Status Review Report

- NOAA Fisheries' ongoing assessment to determine whether to list 82 Caribbean and Indo-Pacific coral species under the Endangered Species Act (ESA) is the most complex listing process NOAA has ever undertaken.

- We are taking additional time to publicly review the information gathered in our two reports to ensure that our findings and future decisions are based on the best available science.

- During this time, NOAA Fisheries will develop and execute a robust engagement process – