. The authors state "in short, whereas coral might exhibit adaptive immunological responses, we show that higher demographic rates naturally reduce the ability of the disease to spread within a population consisting of diminutive colonies under high flux" (Yakob and Mumby 2011). The authors explain further "population turnover is a function of average colony size, with large colonies having slower rates of turnover than small colonies. Epizootics decrease the mean colony size, thereby increasing mean population turnover" (Yakob and Mumby 2011b)

In another modeling experiment, Yee et al. (2011) developed spatially explicit population models of coral disease and bleaching dynamics to quantify the impact of six common diseases on Florida Keys corals, including aspergillosis, dark spots, white band, white plague, white patch, and Caribbean yellow band. Using the model, Yee et al. (2011) found that classic disease transmission from contagious to susceptible colonies provided the best-fit model only for aspergillosis, whereas external disease forcing, such as through a vector or directly from pathogens in the environment, provided the best fit to observed data for other diseases. They also found incidences of white band and white patch disease were associated with greater susceptibility or slower recovery of bleached colonies, and no disease outbreaks were associated with periods of elevated sea temperatures alone (Yee et al. 2011).

Recent research continues to show mixed correlations between thermal stress and disease prevalence; however, bleaching (Palmer et al. 2011, Rogers et al. 2011, Yee et al. 2011) and host abundance (Aeby et al. 2011, Yakub and Mumby 2011) seem to increase the susceptibility of corals to disease contraction.

Specific diseases and "Pristine" environments
Several studies investigated coral disease at specific locations. Roff et al. (2011) report the spatiotemporal dynamics of a coral disease termed 'Acroporid white syndrome' affecting tabular corals of the genus Acropora around Heron Reef on the southern Great Barrier Reef. While all sizes of colonies were affected, white syndrome disproportionately affected larger colonies of tabular Acroporids (>80 cm). Prevalence of disease was strongly related to abundance within transects; however, incidence of the syndrome lacked a spatial pattern and appeared unaffected by proximity between colonies. Further, the Acroporid white syndrome is not transmitted by direct contact, and rates of tissue loss in affected colonies increased threefold during winter months (Roff et al. 2011).

Thinesh et al. (2011) surveyed 18 sites at 9 locations in Palk Bay, finding six disease types among eight coral genera. Overall, 21% of corals surveyed were affected by disease, with prevalence the highest for Acropora and Porites. Thinesh et al. (2011) found white band disease to be widespread and to affect Acropora exclusively.

Williams et al. (2011) assert, "Palmyra Atoll allows us to study disease dynamics under near-pristine, functionally intact conditions." The authors found that host distribution and environmental factors (e.g. temperature) appear to be important for determining spatiotemporal patterns of disease at Palmyra; however, they suggest that more sophisticated analyses are required to tease apart the likely inter-correlated proximate drivers of disease occurrence on remote, near-pristine reefs (Williams et al. 2011).

In a review by Garren and Azam (2012), the authors state "the scope of diversity of bacteria is much clearer than it was before, and we have more information about patterns of distribution and diversity through space and time. However, there remain many levels of spatial and time scales on which we do not understand bacterial behaviors. Further, and critically, our understanding of in situ microbial activity and interactions is still quite incomplete."

Yee et al. (2011) used simulated data under a known environmental effect to assess the ability of standard statistical methods (binomial and linear regression, ANOVA) to detect a significant environmental effect on pooled disease prevalence with varying species abundance distributions and relative susceptibilities to disease. Model simulation results led the authors to recommend that "Investigators should be cautious of underlying assumptions about species similarity in susceptibility and species composition when interpreting pooled data on disease risk," as abundance, distribution, and environmental gradient each led to over- and underestimation of disease prevalence (Yee et al. 2011).

Overall, when Diaz and Madin (2011) integrated observations of coral disease on the Great Barrier Reef from the primary literature as well as morphological, ecological, and biogeographical traits of coral species that have been hypothesized to influence "disease potential," most of the examined traits influence species' disease potential when considered alone. However, when all traits are analyzed together, diversity of predators, geographical range size and characteristic local abundance are the primary predictors of disease potential (Diaz and Madin 2011).

Recent studies expand the collective data catalogue for coral disease in the Caribbean and Indo-Pacific. These studies also reveal there is much to learn about spatiotemporal dynamics of disease transmission among corals (Roff et al. 2011, Williams et al. 2011, Garren and Azam 2012, and Yee et al. 2011), and they reinforce the idea that myriad environmental and physical factors play a role in disease prevalence and incidence (Roff et al. 2011, Diaz and Madin 2011, Williams et al 2011).

3.3.3 Predation

The SRR discusses rates and dynamics of coral predation by several species of corallivorous fishes. Recently, Cole et al. (2011) and Cole and Pratchett (2011a) found that the quantity of tissue removed by butterflyfishes is larger than previously expected (Cole et al. 2011) and predation by juvenile butterflyfishes represents a chronic stress to coral colonies with 88% (38/43) of small (<30 mm) juveniles of *Chaetodon plebeius* feeding exclusively from a single colony (Cole and Pratchett 2011a). Both studies emphasize that predation represents a large energetic cost to the coral colonies.

For particular coral species Cole and Pratchett (2011b) assessed the variation in susceptibility to coral predation as well as the variation in predation intensity. Massive *Porites* experienced the lowest rate of grazing on individual colonies, with *A. hyacinthus* experiencing the highest rate (Cole and Pratchett 2011b). Within coral species, grazing rates showed a linear increase with increasing size of the colony; however, the intensity of predation showed a negative relationship with increasing colony size (Cole and Pratchett 2011b). Additionally Roff et al. (2011) found that parrotfish bites were most frequently observed on the dominant species of reef building corals *(Montastraea annularis, Montastraea faveolata* and *Porites astreoides)*, and when the effects of colony density and size were removed, selective corallivory existed only for the less dominant *Porites porites*. Roff et al. (2011) suggest that the success of *P. porites* in the face of existing disturbance regimes, which result in the decline of dominant framework building corals, might be offset by selective corallivory of parrotfish.

The effects of predation depend on exposure of the species to the threat, which varies spatially and temporally. Spatially, exposure to predation by corallivores is moderated by presence of predators of the corallivores (i.e., predators of the predators). For example, corallivorous reef fish prey on corals, and piscivorous reef fish and sharks prey on the corallivores, thus high abundances of piscivorous reef fish and sharks are expected to moderate coral predation. Abundances of piscivorous reef fish and sharks vary spatially, because abundances of these species are generally increase with distance from human populations. Spatially, exposure to predation is also moderated by distance from physical conditions that allow corallivore populations to grow. For example, in the Indo-Pacific, high nutrient runoff from continents and high islands improves reproductive conditions for the crown-of-thorns (COTS) starfish, thus coral predation by COTS is moderated by distance from such conditions. Predation can also be moderated by depth of many habitats, because abundances of many corallivorous species declines with depth. Temporally, exposure to predation will increase over time as conditions change, but will still be strongly moderated by distance and depth.

Recent studies show that the impact of butterflyfish predation on corals is larger than previously expected (Cole et al. 2011), including the exclusive predation of juveniles on single-host corals (Cole and Pratchett 2011a). Further, while butterflyfish grazing rates seem to increase with coral colony size, grazing intensity seems to decrease (Cole and Pratchett 2011b). Last, in the Caribbean, parrotfish may selectively graze on P. porites (Roff et al. 2011).

From the SRR:
"Large aggregations of crown-of-thorns seastars (Acanthaster planci), termed outbreaks, are among the most significant biological disturbances that occur on coral reefs (Moran, 1986)."

One commenter suggested considering where and when the first crown-of-thorns (COTS) outbreaks occurred because there is evidence that these outbreaks may be caused or facilitated by humans. Additionally, the commenter states that currently COTS outbreaks are not as common or widespread as they have been in the past[cxvii]. Another commenter mentioned that a COTS outbreak in Tinian is causing more damage to corals than sedimentation[cxviii]. It was suggested by one more commenter that NOAA "do something" about the abundance of COTS in Guam[cxix]. A recent paper by De'ath et al. (2012) found that COTS populations are strongly influenced by LBSP, and together COTS and LBSP have contributed strongly to large coral losses on the GBR. See also Section 3.3.3.3.

3.3.3.1 Depensatory effects of predation

No relevant information received for this topic.

3.3.3.2 Synergistic effects of predation

No relevant information received for this topic.

3.3.3.3 Outbreaks of predators

No relevant information received for this topic.

3.3.3.4 Apex predators

One commenter noted, "High populations of apex predators have also been reported from large, well-protected MPAs in the Caribbean."[cxx]

The SRR states apex predators "are now generally common only around remote Pacific islands and atolls where fishing pressure is slight (Sandin et al., 2008; Stevenson et al., 2007; Williams et al. 2011) and, possibly, also in other remote areas of the Indian Ocean and near Papua New Guinea." The SRR does not mention presence/absence of apex predators in the Caribbean.

3.3.3.5 Summary of predation threats

From the SRR:
"*As human population densities increase in coral reef regions, it is almost certain that fishing pressures will likewise increase and that nutrient runoff into coastal waters will increase with land being cleared of native vegetation for agricultural or urban development. Nutrient runoff from land stimulates phytoplankton blooms which provide food for the larvae of invertebrate corallivores and facilitate abundant recruitment of corallivores and so can cause outbreaks of these predators (Birkeland, 1982; Fabricius et al., 2010). Fishing on the predators of corallivores may also contribute to outbreaks."*

One commenter recommends considering the evolution of theories concerning COTS outbreaks, starting with Endean (1982) then Dulvy et al. (2004) who theorized, respectively, that removal of Triton shells and fish predation caused COTS outbreaks. The commenter states "the Birkeland hypothesis" accounts for the weakness of the evidence for these theories (i.e., increased fishing and increased nutrients are correlated with higher population), and Brodie et al. (2005) substantiates the Birkeland hypothesis. The commenter points to Sweatman et al. (2004) as “the strongest evidence in support of the role of fishing in COTS outbreaks,” which shows “that MPA areas on the GBR have fewer COTS outbreaks than non-MPA areas.”[cxxi]

3.3.4 Reef fishing – trophic cascades

From the SRR:

> *“Fisheries management strategies for coral reef ecosystems often include efforts to maintain resilience by trying to sustain populations of herbivorous fish, especially the larger scarine herbivorous wrasses, including parrotfish…Under these conditions of topographic complexity with substantial populations of herbivorous fishes, as long as the cover of living coral is high and resistant to being affected by environmental changes, it is very unlikely that the algae will take over and dominate the substratum.”*

Within MPAs, Edgar et al. (2011) found that poorly enforced MPAs generate food webs more similar to those present in fished areas (e.g., increased densities of habitat-modifying macroinvertebrates and reduced coral cover) than in well-protected MPAs, which possessed a much greater biomass of carnivorous fishes, lower densities of asteroids and *Eucidaris* spp. urchins, and higher coral cover. Observations from Mumby et al. (2011) in Belize record a rapid shift in fish community structure that accompanied a marked decline in grouper and snapper abundance and a switch towards smaller, less desirable, herbivorous parrotfishes. Concurrently, the biomass of mesopredators including *Cephalopholis fulvus, C. cruentatus,* and *Epinephelus guttatus* increased dramatically, likely because of release from predation on them (Mumby et al. 2011).

Based on fish abundance data, Bellwood et al. (2012) inferred the effect of human activity on the ecosystem roles of parrotfishes on coral reefs and determined that rates of bioerosion and coral predation are highly sensitive to human activity, whereas grazing and sediment removal are resilient to fishing. This inference is supported somewhat by model simulations that considered various levels of fishing effort corresponding to several hurricane frequencies and impact levels dependent on geographic location (Blackwood et al. 2011). Blackwood et al. (2011) determined that for sufficiently low hurricane impact and macroalgal growth rate, regions with lower-frequency hurricanes might require stricter fishing regulations, whereas management in regions with higher-frequency hurricanes might be less concerned with enhancing grazing. Consistent also with these modeling results, Edwards et al. (2011) found that coral populations can maintain themselves under all levels of hurricane disturbance provided that grazing levels are high; however, the addition of coral bleaching led to a much more homogenous reef state over the seascape with all reefs exhibiting a decline in health over time. Edwards et al. (2011) suggest that maintaining herbivorous fish populations might delay rates of coral loss even under the most severe thermal and hurricane regimes.

Ceccarelli et al. (2011) examined patterns of succession in both farmer (damselfish) territories and areas outside territories accessed by foragers. The results show that overall, the numerically dominant farmers had more dramatic effects on successional pathways and benthic communities within them than foragers in this system; however, foragers also directly impacted succession, effectively decelerating the rate of succession to a diverse community that included macroalgae (Ceccarelli et al. 2011). Rasher et al. (2012) manipulated herbivory and nutrients on a coral-dominated reef protected from fishing, and on an adjacent macroalgal-dominated reef subject to fishing and riverine discharge, over 152 days in Fiji. Herbivore exclusion at both reefs resulted in increased sediment accumulation, increased upright macroalgal cover, and increased cyanobacteria cover; however, encrusting coralline algae and short turf algae cover decreased (Rasher et al. 2012). The results from Rasher et al. (2012)

suggest that herbivory rather than eutrophication plays the dominant role in mediating macroalgal proliferation, that macroalgae trap sediments that may further suppress herbivory and enhance macroalgal dominance, and that corals are relatively resistant to damage from some macroalgae but are significantly impacted by ambient reef condition.

The trophic effects of reef fishing depend on exposure of the species to the threat, which varies spatially and temporally. Spatially, exposure to the trophic effects of reef fishing in the Caribbean is moderated by distance of many coral habitats and areas from fishing effort. Exposure to the trophic effects of reef fishing in the Indo-Pacific is somewhat more moderated by distance than in the Caribbean, due to a greater proportion of reef-building coral habitats located in remote areas that are much further away from fishing effort. Exposure to the trophic effects of reef fishing is also moderated by the regulation of fishing effort in both the Caribbean and the Indo-Pacific. Exposure to the trophic effects of reef fishing is also moderated by depth of many habitats in both regions, but again more so in the Indo-Pacific than in the Caribbean. Deep habitats are generally thought to be less affected by the trophic effects of reef fishing especially in the Indo-Pacific. Temporally, exposure to the trophic effects of reef fishing will increase as the human population increases over time.

These data show that fishing pressure affects rates of bioerosion, coral predation, succession, and macroalgal proliferation (Edgar et al. 2011, Mumby et al. 2011, Bellwood et al. 2011, Blackwood et al. 2011, Ceccarrelli et al. 2011). Maintenance of herbivorous fish populations might also help coral recovery following hurricane disturbance and thermal stress (Blackwood et al. 2011, Edwards et al. 2011).

From the SRR:
"When herbivorous fish populations are reduced but adult coral colonies maintain their resistance to physiological damage by climate change and human activities, coral-reef communities can persist. However, if herbivorous fish populations are heavily fished and high mortality of coral colonies occurs, then algae can grow rapidly and inhibit the replenishment of coral populations."

"Fisheries management strategies for coral reef ecosystems often include efforts to maintain resilience by trying to sustain populations of herbivorous fish, especially the larger scarine herbivorous wrasses, including parrotfish."

One commenter recommended consideration of Fenner (2012), which reviews the need for herbivorous fish, particularly within the context of resiliency[cxxii]. See also discussion above.

3.3.5 Direct habitat impacts and destructive fishing practices

No relevant information received for this topic.

3.3.6 Ornamental Trade

The effects of collection and trade depend on exposure of the species to the threat, which varies spatially and temporally. Spatially, exposure to collection and trade is moderated by demand, distance, and depth. Demand is highly species-specific, resulting in variable levels of collection pressure. However, even for heavily collected species, geographic and depth distributions strongly moderate collection. Temporally, exposure to collection and trade may increase over time, but will still continue to be strongly moderated by low demand, distance, and depth.

3.3.7 Natural physical damage

From the SRR:
"*Big-wave events generate coral fragments, and massive corals that are a century or older can be toppled (Bries et al., 2004).*"

One commenter noted that reefs not exposed to great expanses of open water "can have remarkably little damage from the most powerful cyclones" because large waves are not generated[cxxiii].

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From the SRR:
"Deep reefs may provide some refuge from tropical cyclone effects (Lugo-Fernández and Gravois, 2010)—as may reefs within about 5 degrees of the equator, since cyclones rarely form or move within those latitudes, where the Coriolis force is weakest (Gray, 1998)."

One commenter confirmed that cyclones rarely formed near the equator, and noted that coral diversity along the equator is high despite low levels of disturbance from hurricanes[cxxiv].

3.3.8 Human induced physical damage

One commenter pointed out that cruise ship anchor chains can destroy large areas of reef as winds move the ship back and forth, similar to the damage caused by vessel groundings[cxxv].

The SRR states, "Vessel anchors can also cause similar types of damage to corals (Rogers and Garrison, 2001); the effects are often smaller in scale but more frequently inflicted."

3.3.9 Aquatic invasive species

From the SRR:
"The lack of information regarding effects of species introductions on coral reefs suggests that invasive species have not been well studied or that there have been few successful invasions in these systems (Coles and Eldredge, 2002)."

One commenter recommended clarifying the distinction between the terms "introduced species" and "invasive species". Clarifying the terminology, in the commenter's view, would prevent misinterpreting the above statement from the SRR to mean that lack of information suggests few successful *introduced* species on coral reefs[cxxvi].

3.3.9.1 Introduced marine invertebrates

No relevant information received for this topic.

3.3.9.2 Introduced corals

From the SRR:
"The azooxanthellate scleractinian Tubastrea coccinea became established in the western Atlantic in the 1940s and is now very abundant and widespread, especially on artificial substrata (Fenner and Banks, 2004)."

One commenter suggested saying that *Tubastraea coccinea* spread first throughout the Caribbean, then the Gulf of Mexico, and most recently to Florida[cxxvii].

3.3.9.3 Introduced algae

From the SRR:
"Later in the 1970s this species was transported to O'ahu and Moloka'i (Eldredge, 1994) for experimental aquaculture and while it is still restricted to these three islands it has spread extensively within each island, most notably O'ahu where it is the single most dominant species in Waikiki and parts of Kāne'ohe Bay and evidence suggests that it is continuing to spread (Smith et al., 2004a)."

One commenter noted that the third island where *G. salicornia* is reported in the SRR as present is not named[cxxviii].

3.3.9.4 Introduced fish: lionfish in the Caribbean

No relevant information received for this topic.

3.3.10 Summary of local changes and their impacts

No relevant information received for this topic.

3.4 Interactive and Unapparent Threats to Coral Populations

Little additional information was received or collected on cumulative (i.e., additive effects of different threats) and interactive (antagonistic or synergistic effects of different threats) effects, with the important exception of Ruiz-Moreno et al. (2012). This paper rates susceptibility and prevalence of coral families to disease, and relates disease to other threats such as ocean warming. A relevant recent paper (De'ath et al. 2012) found that COTS populations are strongly influenced by LBSP, and together COTS and LBSP have contributed strongly to large coral losses on the GBR.

3.5 Summary of Threats

Regarding the threats of ocean warming, disease, and ocean acidification, one commenter concurred with the conclusions of the SRR, which the commenter viewed as consistent with several published reviews of available scientific literature. The commenter recommended consideration of the 12th ICRS consensus statement and urged removal of stressors associated with GHG emissions as part of restoration activities funded by NOAA and its partners. Last, the commenter viewed local stressors to be of higher priority than "medium"[cxxix].

Another commenter requested further explanation of the criteria used to rank threats to extinction (e.g., negligible, low, medium, high)[cxxx].

4 Demographic & Spatial Factors in Evaluation of Risk

4.1 Overview

One commenter recommended considering which "suite of biological traits most influences species' vulnerability to climate change" citing van Woesik et al. (2012) who found a strong relationship between past and present vulnerability of coral species to regional extinction events[cxxxi]. This idea is echoed by another commenter who stated, "Extinction may be caused by more episodic events where life history characteristics may be more critical than demographics[cxxxii]." One last commenter remarked "that local (but often regional as well) biotic processes are more critical (but harder to measure and understand) than is indicated in the status review[cxxxiii]."

The SRR states in Section 4.4:

> *"Genetic and phenotypic diversity help buffer a species against negative effects of environmental variability. In general, a species with high diversity is more likely to have some individuals with traits suitable for altered local conditions at a particular place and time than a population with reduced diversity…Unfortunately; few data are available about diversity within the 82 candidate coral species."*

Commenters referenced several recent and forthcoming publications that look at coral species traits as they relate to recovering from bleaching and to susceptibility to extinction. Darling et al. (in review) evaluates life history strategies of reef corals from species traits (no abstract available), while McClanahan et al. (2007) developed a synoptic analysis of coral community structure, bleaching response, susceptibility of the communities to bleaching, and the relative risk of extinctions in western Indian Ocean coral reefs. The analysis concluded that coral taxa vulnerable to future extinction based on their response to warm water, population density, and commonness include largely low-diversity genera with narrow environmental ranges, such as *Gyrosmilia interrupta, Plesiastrea versipora, Plerogyra sinuosa*, and *Physogyra lichtensteini* (McClanahan et al. 2007). McClanahan et al. (2005) suggested that large predatory fish in areas dominated by coralline algae might considerably retard recovery of eurythermal corals; however this will not necessarily retard total hard coral recovery, as other more predator-tolerant taxa can recover. Based on the results, McClanahan et al. (2005) concluded that global climate change will not necessarily favor eurythermal over stenothermal coral taxa in remote or unfished reefs, where predation is a major cause of coral mortality.

4.2 Abundance & Productivity of Corals

From the SRR:

> *"The IUCN report (IUCN, 2010) and the accompanying publication in Science (Carpenter et al., 2008) were the primary analyses referenced in the petition to list 83 corals."*

One commenter remarks that the references to IUCN (2010) and Carpenter et al. (2008) are mischaracterized. The commenter asserts because Carpenter et al. (2008) was published first, the IUCN (2010) should be considered the accompanying report (not vice versa)[cxxxiv].

Hughes et al. (2012) concluded that global climate change is likely to affect coral community structure, such that more resilient species will become more common than less resilient species coral communities. That is, rather than wholesale loss of entire reef ecosystems as a result of global climate change, coral reefs will persist but they will dominated by more resilient species as mess resilient species dwindle.

4.3 Spatial Structure of Corals

Information collected during the public-information gathering period following release of the SRR and DMR provides additional distribution data for some of the Indo-Pacific candidate coral species. That information is provided by species in Section 7.

From the SRR

> *"The BRT considered a broad geographic distribution across a variety of habitats and microhabitats within a reef to be a significant buffer against the potential impacts of ocean warming and acidification."*

The following additional information was gathered on the habitats of reef-building corals.

Coral Reefs and Other Reef-building Coral Habitats

Reef-building corals have specific habitat requirements, including hard substrate, narrow mean temperature range, adequate light, and adequate water flow. Each of the 82 reef-building coral species in this status review is generally found in the following habitats: (1) Shallow tropical and subtropical reefs in depths of less than 30 m (within the upper photic zone); (2) non-reefal habitats, including marginal habitats such as turbid, high-latitude, and/or upwelling-influenced areas (Brown et al. 2012, Goodkin et al. 2011, Perry & Larcombe 2003, Riegl 1999) and newly available natural (e.g., lava flows, Grigg & Maragos 1974 in Hawaii, Tomascik et al. 1995 in Indonesia) and artificial (e.g., seawalls, Ming et al. 2010) substrates; and (3) mesophotic habitats (i.e., generally between 30 and 100 m; Locker et al. 2010).

Caribbean Reef-building Coral Habitat

The amount of non-reefal and mesophotic coral habitat in the Caribbean is unknown, but some indication is provided by information from U.S. waters. For example, in the U.S. waters of the Gulf of Mexico and Florida, there are approximately 179,000 square km of habitat between 30 and 100 m of depth (Locker et al. 2010), more than 100 times the area of shallow coral reefs in the Gulf of Mexico and Florida (1,250 square km; Spalding 2001, Rohmann et al. 2005). However, in the Gulf of Mexico, much of the mesophotic habitat is likely unsuitable for corals due to turbidity and soft substrates. Nonetheless, the broad gently-sloping shelf located within the northern Gulf of Mexico and west side of the Florida Platform contributes to large areas of potential mesophotic coral habitat, illustrating that continental shelves may provide extensive potential mesophotic coral habitat in the Caribbean and the Indo-Pacific. In contrast, the comparatively steep bathymetric slopes around islands, such as those in the U.S. Caribbean and Pacific islands, provide smaller areas of potential mesophotic coral habitat but nevertheless are still substantial. For example, around the U.S. Caribbean islands (Puerto Rico, Vieques, Culebra, St. Thomas, St. John, and St. Croix), there are approximately 3,900 square km of potential mesophotic coral habitat (Locker et al. 2010), compared to approximately 680 square km shallow coral reefs around these islands (Spalding 2001, Rohmann et al. 2005).

Indo-Pacific Reef-building Coral Habitat

The amount of non-reefal and mesophotic coral habitat in the Indo-Pacific is unknown, but some indication is provided by information from U.S. waters. For example, in the main Hawaiian Islands, there are approximately 3,300 square km of habitat between 30 and 100 m of depth (Locker et al. 2010), about three times the area of shallow coral reefs in the main Hawaiian Islands (1,200 square km; Spalding 2001, Rohmann et al. 2005). Continental shelves may have much larger proportions of potential mesophotic coral habitat than islands, as described above in the comparison of potential mesophotic habitat in the Gulf of Mexico/Florida vs. the U.S. Caribbean. Given that the Indo-Pacific includes more than 50,000 islands and over 40,000 km of continental coastline, potential mesophotic coral habitat in the Indo-Pacific is likely many times greater than the 250,000 square km of shallow coral reefs in this region.

4.4 Diversity in Corals

One commenter views low diversity genera as potentially more extinction prone than high diversity genera, which are frequently listed as vulnerable.[cxxxv]

Another commenter emphasizes the role and importance of microbial biota in the ability of corals to adapt to environmental changes, fend off disease, or develop resistance[cxxxvi], and recommends carrying out genome scans with new sequencing technologies to assess the adaptive potential of corals in response to climate change.[cxxxvii]

From the *SRR:*
"*...reef-building corals are functional holobionts and there is substantial diversity of the symbiotic zooxanthellae and microbial components. The BRT did not formally address this level of diversity in the species analyses, as it is beyond the scope of the petition. However, the BRT acknowledges that the ability to host, for example, multiple clades of zooxanthellae may provide the ability to adapt to different environmental conditions and addressed this in individual species accounts when relevant information was available. This is clearly a complex issue that remains poorly understood.*"

4.5 Critical Risk Threshold

No relevant information received for this topic.

4.5.1 Critical Risk Threshold and depensatory processes

During the public-information gathering period following the release of the SRR, commenters suggested considering the following as the most important scientific information within the context of extinction risk for corals. These suggestions are listed in no particular order.

- Degradation of ecosystem processes (e.g., herbivory, recruitment)[cxxxviii].
- Understanding overall coral host cellular responses to environmental stressors[cxxxix].
- Discerning whether a stressor induces the same response when acting alone or in concert with other stressors[cxl].
- Microbial community shifts and coral disease[cxli].
- Inter-kingdom communication among all coral holobiont members in response to stressors and how this response is affected by climate change[cxlii].
- Evaluation of each species' resistance and resilience to high-temperature extremes, and consequences for resistance to extinction, based on species-specific biological traits[cxliii].
- Recent patterns of ocean warming/high temperature anomalies; projected future warming patterns; evidence that warming has affected corals, particularly at the population level (e.g., demographic projections, but also coral cover, community composition, etc.); and use of warming projections to forecast coral loss[cxliv].

4.5.2 Critical Risk Threshold and sexual reproduction

No relevant information received for this topic.

5 Methods

One commenter recommended referencing the methods for placing species on the IUCN Red List (e.g., Carpenter et al. 2008, IUCN 2010) and explaining the criteria that form the basis for the IUCN Red List[cxlv]. This commenter also remarks that the ranking produced for these species in the SRR are different than those reached by Carpenter et al. (2008), which the commenter believes is a weakness in the SRR[cxlvi]. Another commenter echoes this sentiment by stating the SRR provides few comparisons with (1) other published studies that list the vulnerability of coral species, and (2) the IUCN status of each candidate species[cxlvii].

5.1 Overview

One commenter recommended considering each candidate species individually, instead of the grouped manner used in the SRR[cxlviii].

The SRR explains in Section 5.3:
"Much of the desired species-specific information was largely unavailable for the majority of the candidate species. When biologically justified, the BRT extrapolated characteristics of the genus, related taxa, or taxa with similar physiological or habitat characteristics. This extrapolation introduced additional uncertainty into the analyses, as there are numerous examples in the literature in which ecological or physiological traits are not consistent across species within a genus. In some cases, essentially no species-specific information was available other than the taxonomic species description and some questionable geographic range maps."

5.2 The Species Question

No relevant information received for this topic.

5.3 Data Review

During one public meeting, a commenter asked what references were used for determining species abundance in CNMI[cxlix]. Another commenter recommended mapping the locations and abundance of the candidate species in relation to environmental stresses to help evaluate their status and to identify priority areas for conservation, citing the global stress model developed by Maina et al. (2008, 2011)[cl].

5.4 Defining Extinction Risk

One commenter asked for further explanation for the "foreseeable future" determined by the SRR[cli], whereas another commenter stated that the "foreseeable future" included in the SRR is too long[clii].

The SRR does not define "foreseeable future" as defined in the ESA. The SRR identifies the time horizon over which extinction risk can be evaluated based on coral life history and the threats that affect corals.

5.5 Assessing the Critical Risk Threshold

No relevant information received for this topic.

5.6 BRT Voting

No relevant information received for this topic.

5.7 Strengths and Limitations of the Approach

One commenter remarked on the lack of abundance data for each of the candidate species, and stated the “best available” information on which the SRR is based is “severely lacking”. The commenter states the SRR analysis is based on reviewers’ opinions and the findings are unclear[cliii]. Two other commenters echoed these statements, pointing out that within the Indian and Pacific oceans there remain many unsurveyed areas, which might mean that candidate species are more abundant than the existing available information indicates[cliv, clvi]. One of these commenters believes this uncertainty can complicate the determinations of the percent likelihood of a species falling below the CRT and contribute to a large variability in likelihood percent determined by the BRT. This commenter recommended another assessment report once more comprehensive scientific information is gathered[clv]. The other commenter adds that the lack of abundance information coupled with the taxonomic uncertainties limits applicability of the ESA, particularly for ESA Section 7 consultations. This commenter is concerned the intended benefits of the ESA might not be realized should any of the candidate species be listed[clvi].

Concerning the voting process, one commenter recognized the purpose behind using this method; however, the commenter does not believe any listing determinations should rely on the results of what the commenter terms a “highly subjective and qualitative” process[clvii]. This commenter added the concern that the results of the voting may reflect BRT members’ perception of extinction risk rather than a reliable scientific measure because the voting process relied on limited species information about demographic and spatial factors as well as specific species impacts from global climate change[clviii]. The commenter asserts that this methodology required more quantitative information and standardized measures of spatial and demographic factors because “it is uncertain the degree to which abundance, productivity, and distribution informed the BRT member’s votes[clix].” This commenter recommends more transparency concerning the voting methodology, including providing the curriculum vitae of all voting members of the BRT (to identify biases based on area(s) of expertise) and providing the point allocation spread for each BRT member’s votes[clx]. Last, this commenter takes issue with creating numerical risk values from qualitative categories, as the means and standard errors may represent arbitrary numbers and inaccurately represent BRT member votes[clxi].

One last commenter asserts that scientists from the Florida Fish & Wildlife Conservation Commission should have been included on the BRT.

A recent publication by Huang (2012) applied the phylogenetic approach on all reef corals of the order Scleractinia to identify, first, the most endangered coral lineages, and second, evolutionary patterns associated with extinction probability and various threats. Huang (2012) ranked corals according to both distinctiveness and imperilment, using the “evolutionarily distinct and globally endangered” (EDGE) metric, which combines a unique measure of phylogenetic diversity with the conservation status of each species. Data for the latter measure are based on the IUCN Red List that includes 827 reef-building scleractinians. Of the 82 candidate coral species, 7 appeared in the top 30 rankings of threatened species by Huang (2012) (i.e., *M. annularis* = #2, *M. faveolata* = #3, *Pavona cactus* = #17, *Anacropora spinosa* = #18, *Montipora dilitata* = #25, *Isopora cuneata* = #26, and *Physogyra lichtensteini* = #27). See Figure 5 below.

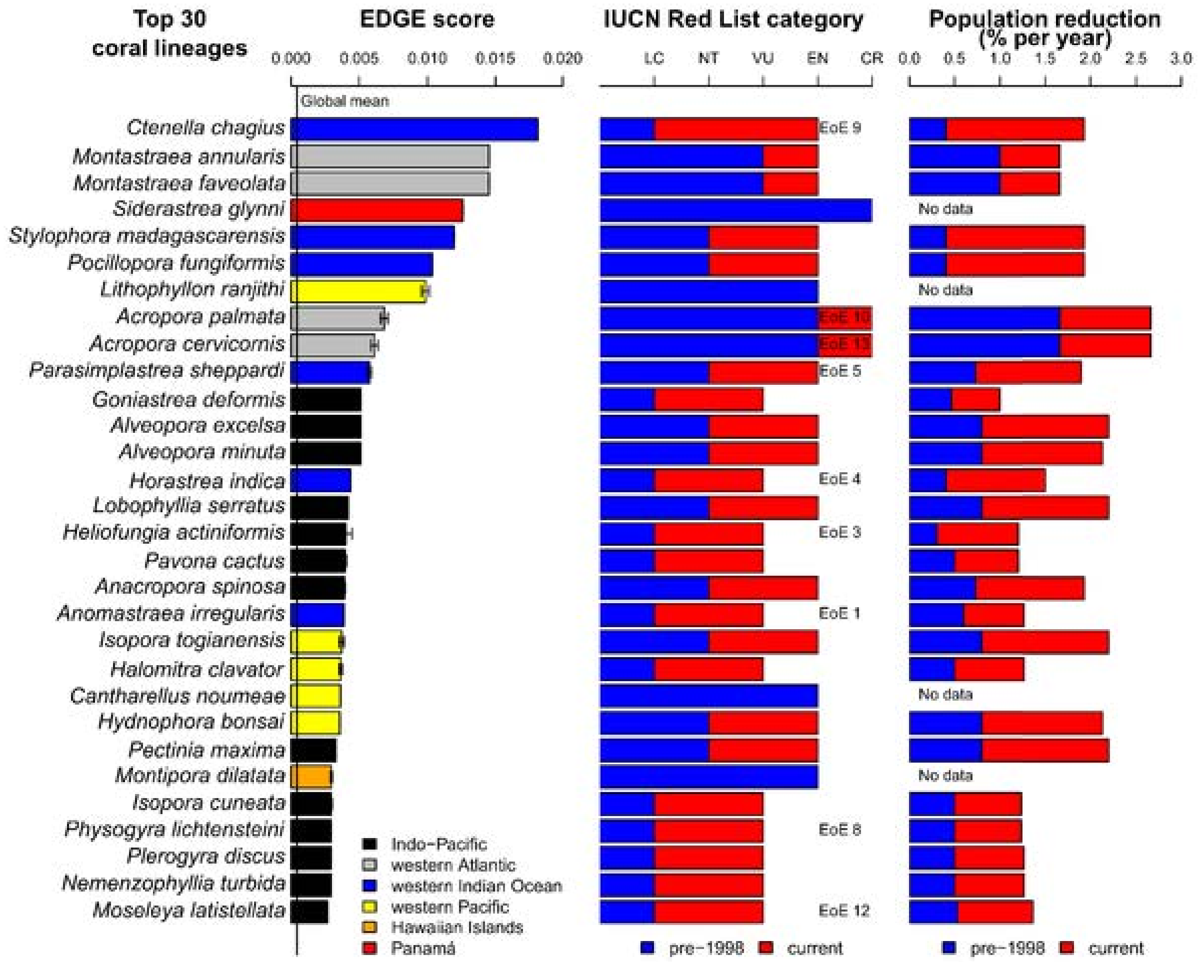

Figure 5. Top 30 reef corals ranked according to EDGE scores (Huang 2012).

6 Individual Species Accounts – Western Atlantic [Also relevant for Draft Mgt Report/DMR: CURRENT RANGES]

General Comments:

One commenter suggested listing the abundance for each species both within U.S. waters as well as internationally[clxii]. Further, for uncommon or rare species, the commenter recommends including a discussion of whether these species always have been rare or whether these species were once common and are now uncommon or rare due to declines[clxiii]. Last, the commenter wonders whether inferring life history and threat impacts a species from the Genus level is valid because of the potential for divergent genetic relationships between species[clxiv].

The SRR splits out the U.S. and international distribution for each species; however, the abundance section for each species is not split out into two distinct descriptions of abundance in U.S. waters and in international waters. The SRR states "Qualitative abundance estimates (e.g., "common" or "rare") for the candidate species were available from several sources. The sources most commonly used by the BRT were Veron (2000), Carpenter (2008), and online IUCN species accounts (IUCN, 2010)." The

SRR does not indicate whether a species was always rare, only that one of the above-referenced sources characterized its abundance as such.

One commenter questioned the rationale used to determine the list of candidate species assessed in the SRR. The commenter is concerned there are other, non-candidate species suffering similar threats and impacts and requiring protection under the ESA (e.g., *Colpophyllianatans, Diploris labyrinthisformis, Montastraea covernos*)[clxv]. As mentioned previously, the SRR discusses the petition; however, it does not discuss why the statuses of only the petitioned coral species were reviewed.

One commenter provided a Microsoft PowerPoint presentation that includes population estimates and species distributions by habitat type, along with population percentages inside and outside of MPAs within the Florida Keys National Marine Sanctuary. The commenter states additional information not included in the presentation is included in several manuscripts under preparation for publication and believes this information is relevant to the ESA process[clxvi].

Referring to three species of Western Atlantic corals classified as "common", one commenter noted that of these, two were ranked as "most threatened[clxvii]."

One commenter noted that the SRR relied on Veron (2000) to describe distribution for the 82 candidate species, which is mostly accurate for the Indo-West Pacific; however, for the 7 Western Atlantic-Caribbean candidate species, the commenter recommends alternative sources for more accurate (and reliable) distribution information (see citations below)[clxviii].
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One commenter stated that of the 7 Caribbean candidate coral species, only 3 could be considered reef builders. The other four, the commenter states, are not prolific reef builders (as shown by core drilling) and "are best considered accessory corals." The commenter considers the prediction that any of the 7 candidate corals species "will become entirely extinct within the next few centuries" speculative[clxix].

One commenter agreed with the rankings given to three of the 7 Caribbean candidate species based on their rarity and coral health concerns[clxx].

6.1 Genus *Agaricia*

According to Armstrong et al. (2010) and Armstrong and Singh (2012), corals of the genus *Agaricia* can be found at depths of 50 to 100 m on mesophotic reefs in Puerto Rico.

6.1.1 *Agaricia lamarcki*

From the SRR:
"Taxonomic issues: None. Agaricia lamarcki is similar to Agaricia grahamae, which lacks white mouths and has evenly sized septo-costae (Veron, 2000)."

One commenter pointed out that this species also has more rounded colines than *A. grahamae*, and colines taper to ends, which fuse with other colines. *A. grahamae* does not have tapering colines[clxxi].

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From the SRR:
"Depth range: Agaricia lamarcki has been reported in water depths ranging from 10 to 76 m (Carpenter et al., 2008; Ghiold and Smith, 1990) and 3 to 50 m (Humann, 1993). Although Agaricia lamarcki can rarely be found in shaded areas in shallow waters, it primarily occurs at deeper depths.

The IUCN Red List review emphasized a need for additional information on the population status and recovery potential for this species in deeper waters (IUCN, 2010). Agaricia lamarcki has often been found on mesophotic reefs in Curaçao, Florida, Jamaica, and the U.S. Virgin Islands (Ghiold and Smith, 1990). However, coral specimens collected on a recent mesophotic coral cruise at Pulley Ridge, Florida, suggest that corals, such as Agaricia, that appear live from video images may actually be covered with algae rather than live coral tissue (J. Voss, Florida Atlantic Univ., Fort Pierce, FL. pers. comm., August 2010)."

As stated above, Armstrong et al. (2010) and Armstrong and Singh (2012) found corals of the genus *Agaricia* can be found at depths of 50 to 100 m on mesophotic reefs in Puerto Rico. Schizas (2012) reports *A. larmarcki* as very common (3% cover) and healthy at 70-80 m depths off Mona Island, south-western Puerto Rico, St. Thomas, and St. Croix (USVI).

The recent data extends the known depth range and refines the geographic distribution for this species.

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From the SRR:
"Thermal stress: Agaricia lamarcki has been reported to be susceptible to bleaching at elevated temperatures (Ghiold and Smith, 1990)…"

6.2 Genus *Mycetophyllia*

6.2.1 *Mycetophyllia ferox*

One commenter pointed out that the photographs of living coral colonies included in Figure 6.2.1 of the SRR "are are not representative of the species and may well not be this species. The collines (ridges) of this species are small and square in profile, not large and rounded as in the photos. There is a small groove visible on the top of the collines[clxxii]."

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From the SRR:
"Characteristics: Mycetophyllia ferox consists of encrusting laminar plates. Colonies are thin, weakly attached plates with interconnecting, slightly sinuous narrow valleys. Corallite centers are usually in single rows. Columellae are rudimentary or absent. Colonies are most commonly greys and browns in color with valleys and walls of contrasting colors (Veron, 2000). Maximum colony size is 50 cm (Veron, 2000)."

One commenter observed in the field valleys and walls not with contrasting colors, but with red mouth areas and small slightly raised knobs. Further, the commenter noted in field observations that collines intersect, enclosing valleys, in some colonies that are otherwise identical to colonies without intersecting collines[clxxiii].

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From the SRR:
"Depth range: Mycetophyllia ferox has been reported in water depths ranging from 5 to 30 m (Carpenter et al., 2008)."

New info on species suggests depth distribution from shallow to 90 m: Nemeth et al. (2008) reported it at 34-47 m., and a submersible report from the 1990s (Roberts et al. 1994, Reefs and Lagoons of Grand Cayman) reported it at 80-90 m.

6.3 Genus *Dendrogyra*

6.3.1 *Dendrogyra cylindrus*

Two commenters recommended reviewing the recent Biological Status Review for the Pillar Coral *(Dendrogyra cylindrus)* produced by the Florida Fish and Wildlife Conservation Commission (FWC) (2011).[clxxiv, clxxv]

FWC staff recommended listing this species as "threatened" under Florida State law (FWC 2011). The SRR contains all of the information discussed in FWC (2011); however, the following depth range was reported in FWC (2011):
"2 to 20 m, but typically occurs from 3-8 m depth; Pressick (1970): rear zone from 2-3 m depth; Cairns (1982): spur-and-groove reefs (14 m) and back reef (1 m); Tomascik and Sander (1987): spur-and-groove reefs; and Wheaton and Jaap (1988): spur-and-groove reefs."

The SRR reports "*Dendrogyra cylindrus* has been reported in water depths ranging from 2 to 25 m (Carpenter et al., 2008)."
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From the SRR:
"U.S. Distribution: Dendrogyra cylindrus has been reported in the waters of south Florida and the U.S. Caribbean but appears to be absent from the Flower Garden Banks."

One commenter noted that there are only a few pillar corals in Broward County, FL located in areas where no beach renourishment occurs, and these corals have been impacted by hurricanes. The commenter hopes these species might be protected by the ESA because of impending changes to Florida State law[clxxvi].

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One last commenter remarked that *D. cylindrus* might be among the coral taxa of most concern because of low species diversity[clxxvii]. The SRR assessed the extinction risk of this species as follows:

"The most important factors influencing the relatively high extinction risk (higher likelihood of falling below the Critical Risk Threshold) of *Dendrogyra cylindrus* included the overall low population density and low population size combined with a gonochoric spawning reproductive mode, corresponding lack of observed sexual recruitment, and susceptibility to observed disease mortality."

6.4 Genus *Dichocoenia*

6.4.1 *Dichocoenia stokesi*

From the SRR:
"Taxonomic issues: Colonies of Dichocoenia stokesi from lower reef slopes or shaded habitats have markedly smaller corallites than those from more exposed environments and are usually identified as Dichocoenia stellaris (Wells, 1973). The petition cites the IUCN species account in differentiating these two species; hence, this Status Review Report addresses Dichocoenia stokesi."

One commenter states, “Veron (2000) and Human (2002) both treat *Dichocoenia* as a genus with just one species. There is a continuous gradation of characters between colonies that fit the descriptions of the two species names[clxxviii].”

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From the SRR:

“U.S. Distribution: Dichocoenia stokesi occurs throughout U.S. waters in the western Atlantic, including the Gulf of Mexico, Florida, Puerto Rico, and the Virgin Islands.”

One commenter mentioned this species occurring in the Florida Middle Grounds of the eastern Gulf of Mexico[clxxix].

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From the SRR:

“Depth range: Dichocoenia stokesi has been reported in water depths ranging from 2 to 72 m (Carpenter et al., 2008). This considerable depth range suggests the potential for deep refugia, but it is not likely that it attains high abundance at deeper depths.”

Venn (2008) reported this species occurring in 45-60 m of water in Bermuda. Two commenters cited Goreau and Goreau (1973) who documented *D. stokesi* in inshore waters out to approximately 60 m[clxxx].

These depth ranges are within the range reported by the SRR.

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From the SRR:

“Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for Dichocoenia stokesi include its documented population-level impacts from disease. Factors that reduce potential extinction risk (decrease the likelihood of falling below Critical Risk Threshold) are its relatively high abundance and persistence across many habitat types, including nearshore and mesophotic reefs. Residency in a wide range of habitat types suggests the species has a wide tolerance to environmental conditions and, therefore, better capacity to deal with changing environmental regimes.”

Two commenters doubt whether this species is “unrecoverable” because the 1995 outbreak of white plague type II disease affected mostly colonies in the Florida Keys and the outbreak was not Caribbean-wide. Additionally, the commenter states the species was relatively abundant during surveys conducted in Florida from 2005-2007, and the species has a high resistance to temperature anomalies[cxv].

One commenter expressed concerns about considering this species a candidate for listing without additional information[clxxxi], whereas another commenter considers this species among the coral taxa of most concern for species extinction because of low species/genera diversity[clxxvii].

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Recent literature documents the following:

- Enzymatic activity of this species in the presence of antioxidant cations (Mydlarz and Palmer 2011);
- The species being unaffected by corallivores (i.e., parrotfish) (Roff et al. 2011);
- A resilience score of “0” for the species (van Woesik et al. 2012);
- Sustained low temperatures did not kill colonies of D. stokesi in the Florida Keys (Kemp et al. 2012);
- *D. stokesi* exhibited significant differences in rates of bleaching between Dry Tortugas and the Upper Keys (Yee et al. 2012)

6.5 Genus *Montastraea*

Montastraea annularis complex

General comments related to all three species in the complex:

Two commenters expressed concern about the placement of *Montastraea annularis* complex species in the “likely” category for falling below the Critical Risk Threshold. This ranking in the SRR contrasts with the assessment conducted by van Woesik et al. (2012) and with the IUCN classifications for these species

Life History

Observations of spawning in *M. annularis* complex species in Panama indicate that there is a genetic component to the timing of spawning, and much of the within-species variation in spawn time is attributed to environmental factors (e.g., yearly, lunar, and local environment) (Levitan et al. 2012). Because of the genetic component to spawning timing, Levitan et al. (2012) assert it is likely evolution will select for sharp spawning peaks. This evolutionary selection of spawning peaks in combination with environmental cues and the more synchronous spawning of closely spaced neighboring colonies will likely influence reproductive success and reproductive isolation in a density-dependent manner (Levitan 2012).

In USVI, Kuffner et al. (2011) observed half-dead colonies (greater than 50% tissue mortality) of *M. annularis* releasing viable gametes, estimating that greater than 90% of the population spawned and released gametes from greater than 95% of their live tissue area.

Foster et al. (2012) compared the genetic structure of 26 *M. annularis senso stricto* sampling locations (empirical genetic data) across the Caribbean to the predicted genetic structure. On a large scale, processes of larval dispersal could largely explain the observed genetic population structure of *M. annularis* (Foster et al. 2012). At a smaller scale, however, the comparison revealed differences in predicted and empirical estimates of connectivity among northern Mesoamerican reefs, which might indicate processes other than dispersal may dominate here (e.g., salinity, storm events) (Foster et al. 2012). The results of Foster et al. (2012) are consistent with previous large-scale studies of genetic structure in Caribbean reef fishes and acroporid corals showing distinguishing genetic discontinuities between the eastern and western Caribbean and a weakly isolated Bahamian Archipelago.

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From the SRR:

"Successful recruitment by Montastraea annularis complex species have seemingly always been rare events."

van Woesik and Jordán-Garza (2011) suggest, "a stable environment through the late Holocene would have resulted in high densities of large, fragmenting *Montastraea* colonies irrespective of recruitment rates."

Threats

From the SRR:

"Because they have traditionally been common and are one of the main reef builders in the Caribbean, Montastraea annularis complex species have been the frequent subject of research attention, including responses to and impacts of environmental threats. This body of work is briefly summarized here, but it should be noted that a large body of work exists for these species."

Two commenters recommended looking at two references concerning thermal stress and disease relationships in the *M. annularis* complex and concerning reproductive activity and disease in *M. faveolata.*[clxxxix] Cróquer and Weil (2009) found a significant linear correlation between bleaching and the prevalence of 2 virulent diseases (yellow band disease and white plague) affecting the *Montastraea* species complex, which suggests if bleaching events become more intense and frequent, disease-related mortality of Caribbean coral reef builders could increase, with uncertain effects on coral reef resilience. Mydlarz et al. (2009) illustrated the complex interaction between disease and temperature stress on immune function by identifying a trend for suppression of activity in corals that bleached previously.

Weil et al. (2009) found yellow band disease (YBD) significantly compromises the reproductive output of *M. faveolata*.

Thermal Stress
From the SRR:
"Published reports of individual bleaching surveys have consistently indicated that Montastraea annularis complex is highly-to-moderately susceptible to bleaching (Brandt, 2009; Bruckner and Hill, 2009; Oxenford et al., 2008; Wagner et al., 2010)."

In addition to known responses of these species to elevated temperatures, two commenters pointed out that these species suffered severe losses during the January 2010 extreme cold weather event in the Florida Keys (Colella et al. 2012, Lirman et al. 2011)[cxc]. Another recent publication also documents the impact of this cold weather event, which resulted in significant reductions in gross photosynthesis and in persistence of dark respiration after a return to 20˚C (Kemp et al. 2011).

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Several researchers documented various bleaching events and the impact on *M. annularis* complex species. Miller et al. (2011) documented high susceptibility of *M. faveolata* during a coral mass-bleaching event off an uninhabited Caribbean island with neglible human influence over water quality. Brandt et al. (2012) documented some bleaching of *Montastraea* corals located on a mesophotic reef (26-70 m depths) in USVI; however, bleaching was less than in counterparts at shallower locations. Bayraktarov et al. (2011) described *M. faveolata* and *M. franksi* as the most sensitive coral species to bleaching at sheltered reef sites in Columbia.

Several recent studies investigated the response of *M. annularis* complex species to bleaching to determine underlying mechanisms for bleaching tolerance/intolerance. Based on observed seasonal fluctuations in tissue biomass and endosymbiont density related to annual temperature variations, Thornhill et al. (2011) suggest *Montastraea* spp. colonies with relatively low tissue biomass (an index of condition) experience increased susceptibility to death following bleaching or other stressors than do conspecifics with higher tissue biomass levels. Additionally, Hennige et al. (2011) suggest that lower repair rates in *Symbiodinium* following photoinhibition may underlie the relatively low bleaching tolerance of *M. faveolata*.

Disease
Using a combination of culture-independent and culture-based analyses, Daniels et al. (2011) documented within- and between-colony variability in the composition of the bacterial community in the mucus of healthy *M. annularis* colonies in the Florida Keys. The results showed a significant amount of spatial heterogeneity across individual colonies, and total bacterial community composition of samples from the mucus vs. the water column were significantly different (Daniels et al. 2011). Abundances of culturable *Vibrio* spp. were highly variable across individual coral colonies, and Daniels et al. (2011) suggest that this parameter should not be used independent of other tests to indicate coral health.

Predation
Roff et al. (2011) investigated spatial patterns of parrotfish corallivory in the Caribbean and observed parrotfish bites most frequently on *M. annularis* and *M. faveolata*. Yet, when accounting for coral size and density, and parrotfish abundance (density, biomass and community structure), Roff et al. (2011) found only evidence for a weak, but significant preference by parrotfish for *Porites porites*. Roff et al.

(2011) concluded that the preference for *P. porites* is independent of colony density, size, and location, and the preference for *M. annularis* and *M. faveolata* is an artifact of their abundance and size.

Reef Trophic Changes
Barott et al. (2012) studied *in situ* interactions between *M. annularis* and four types of benthic algae: encrusting calcified red algae (CCA); fleshy brown macroalgae *(Dictyota bartayresiana)*; upright calcareous green algae *(Halimeda opuntia)* and a mixed assemblage of turf algae. The results from Barott et al. (2012) demonstrate that each alga exerts its own characteristic suite of effects on the coral holobiont, and that microscale dynamics have the potential to drive changes in reef community composition. The authors state "negative impacts span the range from micro-scale changes in microbial communities and oxygen drawdown to coral colony-scale effects such as damage to adjacent polyps and lowered fecundity of the adjacent coral colony, likely leading to reef-scale effects on coral abundance and distribution."

6.5.1 *Montastraea faveolata*

No new information was received or found specifically for *Montastraea faveolata.*

6.5.2 *Montastraea franksi*

No new information was received or found specifically for *Montastraea franksi.*

6.5.3 *Montastraea annularis*

No new information was received or found specifically for *Montastraea annularis.*

7 Individual Species Accounts – Indo-Pacific Species [Also relevant for Draft Mgt Report/DMR: CURRENT RANGES]

Overall, comments received for the Indo-Pacific species provided new information that predominantly falls within two categories: geographic ranges and depth distributions. In particular, most of the information for the geographic distributions of many species was from the CNMI and Guam. For example, according to CNMI's DLNR, of the 52 species mentioned in the SRR as having a distribution in the Marianas (including Guam), only 40 of the 52 species are known to be found in the Marianas.
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In addition, for many of the 75 species, the SRR reports max depths of 20-30 m, which in some cases may underestimate maximum depth. The Indo-Pacific mesophotic papers cited in the SRR (Bare et al. 2010, Kahng et al. 2010, and Rooney et al. 2010), and the new papers/reports listed below, suggest that many Indo-Pacific genera occur deeper than reported in the SRR. However, new species-specific information on depth distribution was found for <5 Indo-Pacific species, as noted below in the 75 species sections.
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Further, one commenter questioned the validity of some species occurrence in U.S. waters, stating that some species have been recorded in U.S. waters in suspected error, including: *Acropora lokani, Acropora tenella, Anacropora puertogalerae, Anacropora spinosa, Pectinia alcicornis, Acanthastrea regularis, Physogyra lichtensteini*.[cxci]
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Other comments raised included taxonomic issues regarding the BRT's decision to lump or split certain candidate species. For example, the state of Hawaii (DLNR) states that due to the unique characteristics

found in Hawaii, "Four species on the proposed list are endemic to Hawai'i and found nowhere else. Three species on the list are grouped together for review purposes, but must be analyzed separately on their own merits…A number of authors list approximately 15-20% of Hawaii's marine species as being endemic (Kay & Palumbi, 1987; Hourigan & Reese, 1987). Others have listed the number closer to 25% (Gulko 1998; Maragos & Gulko 2002). This is in line with endemism rates across numerous groups of terrestrial flora and fauna seen in the Hawaiian Islands. The Hawaiian Archipelago, because of its extreme isolation from large land masses and other island groups, extremely deep water, and relatively young age provides a unique hotspot of species endemism recognized world-wide. These same factors that have allowed Hawaii to have such unique species assemblages also set it apart from the majority of other coral reef areas in the world, both in terms of its species and habitats represented, and to a large extent, the global threats to coral species raised in the NOAA report."

Many of these issues are addressed in the following individual species accounts for the Indo-Pacific species.

7. 1 Genus *Millepora*

Thermal Stress:

One commenter notes that although members of the genus *Millepora* are among the most sensitive to bleaching, there are marked differences among some of the species in susceptibility. For example, in American Samoa, *Millepora dichotoma* bleaches more readily than *M. exesa* and *M. cf. platyphylla* (Fenner, personal comm.) *Millepora* species are generally able to rapidly recover from bleaching, via high recruitment and rapid growth of new colonies. However, repeated bleaching events appear to overwhelm recovery capacity, and there is evidence from the Indian (Souter et al. 2000) and Pacific (Glynn 2011) Oceans of declines following multiple bleaching events.

7.1.1 *Millepora foveolata*

Geographic Distribution:

From the SRR:

"Millepora foveolata has been reported on the southern coast of Taiwan, the Philippines, the Northern Marianas but not the Southern Marianas which includes Guam, Rota, Tinian, Saipan, etc. (Randall, 1995), Palau, and the Great Barrier Reef in Australia."

Supplemental information from Harding et al. 2006 (not included in SRR) extends the range to Madagascar.

Abundance/Habitat

From the SRR:

"Abundance of Millepora foveolata has been reported mostly as occasional (Randall and Cheng, 1984)."

Supplemental information (Harding et al. 2006) supports the statement in the SRR that this species is cryptic, inconspicuous, and resembles crustose coralline algae, resulting in the species being potentially "more common than previously observed" (SRR). These results together support an uncommon rating for abundance.

7.1.2 *Millepora tuberosa*

Global Distribution:

From the SRR:
"…it resembles crustose coralline algae to persons surveying corals who have not been familiarized with Millepora tuberosa."

One commenter suggests that in addition to the confusion between M. tuberosa and coralline algae, it may even be more easily confused with *Psammocora nierstraszi* colonies that have the same or similar color (Douglas Fenner, personal comm.) Additionally, Fenner (2011) extends the range of M. tuberosa to New Caledonia.

U.S. Distribution
In addition to occurring in federally protected areas listed for this species in the SRR, *Millepora tuberosa* has been confirmed in the Mariana Trench Marine National Monument (Houk, personal comm.) and is also highly likely to occur in the War in the Pacific National Historic Park, the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and the Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation) (David Burdick, personal comm).

Abundance/Habitat
From the SRR:
"Abundance of Millepora tuberosa has most often been reported as occasional…"

Based on information not cited in SRR (e.g., Colgan 1987, McArdle 2003), and public comments, the species is common in the Mariana Islands and American Samoa. Additionally, several authors (e.g., Harding et al. 2006), comments, and the SRR state that this species resembles crustose coralline algae, resulting in the species being potentially "more common than previously observed" (SRR). For example, observations from Guam state that *Millepora tuberosa* can be common across multiple reef zones, but it is likely that it has often been misidentified as crustose coralline algae and thus its abundance on Guam (and likely elsewhere throughout its range) has been underreported to date (David Burdick, personal comm.). These results together support a common abundance characterization.

Additional Threat Information:
The relatively high abundance of this species on Guam would suggest that its local population is relatively resilient to local stressors – mainly predation, sedimentation, and other land-based pollutants, and secondary impacts of heavy fishing pressure (e.g., encroachment, loss of recruiting substrate due to fleshy algae proliferation). Guam has not yet experienced a severe, large-scale bleaching event, but populations of *M. tuberosa* appear to remain relatively robust despite moderate thermal stress events recorded in the past several years (David Burdick, personal comm).

7.2 Genus Heliopora

7.2.1 *Heliopora coerulea*

Global Distribution:
From the SRR:
"The extent of distributions into the higher latitudes on the east and west coasts of Australia are indicated substantially differently in maps from the IUCN Red List and from Veron 2000."

One of the most southern locations this species has been reported from is New Caledonia (Zann and Bolton, 1985; Fenner, 2011). The indication of the far southern extension of the range in western and eastern Australia in the IUCN map are in error (Fenner 2011).

U.S. Distribution
This species has been confirmed in Guam's water (Amesbury et al. 1999; Burdick unpubl. Data; CRED unpubl. Data), as correctly noted in the SRR. Randall and Myers (1983) and Paulay et al (2003) also reported this species from the Marianas, and more recently H. coerulea was reported from Apra Harbor, Guam by HDR EOC and CSA International (2011a) and from the War and the Pacific National Historic Park nearshore areas (David Burdick, personal comm.). In addition to occurring in the federally protected areas listed for this species in the SRR, Heliopora coerulea is also expected to occur in the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and the Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation (David Burdick, personal comm.)

Abundance/Habitat
Heliopora coerulea is occasionally encountered within multiple reef zones on Guam, primarily in reef flat and outer reef slope areas; it can be locally abundant at some sites (e.g., parts of the Piti Bay reef flat) (David Burdick, personal comm.)

Additional Threat Information
From the SRR:
Heliopora coerulea has been identified as a potential host for Porites ulcerative white-spot disease (Kaczmarsky, 2006), but disease does not appear to pose a substantial threat to this species.

In the past several years, Dr. Laurie Raymundo, Director of the University of Guam Marine Lab, and Guam Government Biologist David Burdick, have observed a large number of *H. coerulea* colonies on Guam that have exhibited partial or full mortality caused by an unknown stressor; a turfing algae species/community present on these colonies may be the cause of this mortality or may secondarily infect the colony after mortality caused by a pathogen or some other stressor. If mortality as a result of the stressor is positively correlated with water temperature (although no evidence currently exists to support such a claim), we may see increasing levels of mortality in *H. coerulea* associated with climate change, even with the low susceptibility to bleaching as a result of thermal stress. In the event that *H. coerulea* is vulnerable to disease/disease state and if the virulence of this disease/disease state is positively correlated with water temperature, the assessment of this species' risk of extirpation from Guam and its risk of extinction throughout its range may have to be revisited (David Burdick, personal comm.).

7.3 Genus *Pocillopora*

Taxonomic Issues
One commenter stated that it might be worth mentioning that the taxonomy of the genus *Pocillopora* is almost completely dependent on the gross morphology of the colonies and their verrucae. Microscopic structures have not generally correlated with the morphology of colonies. Not only is colony morphology plastic, but there may not be sharp boundaries between some or many species in colony morphology (Fenner, personal comm.).

From the SRR:
"The SRR relied on Carpenter et al. 2008 for the depth ranges of this genus."

More recent reports show that various species in the genus *Pocillopora* have been found at depths up to 50 m in Hawaii (Rooney et al. 2010), and up to 55 m on the Great Barrier Reef (Bridge et al. 2012). This suggests that the potential lower depth range for the candidate *Pocillopora* species is greater than previously stated (between 50-55 m) rather than 1-20 m. However, we only received species-specific information for the candidate species *P. danae.*

Life History

From the SRR:

"Combosch et al. (2008) provided data supportive of genetic isolation between eastern Pacific pocilloporids and those elsewhere in the Pacific and Indian Oceans and an apparent one-way gene flow into Pocillopora damicornis from one or both of congeners in the eastern Pacific, Pocillopora eydouxi and Pocillopora elegans. One distinct issue has long been identified as a concern over the identification of eastern Pacific pocilloporids as conspecifics of corals found elsewhere in the Pacific and in the Indian Ocean: the eastern Pacific corals are broadcast spawners, while elsewhere they are brooders (Glynn et al., 1991). Thus, Pocillopora elegans in these two regions are not only geographically isolated but unlikely to interbreed because of completely different reproductive modes."

A more recent study by Combosch and Vollmer (2011) on congener *P. damicornis* suggests that gene flow is indeed limited in the Tropical Eastern Pacific in *P. damicornis* populations, particularly among regions, but even over meter scale within populations.

Thermal Stress:

From the SRR:

"Pocillopora are widely recognized as being prone to expelling their zooxanthellae when the water becomes anomalously warm… McClanahan et al. (2007) surveyed thousands of corals of 39 genera and found Pocillopora to be among the most sensitive, with only 7 genera ranking higher and just below Acropora and branching Porites."

Disease:

From the SRR:

"There have been a medium number of disease reports for the genus Pocillopora (UNEP, 2010)… The limited number of reports of disease in pocilloporids indicates that infectious disease is not a major threat to members of this genus."

7.3.1 *Pocillopora danae*

U.S. Distribution

In addition to occurring in the federally protected areas listed for this species in the SRR, *Pocillopora danae* is also expected to occur in the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and the Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat

From the SRR:

Abundance of Pocillopora elegans has been reported to be locally common in some regions of the central Indo-Pacific and the far eastern Pacific (Carpenter et al., 2008; Veron, 2000).

In Guam's waters, *Pocillopora danae* is uncommonly to occasionally encountered; it is found across multiple reefs zones, but is most commonly encountered in shallow to moderate depths in protected fringing reef, channel, and lagoon habitats (Randall and Burdick in prep.).

Depth distribution
From the SRR:
Pocillopora danae has been reported in water depths ranging from 1 m to 15 m (Carpenter et al., 2008).

New species-specific information indicates that in some areas, the species is found deeper than 15 m. E.g., in the Mariana Islands, the species commonly occurs at moderate depths (Randall and Burdick in prep.), and at 19 - 27 m in the Red Sea (Perkol-Finkel & Benayahu 2004).

7.3.2 *Pocillopora elegans*

Life History
From the SRR;
P. elegans in the eastern Pacific has ***"...*** *slow recovery, and little evidence of successful recruitment through sexual propagation particularly threaten these corals."*

A report not cited in the SRR supports the notion that *P. elegans* has limited successful recruitment through sexual propagation (Glynn 2009). This report documents rapid recovery of reef-building corals in the Galapagos following a bleaching event, but the recovery is almost entirely due to Porites (sexual and asexual) with very little *Pocillopora* recovery, and no *P elegans* recruitment via sexual reproduction.

U.S. Distribution
In addition to occurring in the federally protected areas listed for this species in the SRR, *Pocillopora elegans* likely occurs in the War in the Pacific National Historic Park, the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Pocillopora elegans has been reported from shallow reef environments (Veron, 2000)."

Pocillopora elegans is uncommonly to occasionally encountered in Guam's waters; it is primarily found in the lower reef front zone and the adjacent submarine terrace to a depth of 20-30 m (Randall unpubl data).

7.4 Genus *Seriatopora*

Depth Range:
New reports show other *Seriatopora spp.* at depths of 55 m (e.g., *S. hystrix* on GBR (Bridge et al. 2012) and 60 m, *S. hystrix* on GBR (Nir et al. 2011)). However, no species-specific information was found for any of the *Seriatopora* candidate species.

7.4.1 *Seriatopora aculeata*

Global Distribution:
Recent reports from India document the species in the Nicobar & Andaman Islands (Mondal et al. 2010, Venkataraman et al. 2012). The Corals of the World page for this species also shows it in Madagascar (http://coral.aims.gov.au/speciesPages/). This new information shows that *S. aculeata* has a slightly wider geographic range than previously documented.

U.S. Distribution
From the SRR:
"Veron (2000) lists the species in the Marianas; however, the Marianas reference is likely an error based on geographic location of photographic evidence."

Seriatopora aculeata has been confirmed from the CNMI (Steve McKagan, personal comm.). Additionally, according to the SRR, this species has not been reported from federally protected waters. While the species may not have been recorded in any federally protected waters on Guam, there is a possibility it may be found in the War in the Pacific National Historic Park, the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and the Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Abundance of S. aculeata has been reported as uncommon and occupies shallow reef environments (Veron 2000). "

Seriatopora aculeata is also rare to uncommon in Guam's waters. According to R.H. Randall (unpubl data) it is primarily found in exposed seaward reef slope zones where there is good water circulation and rates of sedimentation are low; however, the few specimens of *S. aculeata* observed in Guam's waters since 2004 were found along the southwestern coast of Guam in areas with high rates of sedimentation (David Burdick, personal comm.).

7.5 Genus *Acropora*

Characteristics
One commenter suggested beginning the discussion of the genus *Acropora* with a statement from Veron (2002) that *Acropora* is not only the largest genus of corals with approximately 162 species recognized by Veron (2002), but also that this genus is very abundant and often dominates reefs. The commenter states "Veron also makes the point that they are the only genus in which there is a single axial polyp that builds the branch tip, with radial polyps budding off the side of the axial polyp. He credits this with helping in the rapid growth and the ability to evolve many different colony shapes through the control of the pattern of radial corallite growth and growth into incipient axial polyps and new branches. It might be worth mentioning the work on chromosomes that found that some groups of species differ by even numbers of chromosomes that suggested that polyploidy may have been involved in the evolution of additional species. I have a feeling that was an article by Wallace and/or Willis. Willis and Wallace have done studies on the interbreeding of several species of *Acropora*, some crosses are highly fertile in experiments while others are not. This was one of the main pieces of evidence for the "reticulate evolution" view of corals championed by Veron" (David Burdick, personal comm.).

Depth Range
New information suggests that various species within the *Acropora* genus occur deeper than previously thought. Bridge *et al.* 2012 shows various species of acroporid corals reported from between 47 – 55 m on the Great Barrier Reef. Additionally, various species of acroporid corals were reported from Tutuila, American Samoa between 40-50 meters (Bare *et al.* 2010). However, no new species-specific information was received for any of the candidate *Acropora spp.*

Thermal Stress
From the SRR:

"The genus Acropora is widely recognized as being particularly prone to expelling their zooxanthellae when the water becomes anomalously warm. In a series of field assessments, Marshall and Baird (2000) noted that 14 of the 22 species of Acropora showed a "severe" response to increased water temperature. The others were "mixed" and possibly "severe" with them also. McClanahan et al. (2007) surveyed thousands of corals of 39 genera and found Acropora to be among the most sensitive to anomalously warm waters, with only 5 genera ranking higher."

While many new papers and studies have been conducted on thermal stress as a result of ocean warming on corals and coral reefs, most of these studies include information at the genus level. No new species-specific information was received on any of the candidate *Acropora spp.* in particular.

Comments from the Western Pacific Regional Fishery Management Council provided new information and literature regarding thermal stress and adaptation of acroporids in general, stating that:

"…the BRT review was completed in the context of a particularly fertile period for coral reef and oceanographic research related to climate change, and especially impacts to coral reefs. However, the report was finalized in 2011 before several critical papers were published contributing to the growing body of knowledge on coral adaptability to thermal stress and acidification. For example, the top four Indo-Pacific species with the highest likelihood of falling below the Critical Risk Threshold as voted by the BRT belong to the genus Acropora. [The]BRT cited the susceptibility of Acropora to thermal stress and observed high bleaching rate of this genus as reasons for the higher likelihood for extinction risk. However, monitoring of coral reefs following bleaching events has shown recovery of *Acropora* in Okinawa (van Woesik et al. 2011)." Additionally, Richards et al. (2008) concluded: "although it has often been assumed that small populations have a decreased potential for adaptation, our analyses imply that some rare Acroporid corals may actually have increased adaptive potential as a consequence of introgressive hybridization, and therefore may be less vulnerable to extinction than has been assumed."

In contrast, Richards & van Oppen (2012) concluded "*Acropora* corals have lower genetic diversity at neutral microsatellite loci than may be expected from their taxonomic diversity, and this may suggest a heightened susceptibility to environmental change." Thus, in addition to new information that focuses on potential adaptation and acclimatization for some coral species, new information received also suggests that *Acropora* are still among the most susceptible to thermal stress, and thus vulnerable to bleaching. For example, Vargas-Angel et al. (2011) show that while bleaching conditions varied during an El Niño associated coral bleaching event in the U.S. Phoenix Islands, *Acropora* exhibited one of the greatest percentages of affected colonies. Additionally, there has been limited recovery of the formerly dominant *Acropora* even on the world's warmest reefs in the southern Arabian Gulf, likely as a result of recruitment failure due to severe and prolonged bleaching impacts (Burt et al. 2011). There are numerous studies focusing on adaptation mechanisms that corals may be able to implement to facilitate adaptation and acclimatization to increasingly warmer temperatures, while other contrasting studies suggest that the rate of change may be too fast for corals to keep up.

Acidification

From the SRR:

"Acidification can have a variety of effects on Acropora. While increased CO_2 (increased acidity) does not appear to affect the survival of Acropora larvae, fertilization, settlement, rate of zooxanthellae acquisition, and postsettlement growth are all significantly impaired (Albright et al., 2010; Suwa et al., 2010)."

While several new papers have been published on the subject of ocean acidification and its predicted effects on corals and coral reefs, none of the following studies were conducted on any of the candidate *Acropora spp* in particular. In general, increases in ocean acidification have been shown to create conditions where coral reefs (and specifically, reefs dominated by various *Acropora spp.*) may become increasingly susceptible to seaweed proliferation (Diaz-Pulido et al. 2011), bacteria associated with disease and stressed corals (Meron et al. 2011), and lowered resilience due to synergistic effects between acidification and local disturbances such as overfishing and nutrification (Anthony et al. 2011).

Sea Level Rise
No new information was received on the topic of sea level rise for any of the candidate Acropora spp. in particular.

Nutrients
No new information was received on the topic of nutrients for any of the candidate Acropora spp. in particular.

Toxins
No new information was received on the topic of toxins for any of the candidate Acropora spp. in particular.

Disease
From the SRR:
"Acropora are vulnerable to most of the diseases known to affect scleractinian corals and are more commonly affected by acute and lethal conditions (e.g., "white diseases") than some other taxa… in general Acropora species are moderately to highly susceptible to disease."

Recent literature on diseases of scleractinian corals predominantly show similar patterns and conclusions addressed by the BRT. However, it should be noted that these studies were predominantly conducted at the genus level, and no new species-specific information pertaining to diseases were found for the candidate *Acropora spp.* Rasher *et al.* (2011) concludes that while coral species varied markedly in their susceptibility to allelopathic algae, the *Acropora* genus was more strongly affected than others. Likewise, in a study from India, out of eight different genera that were affected by a particular strain of black-band disease, *Acropora* presented with a significantly high prevalence of disease and associated high level of damage in comparison to other genera, such as *Cyphastrea* (Thinesh et al. 2011). Additionally, in a study from Palmyra Atoll in the central Pacific, disease in the form of growth anomalies were the most prevalent, with *Acropora* having one of the highest prevalence atoll-wide (Williams *et al.* 2011). In addition, one study from the Hawaii shows that some diseases have a negative association with thermal stress (Aeby et al. 2011), underlying the presence of potential synergistic effects between disease prevalence and increasing ocean temperatures.

7.5.1 *Acropora aculeus*

U.S. Distribution
This species has been confirmed to occur in the CNMI (Steve McKagan, personal comm.). Additionally, this species has been confirmed in Guam's water (Burdick unpubl data; Randall 2003; Wallace 1999), as correctly noted in the SRR. Randall and Myers (1983) also reported this species from Guam's waters. But note that the specimens identified as *A. aculeus* in Randall (1983) and Randall (2003) appear to be different than that described and depicted as A. aculeus in Veron (2000) and Wallace (1999). With that said, specimens that match the description and images provided in Veron (2000) and Wallace (1999) have been observed on Guam by BSP-GCMP Biologist Dave Burdick.

Abundance/Habitat

From the SRR:

"Acropora aculeus has a broad depth range. It is particularly abundant in shallow lagoons and is common in most habitats where it is protected from direct wave action."

According to Randall and Burdick (in prep), *Acropora aculeus* is uncommon in Guam's waters, having only been found in Cocos Lagoon and by a handful of specimens from several sites along the southwestern coast that were identified by Randall in photographs taken by BSP-GCMP biologist Dave Burdick. Again, however, it must be noted that the specimens identified as *A. aculeus* by Randall do not appear to be consistent with A. aculeus as described and depicted by Veron (2000) and Wallace (1999). The specimens observed by the BSP-GCMP biologist on Guam that do appear to be consistent with Veron (2000) and Wallace (1999) are also uncommon, but appear to have a wider distribution across the island's nearshore waters, being primarily found in exposed seaward slope areas down to at least 30 m.

In addition to occurring in the federally protected areas listed for this species in the SRR, A. aculeus is also expected to occur in the Mariana Trench Marine National Monument, the War in the Pacific National Historic Park, and the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and the Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.5.2 *Acropra acuminata*

Taxonomic Issues

From the SRR:

None. Acropora acuminata was originally called Madrepora nigra, probably because drying specimens turn black (Wallace, 1999; Wells, 1954).

The specimens from Guam identified as *A. acuminata* consistently exhibit an aborescent "staghorn" growth form, which is different from the branching tabular form, with up-turned branches at the periphery of the table that is observed elsewhere throughout the species' reported range. The original description of this species by Verrill in 1864 describes colonies as having "…regularly tapering, often curved branches," which would seem to better fit with the non-Guam populations that exhibit tabular form. Collected specimens of both the Guam and non-Guam forms of *A. acuminata* (if there are indeed the same species) turn black in color, a phenomenon not reported for other *Acropora* species. When considering these differences and similarities, the staghorn form observed on Guam and the branching tabular forms could represent different species or they could be forms of the same species or represent distinct sub-species (David Burdick, personal comm.).

U.S. Distribution

This species has been confirmed from the CNMI (Steve McKagan, personal comm.). This species has also been confirmed in Guam's water (Burdick unpubl data; Randall 2003; Wallace 1999), as correctly noted in the SRR. Wallace (1999) also lists a specimen collected from Guam and HDR and CSA International (2011a) recently reported this species from Apra Harbor, Guam. However, note the potential taxonomic discrepancies above.

In addition to occurring in the federally protected areas listed for this species in the SRR, A. acuminata may occur in the Marianas Trench Marine National Monument, the War in the Pacific National Historic Park, the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area and the Ritidian

National Wildlife Refuge (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Abundance of Acropora acuminata has been reported to occasionally live in extensive clumps with dimensions of several meters (Wallace, 1999)."

According to Randall and Burdick (in prep) *A. acumintata* is most commonly encountered on deeper reef flat areas along the western and northern coasts of Guam in lagoon habitats in Cocos Lagoon and Apra Harbor, and channel slope environments in Mamaon and Manell channels. Randall also notes that this species is rare in upper seaward reef slope and occasionally observed on embayment reefs.

7.5.3 *Acropora aspera*

U.S. Distribution
New information received reports the presence of *A. aspera* at Baker Island (Jim Maragos, unpubl data). Additionally, *Acropora aspera* has been confirmed from the CNMI (Steve McKagan, personal comm.). Finally, this species has been confirmed from Guam's waters (Amebury et al. 1999; Burdick unpubl data; Randall 2003; Wallace 1999), as correctly noted in the SRR. An additional reference, Randall and Myers (1983) also reported this species from Guam's waters. But note that *A. aspera* as reported in Randall and Myers (1983) and Randall (2003) is likely A*. pulchra* and that what was reported as *A. hebes* in these publications is now referred to as *A. aspera* (Randall and Burdick in prep).

In addition to occurring in the federally protect areas listed for this species in the SRR, *A. aspera* may occur in the Marianas Trench Marine National Monument, the Haputo Ecological Reserve Area, the Orote Point Ecological reserve Area, and the Ritidian National Wildlife Refuge (although its occurrence in these areas requires confirmation). This species is reported from the War in the Pacific National Historic Park, but it is likely that the species reported was what Randall had previously been calling A. aspera would now be considered *A. pulchra*. While a less common species, what is now referred to as A. aspera (formerly *A. hebes*) is also expected to occur in the War in the Pacific NHP (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Acropora aspera has been reported to occupy a broad range of habitats and its colony structure varies substantially with habitat (Wallace, 1999)."

According to Randall and Burdick (in prep), *A. aspera* distribution on Guam is restricted to shallow reef flat platform moat and reef margin habitats along the western and northern coasts and the shallow reef platform and terrace along the south side of Cocos Lagoon in water generally less than a meter deep. Randall and Burdick (in prep) report that A. aspera is rather uncommon within its overall habitat range, but can be abundant in small local regions.

7.5.4 *Acropora dendrum*

U.S. Distribution
From the SRR:

"According to the IUCN Species Account, Acropora dendrum occurs in American Samoa, but no supporting reference is given. The CITES species database includes Samoa as a country of occurrence but distinguishes American Samoa from Samoa in other species accounts. Acropora dendrum is not listed as occurring in American Samoa in Lovell and McLardy (2008). Fenner reported tentative identification of Acropora dendrum at Tutuila, American Samoa, with three photographs of two colonies, but no voucher sample. The occurrence of Acropora dendrum in American Samoa remains uncertain."

7.5.6 *Acropora globiceps*

U.S. Distribution

Acropora globiceps has been confirmed from the CNMI (Steve McKagan, personal comm.). This species has also been reported from Guam's waters (Burdick unpubl. Data, Wallace 1999), as correctly noted in the SRR, although the report from Burdick should be considered tentative until Randall and Burdick can resolve the identifications of the various *A. humilis*-like species found in Guam's waters. In addition to occurring in the federally protected areas listed for this species in the SRR, *A. gobiceps* [sic] may occur in the Marianas Trench Mariona National Monument, the War in the Pacific NHP, the Haputo Ecological Reserve Area, the Orote Point Ecological Reserve Area, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.5.8 *Acropora jacquelineae*

Abundance/Habitat:

While SRR reports abundance of this species as uncommon based on Veron (2000), other information reported in the SRR (Richards 2009) indicates the species has a small effective population size. Therefore, the abundance for this species is rated as rare.

7.5.9 *Acropora listeri*

U.S. Distribution

This species has been confirmed from the CNMI (Steve McKagan, personal comm.). Also**,** In addition to occurring in federally protected areas listed for this species in the SRR, *A. listeri* may occur in the Marianas Trench Marine National Monument, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat:

From the SRR:

Abundance of Acropora listeri has been reported as uncommon (Veron, 2000). Acropora listeri has been reported from subtidal shallow reef edges, upper reef slopes, and in strong wave action (Veron, 2000; Wallace, 1999).

Specimens consistent with *A. listeri* that were observed by the BSP-GCMP biologist were primarily found in exposed reef front and upper reef slope environments. This species appears to be relatively uncommon in Guam's waters. This generally supports the abundance and habitat statements provided in the SRR.

7.5.10 *Acropora lokani*

Abundance/Habitat:

While SRR reports abundance of this species as uncommon or common based on Carpenter et al (2008) and Veron (2000), other information reported in the SRR (Richards 2009) indicates the species has a small effective population size. Therefore, the abundance for this species is rated as rare.

7.5.11 *Acropora microclados*

U.S. Distribution
D. Fenner: p. 218 you can add Fenner to those who report A. microclados from American Samoa
Acropora microclados has been confirmed from the CNMI (Steve McKagan, personal comm.). Also, this species is reported from Palmyra Atoll (Jim Maragos unpubl. data). Finally, *A. microclados* has been reported from Guam's waters (Wallace 1999) as correctly noted in the SRR. This species has not been reported from Guam's waters by R.H. Randall, but the BSP-GCMP biologist has observed and photographed a handful of colonies that match the description and images provided for the species in Veron (2000) and Wallace (1999). Images of one of these colonies were recently provided to Doug Fenner, who also thought the photographed specimen was consistent with *A. microclados*. In addition to occurring in the federally protected areas listed for this species in the SRR*, A. microclados* may occur in the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although it occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habita*t*
From the SRR:
"Acropora microclados have been reported to occur on upper reef slopes (Veron, 2000) and subtidal reef edges (Carpenter et al., 2008)."

The handful of specimens consistent with *A. microclados* that were observed in Guam were found on the seaward reef slope below 15 meters depth (David Burdick, personal comm.).

7.5.12 *Acropora palmerae*

Taxonomy
One commenter notes the presence of identification discrepancies (i.e. *Acropora palmerae* could be the same as *Acropora robusta*).[cxcii]

U.S. Distribution:
This species has been identified with a very high degree of confidence [within the CNMI] during CNMI DLNR data collection efforts within the last decade (Steve McKagan, personal comm.). In addition to occurring in the federally protected areas listed for this species in the SRR, this species is likely to occur in the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.)

Abundance/Habitat
From the SRR:
"*Acropora palmerae* has been reported to occupy reef flats exposed to strong wave action and lagoons (Veron, 2000) and intertidal, subtidal, shallow, reef tops, reef flats, and reef edges (Carpenter et al., 2008)."

Acropora palmerae is [in Guam] common to abundant along the seaward edge of the reef margin and reef front zone (David Burdick, personal comm.).

Depth Range
From the SRR:
"Acropora palmerae has been reported in water depths ranging from 5 m to 20 m (Carpenter et al., 2008)."

In the CNMI, *A. palmerae* occur predominantly between 20 ft and 40 ft (Steve McKagan, personal comm.).

7.5.13 *Acropora paniculata*

Global Distribution
From State of Hawaii: "*Acropora paniculata* has a wide geographic range. It stretches from the Red Sea, across the Indo-Pacific, western and central Pacific Ocean to the Papahanaumokuakea Marine National Monument (PMNM) at French Frigate Shoals (FFS)."

U.S. Distribution
From the State of Hawaii: "This species exists only in the Hawaiian archipelago at French Frigate Shoals. Thus, it is rare in Hawaii, although it is found in other Pacific locations under U.S. jurisdiction."

Although *A. paniculata* has been reported from CNMI (CRED unpubl data), neither Randall nor Wallace have reported this species from Guam. However, the BSP-GCMP biologist has observed and photographed specimens from Guam's water that closely match the descriptions of *A. paniculata* in Veron (2000) and Wallace (1999). While further examination is required, it appears as though specimens from Guam identified as *A. rambleri* by Randall are consistent with what Veron (2000) and Wallace (1999) have described as *A. paniculata*. In addition to occurring in the federally protected areas listed for this species in the SRR, specimens consistent with *A. paniculata* have been observed by the BSP-GCMP biologist in the waters of the War of the Pacific NHP. This species is also expected to occur in the Orote Point ERA and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Depth Range
From the SRR:
"Acropora paniculata has been reported in water depths ranging from 10 m to 35 m (Carpenter et al., 2008)."

From the State of Hawaii (DLNR): "This species has a deep water range which protects it from ocean warming. Cooler water ameliorates the effects of bleaching and disease."

Additional Threat Info
From the State of Hawaii (DLNR): The *Acropora* genus is subject to severe bleaching from thermal stress. It may also be susceptible to ocean acidification, disease, and predation from crown-of-thorns starfish. At French Frigate Shoals, this species is protected by three agencies: NOAA NOS, USFWS, and the State of Hawaii. The harvest of any coral is prohibited within the PMNM. There is no human habitation in the PMNM and, therefore, no anthropogenic effects. Fishing, sedimentation, pollution are not factors that could contribute to decline. While it is not common in Hawaii, it is fully protected from anthropogenic impacts (due to state and federal protection). The geographical and geomorphologic characteristics of

the Hawaiian archipelago buffer this species from projected ocean warming, bleaching, and disease. Its wide geographic distribution and its deep depth range (35m) mitigate against its extinction.

Abundance/Habitat:
From the SRR:
"*Acropora paniculata* has been reported to occupy upper reef slopes, just subtidal, reef edges, and sheltered lagoons (Carpenter et al., 2008). Abundance of *Acropora paniculata* has been reported as uncommon to rare on most reefs (Veron, 2000); however, common in Papua New Guinea (Wallace, 1999)."

From the State of Hawaii: It is not common in Hawaii.

Specimens consistent with *A. paniculata* that have been observed by the BSP-GCMP biologist were observed in seaward reef slope environments, typically at depths greater than 20 m (to at least 40 m) (David Burdick, personal comm.).

7.5.14 *Acropora pharaonsis*

Global Distribution
New information extends the global range of this species to New Caledonia (Fenner 2011).

7.5.15 *Acropora polystoma*

U.S. Distribution
Acropora polystoma has been confirmed from the CNMI (Steve McKagan, personal comm.). Additionally, new information reports this species from Tutuila, American Samoa (Jim Maragos, unpubl data). Within the SRR, *A. polystoma* is reported from Guam only by unpublished data by Burdick. This species has previously been reported by Randall and Myers (1983) as *Acropora sp.* 1, and in Randall (2003) specimens were incorrectly thought to be closest to *A. lutkeni* (Randall and Burdick in prep). It should be noted that what has been identified as *A. polystoma* on Guam is not entirely consistent with *A. polystoma* as described by other authors and may represent a separate species. If the species reported from Guam is indeed *A. polystoma*, it is likely to be found in the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, the Ritidian NWR (although its occurrence in these areas requires confirmation) and may occur in the Marianas Trench MNM (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Acropora polystoma has been reported to occupy upper reef slopes exposed to strong wave action (Veron, 2000) and intertidal, just subtidal, shallow, reef tops, reef edges, and high current areas (Carpenter et al., 2008)."

According to Randall and Burdick (in prep), *A. polystoma* is generally restricted to the upper exposed seaward reef slope zone to a depth a 10 m where there is good water circulation.

7.5.16a *Acropora retusa*[1]

Global Distribution

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[1] In the SRR, *A. retusa* and *A. rudis* are both labeled "7.5.16".

Latitudinal distribution is extended for *A. retusa* by new reports of this species from multiple sites in the Solomon Islands (Green et al. 2006) and New Caledonia (Fenner 2011). These range extensions are documented in the updated range map for this species on Corals of the World website http://coral.aims.gov.au/speciesPages/.

U.S. Distribution

As correctly noted in the SRR, *Acropora retusa* has not been recorded from Guam or elsewhere in the Mariana Islands. However, the BSP-GCMP biologist has recently photographed a couple specimens from within Apra Harbor that appear to be similar to descriptions and images of *Acropora retusa* provided by other authors. In addition, R.H. Randall has tentatively applied *A. retusa* to specimens he has collected from Guam (David Burdick, personal comm.).

7.5.16b *Acropora rudis*

Global Distribution

A. rudis has now been reported in New Caledonia as well in Fenner (2011) which includes photographs of a living colony and a skeletal sample.

7.5.17 *Acropora speciosa*

Taxonomic Issues:

From the SRR:

"None. Acropora speciosa is similar to Acropora echinata (which does not form cushions) and Acropora granulosa (Veron, 2000). Taxonomically, it belongs to the Acropora loripes group (Wallace, 1999)."

There is a possible taxonomic issue, since the photographs of living colonies in Veron (2000) and shown in this report, are very different from those shown in Wallace (1999). Re-examination of the type specimen may be required to resolve this difference (Fenner, personal comm.)

U.S. Distribution

From the SRR:

"Fenner reports *Acropora speciosa* in American Samoa at Tutuila at around 20 m depth, where its abundance was characterized as "occasional." The area where it was found was heavily impacted by the tsunami of 29 September 2009, and it has not been searched for since then. *Acropora speciosa* is not listed as occurring in American Samoa in Lovell and McLardy (2008)."

Acropora speciosa has been confirmed in Tutuila, American Samoa (Jim Maragos unpubl data).
As correctly noted in the SRR, *A. speciosa* has not been recorded from Guam or elsewhere in the Mariana Islands. However it should be noted that specimens tentatively identified as "*Acropora speciosa*" were observed during surveys carried out by HDR EOC and CSA International (2011) (David Burdick, personal comm.).

7.5.18 *Acropora striata*

U.S. Distribution

As noted in the SRR, *A. striata* has been reported from Guam by Burdick (unpubl data) and Randall (2003). However, it should be noted that the specimens from Guam's waters identified as *A. striata* by Randall appear to be inconsistent with the description and images of *A. striata* provided by Veron (2000). According to Randall and Burdick (in prep), *A. striata* specimens reported from Guam form caespitose clumps that are profusely branched; this is in contract to the dense thickets described in Veron (2000). It should also be noted that the unpublished data for *A. striata* provided by Burdick that was cited in the SRR was not based on first-hand observations of the species in Guam's waters and instead was intended to make not that Randall had identified this species in Guam's waters. If the species reported from Guam is indeed *A. striata*, it is possible that it could be found in the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, the Ritidian NWR (although its occurrence in these areas requires confirmation); however the rarity of the species identified as *A. striata* in Guam's waters would make its occurrence in these areas unlikely (David Burdick, personal comm.).

Abundance/Habitat
A. striata is rare on Guam, having thus far only been found at the reef platform moat at Luminao Reef, in water less than a meter deep (Randall and Burdick in prep).

7.5.19 *Acropora tenella*

U.S. Distribution
Acropora tenella has been confirmed from the CNMI (Steve McKagan, personal comm.).

7.5.20 *Acropora vaughani*

U.S. Distribution
Acropora vaughani has been confirmed from the CNMI (Steve McKagan, personal comm.). This species has also been confirmed in Guam's waters (Burdick unpubl data; Randall 2003), as correctly noted in the SRR. It should also be noted that Wallace (1999) lists *A. vaughani* specimen collected from Guam. This species was also reported from Guam in Randall and Myers (1983). It is possible, but unlikely that this species may occur in the War in the Pacific NHP, particularly in its waters that occur South of Orote Peninsula. It is even less likely to be found in the Haputo ERA, the Orote Point ERA, or the Ritidian NWR. The BSP-GCMP biologist is not familiar enough with the habitats of the Marianas Trench MNM to confidently estimate its likelihood of occurring within this area, but the protected habitat within the crater at Maug may provide suitable conditions for this species (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Acropora vaughani has been reported to occupy fringing reefs with turbid water (Veron, 2000), protected lagoons and sandy slopes (IUCN, 2010), or protected subtidal waters (Richards, 2009)."

On Guam, *A. vaughani* is uncommon, primarily restricted to Apra Harbor and fringing embayment reef channels and seaward reef slopes along the southwest coast. It is generally found at depths between 10 and 40 meters (Randall and Burdick in prep).

7.5.21 *Acropora verweyi*

U.S. Distribution
This species has been confirmed in Guam's water (Burdick unpubl data; Wallace 1999), as correctly noted in the status review. It should also be noted that this species was reported from Guam's waters in Randall (2003) as "Acropora cf. verweyi" and will be reported as *A. verweyi* in an upcoming publication by Randall and Burdick (in prep). In addition to occurring in the federally protected areas listed for this species in the SRR, A. verweyi has been reported from the Haputo ERA and Ritidian NWR (Burdick

unpubl data)l its occurrence within the War in the Pacific NHP and Orote Point ERA is highly likely (although it occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat
From the SRR:
"Acropora verweyi "...seems to be an exclusively shallow-water species" (Wallace, 1999). It lives on upper reef slopes or other parts of the reef where circulation is good (Veron and Wallace, 1984)."

A. verweyi is a common, and sometimes locally abundant, species found in Guam's exposed reef and upper seaward reef slopes; while typically found in waters less than 7 m it can be found to at least 20 m.

7.6 Genus *Anacropora*

Depth Range:
From the SRR:
The SRR relied on depth distribution for the genus Anacropora from Carpenter et al. 2008, stating that these species have been reported from 5-20 m.

A more recent study reports unidentified *Anacropora* species from Tutuila, American Samoa at 50 m (Bare et al. 2010). However, no new species-specific information was found for any of the candidate *Anacropora* species.

7.6.1 *Anacropora puertogalerae*

Additional Threat Information
In a recent study, *A. puertogalerae* was ranked among the top 30 most endangered coral lineages at number 18 (Huang 2012).

7.7.1 *Astreopora cucullata*

U.S. Distribution
From the SRR:
A search of published and unpublished records of occurrence in U.S. waters indicates Astreopora cucullata has been reported from Tutuila, Ofu-Olosega, Ta'u, and Rose Atoll in American Samoa (Birkeland, unpubl. data; Coles et al., 2003; CRED, unpubl. data; Kenyon et al., 2010a; Lamberts, 1983; Maragos et al., 1994).

Specimens identified as *A. cucullata* were recorded during recent surveys on Guam carried out by HDR EOC and CSA International (David Burdick, personal comm.) Additionally, the type location in American Samoa for *A. cucullata* is Aua, in the harbor, Tutuila, American Samoa. (Fenner, personal comm.).

Abundance
From the SRR:
Abundance of *Astreopora cucullata* has been reported as rare (Veron, 2000).

Additional information supports the BRT's characterization of "rare" for *A. cucullata*. This species was only found in 10-20% of sites in Indonesian national park surveys - e.g., 10 of 51 sites (Donnelly et al. 2003) and 4 of 39 sites (Turak and DeVantier 2003). However, at some American Samoa sites, this species is very common, e.g., 5th or 6th most common reef-building species (Fenner 2008).

7.8.1 *Isopora crateriformis*

Abundance/Habitat

From the SRR:

Abundance of Isopora crateriformis has been reported as sometimes common and occasionally locally abundant. Isopora crateriformis has been reported as common in Indonesia (Veron, 2000) and as one of the most prevalent corals in American Samoa (Birkeland, 1987).

Further, it is one of the most common species on upper reef slopes in the SW area of Tutuila (Fenner, personal comm.)

7.8.2 *Isopora cuneata*

U.S. Distribution

From the SRR:

A search of published and unpublished records of occurrence in U.S. waters indicates Isopora cuneata has been reported from Tutuila and Ofu-Olosega in American Samoa (Birkeland, unpubl. data; Coles et al., 2003; CRED, unpubl. data; Lovell and McLardy, 2008; Maragos et al., 1994; National Park Service, 2009), and Palmyra Atoll (Williams et al., 2008b).

In Veron (2000) (Volume 1, page 185) the distribution map for this species includes a photo taken by Gustav Paulay labeled "Guam." However, G. Paulay (Univ. of Florida, Gainesville, FL, pers. comm., 28 February 2010) indicates a number of photos submitted by him to Veron from Palau, the Cook Islands, and other locations in the Pacific were mistakenly attributed to Guam (similar to the errata later acknowledged by Veron (2002) for *Acanthastrea regularis* and *Porites napopora*). Consequently, there are no substantiated records of its occurrence in the Mariana Archipelago.

Recent reports confirm *Isopora cuneata*'s occurrence in the CNMI. It is found within the CNMI coral skeleton collection (Steve McKagan, personal comm.) Additionally, *I. cuneata* can readily be confused with encrusting colonies of *I. palifera*, a species which is found in Guam's waters. Thus, the occurrence of *I. cuneata* may have been overlooked in the Marianas as it has been lumped with *I. palifera* (David Burdick, personal comm.)

Additional Threat Info:

I. cuneata has been ranked in the top 30 most endangered coral lineages at #26 (Huang 2012).

7.9 Genus Montipora

Taxonomic Issues

From the SRR:

"Taxonomy within the genus Montipora has long been challenging, with species designations based largely on the arrangement and size of protrusions between corallites (e.g., "papillae" are smaller than corallites while "verrucae" are larger) and by colony form (laminar, encrusting, massive, and branching);"

Though there were some questions and comments submitted as to the validity of the lumping of some of the candidate *Montipora spp.* (e.g., *Montipora dilitata/flabellata/turgescens* and *Montipora patula/verrilli*), e.g., by the State of Hawaii. However, we did not receive new information that would reverse the BRT's species determinations, as described in more detail below in the species sections.

Depth Range
From the SRR:
The depth ranges for the candidate Montipora species were reported between 1-20 meters according to Carpenter et al. 2008.

Several new reports indicate that the lower depth range for some unidentified *Montipora* spp. is deeper than previously thought in some locations (46 m, unidentified *Montipora* species on Tutuila (Bare et al. 2010); 55 m, unidentified *Montipora* species in Hawaii (Rooney et al. 2010); 55 – 70 m, 3 species on GBR (Bridge et al. 2012)). However, no new species-specific information was found for any of the candidate *Montipora* spp.

7.9.1 *Montipora angulata*

Abundance/Habitat
Rare in parts of its range at shallow depths, but likely more common in deeper areas. Uncommon in parts of its range, e.g. reported at 3 of 7 study sites in Vietnam (Latypov 2011).

7.9.2 *Montipora australiensis*

Abundance/Habitat
Rare in parts of its range at shallow depths, but likely more common in deeper areas. Uncommon in parts of its range, e.g. reported at 4 of 7 study sites in Vietnam (Latypov 2011).

7.9.3 *Montipora calcarea*

Abundance/Habitat
Rare in parts of its range at shallow depths, but likely more common in deeper areas. Uncommon in parts of its range, e.g. reported at 8 of 51 sites (Donnelly et al. 2003) and 9 of 39 sites (Turak & DeVantier 2003) in Indonesian national park surveys.

7.9.4 *Montipora caliculata*

U.S. Distribution
In addition to the federally protected areas in the SRR, *M. caliculata* has also been recently reported from the War in the Pacific National Historic Park in Guam and from two survey sites just outside of the Orote Point ERA (HDR EOC and CSA International 2011b). *M caliculata* is also likely to occur in the Haputo ERA and Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat
Consistent with the information provided in the status report (based on information presented in Veron 2000), *M. caliculata* appears to be found in a variety of reef environments on Guam, from high-energy reef channel and buttress zones and shallow reef terraces to embayment reefs and deeper seaward reef slopes to at least 20 m (David Burdick, personal comm.)

Uncommon to common in parts of its range, e.g. reported at 5 of 7 study sites in Vietnam (Latypov 2011), and 10 of 51 sites in Indonesia (Donnelly et al. 2003).

7.9.5 *Montipora dilitata*, *Montipora flabellata*, and *Montipora turgescens*

Taxonomic Issues
From the SRR:

"Given that the best available information indicates a lack of discernible genetic differentiation, a lack of distinction in microskeletal morphology, and considerable potential for phenotypic plasticity in color, colony growth form, and skeletal structures, the BRT has chosen to evaluate extinction risk for these respective clades (i.e., Montipora dilitata/flabellata/turgescens) rather than the nominal species."

The State of Hawaii disagrees with the BRT's determination to lump *Montipora dilitata* with *M. flabellata* and *M. turgescens*, stating that in Veron's landmark series Corals of the World (Veron 2000), *M. dilitata* is described as found only in Hawaii and rare in occurrence. Additionally the State states that the species is only reliably known from Kaneohe Bay, on the island of Oahu, Hawaii, and that other reports of its occurrence elsewhere have been discredited or determined to be a misidentification of similar *Montipora* species. The State says it therefore represents a highly restricted species with unique habitat requirements. The state continues by stating: "There remains uncertainty about the distinct species differentiation. While the rarest type, *M. dilitata* appears to be a separate species, *M. flabellata* is an endemic to Hawaii and common throughout the archipelago. The decision to include *M. flabellata* with the other two (*M. dilitata* a potentially rare species, and *M. turgescens*, found only in the northernmost end of the PMNM and in the Indo-Pacific region) is not supported by the evidence without further resolution of the species differentiation issue. By combining a common endemic with a potentially rare species, NOAA expands the affected areas while judging the extinction risk of one based on its very limited geographic location. *M. turgescens* gives the group international status and subjects all three species to global threat factors that are simply not applicable to Hawaii. There is inadequate evidence to support combining three species into a single taxonomic unit. NOAA's use of the genetic study's findings must be weighed in terms of other existing taxonomic determinations. Those other studies suggest otherwise (Fenner 2005, Maragos & Gulko 2002, Veron 2000). Furthermore Dr. Forsman's research on the genetic distinction between the three species is flawed. The time scale he employed is too long to determine the differences that may have evolved on a substantially shorter time scale. Hawaii coral species may have evolved within the last 10,000 years. Dr. Forsman's research (on detectable genetic differences) may be two orders of magnitude greater. Thus, the 'marker' he used to determine species would not differentiate adaptation and changes within the geologic life span of corals in Hawaii."

Abundance/Habitat

From the SRR:

The nominal Montipora dilitata is extremely rare while Montipora flabellata is the fifth most common coral in Hawai`i (statewide average 2.2% cover; http://cramp.wcc.hawaii.edu/LT_Montoring_files/Coral_Species.htm). There have likely been declines in these nominal species over the recent past, particularly Montipora dilitata (http://www.nmfs.noaa.gov/pr/pdfs/species/hawaiianreefcoral_detailed.pdf). However, the nominal Montipora turgescens is described as widespread and common and no evidence of overall declines has been found.

However, one commenter asserts that the statement in the SRR that the species has declined in abundance on certain HI transects cannot be interpreted as evidence of overall decline in abundance, because the transects were not adequately distributed across the species range. It's quite plausible that the species increased in other parts of the range not covered by the transects. (S. Kahng, personal comm.)

7.9.6 *Montipora lobulata*

U.S. Distribution

In addition to occurring in the federally protected areas listed for this species in the SRR, M. lobulata may also occur within the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat
Rare in parts of its range at shallow depths, but likely more common in deeper areas. Uncommon in at least the western portion of its range, e.g. reported at 6 of 24 study sites across the Indian Ocean (Sheppard 1987), and recorded as "uncommon" in the Red Sea (Perkol-Finkel & Benayahu 2004).

7.9.7 *Montipora patula (/verrili)*

Taxonomy
From the SRR:
"Given results of recent genetic and micro-morphological analyses, the BRT has chosen to evaluate extinction risk of Montipora patula/verrilli as a single unit since they are indistinguishable genetically and micro-morphologically (Forsman et al., 2010)."

Comments from the State of Hawaii state that these species should be evaluated separately. However, although some people claim to be able to distinguish these two species, Fenner (2005) considered *M. verrili* to be a doubtful species because no one seems to be able to describe a consistent difference between these two species.

U.S. Distribution
Steve McKagan (personal comm.) confirms the presence of *M. patula* in the CNMI.

Depth Range
From the SRR:
"IUCN describes both these nominal species as restricted to shallow reef flats, up to 10 m. However, Kuhlmann (1983) describes Montipora verrilli as occurring up to 40 m, including a photo at 25-m depth. This suggests the potential for deep refugia."

It [*M. patula*] is commonly observed deeper than 10m almost anywhere you dive in Hawaii. This issue points to a larger flaw in the report methodology that interprets these reported depths as habitat boundaries. There is no known or conceivable physical or ecological process that would restrict any zooxanthellate coral in Hawaii to depths above 10m (Samuel Kahng, personal comm.)

Abundance/Habitat
From the SRR:
"Dollar and Grigg (Dollar and Grigg, 2004) show substantial declines of Montipora patula on a subset of their transects over 12 years, but other transects within sites show high variability between surveys and/or similar cover between the beginning and end of the study."

From the state of Hawaii (DLNR): Two (2) species, *Montipora patula* and *M. verrilli* have been combined into one unit for the purposes of this review and assessment. Although common throughout the Hawaiian archipelago, they are not as widespread in the Indo-Pacific region. Nonetheless, they are found throughout reserve areas, the PMNM, and Johnston, Palmyra, and Kingman reefs marine national monuments. *Montipora patula* is a common species. It is listed as the 4th most common species in Hawaii. It occurs throughout the Hawaiian archipelago. It is a common species and has a sufficient geographic range (PMNM + main Hawaiian islands) to reduce the extinction risk. Finally, these two species must be evaluated separately.

However, one commenter asserts that the statement in the SRR that the species has declined in abundance on certain HI transects cannot be interpreted as evidence of overall decline in abundance, because the transects were were not adequately distributed across the species range. It's quite plausible that the species increased in other parts of the range not covered by the transects. (S. Kahng, personal comm.) Additionally, Fenner (2005) reports *M. patula* as dominant in Hawaii.

Additional Threat Information:
From the SRR:
Factors that increase the potential extinction risk (higher likelihood of falling below the Critical Risk Threshold) for Montipora patula/verrilli include its… generic high susceptibility to a range of threats (bleaching, predation) and documented species-specific impacts from disease.

According to the state of Hawaii's Department of Land and Natural Resources, *Montipora* can withstand degraded environmental conditions and may be found deeper than what has been reported. The DLNR asserts that this depth range mitigates against the risk of bleaching and disease, and that this information was not addressed in the risk assessment. (See above for generic information regarding *Montipora* and new information regarding depth distribution).

7.10 Genus *Alveopora*

Depth Range:
From the SRR:
The depth range for the candidate species in the genus Alveopora mostly relied on reports from Carpenter et al. 2008 (among a couple others).

The lower depth limit of some of these species may reach up to 80 m, as reported by Kuhlmann (1983) for *A. verrilliana* in the Society Islands.

Additional Threat Info:
Disease susceptibility is unknown for *Alveopora* species, but other species in the family (e.g., Porites species) have high to moderate susceptibility to disease, and the family Poritidae has moderate prevalence to disease (Ruiz-Moreno et al. 2012).

7.10.1 *Alveopora allingi*

U.S. Distribution
The type location of *Alveopora allingi* in American Samoa, is Pago Pago harbor, Tutuila,. (Doug Fenner, personal comm.)

In addition to the federally protected areas listed for this species in the SRR, *A. allingi* may also occur within the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.10.2. *Alveopora fenestrata*

U.S. Distribution

From the SRR:

"According to the IUCN Species Account, Alveopora fenestrata occurs in the Northern Mariana Islands. The CITES database does not list its occurrence in U.S. waters. A search of published and unpublished records of occurrence in U.S. waters indicates Alveopora fenestrata has been reported from Guam (Randall, 2003). Alveopora fenestrata has not been recorded from federally protected waters."

A. fenestrata has been confirmed from the CNMI (Steve McKagan, personal comm.)

Although the SRR reports that *A. fenestrata* has not been reported from any federally protected waters, *A. fenestrata* may occur within the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.10.3 *Alveopora verriliana*

U.S. Distribution

In addition to occurring in the federally protected areas listed in the SRR, this species also may occur within the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.11 Genus *Porites*

Depth Range

From the SRR:

"The SRR predominantly relied on depth distribution information from Carpenter et al. 2008."

In a recent study by Bridge et al. 2012, two *Porites spp.* were found up to depths of 55-70 meters on the Great Barrier Reef. Thus, the lower depth range for the genus may be deeper than previously thought in some locations for some species. However, no new species-specific information was found for any of the candidate *Porites spp.*

Additional Threat Info:

From the SRR:

"Medium number of genus level disease reports of subacute (lesions resulting in slow progressive tissue loss) tissue loss, black band disease, and endolithis hypermycosis (UNEP, 2010)."

Myers and Raymundo 2009 found that the genus *Porites* had the highest prevalence of disease throughout Guam; however, it may have also been a function of the fact that portiid corals are also the most common. Likewise, in a study from Hawaii, with twelve diseases recorded among three coral genera, *Porites* was shown to have the highest prevalence of disease (Aeby et al. 2011). *Porites* was also shown to have severe damage as a result of high disease prevalence in a study conducted in Southeastern India that focuses on black-band disease (Thinesh et al. 2011).

7.11.1 *Porites horizontalata*

U.S. Distribution

In addition to occurring in the federally protected areas listed for this species in the SRR, this species also has been reported from the waters of the War in the Pacific NHP (HDR EOC and CSA International

2011b). *P. horizontalata* may also occur within the waters of the Marianas Trench MNM, the Haputo ERA, the Orote Point ERA, and Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.)

Abundance/Habitat:
From the SRR:
"Porites horizontalata has been reported to occupy shallow reef environments (Veron, 2000)."

According to Randall and Burdick (in prep), *P. horizontalata* is uncommon in most habitats (in Guam), generally occurring as widely scattered isolated colonies; however, the species may be locally abundant and form monotypic patches ten more [sic] across, particularly in Apra Harbor lagoon habitats. Colonies are most commonly observed in deeper quieter waters of fringing reef channels, barrier reef channels, Apra Harbor Lagoon, and seaward reef slope zones, particularly along the southwest coast.

7.11.4 *Porites pukoensis*

Characteristics
D. Fenner: Characteristics should include that the skeleton is hard and when hit produces a ringing sound (D. Potts, personal comm.)
Taxonomy
From the SRR:
"Porites is known to be morphologically plastic and multiple sympatric species frequently exhibit intergradation of skeletal characteristics. Only limited molecular genetic analysis has been performed on the Porites so far. In the most comprehensive, Forsman et al. (2009) identified inseparable clades that contain multiple morphological species, in some cases, with morphological species that span more than one clade. This is a particular issue for Porites pukoensis as it is morphologically very similar to Porites compressa and Porites lobata that are both part of genetic Clade 1. However, no live Porites pukoensis could be found for genetic analysis. According to Veron (2000), Porites pukoensis is similar to Porites evermanni, which lacks denticles at the bases of septa. See also Porites nodifera (Veron 2000). However, according to the original description, it may be indistinguishable from forms of Porites lobata and Porites compressa (Vaughan, 1907).

After consultation with experts and key taxonomic references, including the most recent molecular analysis (Forsman et al., 2009) and the original species description (Vaughan, 1907), it was concluded by the BRT that Porites pukoensis does not represent a separate, rare species."

The State of Hawaii asserts that since genetic testing can't be performed because live specimens cannot be located, *P. pukoensis* should not be considered for listing until the species classification, and the range and status are resolved.

U.S. Distribution
From the SRR:
"A search of published and unpublished records of occurrence in U.S. waters indicates Porites pukoensis has been reported from Tutuila in American Samoa (Hoffmeister, 1925; Lamberts, 1983), Hawai`i (Veron, 2000), and Kingman Reef (CRED, unpubl. data). Porites pukoensis was not been found during recent searches conducted from a reef near Pūko'o, Molokai'i (Z. Forsman, Hawai`i Institute of Marine Biology, Kāne`ohe, HI; E. Brown, marine biologist, National Park Service, Kalaupapa, HI, pers. comm., 21 September 2010)."

The type location for *Porites pukoensis* is Puako, south side of Molokai. So whether it is a valid species or synonym, it was there in 1907. Don Potts and Cindy Hunter found it there some years ago, and the pictures in Veron (2000) and which are reproduced in the SRR are Don's, which he took there. Cindy Hunter, Zac Foresman, and Doug Fenner spent an afternoon trying to find the colonies recently, but were unsuccessful, likely due to searching in the wrong location. Records from other locations have not been substantiated with photos of the living colonies and skeletal samples examined by Veron or Potts (Doug Fenner, personal comm.)

7.12 Genus *Psammocora*

Additional Threat Info:

Disease susceptibility is unknown for for Psammocora species, but disease prevalence for Siderastreidae in Pacific is low (Ruiz-Moreno et al. 2012).

7.12.1 *Psammocora stellata*

Depth Range:

From the SRR:

"Psammocora stellata has been reported at depths ranging from 0 m to 20 m (Carpenter et al., 2008)."

In a more recent study, some unidentified *Psammocora* species have been found at >40 m for (Kahng et al. 2010); however, no new species-specific information was found for *P. stellata.*

Abundance/Habitat

From the SRR:

"Psammocora stellata has been reported to occupy shallow wave-washed rock (Veron, 2000). In the eastern Pacific, it is also found on rubble bottoms adjacent to reefs (Feingold, 1996)."

Fenner (2005) reports that in Hawaii, *P. stellata* lives in light to moderate surge in 1-4 feet depth. According to Randall and Burdick (in prep) *P. stellata* is a common to locally abundant species that is mostly restricted to shallow backreef moats that are cut off from open water at low tide, and on shallow lagoon terraces in water generally less than 3 m deep. Additional remarks: In addition to occurring in the federally protected areas listed for this species in the SRR, *P. stellata* has been recorded from the waters of the War in the Pacific NHP (Burdick unpubl data). It also may occur within the waters of the Marianas Trench MNM, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrences in these areas require confirmation) (David Burdick, personal comm.).

7.13 Genus *Leptoseris*

Taxonomic issues:

From the SRR:

No taxonomic issues were reported.

However, the Western Pacific Regional Fisheries Management Council (WPRFMC) provided additional information regarding potential taxonomic issues related to the genus *Leptoseris*. A recent study of the genus *Leptoseris* in Hawaii tested the accuracy of the known conventional species boundaries of this genus using both morphometric and molecular techniques (Luck 2012). The goal of the study was to improve the consistency of species identification across the genus' full depth range. Results showed that the Hawaiian *Leptoseris* spp. have morphs previously unknown to science, providing evidence for morphological plasticity of this species across an environmental gradient. Such plasticity is common to most corals and presents a management challenge, as accurate species identification is a basic requirement in determining and monitoring population status, understanding threats and impacts, developing management strategies, and assessing recovery.

7.13.1 *Leptoseris incrustans*

U.S. Distribution

In addition to occurring in the federally protected areas listed for this species in the SRR, it is likely to occur in the waters of the War in the Pacific NHP, the Marianas Trench MNM, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although it occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat

From the SRR:

"Leptoseris incrustans inhabits shallow reef environments (Veron, 2000)."

According to Randall and Burdick (in prep) *L. incrustans* is the most common and widespread Leptoseris species in Guam's waters. This species can be found in every reef and lagoon habitat except in low tide moats of water on reef flat platforms. It is particularly common in cavernous and cryptic regions of the reef margin, and on scarp wall and overhanging ledge habitats, and deep seaward reef slopes.

7.13.2 *Leptoseris yabei*

Depth Range

From the SRR:

"Leptoseris yabei has been reported at water depths ranging from 3 m to 50 m (Carpenter et al., 2008; Kahng et al., 2010; Kahng and Kelley, 2007; Kahng and Maragos, 2006; Rooney et al., 2010). This species has been reported as a dominant one in mesophotic reefs in Hawai`i (Kahng and Maragos, 2006), suggesting potential deep refugia. However, preliminary genetic work indicates there is likely unresolved taxonomic diversity among these deepwater Leptoseris (Chan et al., 2009) indicating that the species identification of Leptoseris yabei within these mesophotic reef communities is problematic."

A new report confirms *L. yabei* from 74 m in HI (Dineson et al. 2012). As noted in the SRR information, this species is thought to occur to at least 90 m, but the SRR mentioned doubt with regard to species ID. However, Dineson provides a verified ID of a colony from 74 m. Additionally, the Kahng and Maragos 2006 study confirmed deep-water habitat for *Leptoseris yabei* and confirmed its high abundance as a dominant player on mesophotic reefs in Hawaii. Chan et al. 2009 did not address morphology or identify any species so no implications with respect to *L. yabei* can be inferred. The deep-water specimens reported in Kahng and Maragos 2006 were identified as *L. yabei* as it is currently defined in the peer-reviewed published literature based on morphology. This identification was directly verified by Charlie Veron (S. Kahng, personal comm.).

U.S. Distribution

Initial examination by R.H. Randall of images of various species of *Leptoseris* taken by the BSP-GCMP biologist yielded at least one *Leptoseris* specimen from Guam that is more consistent with *L. yabei* than its similar congener*, L. mycetoseroides* (Randall pers comm.). Further confirmation is required before the range of this species is extended to Marianas Islands, but the possibility of occurrence in Guam should be noted (David Burdick, personal comm.) However, this species has been confirmed in the CNMI (Steve McKagan, personal comm.) In addition to the federally protected waters listed in the SRR, L. yabei also occurs in the Hawaiian Islands Humpback Whale National Marine Sanctuary in the Au'au Channel as reported by Kahng and Maragos 2006.

Habitat/Abundance
From the SRR:
Abundance of Leptoseris yabei has been reported as uncommon but conspicuous (Veron, 2000).

Kahng and Maragos (2006) report *L. yabei* being very abundant in Hawaii.

7.14 Genus Pachyseris

Depth Range
From the SRR:
"Pachyseris rugosa has been reported in water depths ranging from 5 m to 20 m (Carpenter et al., 2008). The species may be excluded from shallow waters due to excess light (Titlyanov and Latypov, 1991)."

Unidentified *Pachyseris* species from around Tutuila, American Samoa were reported at depths between 50-70 m (Bare et al. 2010). Additionally, Bridge et al. 2012 reports congener *P. speciosa* from the Great Barrier Reef at depths between 55-60 m. Thus the lower depth distribution for some *Pachyseris spp.* is potentially between 50-70 m; however, no new species-specific information was found for *Pachyseris rugosa.*

7.14.1 *Pachyseris rugosa*

No new information was received or found specifically for *P. rugosa.*

7.15 Genus *Pavona*

Depth Range
From the SRR:
Depth distributions for all of the Pavona species were reported by Carpenter et al. 2008 in the SRR.

A new report from the Great Barrier Reef reported *P. minuta* at 55 m (Bridge et al. 2012). Additionally, unidentified *Pavona spp*. were reported in Hawaii at 73 m (Luck 2012). This new information on depth distributions for various *Pavona spp*. indicates a potential lower depth range for the genus in some locations between 55-70 m. However, no new species-specific information was found for any of the candidate *Pavona spp.*

Susceptibility to Ocean Warming
Unknown for most Pavona species, but Pavona species have been consistently resistant to bleaching in field observations in the South Pacific (Penin et al. 2012), the Great Barrier Reef, and the Indian Ocean (McClanahan et al. 2004), as well as in laboratory experiments (Hill et al. 2012).

7.15.1 *Pavona bipartita*

Taxonomic issues
One comment states: "Veron may say that *Pavona bipartita* is similar to *P. duerdeni*, but it is not clear why he says that. In fact *P. duerdeni* has larger, porkchop-shaped (very short cylinders on edge) colony morphology which is quite different from *P. bipartita*, and the corallites are much smaller than on *P. bipartita*. The corallites of *P. bipartita* are nearly indistinguishable from *Pavona clavus*, though the

colony morphology is quite different, and *P. clavus* does not have the slightly raised ridges between corallites" (Doug Fenner, personal comm.).

Additionally, while this species was previously considered by Dick Randall to be a shallow water form of *P. clavus*, *P. bipartita* will now be considered separate from *P. clavus* in his upcoming publication (Randall and Burdick in prep.).

U.S. Distribution

In addition to occurring in the federally protected areas listed for this species in the SRR, *P. bipartita* also may occur in the waters of the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and Ritidian NWR (although the occurrences in these areas require confirmation) (David Burdick, personal comm.).

Abundance/Habitat:

From the SRR:

"Pavona bipartita has been reported to occupy shallow reef environments (Veron, 2000)."

In Guam, only a handful of *P. bipartita* colonies have been encountered, all of which were found on the sides of channels in high energy reef front environments (David Burdick, personal comm.).

7.15.2 *Pavona cactus*

Taxonomic Issues

According to comments submitted by Doug Fenner, only on rare occasions do *P. frondifera* colonies resemble *P. cactus*, and the corallites are quite different. *P. cactus* has thin smooth fronds that are separated from each other, P. frondifera almost always has thicker blades which intersect and are fused together, and short. *P. cactus* has tiny corallites and tiny septocostae, while *P. frondifera* has much larger corallites and septocostae. *P. frondifera* actually resembles *Leptoseris amatoriensis* much more closely, since *L. amatoriensis* has thin plates, tiny corallites that are essentially identical to those on P. cactus, and tiny septocostae that are essentially identical to those on P. cactus. However, the colony morphology on *L. amatoriensis* is a series of small plates in whorls, and the corallites and septocostae are on only the upper surface, instead of being bifacial like *P. cactus.*

U.S. Distribution

From the SRR:

"According to both the IUCN Species Account and the CITES species database, Pavona cactus occurs in American Samoa. The IUCN Species Account also lists its occurrence in the Northern Mariana Islands and the U.S. minor outlying islands. A search of published and unpublished records of occurrence in U.S. waters indicates Pavona cactus has been reported from Ofu-Olosega in American Samoa (Lovell and McLardy, 2008; National Park Service, 2009), Guam (Burdick, unpubl. data; Randall, 2003) and Palmyra Atoll (Williams et al., 2008b)."

Pavona cactus has been confirmed in the CNMI (Steve McKagan, personal comm.). In addition to occurring in the federally protected areas listed for this species in the SRR, *P. cactus* may also occur in the waters of the Marianas Trench MNM, the War in the Pacific NHP, and Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although occurrences in these areas require confirmation).

Abundance/Habitat:

From the SRR:

"Pavona cactus is usually found in lagoons and on upper reef slopes, especially those of fringing reefs, and in turbid waters protected from wave action, where colonies are sometimes greater than 10 meters across (Veron, 2000)."

According to Randall and Burdick (in prep), *P. cactus* is common to locally abundant in deeper protected seaward slope habitats, fringing embayment reefs, and lagoon habitats. In the lagoon floor of Apra Harbor *P. cactus* commonly form large monospecific thickets meters in extent. This species appears to be tolerant of fairly turbid water conditions.

Additional Threat Info:
P. cactus was ranked in top 30 most endangered coral lineages at #17 (Huang 2012).

7.15.3 *Pavona decussata*

U.S. Distribution
From the SRR:
"According to both the IUCN Species Account and the CITES species database, Pavona decussata occurs in American Samoa and the Northern Mariana Islands. The IUCN Species Account also lists its occurrence in the U.S. minor outlying islands.
A search of published and unpublished records of occurrence in U.S. waters indicates Pavona decussata has been reported from Tutuila and Ofu-Olosega in American Samoa (Birkeland, unpubl. data; Coles et al., 2003; Hoffmeister, 1925; Lamberts, 1983; Lovell and McLardy, 2008; Maragos et al., 1994; Mundy, 1996; National Park Service, 2009) and Guam (Amesbury et al., 1999; Burdick, unpubl. data; Randall, 2003). No substantiated published or unpublished record of its occurrence in the U.S. minor outlying islands could be identified."

Pavona decussata has been confirmed from the CNMI (Steve McKagan, personal comm.). In addition to occurring in the federally protected areas listed for this species in the SRR, it also may occur in the waters of the Marianas trench MNM, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrences in these areas require confirmation) (David Burdick, personal comm.).

Susceptibility to Ocean Warming

P. decussata was highly resistant to bleaching in laboratory experiments (Hill et al. 2012).

7.15.4 *Pavona diffluens*

Taxonomic Issues:
From the SRR:
"None. Pavona diffluens is similar to Pavona gigantea, which forms massive colonies, and Pavona explanulata, which has a laminar growth-form and corallites with less exsert primary septa (Veron, 2000)."

The taxonomy is secure; however, this is a species that is not well known by taxonomists working outside of the Red Sea, and thus may not be recognized (Doug Fenner, personal comm.).

Global Distribution
From the SRR:

"Pavona diffluens has a very narrow distribution, both latitudinal and longitudinal. It is only found in the region of the Red Sea and Arabian Gulf according to Veron (Veron, 2000) but Carpenter et al. (Carpenter et al., 2008) also record it in the Northern Marianas and American Samoa."

According to the updated range map for *P. diffluens*, it also occurs in the western Indian Ocean and several parts of the Coral Triangle (as shown on the Corals of the World website http://coral.aims.gov.au/speciesPages/).

U.S. Distribution
From the SRR:
"According to the IUCN Species Account, Pavona diffluens has been recorded in the Northern Mariana Islands, but the records (Randall, 1995) are considered unlikely."

Pavona diffluens has been confirmed from the CNMI (Steve McKagan, personal comm.). In addition to occurring in the federally protected areas listed for this species in the SRR, it also may occur in the waters of the Mariana Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

Abundance/Habitat:
From the SRR:
"Pavona diffluens has been reported to be found in most reef habitats (Veron, 2000)."

According to Randall and Burdick (in prep), *P. diffluens* is a rare to uncommon species in Guam's waters; this species is widespread around the island, but is most commonly encountered on the seaward slope habitats where there is good water circulation.

7.15.5 *Pavona venosa*

U.S. Distribution
Pavona venosa has been confirmed in the CNMI (Steve McKagan, personal comm.). In addition to occurring in the federally protected areas listed for this species in the SRR, it also may occur in the waters of the Marianas Trench MNM, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrences in these areas requires confirmation)(David Burdick, personal comm.).

Abundance/Habitat:
From the SRR:
Abundance of Pavona venosa has been reported to be usually uncommon but distinctive (Veron, 2000).

According to Randall and Burdick (in prep) *P. venosa* is an uncommon to common species in Guam's waters; this species has a widespread distribution around the island, but is most commonly encountered on the upper seaward reef slope, reef margin, reef flat platform, fringing embayment reef, and lagoon habitats where there is good water circulation.

7.16 Genus *Galaxea*

Additional Threat Info:
Disease susceptibility is unknown for *Galaxea* species, but disease prevalence for Oculinidae in the Pacific is low (Ruiz-Moreno et al. 2012).

7.16.1 *Galaxea astreata*

Depth Range

From the SRR:

Galaxea astreata lives from low tide to at least 20 m, but typically range from water depths of 5 to 10 m.

A recent report documents *Galaxea astreata* from 55 m on the Great Barrier Reef (Bridge et al. 2012)

U.S. Distribution

From the SRR:

"…there are no substantiated records of its occurrence in the Mariana Archipelago."

This species had not been reported from Guam until recently, when specimens identified as G. astreata were recorded during recent surveys in Apra Harbor and at several sites outside the harbor (HDR EOC and CSA International 2011a, 2011b). The BSP-GCMP biologist has also observed a species consistent with *G. astreata* and has tentatively identified these specimens as G. cf. astreata. A colony of G. cf. astreata collected from Apra Harbor was recently provided to R.H. Randall for identification. The species identified as *G. astreata* by HDR EOC biologists and as G. cf. astreata by the BSP-GCMP biologist is [sic] indeed *G. astreata* has been recorded from the waters of the War in the Pacific NHP. This species may also occur in the waters of the Marianas Trench MNM, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (Although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.17 Genus *Pectinia*

Additional Threat Info:

Disease susceptibility is unknown for this genus, but the family Pectiniidae has high prevalence of disease in the Pacific (Ruiz-Moreno et al. 2012).

7.17.1 *Pectinia alcicornis*

Taxonomic issues

From the SRR:

None. Pectinia alcicornis is similar to Pectinia paeonia (Veron, 2000).

P. alcicornis and *P. paeonia*, a similar congener confirmed from Guam's waters, can exhibit highly similar colony growth forms and could easily be confused (David Burdick, personal comm.).

U.S. Distribution

From the SRR:

The IUCN lists this species in the Mariana Islands, but no supporting record is given. Veron (2000) also lists Pectinia alcicornis in the Marianas; however, the Marianas record may be based on geographic errors of photographic records (Kenyon et al., 2010b).

While *P. alcicornis* has not been recorded from Guam or elsewhere in the Mariana Islands as correctly noted in the SRR, specimens tentatively identified as P. alcicornis were recorded from Apra Harbor during recent surveys carried out by HDR EOC and CSA International (2011). It is possible that *P. alcicornis* has inadvertently been lumped with *P. paeonia*. As a result, an effort will be made by the

Guam BSP-GCMP biologist to obtain at least one specimen of colonies believed to be *P. alcicornis* to determine if this species does indeed occur in Guam's waters (David Burdick, personal comm.)

Additional Threat Info:
Results from Ruiz-Moreno et al (2012) suggest potentially higher susceptibility to disease for P. alcicornis than previously reported in the SRR.

7.18 Genus *Acanthastrea*

Additional Threat Info:
Disease susceptibility is unknown for this genus, but the Mussidae has moderate prevalence of disease (Ruiz-Moreno et al. 2012).

7.18.1 *Acanthastrea brevis*

Global Distribution
According to comments submitted by Doug Fenner, since this is a relatively new species, it will not be in older publications, and some workers have not yet learned to identify it. Thus, it may occur in more places than it has been reported so far.

U.S. Distribution
From the SRR:
"According to the IUCN Species Account, Acanthastrea brevis occurs in American Samoa and in the Commonwealth of the Northern Mariana Islands…no supporting reference is given in the IUCN Species Account for the stated record of occurrence in the Northern Mariana Islands."

Acanthastrea brevis has been confirmed in the CNMI (Steve McKagan, personal comm.). Additionally, this species has not been recorded from Guam or elsewhere in the Mariana Islands. As correctly noted in the SRR, the inclusion of the Mariana archipelago within the known distribution of this species in Veron (2000) is an error resulting from the misidentification of photographic records provided to Veron by G. Paulay. However, it should be noted that the BSP GCMP biologist has photographed a specimen from Guam's waters that is more consistent with *A. brevis* than its similar congener, *A. echinata*. Images of the specimen have been provided to R.H. Randall for tentative confirmation and the BSP-GCMP biologist is currently seeking to collect a specimen for further confirmation of the species' identification (David Burdick, personal comm.).

7.18.2 *Acanthastra hemprichii*

Global Distribution:
This species also occurs in the Republic of the Marshall Islands (Maragos, personal comm.).

7.18.3 *Acanthastrea ishigakiensis*

Taxonomic Issues
From the SRR:
None. Acanthastrea ishigakiensis is similar to Acanthastrea hillae, which has smaller corallites with a tendency to form valleys. It resembles Symphyllia erythraea underwater (Veron, 2000).

A comment submitted states that *Acanthastrea ishigakiensis* is also always massive, while *A. hillae* is encrusting. *A. ishigakiensis* is the only massive *Acanthastrea*, and it also has some of its corallites looking pinched (Doug Fenner, personal comm.).

U.S. Distribution
Until recently, this species has not been recorded from Guam or elsewhere in the Mariana Islands. As correctly noted in the SRR, the inclusion of the Mariana archipelago within the distribution of this species in Veron (2000) is likely an error resulting from the misidentification of photographic records provided to Veron by G. Paulay. However, *Acanthastrea ishigakiensis* is now being reported from the Marianas archipelago. (Randall and Burdick, in prep).

7.18.4 *Acanthastrea regularis*

U.S. Distribution
This species has not been recorded from Guam or elsewhere in the Mariana Islands. As correctly noted in the SRR, the inclusion of the Mariana archipelago within the distribution of this species in Veron (2000) is likely an error resulting from the misidentification of photographic records provided to Veron by G. Paulay. However, it should be noted that the BSP-GCMP biologist has photographed numerous specimens from Guam's waters that are highly consistent with *A. regularis* as described and depicted in Veron (2000). Images of the specimen have been provided to R. H. Randall for tentative confirmation and the BSP-GCMP biologist is currently seeking to collect a specimen for further confirmation of this species' identification (David Burdick, personal comm.).

7.19.1 *Barabattoia laddi*

Global Distribution
A recent report documents occurrence of *B. laddi* in the Maldives (Bigot & Amir 2009), the Nicobar & Andaman Islands (Venkataraman et al. 2012), and French Polynesia (updated range map on Corals of the World website http://coral.aims.gov.au/speciesPages/).

U.S. Distribution
From the SRR;
"According to both the IUCN Species Account and the CITES species database, Barabattoia laddi occurs in the Northern Mariana Islands. A search of published and unpublished records of occurrence in U.S. waters indicates Barabattoia laddi has been reported from Rose Atoll in American Samoa (Kenyon et al., 2010a) and Guam (Veron, 2000)."

New information indicates that *B. laddi* was mistakenly reported from the CNMI in the SRR. Personal communication with the local benthic experts (Peter Houk) indicated this coral is not found here but is found in other areas of Micronesia (Steve McKagan, personal comm.).

Additionally, this species has not been recorded from Guam or elsewhere in the Mariana Islands. The inclusion of the Mariana archipelago within the known distribution of this species in Veron (2000) is an error resulting from the misidentification of photographic records provided to Veron by G. Paulay.

Depth Range
From the SRR:
"Barabattoia laddi has been reported in water depths ranging from 0 m to 10 m (Carpenter et al., 2008)."

Surveys in the Maldives and Indonesia (Bigot & Amir 2009, Donnelly et al. 2003, Turak & DeVantier 2003) record the species at multiple sites >10 m.

7.20.1 *Caulastrea echinulata*

No new information was received or found specifically for *Caulastrea echinulata*.

7.21 Genus *Cyphastrea*

Depth Range
From the SRR:
"Cyphastrea agassizi has been reported in water depths from 3-20 m; Cyphastrea ocellina has been reported in water depths ranging from 5 m to 20 m (Carpenter et al., 2008)."

Bridge et al. (2012) reports unidentified *Cyphastrea* species from 55 m on the Great Barrier Reef; however, no new species-specific information was found for either of the candidate *Cyphastrea spp.*

7.21.1 *Cyphastrea agassizi*

Taxonomic Issues
This species is likely what R.H. Randall has been calling *Leptastrea bottae* (Randall and Myers 1983; Randall 2003), but further examination of collected specimens and the literature are required before this species would be synonomized with *C. agassizi* for the upcoming publication by Randall and Burdick (in prep).

Abundance/Habitat:
From the SRR:
Cyphastrea agassizi has been reported from shallow reef environments (Veron, 2000). The species is found in back slopes, fore slopes, lagoons, and outer reef channels (IUCN, 2010).

Leptastrea bottae, which may be changed to *C. agassizi* in the upcoming publication of Randall and Burdick (in prep), is a widely scattered to locally common species that occurs most abundantly on reef flat platforms and shallow lagoon terraces, becoming less common in the upper seaward reef slope habitat (Randall and Burdick in prep).

7.21.2 *Cyphastrea ocellina*

U.S. Distribution:
From the State of Hawaii (DLNR): *Cyphastrea ocellina* (Hawaiian) is as widely distributed as *C. agassizi*.

This species has not yet been reported from Guam's waters or from elsewhere in the Mariana Islands, as correctly noted in the SRR. However, specimens identified by R. H. Randall as *C. ocellina* have been collected from Guam's waters. This species will be reported from Guam's waters in the upcoming publication by Randall and Burdick (in prep). In addition to occurring in the federally protected areas listed for this species in the SRR, this species may also occur in the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation).

Abundance/Habitat:
From the SRR:
"*Cyphastrea ocellina* has been reported to occupy upper reef slopes (Veron, 2000). Stimson (1978) reported Cyphastrea ocellina in shallow water only—reef flats, tide pools, and vertical rock in turbid shallow water. Wright (1986) reported that Cyphastrea ocellina typically colonizes dead substrate. According to an IUCN Red List report, the species is found on shallow upper reef slopes, lagoons, and

outer channels (IUCN, 2010). Jokiel et al. (2007) reported the species on reef flats, reef crest, and fore reefs."

According to Randall and Burdick (in prep), all *C. ocellina* colonies from Mariana waters were collected on seaward or embayment reef slope zones between 2 and 22 meters depth and on the upper platform surface of Galvez Bank at 43 m depth.

Additional threat info:
From the SRR:
"In Hawai`i Cyphastrea ocellina contains Clade C1 zooxanthellae (Thornhill, 2003), which may be relatively bleaching-tolerant (Smith et al., 2004b)."

Comments from the State of Hawaii (DLNR) support the notion that *Cyphastrea ocellina* resists bleaching.

7.22 Genus *Euphyllia*

Additional Threat Info:
Disease susceptibility is unknown for this genus, but the family Euphyllidae has low disease prevalence (Ruiz-Moreno et al. 2012).

7.22.1 *Euphyllia cristata*

U.S. Distribution
From the SRR:
"According to the IUCN Species Account, Euphyllia cristata occurs in American Samoa and the Northern Mariana Islands. The CITES database does not list its occurrence in U.S. waters. A search of published and unpublished records of occurrence in U.S. waters indicates Euphyllia cristata has been reported from Tutuila in American Samoa (CRED, unpubl. data) and Guam (Randall, 2003)."

E. cristata has been confirmed from the CNMI (Steve McKagan, personal comm.).

In addition to occurring in the federally protected areas listed for this species in the SRR, it also may occur in the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas requires confirmation) (David Burdick, personal comm.).

7.22.2 *Euphyllia paraancora*

U.S. Distribution
As noted in the SRR, this species has been reported from Guam's waters (Burdick unpubl data). This occurrence of the species in Guam's waters has not been reported in any published literature, but it will likely be included in Randall and Burdick (in prep). In addition to occurring in the federally protected areas listed for this species in the SRR, it may also occur in the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrences in these areas requires confirmation) (David Burdick, personal comm.).

Depth Distribution:
From the SRR:
Euphyllia paraancora has been reported in water depths ranging from 3 m to 30 m (Carpenter et al. 2008).

This species is recorded at 70 m in great abundance in Rooney 2012, which increases this species' lower depth range.

Abundance/Habitat:

From the SRR:

"Euphyllia paraancora has been reported from shallow and deep reef environments protected from wave action (Veron, 2000)."

The handful of colonies observed by the BSP-GCMP biologist have been found in fairly turbid environments along the east coast of Guam, primarily along the sides of embayment reefs at depths of about 2 to at least 20 m.

7.22.3 *Euphyllia paradivisa*

There was no new information received or found specifically for *Euphyllia paradivisa*.

7.23 Genus *Physogyra*

Additional Threat Info:

Disease susceptibility is unknown for this genus, but the family Euphyllidae has low disease prevalence (Ruiz-Moreno et al. 2012).

7.23.1 *Physogyra lichtensteini*

Habitat

From the SRR:

"Physogyra lichtensteini has been reported to occupy turbid reef environments (Veron, 2000). The species is common in protected habitats (crevices and overhangs), especially in turbid water with tidal currents (Veron, 2000). Physogyra lichtensteini is also reported to be a caverniculous species that prefers shallow but shaded waters, and it is found in caves on the Great Barrier Reef (Dinesen, 1982)".

Physogyra lichtensteinii may be in turbid environments, but it is also known to occur in clear water (Fenner personal comm.).

Additional Threat Info:

As noted in the SRR, based on observations in the Indian Ocean, McClanahan et al. (2007) identified *Physogyra lichtensteini* as vulnerable to extinction due to its high bleaching rate, low diversity of its genus, and limitation to turbid and shaded habitats. However, observations of *P. lichtensteini* in the Pacific during and after the 2010 bleaching event indicated that *Physogyra* species were highly resistant to bleaching in Singapore (Tun et al. 2010) and Indonesia (Wilson et al. 2012). In the Indonesia study, 94 percent of *Physogyra* colonies (species not identified) were unaffected by the bleaching event, and the genus was rated as "resistant" (Wilson et al. 2012). However, it was recently ranked in the top 30 most endangered coral lineages at #27 (Huang 2012). Thus, overall, *P. lichtensteini's* response to ocean warming is variable, but generally the species has been observed to have high bleaching rates.

7.24 Genus *Turbinaria*

7.24.1 *Turbinaria mesenterina*

Taxonomic Issues

Although there may be no taxonomic issues, the skeleton of *Turbinaria mesenterina* is only slightly different from *Turbinaria reniformis*. Identification in living colonies is easy because *T. reniformis* is always yellow-green and *T. mesenterina* never is (Doug Fenner, personal comm.).

7.24.2 *Turbinaria peltata*

No new information was received or found specifically for *Turbinaria peltata*.

7.24.3 *Turbinaria reniformis*

U.S. Distribution
In addition to occurring in the federally protected areas listed for this species in the SRR, it also may occur in the waters of the Marianas Trench MNM, the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas is unlikely and would require confirmation) (David Burdick, personal comm.).

Abundance/Habitat:
From the SRR:
"Turbinaria reniformis has been reported to occupy shallow protected waters with some turbidity (Veron, 2000). The species can live on forereef slopes and can prevail in clear water as well but usually not in areas of heavy wave action."

According to Randall and Burdick (in prep), this species is a widely distributed, but uncommon, species that is most frequently found on lower seaward reef slopes, embayment reefs, reef channels, and lagoon habitats. In protected habitats it occurs at shallower depths than in exposed reef zones.

7.24.4 *Turbinaria stellulata*

U.S. Distribution
In addition to occurring in the federally protected areas listed for this species in the SRR, it also may occur in the waters of the War in the Pacific NHP, the Haputo ERA, the Orote Point ERA, and the Ritidian NWR (although its occurrence in these areas is unlikely and would require confirmation) (David Burdick, personal comm.).

Abundance/Habitat:
From the SRR:
"Unlike Turbinaria mesenteria, Turbinaria reniformis and Turbinaria peltata, Turbinaria stellulata is generally found in clear water and is not often found in turbid waters (Veron, 2000)."

According to Randall and Burdick (in prep), this species is a widely distributed, but uncommon species that is most frequently found on lower seaward reef slopes, embayment reefs, reef channels, and lagoon habitats. In protected habitats it occurs at shallower depths than in exposed reef zones.

8 Synthesis of Risk Assessments

One commenter asserted that low diversity genera are potentially more prone to extinction than the high diversity genera the SRR ranked as "likely"[cxciii]. Examples of low diversity genera provided by the commenter include *Dendrogyra, Dichocoenia, Physogyra, Barabattoia, Caulastrea, Mycetophillia*, and *Pachyseris*[cxciv].

Many comments expressed concern over the risk assessments for the 82 candidate coral species, particularly because of the lack of species-specific information. Many commenters disagreed with combining species at the genus level for assessing risk,[cxcv] stating differences in geography, geomorphology, and rarity of natural occurrence, as well as unresolved taxonomy issues.[cxcvi,cxcvii] Last, while commenters agreed with some of the species' rankings,[cxcviii, cxcix, cc] they questioned the considerations that went into assessing the extinction risk for other species' rankings with which they did not agree.[cci,ccii, cciii]

One commenter recommended, "If listing of the species as endangered or threatened is a potential outcome of the SRR, consider the use of warranted but precluded category for species that occur primarily in foreign waters[cciv]."

Below is a discussion of the comments and information received during the information gathering period that followed the completion of the SRR and the publication of the Federal Register Notice request for information and which pertain to the DMR. In general, commenters provided information missing from the DMR and provided justification for why the existing regulatory mechanisms do or do not protect the 82 candidate coral species from the threats analyzed in the SRR.

9 Draft Management Report/DMR for 82 Corals Status Review under the Endangered Species Act

In addition to the information relevant to the SRR summarized above, we received or gathered information relevant to the Draft Management Report (DMR). That information is organized by DMR section and does not align with any section of the SRR. Sections for which we did not receive or gather additional information are omitted from the summary below. All relevant information has been incorporated into the Final Management Report (NMFS, 2012).

9.1 DMR 2.1.1.2 International Treaties and Conventions

From the DMR:

"The first purpose of this report is to identify existing regulatory mechanisms as per ESA Section 4(a)(1)(D) that are or may be affecting the threats contributing to extinction risk for the 82 coral species, to determine whether regulatory mechanisms themselves are inadequate such that they are contributing to the species' endangerment."

One commenter stated the international treaties and conventions discussed in this section of the DMR do not adequately or effectively address global climate change threats, mentioning in particular that the U.S. has not ratified the Kyoto Protocol and U.S. GHG emissions have "increased 10.5% since 1990 (EPA 2012).[ccv]" The commenter adds the Kyoto Protocol only planned for reductions in GHG emissions through the year 2012 (and not beyond)[ccvi], and subsequent international accords (see Sections 2.1.1.2.5, 2.1.1.2.6, and 2.1.1.2.7) are not-binding. Both the Kyoto Protocol and the subsequent international accords contain GHG emissions targets inadequate for slowing temperature increases[ccvii].

9.2 DMR 2.1.2 National Regulatory Mechanisms Addressing GHG Emissions (Top 25)

As stated in the DMR,

"The 25 countries responsible for the highest percentages of global GHG emissions account for approximately 85% of global emissions. Twelve of these are Annex I countries that signed and ratified

the Kyoto Protocol and therefore committed to GHG emission reductions by 2012. Those 12 account for ~24% of global emissions. The U.S. alone accounts for ~20% of global emissions."

One commenter emphasizes that the continued failure of the U.S. and the international community to implement effective and comprehensive GHG emissions reduction measures places the candidate coral species at risk for extinction[ccviii]. Another commenter echoes this statement and recommends that the "final version of the Management Plan should stress the need to go beyond existing measures, especially the need for much more rapid progress for reducing greenhouse gas emissions at the national and international levels. It also must include take prohibitions and protective regulations as required under Sections 9 and 4(d) of the ESA for species listed as endangered or threatened." Based on the commenter's terminology, it is not clear whether this recommendation applies to the current DMR, or to a future "Management Plan" for any candidate species listed as threatened or endangered under the ESA[ccix].

9.3 DMR 2.1.2.1 UNFCCC Annex I Countries

2.1.2.1.1 The United States

One commenter emphasized the failure of the EPA's implementation of the current laws, which provide authority to require GHG emissions reductions from "virtually all major sources in the United States," by providing specific examples[ccx]. These examples include the final rule on EPA, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (75 FR 25324, May 7, 2010)[ccxi]; and the proposed rule on EPA, Standards of Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units (77 FR 22392, April 13, 2012)[ccxii]. The commenter states, "While full implementation of our flagship environmental laws, particularly the Clean Air Act, would provide an effective and comprehensive greenhouse gas reduction strategy, due to their non-implementation, existing domestic regulatory mechanisms must be considered inadequate to protect the 82 coral species from climate change and ocean acidification[ccxiii]."

9.4 DMR 2.2 Regulatory Mechanisms Addressing Local Threats

With regard to fishing regulations, one commenter remarks that overfishing continues despite international and domestic efforts to reduce fishing pressure on coral reef resources. Therefore, this commenter considers overfishing an ongoing threat to coral reefs[ccxiv].

For coral trade, the commenter states, "many countries lack adequate capacity or political will to enforce laws," and the commenter provides data showing that "trade in coral and coral reef species is substantial and growing[ccxv]."

Last, one commenter points out that there is not regulatory mechanism currently addressing "the growing stresses on coral reefs from increasing human populations and poverty[ccxvi]."

2.2.2 National Regulatory Mechanisms – Indo-Pacific (68 Countries)

2.2.2.1 Australia

One commenter provided extensive information on the laws and regulations for coral harvesting in Australia[ccxvii]. There are 3 coral harvest fisheries in Australia – Western Australia Marine Aquarium Fish Managed Fishery, Queensland Coral Fishery, and Northern Territory Marine Aquarium Fish Fishery[ccxviii]. Recently, non-detriment findings for both the Western Australia and Queensland fisheries were developed[ccxix]. The commenter points out "For most species of coral, the CITES Scientific Authority has found that due, in part, to their similarity in appearance and ecology, it is difficult to manage most corals at a species level."

9.5 DMR 2.1.1 International Regulatory Mechanisms Addressing Local Threats

One commenter mentioned that of the 82 candidate coral species, all are listed on CITES, and 51 occur in Australia. The 51 species occurring in Australian waters are subject to the CITES Non-Detriment Finding (NDF) process prior to receiving export approval. The commenter adds that "CITES recognizes the difficulty associated with being able to correctly identify coral species, by allowing some species to be listed on export permits at the higher taxonomic level of genus (when identification to species is not feasible) instead of the normal requirement to label to species level[ccxx]."

9.6 DMR APPENDIX A – USA Regulatory Mechanisms & Conservation Efforts Addressing Local Threats Within the Ranges of the 82 Candidate Coral Species

1.3.3 Guam

A commenter from this region points out that Public Law 24-87 is missing from the applicable regulatory mechanisms for Guam. Public Law 24-87, according to the commenter, "ensures that Guam's marine preserves are protected from recreational/commercial activities that may prove detrimental to the fragile ecosystem. Currently, there are draft rules and regulations from Public Law 24-87 and a management plan that was written[ccxxi]." The commenter also "feels that local/state Government should be taking the lead to protect corals[ccxxii]."

1.3.4 CNMI

One commenter provided a description of the following laws and regulations for the Commonwealth:

- The Fish, Game, and Endangered Species Act, which protects species designated as threatened or endangered by the Commonwealth, as well as the enforcement policies for that Act[ccxxiii].
- The Submerged Lands Act, which sets forth the management guidelines for Commonwealth submerged lands. "Environmental protection" is included with these guidelines, as is a requirement that the Department of Lands and Natural Resources shall not grant, lease, or otherwise permit the use of submerged lands if doing so "would adversely affect the protection and preservation of marine resources[ccxxiv]."
- Earth Moving and Erosion Control regulations, which require a permit from the Department of Environmental Quality and cessation of all earthmoving activities during the annual coral spawning period[ccxxv].
- The Anti-Degradation Policy for water quality standards, which provides for the "protection, maintenance, conservation, and improvement of the quality of the waters for the growth and propagation of aquatic life, for marine research and for the conservation of coral reefs and wilderness areas[ccxxvi]."
- Classification of marine waters (NMIAC § 65-130-101(a)(1)–(2))[ccxxvii].
- Requirements applying to activities during coral spawning events, including suspension of dredging activities[ccxxviii].
- Regulations regarding solid and hazardous waste, used oil, above-ground and underground storage tanks, pesticides, air pollution, underground injection wells and wastewater[ccxxix].
- Coastal Resources Management Regulations, which are related to the Coastal Resources Management Act mentions in the DMR. These regulations provide management and use standards for Areas of Particular Concern (APCs), including coral reefs[ccxxx].
- Commonwealth Ports Authority (CPA) Regulations, which state the general policy ""that the air, land, and water environment of the ports and harbors of the Commonwealth shall be preserved,

to the maximum extent possible."(NMIAC § 15-20.1-155)." There are civil and criminal penalties for violations[ccxxxi].

- CPA Regulations also limit the type and amount of explosives entering Commonwealth harbors and the manner in which explosives shall be handled and hauled. CPA prohibits the use of explosives on property that is under its control as well as in the waters in the immediate vicinity of such property, unless permission is obtained from the Executive Director (NMIAC § 40-20.1-224)[ccxxxii].
- CPA prohibits delivery of leaking containers, and requires immediate removal of any leaky containers[ccxxxiii].
- A person cannot move dead animals through the waters of CPA harbors, nor can a person leave a dead animal on the shores of CPA harbors or on reefs adjacent to harbors (NMIAC § 40-20.1-248(d), (e)).
- A vessel that enters into a Commonwealth port is required to carry a certificate of financial responsibility issued by the Federal Maritime Commission (NMIAC § 40-20.1-272). In the event of an oil spillage, the responsible vessel shall be liable for the cost of cleaning up the spillage (Id).

9.7 DMR 2.3 MPA Regulations

One commenter states that MPAs are insufficient to conserve the 82 candidate corals species because many are ineffective or offer only partial protection. Additionally, the commenter states only 6% of the world's coral reefs occur in effectively managed MPAs[ccxxxiv].

2.3.3 Guam

One commenter mentioned that there are 5 established MPAs on Guam that protect corals[ccxxxv].

2.3.4 CNMI

One commenter provided information on two pieces of legislation that established the Managaha Marine Conservation Area (Public Law No. 12-12, codified at 2 CMC §§ 1631–1638) and Bird and Forbidden Island Sanctuaries (Public Law No. 12-46, codified at 2 CMC §§ 1640–1645), respectively[ccxxxvi]. These laws prohibit removal of resources from these protected areas.

9.8 DMR 3.3.4 CNMI

One commenter submitted a list of current conservation management mechanisms and policies for the Commonwealth, which is not included in the DMR[ccxxxvii].

- CNMI is committed to the Micronesia Challenge, which has an overall goal of effectively conserving at least 30% of nearshore marine resources including coral reefs[ccxxxviii].
- Through the Resolution of the 17th Micronesian Chief Executives' Summit to Address the Global Environmental Impact of Climate Changes in Micronesia (See Resolution 17-03, March 15, 2012) the Commonwealth, and other Micronesia Challenge members, would "collaborate with local scientists, community members, educators, leaders and decision-makers in Micronesia to place climate change issues at the forefront of coral reef management through efforts to decrease global contributions to global emissions."[ccxxxix]
- The Commonwealth of the Northern Mariana Islands Climate Change Working Group is a multi-agency climate change working group established in June 2012. The objectives of the working group include the following:

- Identify the communities, livelihoods, and ecosystems in CNMI that are most vulnerable to the impacts of climate change;
- Identify, assess, and prioritize adaptation strategies and policies;
- Identify gaps in knowledge and areas for future research; and
- Build capacity within CNMI departments and agencies to begin dealing with the impacts of climate change[ccxl].

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Endnotes

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[i] Roxanna Miller : The threat of coral disease can be partially dealt with by addressing poor water quality and runoff/sedimentation issues locally. With the finding that a bacterium found in human waste is responsible for White Pox of Acopora palmata (Sutherland et al. 2011, PLoS ONE), it is now apparent that addressing wastewater treatment issues of populations living along the coast will most likely have an effect on coral health. There have also been recent studies which have found that intact and diverse fish communities (protected by MPAs) ameliorate coral disease (Raymundo et al. 2009, PNAS). This suggests that by dealing with local stressors and by providing sufficient management of reef resources, corals can become more resilient to at least one of the top three threats. It may be better to put money into local coral reef protection and improvement of wastewater treatment facilities to reduce the compounding of stressors than to list them under the ESA.

[ii] MAFAC: Encourage a multi-species management approach when possible. Encourage an analysis of the effectiveness of current regulations and management actions in actually protecting coral.

[iii] Roxanna Miller: The listing of any of the proposed 82 coral species under the ESA would not effectively protect these corals from the top three threats listed in the Status Review Report: ocean warming, disease, and ocean acidification. In order to address ocean warming and ocean acidification, laws and legislation must be passed to reduce carbon emissions and green house gases (GHGs).

[iv] MAFAC: Discuss the extent to which there is a protective benefit to invoking the ESA regulatory process -- could be one criterion for listing decision for coral species.

[v] Roy Rios [Guam]: “Against listing as he understands that 40 has been recorded in the CNMI. He indicated that there has never been an extensive study for Saipan, Rota, and Tinian. He further stated that here are two species of corals that are thriving everywhere in all chain of islands in the Marianas. NOAA has limited local data including socio-economic impact of corals in the CNMI. There’s limited information and maybe NOAA should provide funding for a study on CNMI reef. He stated that the CNMI reef is one of the healthiest in the world; there’s minimal impact. Lastly, he stated that the greatest impact is the pre-position ships that are allowed granted by NOAA.”

[vi] Senator BJ Cruz [Guam]: “He commented about sustainability of corals, in that it may be only threatened in one area and not other areas.”

[vii] John Tagabuel [Guam Commenter]: He questioned peer review as it does not have affiliation on doing business here in the CNMI. He also questioned years of experience in dealing with CNMI issues. He stated that NOAA should have a local speaking experience people; and should invest on local resources.

[viii] John Bruno:
A major science need is the development of fine-grained climate models particularly near the costs, where most coral reefs are found. Such models do not really exist (not including the controversial downscaling models), so they couldn’t be included in the BSR. We also need to know how patterns of warming will change or if they will. For example, will the scale of hot spots increase in the future? And what about the intensity of ENSO?
I understand that it is far outside the scope or ability of the BRT to build and assess population models for each of the 82 coral species to estimate their sensitivity to climate change (e.g., Bruno et al 2011), but if resources ever became available to do this (even for a subset of the species) this would be immensely valuable.
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[ix] [Guam Commenter]: He commented that runoff has impacted Guam, and not enough is being done by government of Guam to protect affected areas such as the water in the bay. He asked if a coral species is listed in the Endangered Species Act, and with threats from current green house affect, pollution, man-made organic or inorganic, how long would a certain species survive. He commented that if fishing is a concern, he wished to state that there is no over-fishing. He stated that people in Guam are doing their part to protect the ocean.

[x] [Guam Commenter]: This person stated that from a management perspective, Guam needs more shallow water designated moorings. He asked what protection will take place if a coral species is listed in ESA.

[xi] John Bruno: I would have liked to see a clearer statement on the potential of local management, e.g., MPAs, to facilitate recover of the corals (assuming they become listed). In my view, there is a large amount of evidence that MPAs and other forms of local fisheries management, although a very good thing, will do little to protect corals from climate change impacts. The reduction and eventual elimination of greenhouse gas emissions rather than the creation of more (largely unenforced) MPAs should be the cornerstone of coral the recovery plans.

[xii] Julia Olson - We recommend that due to the urgency of the threat to these coral species from anthropogenic climate change, the proposal for listing should include designation for critical habitat, and that a comprehensive recovery plan be developed, released and implemented as quickly as possible and more quickly than the time frame allowed under the ESA.

[xiii] MAFAC: If listing of the species as endangered or threatened is a potential outcome of the SRR, consider the use of warranted but precluded category for species that occur primarily in foreign waters.

[xiv] John Bruno: “I was thrilled with how thoroughly and accurately climate change impacts were covered in the BSR. I agree completely with the summary finding of the BRT: After extensive review of available scientific information, the BRT considers ocean warming, disease, and ocean acidification to be the most influential threats in posing extinction risks to the 82 candidate coral species between now and the year 2100.' I consider this a watershed statement by a federal US Government agency."

[xv] Sierra Club: After an extensive literature review, the BRT concluded that rising ocean temperature, disease (which often follows warm bleaching events), and ocean acidification “are likely to represent the greatest risks of extinction to reef corals, including many of the candidate species over the next century” (SRR, p. 52). The Sierra Club concurs with this conclusion, which accords with a clear majority of other recent scientific reviews (e.g., Baker et al., 2008; Penaflor et al., 2009; Eakin et al., 2010); see also the 12th International Coral Reef Symposium consensus statement (www.icrs2012.com/Consensus_Statement.htm). Furthermore, Sierra Club emphasizes that removing the stressors associated with greenhouse gas emissions would be essential for any long-term success of the coral restoration activities funded by NOAA and its partners.

[xvi] Eugene Shinn: “The NOAA/Biological Research Team report http://www.nmfs.noaa.gov/stories/2012/04/docs/exec_sum_and_intro_corals_status%20review%20report.pdf makes it clear that the core prediction is based on rising water temperature and reduced alkalinity (incorrectly called acidification) based on computer-model projections. Such projections of future temperatures and alkalinity remain controversial and are rejected by many in the meteorological/climate community as well as by many geologists and physicists. The science is not settled, as proponents of anthropogenic climate change profess, but remains a highly political issue. Because of these uncertainties, the listing of corals based on anthropogenic climate-change computer models and projections is at best political in nature. NOAA claims to make science-based decisions; therefore, NOAA should base decisions about coral longevity purely on proven empirical science. Climate-change computer-model projections are not empirical science."

[xvii] Manny Duenas [Guam]: “He commented that Guam is not the cause of ocean warming. He further that Guam does not have authority on this matter, but asked what can be done to the top three threats, ocean warming, disease, and ocean acidification.”

[xviii] On page i of the executive summary alone there are 23 words or phrases which convey the uncertainty of the extent and detail of the knowledge base. Further, the "score" is opinion based and not objective

[xix] Sierra Club: The BRT found widespread local threats to coral reefs, such as sedimentation, nutrient enrichment and fishing to be of “medium importance” in determining extinction risks. We consider the priority for action to reduce local stressors to be of higher importance than “medium,” but local actions will be insufficient overall so long as global climate change remains a pervasive threat.

[xx] CBD: We have reviewed the status review and management reports, and concur with the conclusions that most of the candidate corals are more likely than not to face a critical risk of extinction before the end of the century. Moreover, the best available science suggests that coral reefs around the world are imperiled, and the threats of ocean warming and acidification are severe and ongoing.

[xxi] In summary, under BRT’s review process about 2/3 (56/82) of the candidate coral species appear to qualify for consideration by NMFS to determine whether or not they warrant listing under the ESA. [According to the SRR (page xxxiii), “This document makes no recommendations for listing, as that is a separate evaluation to be conducted by the NMFS”.] We recommend ESA listing for those species that have the strongest scientific basis for

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listing, and thus would stand up under possible challenge, and for which it would be feasible to develop recovery plans specific enough to make a real difference in dealing with local or regional stressors. Given uncertainties concerning the respective taxonomic designations, geographic distributions, densities and current trajectories for many of these species, we feel that more extensive discussion is warranted before moving forward with all 56 at the present time. Rather we urge the expeditious listing of species like the M. annularis complex that are of reasonably assured taxonomy and common enough to be conspicuously declining from the combined effects of bleaching and disease.

[xxii] Although the candidate Pacific corals overall are currently less vulnerable than those in the Caribbean, their long-term prognosis overall is also in jeopardy unless action is taken to reduce global and local threats there. Possible candidates among taxa not included in the list of 82 include Mussismilia spp. in the South Atlantic, the Eastern Pacific population of Leptoseris papyracea and Acropora cythera in the Central-Western Pacific.

[xxiii] [Guam Commenter]: “He asked how best available science is different from cultural traditional experiences such as from local fishermen. He further asked why NOAA is requesting for input when it is only allowed to look into science.”

[xxiv] Benigno Sablan: “He took issue on the term ‘best available science.’ He stated that local people think that the best available science is incorrect. He pleaded that the fishing community is concern of all areas from Rota, Tinian, Saipan and up to the northern islands of our livelihood, keeping our corals healthy. He is also equally concern of what is currently ‘best available science.’ The CNMI should not be penalized as it does not produce as much carbon. CNMI has healthy population of fish.”

[xxv] Mark Hardgrove, VINP: …we are unsure of the rationale that was used to determine the list of species and are concerned that many other species of scleractinian corals are suffering similar threats and impacts and require equal protection under the ESA. Almost every species of coral occurring in our two park units are significantly reduced in numbers and colony health. Several species such as Diploria clivosa and strigosa, Porites astreoides, and some of the other "weedy" species appear to be increasing in number and distribution on our corals reefs. However, other major reef-building species such as Colpophyllianatans, Diploris labyrinthisformis, Montastrea covernos, and others, have suffered considerably from bleaching/disease events and are becoming rare in our waters. We are curious as to why they were not included on the list of proposed candidate species.

[xxvi] D. Fenner: Although most species in the family Fungiidae exist only as solitary polyps, there are a substantial number that are colonial, such as species of general Halomitra, Sandalolitha, and Podabacia. There are a few species in other families that are also solitary, such as Scolymia in the Mussidae.

[xxvii] D. Fenner: I disagree with the view expressed of genetics. Genetics is not direct information on which organisms are interbreeding or not interbreeding. It is information that can be interpreted to be relevant to that, but it is not direct records of interbreeding. This analysis assumes that current techniques in genetics represent directly the “true” interbreeding groups. That remains to be seen. Most of the current genetics is based on just 2 genes, out of perhaps 10 or 20 thousand genes. Current genetics has just begun to tap information in coral genomes. Some of the results are in strong conflict with morphology, as you correctly point out. An extreme example is the finding that Acropora is most closely related to Alveopora. Those two are wildly morphologically different. This report simply assumes that if the conclusions of the present early genetics results differ from the morphology, the genetics is right and the morphology is wrong. That is more a statement of faith in the current, early form of genetics, than a statement based on evidence. If they differ, there is some sort of resolution for why, but we don’t have that yet. I would recommend a more neutral stance on whether the genetics or morphology will eventually prove to be correct. I cite in support the world [sic] of Steven Palumbi, who has used 30,000 loci in work on Acropora hyacinthus, where he is able to not only distinguish A. hyacinthus from other morphological species, but cryptic species within A. hyacinthus. In my understanding, his results are in agreement with the morphological taxonomy, and is able to distinguish even more than the morphology. I think it is far too early to assume that genetics based on just 2 genes will prove to be correct and whenever it conflicts with morphology that morphology is wrong."

[xxviii] Eugene Shinn: “As a geologist/biologist who has studied corals and coral reefs ranging in age from the Mesozoic to the Holocene (modern) for more than 50 years, I am well aware that corals have survived for more than hundreds of millions of years. That the corals living today will go extinct within the next century is considered doubtful. In more recent times, the Holocene (past 10 ka) and especially during the past 7 ka to 6 ka, various coral

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species worldwide have experienced periods of local demise. All of these periods of coral demise occurred well before the Industrial Revolution and thus were not the result of human activity."

[xxix] D. Fenner: There is another reason for lack of carbonate buildup in some coral communities, and that is the frequent removal of corals by storm events. This is the rule outside bays in Hawaii (Grigg) and on the Solitary Islands in Australia (Harriott).

[xxx] Monica Medina: next-generation sequencing technologies have advanced at such incredible speed in the last few years that there is a vast increase on available genomic information that should be considered in the future...Knowledge of genomic composition of a coral and its microbiome provides insight into the functional potential to cope with different environmental perturbations. Knowledge of overall relative gene expression in response to stressors is helpful in understanding how corals cope with different environmental conditions.

[xxxi] D. Fenner: Although some coral reefs indeed have very high diversities, there is a wide range of diversity, and some have low diversities, such as the Eastern Pacific and Brazilian reefs.

[xxxii] CBD: The status review noted that some of the 82 candidate species occur in mesophotic habitats, and that mesophotic reefs "may provide refugia habitat and replenishment potential for presumably more vulnerable shallow reef populations of taxa that can occupy both shallow and mesophotic reef habitats" (Brainard et al. 2011: 13-14). Based on the mesophotic coral reef "refugia hypothesis," the status review team determined that "[o]ccurrence in mesophotic habitats was considered to reduce extinction risk since these habitats are somewhat buffered from surface- based threats" for a number of candidate corals. However, studies examining the mesophotic coral refugia hypothesis cast doubt on the ability of mesophotic habitats to buffer corals from threats, and caution against relying on the assumption that mesophotic habitats will reduce extinction risk. As discussed in detail below, mesophotic reefs are subject to a large number of threats that can impair their health and ability to serve as refugia. Additionally, mesophotic reefs may not provide a reliable source of propagules for shallow reef areas following disturbance.

[xxxiii] CBD: In regard to the hypothesis that mesophotic reefs provide refugia from disturbances, Bongaerts et al. (2010) concluded for Caribbean reefs that "[a]lthough there is evidence to support that deep reefs (>30 m) can escape the direct effects of storm-induced waves and thermal bleaching events, deep reefs are certainly not immune to disturbance." Mesophotic reefs are subject to a wide range of negative effects from (a) ocean acidification, especially since deeper waters have lower levels of carbonate saturation; (b) warm-water bleaching (which has been documented to 60 meters), although the effects of bleaching are more pronounced in shallow water; (c) cold-water bleaching; (d) sea-level rise which "has the potential to push deep reefs below the euphotic zone"; (e) indirect effects of storms including debris avalanches and sedimentation; (f) diseases which typically affect corals across their depth range (i.e., black band, dark spots, white syndrome, and yellow blotch disease have been reported on mesophotic reefs); (g) nutrient enrichment; (h) toxins such as herbicides and pesticides; (i) sedimentation; and (j) invasive species (Bongaerts, Ridgway, Sampayo, & Hoegh-Guldberg, 2010; Lesser & Slattery, 2011). Lesser and Slattery (2011) noted that mesophotic reefs may be sensitive to disturbances in the upper water column that reduce light penetration, and "[i]n this respect, they are probably even more vulnerable to stress than shallow reef counterparts, especially near human population centers." Lesser and Slattery (2011) documented that the Indo-Pacific lionfish (Pterois volitans) has invaded mesophotic reef habitat in the Bahamas down to 91 meters, which has reduced the health of the mesophotic reef. Specifically, lionfish have reduced the diversity of several important fish guilds, including herbivores, which appears to have pushed the reef to an algal- dominated community, causing significant declines in corals and sponges at mesophotic depths. The study concluded that "[t]he significant ecological effects of the lionfish invasion into mesophotic depths of coral reefs casts doubt on whether these communities have the resilience to recover themselves or contribute to the recovery of their shallow water counterparts as refugia for key coral reef taxa." In sum, the evidence to date suggests that the potential for mesophotic reef habitat to provide a refuge from threats may be limited.

[xxxiv] CBD: Several studies that have reviewed the potential for mesophotic reefs to provide propagules for shallow reef areas following disturbance also suggest that this potential is limited. Bongaerts et al. (2010) concluded that "the evidence to support the idea that mesophotic reef areas will act as a viable reproductive source for shallow reef areas is, however, limited." Specifically, the review noted that only "depth-generalist" coral species could provide propagules to shallow areas and these corals constitute only a quarter of coral species; in addition, larval connectivity between shallow and deep populations of depth-generalists may be limited due to life history traits

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such as a brooding reproductive strategy and vertical symbiont acquisition. Slattery et al. (2011) noted that there is little information on genetic connectivity between deep and shallow coral reef populations. Finally, van Oppen et al. (2011) assessed vertical connectivity in the brooding coral Seriatopora hystrix across a depth profile in both northwest (Scott Reef) and northeast Australia (Yonge Reef). The study found different levels of connectivity depending on region. On Yonge Reef, the study found no evidence of migration from the deep slope populations to shallow habitats,"making recovery of shallow habitats from deeper waters at this location highly unlikely." Conversely, on Scott Reef, there was evidence for recruitment of larvae of deep water origin into shallow habitats, making the potential for recovery more likely.

[xxxv] CBD: Finally, two studies that examined whether upwelling can minimize thermal stress caused by ocean warming found that the protective role of upwelling is very limited geographically (Chollett et al., 2012; Karnauskas & Cohen, 2012), and that upwelling areas do not always offer corals protection from thermal stress (Chollett et al. 2012).

[xxxvi] Eugene Shinn: Ironically, it was found that corals surrounding nuclear-bomb craters recovered, and some were recruited within a year of the atomic tests (Hudson, 1985). A recent publication (Roff and Mumby, 2012) concluded that Pacific reefs are actually more resilient than Atlantic reefs. Those authors noted that Atlantic reefs occupy a smaller basin and are thus more susceptible to runoff and the impact of airborne African dust. In addition to abundant viable microbes and radionuclides such as Be-7, African dust contains iron that is known to stimulate the growth of algae. Iron is also implicated in red tides caused by harmful algal blooms (Walsh et al., 2006).

[xxxvii] Eugene Shinn: Before making costly decisions, it is useful to review corals and coral reef history over the past few thousand years. First, it is well established that in Florida and the Caribbean, most modern reefs are located over substrates that were dry land between 7 ka and 6 ka (Shinn, 1988; Lidz and Shinn, 1991; Lidz, Reich, and Shinn, 2007; Macintyre and Glynn, 1976). These areas were high and dry because sea level was lower by at least 125 m below present level as recently as 18 ka. When glaciers began melting, sea level rose at a rapid rate, and few shallow-water corals along the steep slopes that existed throughout the Caribbean could keep pace. Between 7 ka and 6 ka, the rate of rising sea level slowed and flooded most of the flatter slopes where coral reefs exist today. The timing of flooding and reef initiation has been determined by carbon-14 age dating of corals recovered from the base of Florida reefs (Shinn, 1980; Lidz and Shinn, 1991). After initial flooding and initiation of coral growth, the rate of rise slowed around 4 ka, allowing many reefs to flourish and keep pace with the slowed rise (Toscano and Macintyre, 2003). Sea level has continued to rise but at a much slower rate than even at 4 ka.

[xxxviii] Eugene Shinn: In Florida and elsewhere in the Caribbean, reefs that began growing around 6 ka for the most part consist of veneers over pre-existing substrate and are only 1 to 2 m thick. In some places, there has been no upward-growing in-situ accumulation. In such places, there are only scattered individual live corals that grow directly on Pleistocene limestone. An example is the so-called reef where the NOAA National Underwater Research Program (NURP) Aquarius underwater habitat is located off Key Largo, Florida. The author drilled a 15-m-long core at that site and encountered only caliche-coated Pleistocene limestone. Meter-high massive head corals are scattered around the site along with the usual gorgonians and sponges, but there has been no upward reef accumulation at that site during the past 6 ka.

[xxxix] Eugene Shinn: Many such areas exist off the Florida Keys as well as at Caribbean sites, such as at Hogsty Reef Atoll in the southern Bahamas (Pierson and Shinn, 1985). There is no human habitation at Hogsty Reef. The small atoll is surrounded by more than 50 miles of deep Atlantic waters. Locally, there are many discontinuous reef accumulations 10 to 15 m thick along the Florida reef tract. These are the well-known named reefs generally marked by lighthouses and other nautical markers. Such reefs constitute less than 2 percent of the reef areas in Florida. The Florida coral reefs and associated reef sediments have been studied by dozens of scientists for more than 50 years, and the data from these studies, including maps of the underlying Pleistocene limestone, can be found in several USGS publications authored by B. Lidz, and others including R.N. Ginsburg and the author (for example, Lidz, 2005; Lidz et al., 2006, 2007, 2008; and Lidz, 2011a and 2011b; Ginsburg and Shinn, 1964).

[xl] Eugene Shinn: The larger reef-building elkhorn coral Acropora palmata began dying around 2 ka at Molasses Reef. A veneer of encrusting Millepora sp. and coralline algae coated Molasses Reef spurs under 6 to 8 m of water in the 1950s. There were also scattered large living colonies of massive Montastraea sp., Diploria sp., Colpophyllia sp., and Acropora palmata. Internal examination of coral cores showed that the actual spurs had been constructed

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entirely by A. palmata about 2 ka (Shinn, 1963). For the most part, the spurs that compose Molasses Reef looked about the same in the 1950s as they do today, except there is now less living A. palmata.

[xli] Eugene Shinn: By far, the largest and thickest Holocene reef in Florida is located off Ft. Lauderdale in approximately 15 m of water. That reef, a drowned fringing reef originally built principally by Acropora palmata, grew upward to sea level and then died around 7 ka. This reef, often locally called the third reef, is well known to local divers, fishermen, and researchers at NOVA University. Banks et al. (2007) recently summarized the geography and composition of the reef. The age of this reef was based on carbon-14 dating of its primary builder, Acropora palmata. The samples that were dated were collected in situ from the walls of a deep trench excavated for a sewage-outfall pipe in the 1970s (Lighty, 1977; Lighty et al., 1978; Lighty et al., 1982). Today, the surface of that dead reef supports only scattered species of Montastraea, Dichocoenia, various gorgonians, and sponges. The community encrusting this dead reef surface can best be described as a hardbottom community. It is no longer a viable accreting coral reef. Clearly, this Acropora reef succumbed long before human interference was possible. The cause was natural climate and water-temperature change combined with sea-level rise or other unknown factors (Banks et al., 2007).

[xlii] Eugene Shinn: Areas of little or no growth, versus abundant growth, are a clear indication that coral reefs have waxed and waned during the past 7-6 ka. In addition, those periods of rapid and/or no growth were entirely natural even if not well understood (Shinn et al., 2004). That reef corals have experienced booms and busts may imply that the widespread decline of coral reefs beginning in the late 1970s is yet another natural cycle. Proving otherwise remains elusive and speculative, exceptions being local and obvious examples caused by dredging, silt, ship groundings, and anchors, all of which are clearly anthropogenic in origin. Nevertheless, the current demise of widespread Caribbean corals at this writing continues and is occurring around many far-flung Caribbean islands and reef areas where human effects are negligible or absent (Shinn, 2011).

[xliii] Eugene Shinn: The author has photographically documented coral demise in Florida using serial photographs of specific corals ranging from 1960 to the present http://gallery.usgs.gov/videos/334. These serial photographs show that the rate of demise culminated in 1983 and 1984—at roughly the same time the urchin Diadema, a key component of coral reef health, began to die throughout the Caribbean (Lessios et al., 1984). Also at roughly the same time period, a disease caused by a soil fungus began attacking the common sea fan. That soil fungus, Aspergillus sydowii, has been linked to spores transported in African dust (Weir-Brush et al., 2004).

[xliv] D. Fenner: "Page 17, the table omits the Brazilian coral reef zone, which has a unique, low diversity, set of species"

[xlv] D. Fenner: "Quite right about the gradient, but that is the latitudinal gradient. There are also strong longitudinal gradients, as documented in Japan and Australia by Veron."

[xlvi] Margaret Miller: I agree that new lit and lots of 'resilience' discussion at ICRS emphasize and confirm the BRT's notion of a 'Caribbean factor' as justifying higher risk for spp. in this region.

[xlvii] GFMC : The report lacks specific threats to individual coral species, but is blanketed by universal threats to corals.

[xlviii] Dr. Peter Houk: Once taking into account these natural drivers, human influences become the next most prominent, secondary drivers. The point is, no evidence exists to suggest that climate change is impacting any of these species in a stronger manner than any others, as natural environmental regimes (primary) and human influences (secondary) dictate where coral species can grow and flourish at the present time. Certainly climate change may eventually become a bigger threat to our reef ecosystems as a whole, this is a well-accepted fact of the doctrine. However, at the present time, which is what ESA listings must be based upon, there is a lack of a direct relationship between climate change and these species on our reefs, and thus, no scientific foundation for their potential listing as argued by the CBD team. I think this is key and needs to be brought out.

[xlix] D. Fenner: Page 19, last paragraph on human population. One sentence refers to the relationship not always being strictly multiplicative. An example is the Kuznets hypothesis that damage to the environment increases with initial economic development, then decreases.

[l] Eugene Shinn: These geological and biological observations raise a rhetorical question. If those species, including Acropora palmata and A. cervicornis, had been listed as endangered or threatened more than 30 years ago in the mid-1980s when their demise was obvious, would their death rate have been curtailed? The answer is clearly no! It should also be pointed out that acroporids and other reef dwellers began their demise before global warming and

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rising CO2 levels became an issue. Ironically, the climate had been cooling since the 1940s, and some scientists were predicting a return of glaciers during the 1970s. A Central Intelligence Agency (CIA) 1974 report predicted a lowering of global temperature that would reduce agriculture and increase likelihood of wars http://www.climatemonitor.it/wp-content/uploads/2009/12/1974.pdf.

[li] WPRFMC: Ocean warming and acidification are two global threats to corals identified by the BRT as being high importance in assessing extinction risks to the 82 candidate coral species. As discussed in the BRT Report, these global threats are tied to increasing atmospheric C02 emissions resulting from human population increase and high rates ofnatural resource consumption. However, ESA was not intended to address global threats to wide-ranging marine species such as corals, and lacks regulatory power outside of the U.S. to control emissions, consumption, and human population growth at the global level. Furthermore, scientific literature on long-term impacts ofthermal stress and acidification on corals are highly uncertain, making it nearly impossible to develop effective conservation measures to address global threats under the ESA framework.

By contrast, the BRT ranked most localized threats including fisheries as relatively minor, yet ESA listing of these species will likely have significant impacts on these activities in the U.S. while having limited corresponding conservation benefit to coral species throughout their range. Moreover, as outlined in the draft Management Report, U.S. federal and local regulations already provide the maximum protection to corals through prohibitions on coral and ‘live rock’ harvests, prohibition or restriction of fishing on extensive areas of coral reef, various forms of marine protected areas, pollution control, and coastal management.

The Council therefore believes that ESA listing on the basis of these global threats will have no benefits to the conservation or protection of these coral species while placing burden on localized activities and associated communities that are not contributing to the increased risk of extinction of coral species. Further, the Council requests that NMFS thoroughly evaluate the conservation and management actions summarized in the draft Management Report against the 2003 policy for evaluation of conservation efforts when making listing decisions (PECE) under the ESA, and consider whether existing mechanisms provide sufficient protection of these coral species for the foreseeable future.

[lii] WPRFMC: ICRS Presentation by Janice Lough - The changing thermal environment for tropical coral reefs: a. Significant warming, between the two 30-year periods, occurred in 63% of the tropical oceans, <1% significantly cooled and 36% showed no significant change; b. Greatest absolute warming has occurred in regions of largest inter-annual SST variability but, when standardized by the inter-annual variability, greatest relative warming has occurred in the near-equatorial Indo-Pacific region and, to a lesser extent, in the equatorial Atlantic; c. Higher latitudes have and will experience greatest absolute warming of the surface oceans; d. near-equatorial regions, where tropical marine organisms exist within a much narrower temperature range, are experiencing the greatest relative changes in their thermal environment.

[liii] CBD: Global greenhouse gas emissions are tracking the worst IPCC emissions scenario -- The current CO2 concentration has not been exceeded during the past 800,000 years and likely not during the past 15 to 20 million years (Denman et al. 2007; Tripati et al. 2009). Atmospheric CO2 emissions have risen particularly rapidly since the 2000s (Raupach et al. 2007; Friedlingstein et al., 2010). The global fossil fuel CO2 emissions growth rate was 1.1% per year during 1990-1999 compared with 3.1% during 2000-2010, and since 2000, this growth rate has largely tracked or exceeded the most fossil-fuel intensive emissions scenario projected by the IPCC (A1FI) (Raupach et al. 2007; McMullen & Jabbour 2009; Global Carbon Project 2011). The CO2 emissions growth rate fell slightly in 2009 due largely to the global financial and economic crisis; however, the decrease was less than half of what was expected and was short-lived (Fiedlingstein et al. 2010). Global CO2 emissions increased by 5.9% in 2010 resulting in a record 33 billion tons of CO2 emitted (Olivier et al. 2011), and CO2 emissions reached another record high in 2011 (See International Energy Agency, Global carbon-dioxide Emissions Increase by 1.0 Gt in 2011 to Record High, http://www.iea.org/newsroomandevents/news/2012/may (last visited June 5, 2012).

In order to preserve a likely chance of limiting overall temperature increases to 1.5° or 2°C above pre-industrial levels, recent scientific assessments have found that global emissions must peak within the next several years, decline very sharply thereafter, reach zero net emissions by mid-century, and become net-negative after 2050 (i.e. where more carbon is removed from the atmosphere than is produced) (Höhne 2009; UNEP 2010). Scientists have estimated that cumulative CO2 emissions must not exceed 1000 GtCO2 (gigatonnes CO2) between 2000 and 2050 in order to have a 75% chance of staying below 2°C (Meinshausen et al. 2009, NAS 2010); and must not exceed 750

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to 824 GtCO2 between 2000 and 2050 to meet a 350ppm CO2/1.5°C target (Ackerman et al. 2009; Baer et al. 2009). Because pathways for 1.5°C and 2°C require staying within a tight cumulative carbon budget, continuing increases in greenhouse gas emissions and corresponding delays in reaching a global emissions peak make it increasingly difficult to meet these targets. For example, global emissions from 2000 to 2010 accounted for roughly 360 GtCO2, which is a third of the allowed emissions until 2050 consistent with a 75% chance of staying within 2°C and nearly half of the allowed emissions until 2050 consistent with staying within 1.5°C (Höhne et al. 2009). Thus, global emissions in the past decade have eliminated a large portion of the available carbon budget, and every year at current emissions (~33 GtCO2) consumes a significant share and makes meeting this budget less feasible. Every additional contribution to global greenhouse gas emissions, especially over the next few decades, means that meeting a 1.5°C or 2°C target becomes less likely as does the likelihood of survival of the 82 coral candidates.

[liv] John Bruno: I would include and emphasize the striking patchiness in warming that we have seen in shallow, tropical seas over the last 25 years (e.g., Selig et al. 2010). We know there is a lot of spatio-temporal variability in patterns of warming at very small spatial scales, 1 – 5 km. It is important that we figure out: (a) whether these warming patches are positively or negatively spatially autocorrelated (I think they are negatively). If the latter, impacts of warming would be more general across space, but perhaps more diffuse temporally with lower return times. What the patterns at small scales of warming are and will be this century will profoundly affect coral evolutionary adaptation to warming, patterns of impact and recovery, possibly meta-community dynamics, etc. Presumably, this would influence the threat of warming to coral species extinction.

[lv] John Bruno: I'd add work by Selig et al. (2012) that quantified the relationship between thermal stress and coral loss: 'The annual effect of temperature anomalies (weeks that were > 1 °C warmer than usual) on the change in living coral cover when coral cover is initially 50%. The 95% confidence intervals (thin black line), 50% intervals (thick gray line), and point estimates (median) of the posterior distributions are shown. Results are based on a multilevel model analysis of 8040 live coral cover surveys performed around the world between 1985 and 2005. From Fig. 4B in Selig et al. 2012.' This work builds on related work by Donner (2009) that linked ocean warming projections under different IPCC social scenarios with the frequency and spatial extent of bleaching (science that was covered in the BSR).

[lvi] Margaret Miller: Agreed, lots of info forthcoming on potential mesophotic refugia. There was also some discussion of the notion of the general patchiness of warming at our Atlantic Science Workshop (particularly presentation by John Bruno). The jist of this discussion was that there is potential for this patchiness to provide warming refugia, but only if the warming patches are spatially consistent (rather than simply popping up in different places in different years). The answer to this question has strong scale dependence – but overall seems to remain unclear.

[lvii] CBD: Several new studies provide estimates of ocean warming due to climate change. Chollett et al. (2012) reported 25 years of sea surface temperatures in the wider Caribbean across regions and seasons. The study found that most warming has been due to increases in summer rather than winter temperatures; that warming has been faster in winter in the Loop Current area and the southeastern Caribbean, narrowing the amplitude of annual temperature ranges; and that waters off Florida, Cuba and the Bahamas had a tendency towards cooling in winter, increasing the amplitude of annual temperature ranges. Levitus et al. (2012) estimated the change in ocean heat content for the 0–700 and 0–2000 meter layers of the global ocean for 1955–2010, and found that all major ocean basins have warmed at nearly every latitude. The study noted that if the heat gained since 1955 were instantly transferred to the lower 10 km of the global atmosphere, this atmospheric layer would warm by 36˚C (65oF), which conveys just how much heating has occurred. Finally, Gleckler et al. (2012) provided strong evidence of an anthropogenic fingerprint in upper-ocean (0-700 meters) warming.

Several studies have suggested that the susceptibility and response of corals to heat stress may be related to their level of exposure to temperature variability, where corals in regions that experience more variable temperatures may be more resistant to thermal stress than those in less variable environments (Carilli, Donner, & Hartmann, 2012; Castillo, Ries, Weiss, & Lima, 2012; Guest et al., 2012). However, the ability of corals to maintain resistance to bleaching under the rapid ocean warming and acidification that is occurring is extremely unlikely (Ove Hoegh-Guldberg, 2012).

Buddemeier et al. (2011) estimated future coral cover in areas of the eastern Caribbean that were impacted by a massive coral bleaching event in 2005, under warming sea surface temperatures, ocean acidification, and episodic

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bleaching events. Under the SRES B1, A1B, and A1FI emissions scenarios, coral cover on most Caribbean reefs is projected to drop below 5% by the year 2035. When corals are allowed to gain 1–1.5oC of heat tolerance by changing their symbionts, coral cover dropped below 5% in 2065. The study noted that adding other stressors such as storms and anthropogenic damage would result in more severe declines, and concluded that the "[r]esults suggest a bleak future for coral reefs in the eastern Caribbean."

[lviii] WPRFMC: ICRS Presentation by Susannah Leahy et al. – Do clouds save the Great Barrier Reef? -- Cloud cover mitigate sever increase in SST thus minimizes impacts of bleaching

[lix] D. Fenner: Page 31 there is significant information about the possibility of adaptation that needs to be added. For instance, the paper by Berkelmans and van Oppen entitled "nugget of hope." There are several papers that demonstrate different bleaching thresholds at different locations. This essay correctly points out that the thresholds vary locally, and tend to be relative to local temperature maxima. That implies that corals have adapted to local conditions. On the other hand, the information about bleaching in the Arabian Sea indicates that even corals that are regularly exposed to some of the highest temperatures anywhere, may have a limit to how far they can adapt to high temperatures.

[lx] Dr. Peter Houk [Guam]: He stated that in 1998 there are many publications of coral bleaching events; then also noted in 2009 and 2010 in the same areas. Corals are most resilient. Referring to IUSN listing. How can important science be missed?

[lxi] Jude Hofschneider [Guam]: He asked what kind of disease is related to coral bleaching and or global warming. What other factors are involved that are not direct cause by disease?

[lxii] D. Fenner: Page 33 at the end says that studies found that microbes cause bleaching in one coral. However, there is a paper by Hoegh-Guldberg that presents evidence that the bleaching of that coral is not caused by bacteria.

[lxiii] Sierra Club: "Improving bleaching predictions: Van Hooidonk, R., M. Huber. 2012. Effects of modeled tropical sea surface temperature variability on coral reef bleaching predictions. Coral Reefs 31: 121-131.

[lxiv] D. Fenner: Page 31 near the end talks about when the repeat frequency of bleaching events gets too short for corals to recover between bleaching events. An early study that looks at this, Sheppard (2003), should be mentioned and referred to here. The citation is already in the references.

[lxv] Margaret Miller: Yep. Upshot of van Oppen plenary seemed to be that there are lots of potential mechanisms of adaptation but the jury is out on all of them in terms of providing reasonable expectation of lowered extinction risk. Also, I think it deems noting that at some (or possibly most) of these papers documenting 'altered bleaching response' (Guest et al 2012 is the one I am most familiar with) score bleaching at the generic level (with no notation of overall abundance). Hence, it is quite possible that this 'altered response' is not manifest by a single species, but represents to some degree a shift in the species being observed.

[lxvi] WPRFMC: While some coral species are known to respond to environmental change by shifting the composition of their algal symbiont communities, studies had suggested that this adaptive capacity may not be widespread. However, Silverstein and colleagues (2012) showed that conventional methods to study symbiont communities may fail to detect symbiont clades, and applying a high- resolution technique increases the detection. As a result, the study found that scleractinian (stony) corals commonly associate with multiple symbiont clades, and potential for reef corals to adapt to environmental change may therefore be more widespread than had previously assumed.

[lxvii] WPRFMC: Notes from ICRS Presentation by Roxanne Boonstra – Latitudinal distribution of algal symbiont in corals of Madagascar -- Latitudinal gradients in Symbiodinium may provide important insight into how coral species can adapt or acclimatize to changing environmental conditions through shifts in symbiont community composition

[lxviii] WPRFMC: Notes from ICRS Presentation by Carly Kenkel et al. – Evidence of local thermal adaptation in a Caribbean coral – a. The long-term persistence of coral reefs under global climate change scenarios depends largely on the ability of corals to track increasing temperatures with evolutionary adaptation; b. The presence of conspecific corals across broad latitudinal gradients suggests that local adaptation does occur; c. Inshore corals are locally adapted to sustained temperature stress

[lxix] D. Fenner: Page 31 there is significant information about the possibility of adaptation that needs to be added. For instance, the paper by Berkelmans and van Oppen entitled "nugget of hope." There are several papers that demonstrate different bleaching thresholds at different locations. This essay correctly points out that the

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thresholds vary locally, and tend to be relative to local temperature maxima. That implies that corals have adapted to local conditions. On the other hand, the information about bleaching in the Arabian Sea indicates that even corals that are regularly exposed to some of the highest temperatures anywhere, may have a limit to how far they can adapt to high temperatures.

[lxx] WPRFMC – ICRS presented by Steve Palumbi et al. – Acclimate and adapt? How will corals respond to future climate change? -- Mapping of genes that reacts to heat stress can help pin point locations that may be resilient to global ocean warming

[lxxi] CBD: Several new studies suggest that climate change is likely to increase the exposure of corals to severe cold stress and associated mortality in some regions. Several studies have linked the cold winter conditions and cold extremes experienced in the Northern Hemisphere in recent years to Arctic sea ice loss due to climate change (Cohen, Furtado, Barlow, Alexeev, & Cherry, 2012; Liu, Curry, Wang, Song, & Horton, 2012; Overland & Wang, 2010). These studies raise cause for concern that climate-change-driven increases in the intensity and frequency of cold (as well as hot) extreme events will contribute to coral reef decline by causing widespread coral bleaching and mortality.

[lxxii] CBD: Two studies have documented the negative effects that cold extremes exert on corals. Kemp et al. (2011) reported a massive die-off of reef-building corals in the Florida Keys, particularly Montastraea faveolata (one of the candidate corals) and Porites astreoides, following two closely spaced cold fronts in 2010. The study measured the physiological effects of low- temperature stress on Montastraea faveolata, Porites astreoides, and Siderastrea siderea over a range of temperatures similar to the inshore cold-water anomaly (i.e., from 20 to 16 to 12 °C and back to 20 °C), and found that M. faveolata and P. astreoides were particularly affected. Roth et al. (2012) exposed the branching coral Acropora yongei to a ± 5°C temperature change over time. The study found that short-term cold temperature is more damaging for branching corals than short-term warm temperature, whereas long-term elevated temperature is more harmful than long-term depressed temperature.

[lxxiii] We support the conclusion of the Biological Review Team that ocean acidification is a key threat to the 82 coral species. There have been sufficient studies on ocean acidification and corals to conclude that the biological response of corals to ocean acidification will be overwhelmingly negative. The status review report section on ocean acidification, however, is brief and tends to understate the risks of ocean acidification as a threat to corals.

[lxxiv] WPRFMC: Hoffman and colleagues (2011) found that upper ocean pH levels over a range of ecosystems were highly variable and site-dependent with characteristic diel, semi-diurnal, and stochastic patterns of varying amplitudes. Biome-specific pH signatures disclose current levels of exposure to both high and low dissolved CO2, often demonstrating that resident organisms are already experiencing pH regimes that are not predicted until 2100.

[lxxv] GFMC, Sierra Club: Caribbean-area example of the effects, in terms of reduced coral species richness and diminished colony size, near naturally low pH waters (Crook et al. 2012).

[lxxvi] There is also much to be learned from areas that have naturally low pH and aragonite saturation states. Recent in situ studies of areas that have low saturation provide a glimpse into the future for other coral reefs. In a study of areas with a groundwater seeps, called “ojos,” causing conditions of low pH and aragonite saturation, the coral cover and diversity was significantly reduced (Crook, Potts, Rebolledo-Vieyra, Hernandez, & Paytan, 2011). While there were still corals, only a few species persisted and they were the corals that do not contribute to the reef framework. The surveys revealed that the number of species increased significantly as saturation values increased with distance from the ojos (Id.).

[lxxvii] CBD: Similarly, an in situ study of an area in the Indo-Pacific that is naturally low in pH due to volcanic carbon dioxide seeps, Fabricius et al. observed reductions in coral diversity, recruitment and abundances of structurally complex framework builders, and shifts in competitive interactions between taxa (Fabricius et al., 2011). Despite overall coral cover withstanding reductions in pH from 8.1 to 7.8 and low rates of calcification, the structural corals were replaced by massive Porites thus reducing diversity. The diversity of hard coral species declined by 39% between the high CO2 and low CO2 sites. Reef development ceased below pH 7.7, suggesting a threshold for coral development at 980 ppm and 2.0Ω arag -- this is an overly conservative threshold estimate and higher than other predictions likely because it does not include the additional stressor of ocean warming (Id.).

[lxxviii] WPRFMC: ICRS presentation by Christopher Jury and Rob Toonen – Coral adaptation to hotter, more acidic oceans

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a. Temperature and pCO2 vary significantly on reefs over regional and local scales and some corals appear to have adapted to these temperature differences, though it is unclear whether they have adapted to differences in pCO2
b. Reefs in the inner portion of Kane'ohe Bay experience both elevated summertime temperature (1-3 °C) and elevated pCO2 (~100 µatm) as compared to regional normal-conditions not expected on most reefs for another 30-80 yrs, depending on CO2 emissions scenario
c. In spite of high summertime temperature and low Ωarag coral growth is strong and reef development robust within Kane'ohe Bay, offering a unique opportunity to investigate coral adaptation to global change

[lxxix] CBD: The status review report fails to examine the magnitude of the changes in ocean chemistry that are occurring throughout the range of these corals. The rate of change in ocean acidity is unprecedented in the past 300 million years, a period that includes four mass extinctions (Honisch et al., 2012; Zeebe, 2012). The seawater chemistry change is an order of magnitude faster than what occurred 55 million years ago during Paleocene-Eocene Thermal Maximum, which is considered to be the closest analogue to the present, and during that period 96 percent of marine species went extinct (Id.). Anthropogenic ocean acidification exceeds the trend in natural variability significantly, up to 30 times in some regions (Friedrich et al., 2012). This means that the ocean chemistry changes that are occurring due to ocean acidification are unprecedented and are cause for concern that the oceans may face mass extinctions of many species that we care about including these 82 corals….Modeling of the oceans' aragonite saturation predicts that by the end of the century up to 75 percent of ocean volume could be undersaturated with respect to aragonite (Joos et al. 2011).

[lxxx] CBD: A new modeling study showed that under various emissions scenarios the coral reefs in the Caribbean are thermally and chemically stressed between now and 2030 (Meissner, Lippmann, & Sen Gupta, 2012). They found that even under the most optimistic scenario, 98 percent of reefs would be stressed by 2050 (Id.). Under an intensive emissions scenario, the model shows mean annual open ocean surface water aragonite saturation thresholds for corals (3.3 Ω) exceeded by mid-century (Id.).

[lxxxi] CBD: In addition to modeling, decreasing aragonite and calcite saturation states have been observed in the Pacific and Atlantic. Based on observations from cruise surveys, Feely et al. report that in the Pacific Ocean there has been a decrease of the saturation state of surface seawater with respect to aragonite and calcite as well as an upward shoaling of the saturation horizon by about 1-2 meters per year on average (Feely et al., 2012). They report that aragonite saturation state has declined 16% since the industrial revolution due, in large part to anthropogenic CO2 (Id. see also Ishii et al. 2011). The authors conclude: "If CO2 emissions continue as projected out to the end this century, the resulting changes in the marine carbonate system would mean that many coral reef systems in the Pacific would probably no longer be able to maintain the necessary rate of calcification required to sustain their vitality" (Id.: GB3001). Dore et al. report the results of nearly 20 years of time-series measurements of seawater pH and associated parameters at Station ALOHA in the central North Pacific Ocean near Hawaii (Dore, Lukas, Sadler, Church, & Karl, 2009). They documented a significant long-term decreasing trend of -0.0019 +/- 0.0002 y(-1) in surface pH, which is indistinguishable from the rate of acidification expected from equilibration with the atmosphere (Id.). The long-term pH trend at 175m at HOT is −0.001930y−1 (See figure 2) (Beman, Chow, King, Feng, & Fuhrman, 2011).

[lxxxii] CBD: A model of Hawaiian scleractinian coral cover for years 2000–2099 were calculated assuming a single middle-of-the-road greenhouse gas emissions scenario and found that ocean acidification lowered long-term estimates of coral on the order of 20%–30% at the end of century (Hoeke, Jokiel, Buddemeier, & Brainard, 2011). Using parameters that corals are less adaptable to temperature and pH they found that corals precipitously declined after 2050 and probabilities of total loss of coral at some sites were nearly certain by the end of the century (Id.). This, however, was a simplified model of ocean acidification and the authors note that impacts may be much greater. For example, they noted that "susceptibility of crustose coralline algae calcification rates (a major component of Hawaiian reefs) and reef matrix cementation (relative to corals) may significantly impact coral populations by altering recruitment success, competition for space, and increased bio- and physical erosion of reefs (Id.). It should also be noted that in general, the CO2 emissions trend has largely tracked the worst-case scenario, not a middle-of-the-road emissions scenario.

Looking at the reef community for Acropora, Anthony et al., concluded that ocean acidification and warming alone can lower reef resilience, impairing growth and increasing mortality (Anthony et al., 2011). Modeling of the

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interaction between coral cover and macroalgae, the researchers showed that at levels likely to occur within this century coral abundance would decrease by more than 50% -- even with high herbivore grazing and low nutrient water quality. When grazing was reduced in the model, the regime shift away from coral dominance occurred at an even earlier stage of 600ppm (Id.). Accordingly, ocean acidification and warming were instrumental in contributing to loss of coral cover and management of local stressors is also important for resilience.

Modeling the impacts of warming and acidification on corals, Buddemeier made the bleak conclusion that: "Coral reef communities are likely to be essentially gone from substantial parts of the Southeast Caribbean by the year 2035." (Buddemeier et al., 2011). You can see from the figure below that the coral cover declines to less than 10% by the end of the century under all scenarios.

[lxxxiii] Table 3.2.2. The status review report's table on coral responses to ocean acidification (Status Review at 42) is notable. Andersson et al. provides a good supplement to this table (Andersson et al. 2011). It shows that the response of corals to ocean acidification is overwhelmingly negative, and that there are a plethora of studies to support a conclusion that ocean acidification poses a significant threat to corals. Both in situ studies and laboratory studies indicate that many corals have difficulty with calcification and growth under ocean acidification, with some being more susceptible than others.

[lxxxiv] WPRFMC: Recent studies have also shown that corals have the ability to regulate its internal calcification mechanism to accommodate increase in ocean acidity brought about by this membrane, which is present in all corals. Corals subject to increased temperature (ocean warming) and lower pH (ocean acidification) showed enhanced calcification without increase demand for energy (McCulloch et al. 2012). This allows corals to maintain formation of their coral skeleton, although this ability may not be ubiquitous to calcifying organisms.

[lxxxv] WPRFMC: Studies conducted in Western Australia also showed that a latitudinal gradient exist in coral calcification rates for massive Porites corals where calcification responds to temperature rather than ocean acidification (Cooper et al. 2012). There was no widespread and consistent pattern of decline in calcification rates of massive corals over time. The study also showed that there is no uniformity that ocean acidification would limit coral calcification on a global scale.

[lxxxvi] CBD: An in situ study of a coral reef in the Great Barrier Reef showed the potential impacts of ocean acidification on reef calcification where aragonite saturation varied between marginal 1.1Ω and optimal 6.5Ω (Shaw, McNeil, & Tilbrook, 2012). The researchers observed the calcification and other parameters on the reef and analyzed those data. They predict that since preindustrial levels under a business-as-usual scenario of emissions, community calcification will decline by 55%, with both decreasing calcification and dissolution increasing, this century (Id.).

[lxxxvii] CBD: Acorpora muricata exposed to ocean acidification corresponding with a doubling of pCO2 at an area with nutrient loading and one without found that calcification declined 22% regardless of the nutrient loading (Chauvin, Denis, & Cuet, 2011).

[lxxxviii] Based on observations and modeling, researchers found that calcification rates at coral reef locations in the Caribbean may have already dropped by ~15% with respect to their pre-industrial values (Friedrich et al., 2012). Researchers looked at continuous records of monitored sites in the Caribbean to determine aragonite saturation over the past two or three decades. They observed a strong trend in the Caribbean of −0.09 units per decade. The anthropogenic rate of change in the Caribbean was the largest regional trend reported, and the ΩsurfAr ~20 years reaches 78(136) times the glacial–interglacial rate of change.

[lxxxix] CBD: Additionally in the Indo-Pacific, Fabricius et al. (2011) reported that mean calcification rates of some massive Porites over the past 12 years were 30% lower than expected given their latitude, which collaborates that rates of calcification in massive Porites, P. damicornis and other corals have declined by 14–30% over the past 20 years in large geographic regions around the world, with ocean warming and acidification considered the most likely causes

[xc] CBD: Even corals that are able to calcify under ocean acidification conditions often do so at the expense of other biological functions, such as reduced metabolism or reproduction. For example, corals depend on nitrogen and phosphorous for their metabolic functions and experiments show that low pH combined with high temperatures can significantly decrease the phosphate and nitrate uptake rates of a scleractinian coral (Godinot, Houlbrèque, Grover, & Ferrier-Pagès, 2011).

[xci] CBD: A study of the effect of ocean acidification on calcification and symbiotic algae of Porites australiensis, found that acidified seawater significantly decreased calcification and fluorescence yield of the coral (Iguchi et al., 2012).

[xcii] CBD: Another study of Acropora millepora, found that acidified seawater caused the coral to lose more than 50% of their symbionts and to decrease their photosynthesis and respiration (Kaniewska et al., 2012).

[xciii] Shell: The "Status Review" document repeatedly notes that BRT considers ocean acidification to be a significant threat to corals by 2100. It is curious then that three of the proposed Caribbean species for listing, which are all in the genus Montastraea, have been described as having suffered "profound population declines" due to disease as well as decreasing growth rates from sediment and nutrient- impacted water quality. Also described in the "Status Review" document is a single field study that was conducted to determine the impact of acidification on this genus; however, it did not find any change in Montastraea faveolata calcification in colonies sampled from the Florida Keys. Therefore, we recommend that the BRT reassess the urgency related to extinction risks associated with ocean acidification, which has a somewhat manipulated tone in contrast to other widespread and persistent destructive activities that are known to have caused significant declines in coral cover, and if reversed, could help ameliorate effects from other impacts. For example, adaptation and resilience to heat stress are known to be possible as long as reef communities are not already struggling under other stressors.

[xciv] CBD: The status review report discounts scientific reports that have shown that effects of ocean acidification on corals have already been observed without support for questioning the results of those studies. The rapidly declining aragonite saturation state in the Caribbean has already affected coral reefs resulting in reduced calcification (Bates, Amat, & Andersson, 2010; Gledhill, Wanninkhof, Millero, & Eakin, 2008). Reduced calcification rates have also been observed in the Pacific, including the Great Barrier Reef, which must be considered (Cooper, De'Ath, Fabricius, & Lough, 2008; De'ath, Lough, & Fabricius, 2009). These observations of reduced calcification suggest that ocean acidification impacts are already occurring in the water, and it is quite certain that the problem will become more severe.

[xcv] CBD: Ocean acidification affects three sequential life history phases necessary for successful coral recruitment of A. palmata: (i) larval availability (by compromising fertilization), (ii) settlement ecology (by reducing settlement success), and (iii) postsettlement ecology (by impeding postsettlement growth) (Albright, 2011a, 2011b; Albright, Mason, Miller, & Langdon, 2010). Albright et al. concluded that with increased carbon dioxide concentrations, fertilization success decreased by 12-13%, settlement success reduced 45-69%, and linear extension was significantly reduced. The compounding effect of these impacts translates to 52-73% reduction in the number of larval settlers on the reef. Albright et al. predicts that the net impact on recruitment will actually be greater than that given that the depressed postsettlement growth is likely to result in elevated rates of postsettlement mortality (Albright et al., 2010). In a study of Porites astreoides, Albright and Langdon tested the effects of ocean acidification on sexual recruitment of corals (Albright & Langdon, 2011). Larval metabolism was depressed by 27% at acidification expected by mid-century and 63% at end-of-century acidification levels. Settlement was also reduced 42-45% and 55-60%, at the mid and end-of-century levels respectively, relative to controls (Id.). A study of Acropora digitifera larvae showed that short-term or long term exposure of larvae to ocean acidification decreased their metamorphosis (Nakamura, Ohki, Suzuki, & Sakai, 2011). This means that even when larval survivorship is unchanged, the success of recruiting new corals could be inhibited by ocean acidification (Id.). Additionally, under conditions of acidification planktonic larvae lose their preference for settlement on the optimal crustose coralline algae communities (Doropoulos, Ward, Diaz-Pulido, Hoegh-Guldberg, & Mumby, 2012). Accordingly, at CO2 concentrations predicted to occur by the end of this century, Acropora millepora settlement and crustose coralline algae cover was significantly reduced by ~ 45% (Doropoulos et al., 2012).

[xcvi] Margaret Miller: While the data is still scant for corals, the recent results presented at ICRS extending what is known about nurological effects in fish, combined with the point you cite here suggests that general disfunction of signaling and sensing may be one of the most overarching effects of OA. Though we don't think of corals as very sophisticated in this regard, evidence continues to mount that complex sensory processes (including microbial chemical cues and neurotransmitters, as well as CCA chemical cues, in addition to sound and light) are involved in coral larval settlement choices.

[xcvii] CBD: Recent studies projecting sea-level rise have found that a mean global sea-level rise of at least 1 to 2 meters is highly likely within this century (Grinsted, Moore, & Jevrejeva, 2009; Jevrejeva, Moore, & Grinsted, 2010;

NRC, 2012; Pfeffer, Harper, & O'Neel, 2008; Rahmstorf, 2007; Vermeer & Rahmstorf, 2009). Rahmstorf (2007) used the tight, observed relationship between global average temperature rise and sea-level rise over the recent observational record (~120 years) to project a global mean sea-level rise of 0.5 to 1.4 m by 2100. Other studies estimate a global mean sea-level rise by 2100 at 0.75 to 1.90 m (Vermeer and Rahmstorf 2009), 0.8 to 2.0 m (Pfeffer et al. 2008), 0.8 to 1.3 (Grinsted et al. 2010), and 0.6 to 1.6 m (Jevrejeva et al. 2010). The U.S. National Research Council concluded that mean global sea level is likely to rise 8-23 cm (3-9 in) by 2030, relative to 2000 levels, 18-48 cm (7-19 in) by 2050, and 50–140 cm (20-55 in) by 2100 (NRC 2012). Moreover, studies that have reconstructed sea-level rise based on the geological record, including oxygen isotope and coral records, have found that larger rates of 2.4 to 4 m per century are possible (Milne, Gehrels, Hughes, & Tamisiea, 2009).

[xcviii] Eugene Shinn: Exactly why the Florida reef tract and many other areas of the Caribbean have been unable to keep pace with rising sea level during the past 6 ka remains mostly unknown, although periods of intense and frequent hurricanes are considered a likely cause (Macintyre and Adey, 1990; Macintyre et al., 2007). In all such cases, the growth rates of even the slowest-growing Atlantic corals are sufficient to easily keep pace with rising sea level (Shinn et al., 1989). Acropora can grow upward at a rate of 10 m/1,000 years (Macintyre and Adey, 1990; Shinn et al., 1989; Macintyre et al., 2007).

[xcix] D. Fenner: Page 46, 3.2.4.2 This is a generally good section, but the point made in the first sentence is not considered sufficiently. There are now two papers that report just such an effect. Low tides on reef flats normally act like a lawn mower (Fenner, 2012) to kill coral which has grown too high, while allowing coral that is lower to survive and continue growing. With sea level rise there will be less coral killed from low tides, if sea level rise exceeds coral growth rates. Sea level rise of only 3 mm/yr is well within the range of reefs to grow upward (3-6 mm/yr most commonly, Montaggione, 2005) and far less than the rate of growth of the fastest corals, which are branching Acropora that can grow at least 10 cm/yr. Periods without exceptionally low tides have been shown in two studies to lead to higher coral cover on reef flats (Brown, 2011; Scopélitis, 2011).

There is a series of studies by Field et al (2012) which demonstrate increased terrestrial sedimentation on reef flats due to increased water depth on reef flats on the south side of Molokai, Hawaii. Those sediments that are mobilized by the larger waves allowed by the greater water depths on the reef flats will impact the corals. Although there are many reefs with high terrestrial sediment situations, there are many that have little or no terrestrial sediments, such as reefs in desert situations like the Red Sea and the west coast of Australia (where the world's largest fringing reef, Ningaloo Reef is), and on the many atolls of the Indo-Pacific. So the effects of sea level rise on reef flat corals will depend on the terrestrial sediment environment, with negative effects in the presence of sediment, and positive in the absence.

However, any positive effects where sediment is lacking will be likely relatively short lived, with bleaching reducing coral cover in a few decades, and only 3 cm sea level rise per decade, the positive effects will probably be small before coral mortality reverses any positive effects (Fenner, 2012).

[c] CBD: Field et al. (2011) concluded that sea level rise may cause the decline of fringing reefs. The study found that coral growth and reef accretion at existing sites may not be sufficient in many areas of the world to keep pace with the rising sea level and its effects:

Many corals are rapid growers, extending in length by an average of 2 to more than 30 millimeters per year, seemingly fast enough to keep pace with the 2–4 millimeters per year of estimated sea level rise. However, overall net vertical accretion of reefs is much slower, perhaps by a factor of 10, than the growth of individual coral colonies [Hubbard et al., 2008], and thus even reefs that are vertically accreting will do so at rates below the rate of sea level rise. Further, reef accretion at present appears to be limited, at least in Hawaii, to a relatively few wave-sheltered areas [Grigg, 1998; Fletcher et al., 2008]. The impacts to coral reefs from ongoing stresses due to climate change, sediment runoff, disease, incursions of alien algae, and overfishing make sustained net reef accretion problematic everywhere [Pandolfi et al., 2003]. Indeed, a modeling study of Caribbean reefs showed that wave forces alone over a reef deepened by sea level rise would lead to a failure of reefs to keep up with that rise [Graus and Macintyre, 1998]. Projected increases in sea surface temperatures, dissolved carbon dioxide, and associated oceanic acidity will likely further stress reefs and inhibit their capability to accrete. Thus, although some reefs have the potential to keep pace with the average accelerated rates of sea level rise projected for this century, sustained vertical reef accretion is unlikely, and many existing reefs will not keep pace. (Field et al. 2012: 274-275).

[ci] D. Fenner: Page 46 The last sentence before the diagram is not quite justified in the form in which it is written. This is true about corals on reef flats and/or lagoons, but not on reef slopes, barrier reefs, or atolls.

[cii] D. Fenner: Page 48, first paragraph is certainly correct that people resort to hardening shorelines as shorelines erode. But then it jumps to saying that societies will choose to protect themselves even if it causes destruction of coral reefs. No evidence is presented that hardening shorelines will damage coral reefs. If that evidence exists, then certainly present it. Hardening might lead to more rapid erosion of remaining sand or sediment on the shoreline below the hardening, I don't know as I'm not an expert on that. If so, that sediment could be deposited on the reef and negatively impact the reef. But if a shoreline is hardened and sea level rise puts the sea level up on that hardened shoreline, then any part of the hardened shoreline below low tide level is potential habitat for corals, and can be colonized, potentially even leading to lush coral communities. I have seen just this in at least one location in American Samoa.

[ciii] D. Fenner: Page 50, 3.2.6, second paragraph. One sentence talks about hurricanes reducing bleaching by causing mixing with deeper water which cools the water. A hurricane was observed keeping bleaching at a minimum at Mauritius and Rodrigues in the Indian Ocean in 1998 (Turner 2000). Part of the effect may also be due to clouds reducing the intensity of sunlight.

Turner, J.R., Hardman, E., Klaus, R., Fagoonee, I., Daby, D, Baghooli, R., and Persands, S. 2000. The reefs of Mauritius, in D. Souter, D. Obura, and O. Linen (eds.) Coral Reef Degradation in the Indian Ocean. Status Reports and Projects Presentations 2000 (Stolkholm: CORDIO), pp. 94-107. Areas that suffered minimal bleaching and mortality included the more southerly islands of Mauritius and Reunion, where cyclonic activity retarded increases in sea-surface temperature. Also, in other areas, such as western Unguja and Pemba Islands and on some reefs of the Seychelles Bank, upwelling of cooler waters from off the continental shelf and bank slopes moderated increased sea surface temperatures and prevented the subsequent bleaching of corals.

[civ] GFMC, Sierra Club: Pages 50-51. Dust could also be a source of a limiting nutrient (e.g., iron) facilitating the growth of benthic cyanobacteria or algae that, unchecked by herbivores, can outcompete corals.

[cv] GFMC + Sierra Club: Page 52. Summary. Sokolow (2009) has reviewed the effects of climate change on coral disease.

[cvi] WPRFMC: Taken together, these recent studies indicate that the ecosystems in which coral reef are found are already highly dynamic in terms of temperature and acidity, and that the response of different coral species will be highly variable and is still not fully understood. Indeed all but a handful of the species in the listing petition range widely over the Indo-Pacific region, with some species like Acropora horrida being found in extreme environments for corals such as the northern Persian Gulf—where temperatures and salinity may change by as much as 50% between seasons—to oceanic atolls in eastern Polynesia. Even species that are more restricted to the core of the Indo- Pacific faunal continuum, popularly known as the Coral Triangle, are distributed from equatorial latitudes to the sub-tropics across a variety of marine ecosystems. Far from being the fragile organisms that environmental advocates would have us believe, many coral appear to be successful and adaptive to a range of environments and stressors, hence their persistence from geologic time to the present.

[cvii] BYU Student "Being familiar with Endangered Species Act… listing endangered species, one would need to take into account activities such as snorkeling, fishing-type of fishing or technique of fishing. In the Caribbean for example….limits on commercial fishing as certain fish are important to corals; protect corals from going extinct; prohibit activities that harms species."

[cviii] [Guam commenter]: "He commented regarding infiltration of aquifers, run off, oil from river to ocean. He is concerned of federal projects pushing their construction in flood-prone areas. He recommends environmental impact statement on all houses to be built"

[cix] [Guam commenter]: "He commented that he sees inappropriate equipment being used at dredging site of Apra Harbor."

[cx] [Guam commenter]: He asked – are there going to be land-based activities affecting corals? He further stated that NOAA needs to look at steps, consultations as it also affects military activities.

[cxi] WPRFMC: Additionally, NMFS should evaluate impacts of non-point source pollution on coral reefs, including those from heavy metals from tires.

[cxii] D. Fenner: Page 61, Salinity. You might mention that corals are osmoconformers, not osmoregulators, the salinity inside cells reflects the salinity outside the cells. You might also mention that no corals have ever adapted to fresh water, although Hydra and a few jellyfish have

[cxiii] Laurie Raymundo: Kaczmarksky, L.T. 2006. Coral disease dynamics in the central Phillippines. Diseases of Aquatic Organisms 69: 9-21. - Correlation analyses linked higher disease prevalence to anthropogenic influence (Spearman's rank correlation coefficient [rs] = –0.54, p = 0.04 for tumors and rS = –0.69, p = 0.005 for PUWS). In most sites disease prevalence was lower than in the sites near Dumaguete. High PUWS prevalence near uninhabited Sumilon Island appeared to be linked to the highly diseased reefs near Dumaguete City due to transmission of disease along a cross-shelf front formed between the Tañon Strait and Bohol Sea.

[cxiv] D. Fenner: p. 64, 3.3.2 Disease. An excellent paper reports that coral disease is lower in MPAs because predators reduce butterflyfish populations, which probably transfer disease by biting polyps on infected corals and then on uninfected colonies. Only the population densities of those species of butterflyfish that eat coral polyps correlates with disease levels. Raymundo, L.J.; Halford, A.R.; Maypa, A.P.; Kerr, A.M. Functionally diverse reef-fish communities ameliorate coral disease. Proc. Natl. Acad. Sci. USA 2009, 106, 17067–17070.

[cxv] GFMC, Sierra Club: Page 64, 2nd paragraph, lines 7-8. The 1995 outbreak of white plague type II that so devastated Dichocoenia stokesi was limited to the Florida Keys and not Caribbean-wide. Even there, we doubt it is "unrecoverable" in the short term, given its relative abundance in the 2005-2007 FRRP surveys (Wagner et al., 2010) and its "high resistance to both warm and cold-water anomalies" (Lirman et al., 2011, p. 4).

[cxvi] D. Fenner: Another paper of interest, showing that human sewage is the likely ultimate cause of white pox disease in Acropora: Sutherland, K.P., Porter, J.W., Turner, J.W., Thomas, B.J., Looney, E.E., Luna, T.P., Meyers, M.K., Futch, J.C., Lipp, E.K. 2010. Human sewage identified as a likely source of white pox of the threatened Caribbean elkhorn coral, Acropora palmata. Environmental Microbiology 12(5): 1122-1131. In 2002, we identified the faecal enterobacterium, Serratia marcescens, as an etiological agent for white pox. During outbreaks in 2003 a unique strain of S. marcescens was identified in both human sewage and white pox lesions. This strain (PDR60) was also identified from corallivorious snails (Coralliophila abbreviata), reef water, and two non-acroporid coral species, Siderastrea siderea and Solenastrea bournoni. Identification of PDR60 in sewage, diseased Acropora palmata and other reef invertebrates within a discrete time frame suggests a causal link between white pox and sewage contamination on reefs and supports the conclusion that humans are a likely source of this disease.

[cxvii] D. Fenner: Predation, Crown-of-Thorns. Perhaps mentioning when and where the first known COTS outbreaks occurred, that there is evidence indicating that COTS outbreaks were not common before then, and thus they may be caused or facilitated by humans. Perhaps worth mentioning that while there was a period when COTS outbreaks became more common and spread around the Indo-Pacific, they have not continued to be common most places, except that the GBR continues to have outbreaks periodically, which move south over time.

[cxviii] Eugenio (Wayne) Villagomez: He stated that what Tinian is experiencing is outbreak or over-run of crown of thorns, damage done more so that sedimentation. He asked about assessment of the Endangered Species Act on proposed corals.

[cxix] Mr. Duenas further stated that NOAA should do something to abundance of crown of thorns.

[cxx] D. Fenner: p. 69, 3.3.4 apex predators. High populations of apex predators have also been reported from large, well-protected MPAs in the Caribbean that have been around for a long time.

[cxxi] D. Fenner: Page 62, end of the predation section. You probably should include the early theory by Endean that the removal of predators like Triton shells caused outbreaks by release from predation. That's been pretty well discredited since Triton shells are too rare to control COTS outbreaks. The evidence from Dulvy for fish predation causing COTS outbreaks is very weak, since their results can be easily accounted for by the Birkeland hypothesis since higher population not only is correlated with more fishing but also with increased nutrients (stated in Fenner, 2012). There is almost no evidence of fish eating crown of thorns, there is just one individual star reported in the stomach of one Napoleon wrasse in a study by Jack Randall. The Birkeland hypothesis correctly predicts several things that other hypotheses can't account for, such as the fact that outbreaks are on high islands not low islands, and they often follow heavy rain by 3 years. The Brodie study tested and confirmed all but one of the individual steps in the BIrkeland hypothesis. My reading of the Brodie paper was that it substantiated the Birkeland hypothesis, it didn't replace it. That's reflected in the title which only mentions nutrients, not urbanization (which of course can independently produce nutrients, that's just an extension of Birkeland's hypothesis). The report

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paragraph implies that there is no difference in the empirical support for these hypotheses, I don't think that's true. The strongest evidence in support of the role of fishing in COTS outbreaks is Hugh Sweatman's paper showing that MPA areas on the GBR have fewer COTS outbreaks than non-MPA areas (as stated in Fenner, 2012).

[cxxii] D. Fenner: P. 70, fishing of herbivores. The need for herbivorous fish was reviewed by Fenner (2012) in the context of the resiliency problem, and several additional papers were referred to there.

Fenner, D. 2012. Challenges for managing fisheries on diverse coral reefs. Diversity 4(1): 105-160.

[cxxiii] D. Fenner: p. 77, cyclones require long distances of open water to generate the largest waves; reefs that are not exposed to long distances of open water can have remarkably little damage from the most powerful cyclones (Fenner, 1991)

Fenner, D. P. 1991. Effects of Hurricane Gilbert on coral reefs, fishes and sponges at Cozumel, Mexico. Bulletin of Marine Science 48: 719-730

[cxxiv] D. Fenner: p. 77, paragraph beginning with "cyclone distribution" near the end points out that cyclones do not occur near the equator. This was pointed out, with a map of hurricane track in the Indo-Pacific, and it was pointed out that coral diversity is high near the equator in spite of the lower levels of disturbance produced by the lack of cyclones, contrary to the intermediate disturbance hypothesis Fenner, 2007, pages 785-786.

Fenner, D. 2007. The Ecology of Papuan Coral Reefs. Pages 771-799 in: The Ecology of Papua, Vol. 2. Periplus Publishing, Singapore.

[cxxv] D. Fenner: P. 78, vessel groundings. Cruise ship anchor chains can destroy large areas of reef as winds move the ship back and forth (Allen, 1992)

Allen WH (1992) Increased dangers to Caribbean marine ecosystems. Bioscience, 42: 330-335.

[cxxvi] D. Fenner: "P. 79, 3.3.9 The statement that lack of information could be due to the lack of successful invasions is true, but unless a clear distinction between introduced species and invasive species is made, this could be misinterpreted by some readers as saying there are few introduced species. My vague memory was that Hawaii had something like 700 introduced marine species, but only a few are invasive. Perhaps it could be restated, by saying that the lack of information could be due to few introduced species being invasive. But best to define invasive and introduced as well.

[cxxvii] D. Fenner: p. 80. I would suggest saying that Tubastraea coccinea spread throughout the Caribbean, then the Gulf of Mexico and most recently to Florida. There is now a reference to the paper on Tubastraea micrantha on an oil rig in the Gulf of Mexico, paper is by Sammarco, P.W., et al. 2010. A new coral species introduced into the Atlantic Ocean, Tubastraea micranthus…. Aquatic Invasions.

[cxxviii] D. Fenner: p. 81 For G. salicornia, two islands where it is present are named, and it states that they are on these three islands, without saying what the third island is.

[cxxix] Sierra Club: After an extensive literature review, the BRT concluded that rising ocean temperature, disease (which often follows warm bleaching events), and ocean acidification "are likely to represent the greatest risks of extinction to reef corals, including many of the candidate species over the next century" (SRR, p. 52). The Sierra Club concurs with this conclusion, which accords with a clear majority of other recent scientific reviews (e.g., Baker et al., 2008; Penaflor et al., 2009; Eakin et al., 2010); see also the 12th International Coral Reef Symposium consensus statement (www.icrs2012.com/Consensus_Statement.htm). Furthermore, Sierra Club emphasizes that removing the stressors associated with greenhouse gas emissions would be essential for any long-term success of the coral restoration activities funded by NOAA and its partners.

The BRT found widespread local threats to coral reefs, such as sedimentation, nutrient enrichment and fishing to be of "medium importance" in determining extinction risks. We consider the priority for action to reduce local stressors to be of higher importance than "medium," but local actions will be insufficient overall so long as global climate change remains a pervasive threat.

[cxxx] MAFAC: Further explain the criteria used to rank threats to extinction (e.g., negligible, low, medium, and high) in Summary of Threats, Section 3.5.

[cxxxi] Van Woesik: "There is a strong relationship between past and present vulnerability of coral species to regional extinction events (van Woesik et al 2012). That positive relationship suggests that the vulnerability of coral species to extinction risks is largely dependent on their biological traits. The key question therefore is: Which suite of biological traits most influences species vulnerability to climate change?"

[cxxxii] Tim McClanahan: “Evaluations of corals specifically have used demographic metrics to estimate extinction risks, such as described in Carpenter et al. (2008). These may be useful but there is a good chance that species that exhibit population declines are not necessarily those that will go extinct. Extinction may be caused by more episodic events where life history characteristics may be more critical than demographics. The demographic approach suffers from missing data on population trends, too brief of a time series for long-lived organisms, an inability to validate the results, and difficulties in distinguishing decline from extinction dynamics.”
Carpenter, K. E., M. Abrar, G. Aeby, R. B. Aronson, S. Banks, A. W. Bruckner, A. Chiribora, J. Cortes, J. Charles Delbeek, L. DeVantier, G. J. Edgar, A. J. Edwards, D. Fenner, H. M. Guzman, B. W. Hoeksema, G. Hodgson, O. Johan, W. Y. Licuanan, S. R. Livingstone, E. R. Lovell, J. A. Moore, D. O. Obura , D. Ochavillo, B. A. Polidoro, W. F. Precht, M. C. Quibilan, C. Reboton, Z. T. RIchards, A. D. Rogers, J. Sanciangco, A. Sheppard, C. Sheppard, J. Smith, S. Stuart, E. Turak, J. E. N. Veron, C. C. Wallace, E. Weil, and E. Wood. 2008. One-third of reef-building corals face elevated extinction risk from climate change and local impacts. Science 321:560-563.

[cxxxiii] Mark Hay: “My feeling is that local (but often regional as well) biotic processes are more critical (but harder to measure and understand) that is indicated in the status review – reasonable people can disagree on this”

[cxxxiv] D. Fenner: “P. 90 near the top refers to the IUCN report (2010) and the accompanying Science article (2008). I think these are out of order. The Science article came first, then it was adopted by the IUCN. The work was done by two groups gathered by Kent Carpenter, using the IUCN criteria. The Science article was published, and then IUCN adopted the results and put them on its website. So the IUCN report is the accompanying report, as the two dates you give show, it was second. The Science article was not based on work done at IUCN (other than the set of criteria).

[cxxxv] T. McClanahan: I consider these low diversity genera as possibly more extinction prone then the high diversity genera that are frequently listed as vulnerable.

[cxxxvi] Kushmaro: “production of anti-microbial compounds…perceiving the coral as a holobiont…" Shifts in coral-associated bacteria may help coral adapt to environmental changes and may fend off disease or help the coral develop resistance.”

[cxxxvii] Kushmaro: “The possibility of carrying out genome scans with these new sequencing technologies over the geographic range of the species listed to assess the adaptive potential under the threats of climate change. This effort should be planned hand in hand with experimental manipulations.”

[cxxxviii] Mark Hay: Degradation of ecosystem processes (herbivory, recruitment, etc.) is the most important scientific information that should be considered in the context of the extinction risk for corals.

[cxxxix] Medina: A better understanding of the overall cellular responses of the coral host to environmental stressors

[cxl] Medina: whether a stressor induces the same response when acting alone or in concert with other such insults.

[cxli] Kushmaro: [the most important scientific information that should be considered in the context of the extinction risk for corals is] To sum up: microbial community shifts and coral disease.

[cxlii] Medina: What is the inter-kingdom communication that takes place among all coral holobiont members in response to…stressors and how this response is being affected by climate change.

[cxliii] Aronson: If temperature effects—directly via coral bleaching and indirectly via the promotion of infectious diseases—are expected to pose the greatest threat to coral populations in the coming decades, any assessment of extinction threat should evaluate each species’ resistance and resilience to high-temperature extremes, and consequence resistance to extinction, based on species-specific biological traits. Van Woesik et al. (2012) have done such an analysis at the generic level and for the Montastraea annularis species complex. Inclusion of this type of information would have strengthened dataset upon which the extinction-threat assessments in the BRT Report were based.

[cxliv] John Bruno: “The most important scientific information that should be considered in the context of extinction risks are "in particular order: recent patterns of ocean warming/high anomalies (which the BSR [sic] included); projected future warming patterns; evidence that warming has affected corals, particularly at the population level (e.g., demographic projections, but also coral cover, community composition, etc.); use of warming projections to forecast coral loss.”

[cxlv] D. Fenner: “I think I remember sometimes the report refers to the “IUCN Red List” ranking. I would recommend referring to the Science paper that used the IUCN Red List methods. It really wasn’t IUCN that did the evaluation, but two groups of people assembled by Kent Carpenter. Many people confuse the two. Perhaps in the methods

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section, it would be good to explain a little bit about their criteria and refer to the two papers that document the basis for their criteria.

[cxlvi] Also, the rankings that were produced by this report are different from those produced by the Science paper. At some point someone is going to start asking “why?” Might be good to have an explanation. The actual species info is heavily based on the Science paper info, yet the conclusions are at least somewhat different (I haven’t compared carefully, maybe they are closer than I think!) But if I was going to try to sue, I’d be asking “why the difference?” to try to find some weakness I could exploit.”

[cxlvii] Van Woesik: The treatment of our ‘biological traits’ theme was appropriate within the biological status review; however, the report makes few comparisons with other published studies that also list the vulnerability of corals species, and there was no consideration or comparison of the 82 coral species with their IUCN status.

[cxlviii] GFMC: The petition would be better served if each individual species was considered for listing separately.

[cxlix] Dr. Peter Houk: “Commented regarding collection of information, asking what references were used as some coral species are abundant in the Northern Mariana Islands (CNMI). He said he has done extensive data recording of coral species in the CNMI.”

[cl] T. McClanahan: Finding the locations and abundance of these taxa exist in relationship to environmental stresses will both help to evaluate their status and priority areas for conservation. A global stress model has been developed specifically for coral responses to thermal stresses and this multilayer spatial model can be used to evaluate the taxa distributions in relation to stress (Maina et al. 2008, 2011).

[cli] MAFAC: Please explain why the authors used 2100 as the CRT.

[clii] GFMC: The planning horizon is too long 88 years into the future.

[cliii] CNMI DLNR: [The SRR] shows that there is little data with regards to individual species population numbers and trends. The analysis present although possible the "best available" is severely lacking and based on reviewers' opinions. The reviewers were Federal experts and researched all available literature, but their findings are unclear.

[cliv] Roxanna Miller: It is very hard to make determinations on risk to coral survival when information from the species’ entire range is incomplete.

[clv] If a coral is assumed to be present in an area without any clear supporting evidence, this can complicate the determinations of the percent likelihood of a species falling below the CRT (the percent may be assessed as being lower or higher than it should be). This also contributes to the large variability in likelihood percent determined by the BRT. Once more comprehensive scientific information is gathered from the comments on the Status Review, another assessment report may be necessary.

[clvi] AIC: The consultation process also relies on best available information to complete this process. We have concerns that the present data set is very limited and in many cases we do not even know the extent of the absence or presence of these species, let alone the population structure and density. Between the Indian and Pacific oceans there are over 50,000 islands that lie within the tropics that support coral reefs, but very few of which have been comprehensively inventoried for coral reef species. This limited knowledge coupled with the taxonomic challenges of identifying corals to the species level further limits the meaningful application of ESA to corals and may require significant additional corals to be listed due to taxonomic identification similarity concerns. If we use the example of the two existing threatened species listed in the Atlantic, it is not clear that the intended benefits to the species are being realized and there have certainly been community and local government impacts that were not realized until after the listing.

[clvii] WPRFMC: Given the lack of quantitative data on the 82 individual species, BRT evaluated extinction risk qualitatively using a voting process. Citing that it is challenging to predict risk of absolute extinction, the BRT instead estimated the likelihood that a population would fall below a Critical Risk Threshold by the year 2100. Critical Risk Threshold was defined qualitatively as “a condition where a species is of such abundance, or so spatially disrupted, or at such reduced diversity, that the species was at extremely high risk of extinction with little chance for recovery.” The Council understands that the BRT’s voting process was a necessary approach given the limited amount of available scientific data and limited time allotted to complete the review despite the large scope of the petition. The Council further notes that the voting process incorporated uncertainty within and among the seven BRT members. However, listing decisions for the 82 individual species under the ESA should not heavily rely on the BRT’s voting results due to their highly subjective and qualitative nature.

[clviii] Much of the information regarding threats such as thermal stress, acidification, and disease on which the BRT based their voting were only available at the genus level and very little information was available at the species level. In addition, limited information was available to the BRT regarding demographic and spatial factors, such as abundance, productivity, and diversity, which are critical in evaluating susceptibility to threats. Most of the voting was therefore conducted using qualitative and uncertain information. As a result, results of the voting may reflect BRT members' perception of extinction risk rather than a reliable scientific measure that would be more desirable for the basis of ESA listing decision.

[clix] It is important to note that previous ESA status reviews that employed voting methodologies also had substantial amount of quantitative information regarding the species' population abundance and status. Furthermore, other BRTs have used scoring for a series of factors, unlike the Coral BRT, which only voted on the overall extinction risk for each species. The BRT cites the 2005 salmon and steelhead status review9 as an example of another BRT using a similar voting approach. However, the salmon and steelhead species considered in the review had long-term data on abundance, productivity, harvest impacts, and in some cases results from population viability analysis (PVA) to inform the overall risk assessment. The salmon and steelhead BRT also quantified risk for four population categories (abundance, productivity, spatial structure and connectivity, and diversity) using a scoring system, creating more standardized and transparent measures that informed the overall risk assessment by the BRT. In contrast, the Coral BRT did not standardize measures of demographic and spatial factors, and it is uncertain the degree to which abundance, productivity, and distribution informed the BRT member's votes. Another more data-rich species for which voting procedures were used in a BRT's status review was the Hawaiian insular false killer whale10. In this case, the BRT scored factors for evaluating distinct population segment (DPS) and specific parameters to be used in the PVA.

[clx] The Council's SSC Subcommittee was tasked to review the voting methodology used in the BRT Report. Subcommittee members disagreed on whether the voting methodology represented a valid approach for evaluating extinction risk, but agreed that the results from this approach are easily influenced by the composition of the BRT membership. Given this, the SSC recommended that NMFS make available curriculum vitae of BRT members with specific emphasis on their expertise for the 82 species of corals to increase transparency and validity of the extinction risk evaluation. Similarly, Subcommittee members noted that spread of point allocation (degree of uncertainty) for each BRT member's vote on each species should be made available for the same reason above.

[clxi] WPRFMC: The SSC also noted that it is misleading to create precise numerical risk values from qualitative categories, as it creates a false impression of precision in the decision-making. This is particularly a concern given that mean likelihood and standard error measures are calculated from categories with unequal distances between them. Typically in survey research, categorical responses assume equal distances between each category so that meaningful statistics can be calculated. However, in the BRT's approach, the extreme ends of the categories ("exceptionally unlikely" and "virtually certain") each represent one percent of the likelihood while the "unlikely" and "likely" categories represent 23 percent of the likelihood. The means and standard errors may therefore represent arbitrary numbers that do not accurately reflect the intent of the BRT member votes.

[clxii] Roxanna Miller – It would be good to list the abundance of the species in U.S. waters as well as globally. If they are locally common and abundant in U.S. waters, would that change the decision for listing?

[clxiii] Roxanna Miller – For those species that are uncommon or rare, it would be nice to know if they have always been rare (even before a 30% decline over 30 years), or if they have gone from common to uncommon/rare due to the declines.

[clxiv] There is very little species specific information available on life history and threats for the 82 species. There is, however, a lot of inference from the Genus and Family level. Are these comparisons and assumptions valid? With recent studies identifying the genetic relationships of coral species, it has become evident that some species thought to be closely related due to morphological and skeletal characterization are deeply divergent genetically. This suggests that inferring similar responses to threats of other species may not necessarily be legitimate.

[clxv] Mark Hardgrove, VINP: …we are unsure of the rationale that was used to determine the list of species and are concerned that many other species of scleractinian corals are suffering similar threats and impacts and require equal protection under the ESA. Almost every species of coral occurring in our two park units are significantly reduced in numbers and colony health. Several species such as Diploria clivosa and strigosa, Porites astreoides, and

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some of the other "weedy" species appear to be increasing in number and distribution on our corals reefs. However, other major reef-building species such as Colpophyllianatans, Diploris labyrinthisformis, Montastrea covernos, and others, have suffered considerably from bleaching/disease events and are becoming rare in our waters. We are curious as to why they were not included on the list of proposed candidate species.

[clxvi] Steven Miller: [Provided a PPT presentation that includes] population estimates and species distributions by habitat types, not including the Dry Tortugas (would have shown more Agaricia lamarcki on deeper reefs in the Park and on the Tortugas Bank), along with the percentages of populations inside and outside MPAs in the sanctuary. The presentation was prepared for the June science meeting at NOVA. I wasn't able to attend and Mark was not able to present. Much additional information is available that is not included in the slides, including several manuscripts in preparation. We believe that population data are relevant to ESA deliberations.

[clxvii] GFMC: Of the seven Western Atlantic corals listed, three common species appeared on the list. Surprisingly, two of these were listed as most threatened.

[clxviii] D. Fenner: The report relied heavily on a publication by Charlie Veron to describe Atlantic-Caribbean species distribution. I highly respect Charlie for his expertise in the Indo-west Pacific; however, not so much in the Atlantic-Caribbean. They should have dug a bit deeper into the local relative literature for the distribution information. As an example; Dichocoenia stokesii occurs in the Florida Middle Grounds, eastern Gulf. Details like this are missed when using a big picture book. They seem to be oblivious to these good works:
Cairns S.D., D. R. Calder, A. Brinckmann-Voss, C. B. Castro, D. G. Fautin, P. R. Pugh, C. E. Mills, W. C. Jaap, M. N. Arai, S. H. D. Haddock, et al. 2002. Common and Scientific names of aquatic invertebrates from the United States and Canada: Cnidaria and Ctenophora. 2nd ed. Am. Fish. Soc. Spec. Pub. 28.

Cairns S.D., W. C. Jaap, and J. C. Lang. 2009. Scleractinia (Cnidaria) of the Gulf of Mexico. Pages 333-341 in D. L. Felder and D. K. Camp, eds. Gulf of Mexico: origin, waters, and biota, 1. Biodiversity. Texas A&M Univ. Press, College Station.

Coleman, C., G. Dennis, W. C. Jaap, G. P. Schmahl, C. Koenig, S. Reed, and C. Beaver. 2005. Status and trends of the Florida Middle Grounds. Tech. Rept. to the Gulf of Mexico Fish. Mgmt. Council, Tampa.

[clxix] E. Shinn: Of the seven [Caribbean candidates], only three, the Montastraea group, can be considered true coral reef builders. The other four are best considered accessory corals. That they are not prolific reef builders has been made abundantly clear by core drilling throughout the Caribbean (Macintyre and Glynn, 1976). That any of the seven species will become entirely extinct within the next few centuries is considered speculative. They can be found living on most any of the coral reefs within the NOAA Florida Keys National Marine Sanctuary"

[clxx] GFMC: Some committee members concurred with listing the following species in the Western Atlantic as threatened: Dendrogyra cylindrus, Agaricia lamarcki, and Mycetophyllia ferox due to their rarity and concerns about coral health.

[clxxi] D. Fenner: P. 104. Taxonomic issues. A. lamarcki also has more rounded ridges (colines) than A. grahamae, and ridges taper to ends where they fuse with other ridges while on A. grahamae the ridges don’t taper (Fenner, 1999).
Fenner, D. 1999. New Observations on the Stony Coral Species (Scleractinia, Milliporidae, Stylaseridae) of Belize (Central America) and Cozumel (Mexico). Bulletin of Marine Science 64: 143-154.

[clxxii] D. Fenner: P. 108; Figure 6.2.1. Mycetophyllia ferox. The photographs of living colonies are not representative of the species and may well not be this species. The collines (ridges) of this species are small and square in profile, not large and rounded as in the photos. There is a small groove visible on the top of the collines.

[clxxiii] D. Fenner: Characteristics- in my experience, valleys and walls are not contrasting colors, but the mouths areas are red, and they are small slightly raised knobs. In some colonies, the collines intersect, enclosing valleys. Otherwise those colonies are identical to colonies with collines that don’t intersect.

[clxxiv] Walt Jaap: See Biological Status Review for the Pillar Coral (Dendrogyra cylindrus)" by FWC.

[clxxv] GFMC: Note: Florida Fish and Wildlife Conservation Commission (FWC) evaluated Dendrogyra cylindrus and their Biological Review Group concluded that it should be listed as a threatened species. More information: http://www.myfwc.com/WILDLIFEHABITATS/imperiledSpp_listingprocess.htm

[clxxvi] SoFL Commenter: There are only a few pillar corals (Dendrogyra cylindrus) in Broward County, Florida. The pillars have been torn off by hurricanes causing them to look different. The best colonies of the proposed species

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are located nearshore off Lauderdale-By-The-Sea, north of Port Everglades where there has been no beach nourishment. The hope is that the ESA listing process can be worked through in a timely manner to protect these areas. Federal agencies need to step in because of new state laws.

[clxxvii] Tim McClanahan: "Plotting the species/genera and life history relationships finds that Dendrogyra, Dichocoenia, Physogyra, Barabattoia, Caulastrea, Mycetophillia, and Pachyseris are among the coral taxa that may be of most concern and candidates for species extinction because of this low species/genera diversity. Many of these taxa are stress, weedy or generalist taxa."

[clxxviii] D. Fenner: P. 118. Dichocoenia stokesi. Taxonomy. Veron (2000) and Human (2002) both treat Dichocoenia as a genus with just one species. There is a continuous gradation of characters between colonies that fit the descriptions of the two species names.

[clxxix] D. Fenner: As an example – Dichocoenia stokesii occurs in the Florida Middle Grounds, eastern Gulf.

[clxxx] GFMC, Sierra Club: Page 120, 2nd paragraph, line 1. Carpenter et al. (2008) may have included D. stellaris is in the depth range of 2-72 m for D. stokesi, as no depth information is given for the former in their Supplementary Materials. (Goreau and Goreau [1973] show D. stokesi as extending from inshore to about 60 m deep and D. stellaris as ranging from about 7 m deep [probably in crevices or other shaded habitats] to deeper than 60 m.)
Goreau, T.F. and N. I. Goreau. 1973. Coral Reef Project–Papers in Memory of Dr. Thomas F. Goreau. 17. The ecology of Jamaican coral reefs. II. Geomorphology, zonation, and sedimentary phases. Bull. Mar. Sci. 23: 399-464.

[clxxxi] GFMC: The Committee expressed specific concerns about listing Dichocoenia stokesi and was unsure if it was appropriate to consider this species as threatened or endangered without additional information.

[clxxxii] Van Woesik: "There was a slight disconnect between the vulnerability of Montastrea spp. In the biological status review and other studies that show that Montastrea is not as vulnerable as indicated by the biological status review.

[clxxxiii] Aronson: The Montastraea complex is of concern because BRT and IUCN ranked these species as vulnerable, but van Woesik's paper did not.

[clxxxiv] Van Woesik: a more thorough comparison would be useful between other studies and the findings in the Status Review Report of 82 Species of Corals Under the US ESA.

[clxxxv] Aronson: We may need to consider the evaluation of these rankings within the two ocean basins separately.

[clxxxvi] GFMC: Some committee members concurred with listing the following species in the Western Atlantic as endangered: Montastraea annularis, Montastraea faveolata, and Montastraea franksi. These three species have been subject to numerous disease phenomena (white plague, yellow band, black band, etc.) and have rapidly declining populations and poor recruitment success. In the Florida Keys, there has been up to a 90% reduction in population levels over the last several decades.

[clxxxvii] Margaret Miller: I would be somewhat cautious here with what is reported as 'complex' and what is not. The SRR notes currently notes that M. faveolata and M.franksi are present at much greater depths (I think we said 40-50 m) than M.annularis sensu stricto. It is quite reasonable that these two may persist down to 70m. However, I really don't think that M.annularis sensu stricto (the lobed form) does. . . .I'm pretty sure these authors describing mesophotic systems are all referring to Ma COMPLEX, namely M.faveolata and/or M.franksi.

[clxxxviii] D. Fenner: P. 123. Montastrea annularis taxonomic issues. You should mention that Veron (2000) recognizes only one species. Mentioning it does not mean that you necessarily agree, but Veron is the top reef coral taxonomist in the world so his view should be at least mentioned. By the way, he also retains the spelling Montastrea.

[clxxxix] GFMC, Sierra Club: Page 126-127. Thermal stress and disease relationships for the M. annularis complex are also treated in Cróquer and Weil (2009) and Mydlarz et al. (2009). Weil et al. (2009) described reduced sexual reproductive activity in Montastraea faveolata afflicted with yellow band disease.

[cxc] GFMC, Sierra Club: Severe losses, particularly in the Montastraea annularis complex, during the Jan. 2010, extreme cold-weather event in the Florida Keys:
Colella, M.A., R.R. Ruzicka, J.A. Kidney, J.M. Morrison, V.B. Brinkhuis. 2012. Cold-water event of January 2010 results in catastrophic benthic mortality on patch reefs in the Florida Keys. Coral Reefs 31:621-632.

Lirman et al. 2011. See above.

[cxci] From Roxanna Miller – Some of the species listed are not undoubtedly confirmed to be within the US jurisdictional waters, but they were still considered to be put on the list. If there is so much uncertainty in species reports from U.S. waters, can they even be considered for listing? Their occurrence in U.S. waters should be verified before the listing. These species listed below have either not been recorded in U.S. waters or been recorded in suspected error: Acropora lokani, Acropora tenella, Anacropora puertogalerae o Anacropora spinosa, Pectinia alcicornis, Acanthastrea regularis, Physogyra lichtensteini

[cxcii] Roxanne Miller – When there are species identification discrepancies (i.e. Acropora palmerae could be the same as Acropora robusta), some of the species are still assessed as separate within the Status Review. However, A. robusta isn't even considered in the listing.

[cxciii] T. McClanahan: I consider these low diversity genera as possibly more extinction prone then the high diversity genera that are frequently listed as vulnerable.

[cxciv] Tim McClanahan: "Plotting the species/genera and life history relationships finds that Dendrogyra, Dichocoenia, Physogyra, Barabattoia, Caulastrea, Mycetophillia, and Pachyseris are among the coral taxa that may be of most concern and candidates for species extinction because of this low species/genera diversity. Many of these taxa are stress, weedy or generalist taxa."

[cxcv] State of Hawaii: NOAA ranks species by the CRT assessment (see p. 458) from most to least severe. The Hawaii corals are rated among the highest for risk of extinction: Montipora patula (11th), M. verrilli (11th), M. dilatata (20th), M. flabellata (20th), M. turgescens (20th), and Acropora paniculata (47th). This is inappropriate because the ranking is based on combining species for review.

[cxcvi] From the State of Hawaii: In addition, inadequate consideration is given to the unique geographical and geomorphologic characteristics of the Hawaiian archipelago that buffer these species from ocean warming, bleaching, and disease. These species should not be listed.

[cxcvii] GFMC: The biological review team used the knowledge provided by the scientific community and at this time there are insufficient data on range, occurrence, density, resilience, and many other dynamics of the natural history to justify listing many of the proposed coral species.

[cxcviii] From the State of Hawaii: The remaining Hawaii species are ranked from 71st to 82nd. The graph on page 461 lists all 82 species by risk category. We concur with these assessments. They should not be listed.

[cxcix] GFMC: In general the committee feels less comfortable ranking the Pacific U.S. species; however, the ranking of the Western Atlantic species is reasonable.

[cc] Sierra Club: Particularly in the Pacific region, unresolved species-level taxonomy constrains the accuracy of geographic range, abundance, population trend and specific threat data for many of the 82 candidates, introducing uncertainty to the BRT's estimates of their relative likelihood of extinction. Details aside, stressors that range in scale from local to global threaten to terminate the existence of functional coral reefs in the Caribbean region. The declines in populations of large, primary framework-building species like Acropora spp. (which were listed as threatened under the ESA in 2006) and the Montastraea annularis complex are precipitous and well documented. Two species of the M. annularis complex (M. annularis, M. faveolata) top the BRT's Critical Risk Threshold list, and the third (M. franksi) is not far behind in 6th position. Other species of the wider Caribbean also show signs of disease and of widespread partial or complete mortality and should be considered vulnerable to extinction, including many that are not included among the 82 candidates.

[cci] GFMC: The Standard Deviation (a measure of variability) of the scores is high for individual species and as a group. Due to this high variability, is the true vulnerability to extinction being precisely estimated? In the "likely" category for the Indo-Pacifc are: Acropora lokani (apparently restricted to the central Indo-Pacific and erroneously thought to be in American Samoa) and A. jacquelineae (probably rare in American Samoa); A. rudis (thought to occur in American Samoa), A. dendrum (may or may not occur in American Samoa; and Pocillopora elegans from the eastern Pacific (assuming it is a valid population or species).

[ccii] Manny, GFCA: ESA does not consider any affects to adjacent communities. It mainly is focused on the existence of the species throughout its range. Being that said, these species do not merit protection under ESA for they are not in jeopardy throughout such range within the Marianas. Apra Harbor only represent [sic] a insignificant portion of the population.

[cciii] Roxanne Miller – How can Alveopora allingi be only 9% less likely to go extinct than Montipora patula/verilli when its only threat is bleaching, but Montipora patula/verilli doesn't show any characteristic that would reduce

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its extinction risk (i.e. it is affected by multiple threats, including bleaching)? I think A. allingi would be even less likely than M. patula/verilli to go extinct given its wide range of habitat types and broad distribution, putting it "less likely than not". Did the presence of these species in federally protected waters affect the likelihood rating? I feel it should given that this means they are already being protected at some level, but this wasn't even brought up in the likelihood considerations. Why is Acanthastrea brevis split between "less likely than not" and "more likely than not" at 50% likelihood when others that had a likelihood of 50% were considered "less likely than not" (i.e. Acanthastrea hemprichii)? Pocillopora elegans had a likelihood of 50% and is listed as "as likely as not".

[cciv] MAFAC: If listing of the species as endangered or threatened is a potential outcome of the SRR, consider the use of warranted but precluded category for species that occur primarily in foreign waters.

[ccv] CBD: International initiatives are also currently inadequate to effectively address climate change. The United Nations Framework Convention on Climate Change, negotiated in 1992 at Rio de Janeiro, Brazil, provides the forum for the international negotiations. In the Framework Convention, signed and ratified by the United States, the world agreed to take the actions necessary to avoid dangerous climate change. Parties to the Convention also agreed as a matter of fairness that the world's rich, developed countries, having caused the vast majority of emissions responsible for the problem, would take the lead in solving it. It was not until the 1997 meeting in Kyoto, Japan, that the first concrete, legally binding agreement for reducing emissions was signed: the Kyoto Protocol. The Protocol requires the world's richest countries to reduce emissions an average of 5 percent below 1990 levels by 2012, while developing nations also take steps to reduce emissions without being subject to binding emissions targets as they continue to raise their standard of living. The United States has been a major barrier to progress in the international negotiations. After the Clinton administration extracted many concessions from the rest of the world in exchange for the United States signing on in Kyoto, the Senate rejected the equity principles behind the Convention, saying the United States shouldn't agree to reduce its own emissions unless all other countries — regardless of their responsibility or ability — were similarly bound. Citing the same excuses, President George W. Bush repudiated the Kyoto Protocol entirely. Thus the United States is the only industrialized country in the world that has yet to ratify the Kyoto Protocol. The United States negotiating team under both the George W. Bush and the Obama administrations has pursued two primary objectives in the international talks: to refuse any legally binding emissions reduction commitments until all other countries— but particularly China and India — do so, and to push back the date for a new agreement. Not surprisingly, the United States had failed to meet its (never ratified) Kyoto pledge to reduce emissions to 7.2% below 1990 levels by 2012; to the contrary, U.S. emissions have increased by 10.5% since 1990 (EPA 2012).

[ccvi] CBD: Moreover, Kyoto Protocol's first commitment period only sets targets for action through 2012, and there is still no binding international agreement governing greenhouse gas emissions in the years beyond 2012.

[ccvii] Moreover, Kyoto Protocol's first commitment period only sets targets for action through 2012, and there is still no binding international agreement governing greenhouse gas emissions in the years beyond 2012. While the 2009 U.N. Climate Change Conference in Copenhagen called on countries to hold the increase in global temperature below 2C (an inadequate target for avoiding dangerous climate change), the non-binding "Copenhagen Accord" that emerged from the conference, and the subsequent "Cancún Accords" of 2010 and "Durban Platform" of 2011, failed to enact binding regulations that limit emissions to reach this goal.1 Even if countries were to meet their Copenhagen and Cancún pledges, analyses have found that collective national pledges to cut greenhouse gas emissions are inadequate to achieve the 2°C target, and instead suggest emission scenarios leading to 2.5°C to 5°C warming (Rogelj et al. 2010, UNEP 2010, UNEP 2011). As of May 2012, many governments were not implementing the policies needed to meet their 2020 emission reduction pledges, making it more difficult to keep global temperature rise to 2C (Höhne 2012). As noted in the management report, the US has yet to issue regulations to limit GHG emissions in accordance with the US pledge under the Copenhagen Accord. (MR at 14). Due to these failures, the planet is heading for a temperature rise of at least 3.5C, and higher if the 2020 pledges are not met (Höhne 2012). See also http://www.climateactiontracker.org for information on how countries are failing to meet their pledged reductions. Despite international pledges to reduce greenhouse gas emissions, carbon dioxide emissions have largely tracked the worst-case scenario projections made by the IPCC. The figure above shows that global carbon dioxide emissions have not declined, with the exception of during the economic downturn—from which they have rapidly accelerated back to high levels. All efforts combined to address greenhouse gas emissions are inadequate to protect the 82 candidate corals from the threats of global warming and ocean acidification.

[ccviii] CBD: As acknowledged by NMFS in the Management Report, no countries are reducing emissions enough to keep the increase in global temperature below 2° C; and the top ten emitters, accounting for over 60% of the global emissions, are performing poorly or very poorly at meeting needed greenhouse gas reductions (MR at 43). The continued failure of the U.S. government and the international community to implement effective and comprehensive greenhouse gas reduction measures places the 82 corals species that are candidates for threatened or endangered status at ever-increasing risk of extinction.

[ccix] Sierra Club: The Draft Management Plan lists numerous existing regulatory and conservation measures, including measures for reducing greenhouse gas emissions at national and international levels. Despite these existing measures, however, corals are in general decline throughout the world. The many pages that document US-based programs that should be addressing global climate issues versus the nation's collective lack of accomplishment are depressing, but not very surprising. The final version of the Management Plan should stress the need to go beyond existing measures, especially the need for much more rapid progress for reducing greenhouse gas emissions at the national and international levels. It also must include take prohibitions and protective regulations as required under Sections 9 and 4(d) of the ESA for species listed as endangered or threatened.

[ccx] While existing domestic laws including the Clean Air Act, Energy Policy and Conservation Act, Clean Water Act, Endangered Species Act, and others provide authority to executive branch agencies to require greenhouse gas emissions reductions from virtually all major sources in the United States, these agencies are either failing to implement or only partially implementing these laws for greenhouse gases.

[ccxi] CBD: For example, the EPA has issued a rulemaking regulating greenhouse gas emissions from automobiles that will reduce greenhouse emissions emitted per vehicle mile traveled by passenger vehicles in the future, but because the improvements are modest and more vehicles are projected to be driven more miles in the future, the rule will not reduce emissions from this sector overall but will only slow the rate of increase somewhat compared to what it would be without the rule. EPA, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, 75 Fed. Reg. 25,324 (May 7, 2010). Meanwhile even the government concedes that "these reductions in emissions are not sufficient by themselves to reduce total HD vehicle emissions below their 2005 levels by 2020." NHTSA, Medium- and Heavy-Duty Fuel Efficiency Improvement Program – Final Environmental Impact Statement (June 2011). This means that the vehicle rule is far from achieving emissions goals agreed to by the US in the Copenhagen Accord, which aim to keep global warming below 2°C.

[ccxii] CBD: The EPA has also to date issued only a single proposed rule under the new source pollution standard program for stationary sources of pollution, for electric generating units (power plants). While there is enormous potential to reduce emissions through this program overall and through the power plants rule in particular, the EPA has instead proposed a weak and flawed rule that it admits will not reduce emissions from these sources between now and 2020 compared to what would be expected without the rule. EPA, Standards of Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units, 77 Fed. Reg. 22392, 22430-33 (April 13, 2012). Indeed, in the rulemaking the EPA conceded that new power plant rule on greenhouse gas emissions "will not have direct impact on U.S. emissions of greenhouse gases under expected economic conditions." Id. at 22401.

[ccxiii] CBD: Existing domestic laws are inadequate to result in the greenhouse gas reductions needed to prevent the degradation of coral reefs. World Resources Institute issued a report that quantified potential emissions reductions using existing law under three basic scenarios. Even the most ambitious scenario, which includes significantly more regulatory mechanisms to reduce greenhouse gases than have been enacted, wouldn't achieve the reductions pledged by the US in Copenhagen (17% below 2005 levels) (Bianco et al. 2010). While full implementation of our flagship environmental laws, particularly the Clean Air Act, would provide an effective and comprehensive greenhouse gas reduction strategy, due to their non-implementation, existing domestic regulatory mechanisms must be considered inadequate to protect the 82 coral species from climate change and ocean acidification.

[ccxiv] CBD: Despite international and domestic efforts to reduce overfishing, it continues to pose an ongoing threat to coral reefs. Overfishing continues to affect more than 55% of the world's coral reefs (Reefs at Risk Revisited in the Coral Triangle 2012). For example, overfishing of parrotfish can adversely impact coral reef habitats and affect coral recruitment. In the Caribbean, the already over exploited sea urchin, and its slow recovery rate, herbivorious fish populations, parrotfish, appear to be the most likely source for the herbivory of benthic algae. More broadly,

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herbivorous fish grazing is critical for coral recruitment, growth, and the mediation of competition between corals and macroalgae. Notably, maintaining a diverse population with regard to abundance, biomass, size structure, and species is important for keeping algae in check.

[ccxv] Even with laws that aim to conserve coral reefs, many countries lack adequate capacity or political will to enforce laws. Despite international and domestic laws prohibiting trade in stony corals, there is still significant coral trade that degrades coral reefs. Using data from the United Nation's conservation monitoring program, a 2010 analysis shows that trade in coral and coral reef species is substantial and growing, removing 30 million fish and 1.5 million live stony corals a year (Tissot et al. 2010).

[ccxvi] With nearly all of the threats to coral reefs due to human activities, population increases threaten coral reefs. There are currently no effective regulatory mechanisms to address the growing stresses on coral reefs from increasing human populations and poverty.

[ccxvii] K. Winfield (AUS): Fisheries Queensland:

1. Australia's Queensland Coral Fishery is a low volume, high value fishery operating primarily within the Great Barrier Reef Marine Park. The commercial fishery operates in accordance with the Fisheries Act 1994 and the regulations set out in the Fisheries Regulation 2008, the Policy for the Management of the Coral Fishery 2009 and State and Australian federal government marine parks legislation (i.e. the Great Barrier Reef Marine Park Act 1975).
2. Participation is limited to 59 licences, which are operated by 24 businesses. No additional licences can be issued for the fishery. There are limits on the number of collectors that can operate under each licence and restrictions of gear used for collecting corals. Harvest levels are limited to an annual Total Allowable Catch (TAC) of 200t. Within the overall TAC limit of 200t a maximum of 60t of living coral and 140t dead coral (mostly live rock) can be harvested. A system of Individual Transferable Quota (ITQ's) applies with the harvest tracked through a quota monitoring system that is run by Fisheries Queensland.
3. The primary resource sustainability assessment tool for the fishery is an Ecological Risk Assessment (ERA) based upon the AS/NZ Standard. Coral taxa from over 36 families are harvested. The current ERA identified 12 coral taxa and two live rock collection areas that were at low risk from the fishery. In addition, the aquarium supply industry has implemented a Stewardship Action Plan that defines collection standards that specifically address the species identified in the ERA in order to mitigate risk. The outcomes of the ERA are used to focus monitoring of the fishery through a Performance Measurement System (PMS). The PMS measures the fishery's performance against defined ecological, economic and social management objectives with response action required if performance falls outside of defined acceptable ranges.

[ccxviii] K. Winfield (AUS): Corals are only allowed to be exported from Australia if the fishery harvesting the coral specimens is considered to be sustainable or not causing detriment to the species in the wild, as required by CITES. In Australia, we have 3 coral harvest fisheries, WA Marine Aquarium Fish Managed Fishery, Queensland Coral Fishery and Northern Territory Marine Aquarium Fish Fishery. For more information about these fisheries visit http://www.environment.gov.au/coasts/fisheries/index.html.

[ccxix] K. Winfield (AUS): Two of these fisheries (WA and QLD) have recently been re-evaluated, and associated non-detriment findings developed. For most species of coral, the CITES Scientific Authority has found that due, in part, to their similarity in appearance and ecology, it is difficult to manage most corals at a species level. ALSO: 4. In 2012 under the Environmental Protection and Biodiversity Conservation Act 1999 the fishery has been assessed as an approved Wildlife Trade Operation (see http://www.environment.gov.au/coasts/fisheries/qld/coral/index.html) and subject to a series of stringent monitoring requirements, species taken in the fishery are approved for export. In 2012 a Non-Detriment Finding (NDF) assessment has also been undertaken by the Australian government Department of Sustainability, Environment, Water, Population and Communities (SEWPaC's) CITES Scientific Authority for Marine Species.

[ccxx] From K. Winfield (AUS): All the Corals listed in the US Status Review are listed on CITES. Of the 82 corals listed, 51 occur in Australian waters and are subject to the CITES Non Detriment Finding (NDF) process, prior to any export approval being granted. CITES recognises the difficulty associated with being able to correctly identify coral species, by allowing some species to be listed on export permits at the higher taxonomic level of genus (when identification to species is not feasible) instead of the normal requirement to label to species level.

[ccxxi] Dept. of Ag. (GUAM): The Draft Management Report describes many of the statutory/regulatory mechnisms under DOAg to protect corals. However, Public Law 24-87 is missing. Public Law 24-87 ensures that Guam's marine preserves are protected from recreational/commercial activities that may prove detrimental to the fragile ecosystem. Currently, there are draft rules and regulations from Public Law 24-87 and a management plan that was written."

[ccxxii] DOAg [Guam]: feels that the local/state Government should be taking the lead to protect corals. DOAg has laws in place to protect corals and is working on other regulatory mechanisms that will help to protect corals. These include laws protecting the take and destruction of corals, restrictions on the use of explosives and poisons, and marine preserves to protect fish and habitat such as corals.

[ccxxiii] CRI Policy Committee - Fish, Game, and Endangered Species Act - The Fish, Game, and Endangered Species Act vests the power and duty to protect fish, game, and endangered and threatened species in the Department of Lands and Natural Resources.9 Under the act, the Secretary of Lands and Natural Resources “shall, by regulation, determine whether any species should be designated as an endangered species or a threatened species, taking into consideration the status of its habitat or range, its utilization by man for various purposes, diseases or predators, other natural or manmade factors affecting its continued existence, and the need for adequate regulation or management” and shall also designate critical habitats for species so designated as endangered or threatened (2 CMC § 5108(a).). Conservation officers of the Division of Fish and Wildlife have the power of law enforcement officers and can make arrests for violations of the act and regulations promulgated under the authority of the act (2 CMC § 5103(b)). Violations of the act and its regulations carry a range of civil and criminal penalties, including imprisonment (2 CMC § 5109.) Furthermore, any governmental entity or instrumentality that plans to conduct, permit, or license an activity that may adversely affect an endangered or threatened species must first consult with the Secretary of Lands and Natural Resources.

[ccxxiv] CRI Policy Committee - Submerged Lands Act (Public Law No. 1-23 as amended by Public Law No. 6-13, codified at 2 CMC §§ 1211–1231). - The Submerged Lands Act sets forth the management guidelines for Commonwealth submerged lands (The Submerged Lands Act defines “submerged lands” as “all lands below the ordinary high water mark extending seaward to the outer limit of the exclusive economic zone.” However, this definition was declared preempted, and the Commonwealth’s submerged lands are limited to those under its internal waters. See N. Mariana Islands v. United States, 399 F.3d 1057, 1060 n.2 (9th Cir. 2005); see also In Re: The CNMI’s Rights Over its Submerged Lands, CNMI Att’y Gen. Op. 07-01 (Apr. 2007) (explaining the extent of the Commonwealth’s jurisdiction over submerged lands)) and includes “[e]nsuring environmental protection” as one of the guidelines. The act further provides that the Department of Lands and Natural Resources shall not grant, lease, or otherwise permit the use of submerged lands if doing so “would adversely affect the protection and preservation of marine resources.” (2 CMC § 1212(c)). Furthermore, a person or entity seeking to explore, develop, or extract petroleum or mineral deposits on or from submerged lands or develop submerged lands for other uses must finance the cost of an environmental protection plan and a coastal engineering plan (2 CMC § 1221(f); see also § 1213(a) (“‘Coastal engineering plan’ shall mean a survey and or a profile including the effects of a proposed development on currents, winds, waves, tides, and other ocean movements; the effects of a proposed development on erosion control and other protective controls through measures such as seawalls, bulkheads, revetments, groins, jetties and inlet control, and beach nourishment on natural marine and shoreline processes; a hydrographic survey and bathymetric data both onshore and offshore; and, shall address both long-term and short-term impacts of the surrounding areas of a proposed development project.”); § 1213(e) (“‘Environmental protection plan’ means a detailed statement on the environmental impacts of the proposed actions of a proposed development project in the project area and the natural resources contained therein and in the surrounding area; the measures to be used before, during, and after construction to mitigate any adverse environmental impacts including, but not limited to those associated with: air, water, solid waste, sanitary waste, hazardous materials, noise, erosion control, and pest control; shall include a construction schedule and a monitoring schedule; and, shall include a detailed statement of any adverse environmental effects which cannot be avoided should the proposed development project be implemented.”).).

[ccxxv] CRI Policy Committee: Earthmoving and Erosion Control – A person wishing to engage in an earthmoving activity that may cause erosion of soil must obtain a permit from DEQ before engaging in such activity (NMIAC §§ 65-30-015, 65-30-105(a)). As relevant to the conservation of coral, all earthmoving activities are strictly prohibited

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and must cease during the annual coral spawning period and extra measures and precautions must be taken during this period (NMIAC § 65-30-315).

[ccxxvi] CRI Policy Committee: The Commonwealth's Anti-degradation Policy sets forth the water quality standards for the Commonwealth and provides that "[t]he protection, maintenance, conservation, and improvement of the quality of the waters for the growth and propagation of aquatic life, for marine research and for the conservation of coral reefs and wilderness areas, . . . are an historic and legal right of the people of the Northern Mariana Islands." (NMIAC § 65-130-010)

[ccxxvii] CRI Policy Committee: There are two classes of marine waters—Class AA and Class A (See NMIAC § 65-130-101). Class AA waters are to remain as close to their natural pristine as possible, and the use of such waters are limited to "the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, oceanographic research, and aesthetic enjoyment and compatible recreation with risk of water ingestion by either children or adults." (NMIAC § 65-130-101(a)(1)–(2)).

[ccxxviii] CRI Policy Committee: The water quality standards also require a 21-day suspension of "activities which have the potential to adversely affect coral reproduction" during the primary coral spawning event of the summer, in either May or June, as determined by DEQ (NMIAC § 65-130-530(b)(3)(iii)). This requirement would apply to most dredging activities (id.).

[ccxxix] CRI Policy Committee: DEQ also has regulations regarding solid waste, hazardous waste, used oil, above-ground and underground storage tanks, pesticides, air pollution, underground injection wells and wastewater that serve to protect corals (See NMIAC Title 65).

[ccxxx] CRI POLICY Committee: Coastal Resources Management ("CRM") Regulations (The Draft Management report makes reference to the Coastal Resources Management Act, but does not mention the related regulations that are described herein. See 82 Corals Draft Management Report, App'x A at 37–38). Areas of Particular Concern: An "area of particular concern (APC)" is a delineated area that is subject to special management standards (NMIAC §§ 15-10-020(f)(1), 15-10-310). Before issuing a permit for a project in an APC, CRM must consider APC-specific criteria and use priorities (See NMIAC § 15-10-310). As relevant here, the Lagoon and Reef APC includes all "partially enclosed bod[ies] of water formed by sand spits, baymouth bars, barrier beaches or coral reefs, of the Northern Mariana Islands chain." (NMIAC § 15-10-020(hh)) The management standards for the Lagoon and Reef APC provide that "[s]ignificant adverse impacts to reefs and corals shall be prevented."(NMIAC § 15-10-310(a)(3)) The highest use priorities for coral reefs are uses that maintain the highest levels of primary productivity and uses that create underwater preserves in pristine areas, while the lowest use priorities are uses involving the taking of coral for cultural uses (NMIAC § 15-10-310(b)(4)(i), (iii)). Additionally, unacceptable uses include the "[d]estruction of reefs and corals not associated with permitted projects" and "[t]aking of corals for [reasons] other than [for] scientific study."(NMIAC § 15-10-310(b)(4)(iv)).

[ccxxxi] CRI Policy Cmt - Commonwealth Ports Authority (CPA) Regulations – Environmental Control: It is the general environmental policy of CPA "that the air, land, and water environment of the ports and harbors of the Commonwealth shall be preserved, to the maximum extent possible."(NMIAC § 15-20.1-155). A person who violates a regulation that is designed to carry this policy shall be subject to civil and criminal penalties (Id).

[ccxxxii] CRI Policy Committee: CPA limits the type and amount of explosives that may enter the Commonwealth harbors: "No vessel containing more than 25 short tons of class A, 25 short tons of class B, and an unlimited amount of class C explosives (net explosive content) shall enter or be loaded in Commonwealth harbors except on written permission of the Executive Director." (NMIAC § 40-20.1-202). CPA also regulates the manner in which explosives should be handled: "All handling and loading or unloading of explosives shall be done in a safe and careful manner and shall be in accordance with federal regulations pertinent thereto in force at the time."(NMIAC § 40-20.1-204). Additionally, CPA regulates the manner in which explosives should be hauled: "All hauling of explosives away from or to the pier shall be done in a safe and careful manner and shall be in accordance with regulations of the Department of Public Safety."(NMIAC § 40-20.1-206). Lastly, CPA prohibits the use of explosives on property that is under its control as well as in the waters in the immediate vicinity of such property, unless permission is obtained from the Executive Director (NMIAC § 40-20.1-224).

[ccxxxiii] CRI Policy Cmt: CPA prohibits the delivery of leaky containers holding gasoline, distillate, kerosene, benzene, naphtha, turpentine, paints, oils or other flammable substances onto any wharf under its control (NMIAC § 40-

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20.1-212). If any of the listed substances are delivered in what is determined to be a leaky container, the container must be removed immediately.

[ccxxxiv] CBD: According to Reefs at Risk Revisited, approximately 75% of the world's coral reefs are threatened."The combined impacts of ocean warming and acidification will increase the threat levels on more than half of all reefs by 2030, pushing the percentage of threatened reefs to more than 90 percent by 2030. By 2050, nearly all reefs will be affected by warming and acidification and almost all reefs will be classified as threatened, assuming there is no change in local pressure on reefs" (Reefs at Risk 2011: 6). While coral reefs in the Pacific have tended to fair better than those in many other regions, the Pacific coral reefs have experienced the largest increase in threat over the past ten years (Reefs at Risk Revisited in the Coral Triangle 2012). Marine protected areas, while potentially beneficial, are insufficient to conserve the 82 corals. Even with one-quarter of the world's coral reefs within protected areas, many are ineffective or only offer partial protection. Only 6% of coral reefs are in effectively managed MPAs (Reefs at Risk 2011). The success of marine reserves to recover coral reefs has been brought into question. While some reserves do well (see Mumby et al. 2010), others have failed to recover despite no-take reserves (Huntington et al. 2011). This could be due to lack of enforcement or other factors.

[ccxxxv] DOAg [Guam]: There are 5 MPAs established on Guam that serve to protect corals and other marine organisms that inhabit these preserves.

[ccxxxvi] Managaha Island Marine Conservation Act of 2000 (Public Law No. 12-12, codified at 2 CMC §§ 1631–1638) - The Managaha Island Marine Conservation Act established a conservation area called the "Managaha Marine Conservation Area." The conservation area includes the island of Managaha and its surrounding waters. Among other things, the act prohibits the harvesting or catching of marine life or natural resources with the designated Managaha Marine Conservation Area, unless otherwise approved for scientific, cultural, traditional, or educational purposes (2 CMC § 1634(a)). Bird Island and Forbidden Island Sanctuaries (Public Law No. 12-46, codified at 2 CMC §§ 1640–1645) - The act designated Bird Island and Forbidden Island as sanctuaries for the conservation of wildlife and marine life (2 CMC § 1640). Among other things, the act prohibits the following in the sanctuaries: (1) destruction, harassment, and removal of marine species of any kind; (2) fishing; (3) and walking on exposed sections of the reef (2 CMC § 1644).

[ccxxxvii] CRI Policy Committee: Upon reviewing the Draft Management Report, the CRI Policy Committee submits that the conservation management mechanisms and policies listed herein are currently in place in the Commonwealth and are not included in Appendix A of the Draft Management Report.2 The CRI Policy Committee respectfully requests that NMFS add the Commonwealth's conservation efforts contained herein to the Final Management Report and give them due consideration when determining whether the candidate corals should be listed.

[ccxxxviii] CRI Policy Committee: In 2006, the Governor committed the Commonwealth to the Micronesia Challenge (See The Micronesia Challenge, http://www.micronesiachallenge.org, About the Challenge tab) "The overall goal of the Challenge is to effectively conserve at least 30% of the near-shore marine resources and 20% of the terrestrial resources across Micronesia by 2020."(Id) Among the marine resources in Micronesia are 483 species of coral, and the Challenge strives to protect them (Id).

[ccxxxix] Resolution of the 17th Micronesian Chief Executives' Summit to Address the Global Environmental Impact of Climate Changes in Micronesia (See Resolution 17-03, March 15, 2012), attached hereto). The resolution recognized that the increase in carbon emissions has a negative impact on coral reefs and that the implications of climate change must be addressed (Id). Additionally, it was resolved that the Commonwealth, and other Micronesia Challenge members, would "collaborate with local scientists, community members, educators, leaders and decision-makers in Micronesia to place climate change issues at the forefront of coral reef management through efforts to decrease global contributions to global emissions, . . ."(Id).

[ccxl] Commonwealth of the Northern Mariana Islands Climate Change Working Group (See Climate Change Working Group Handout, attached hereto). A multi-agency climate change working group was established in June 2012. The working group is a collaborative effort spearheaded by CRM and NOAA. The objectives of the working group include the following: Identify the communities, livelihoods, and ecosystems in CNMI that are most vulnerable to the impacts of climate change; Identify, assess, and prioritize adaptation strategies and policies; Identify gaps in knowledge and areas for future research; and Build capacity within CNMI departments and agencies to begin dealing with the impacts of climate change.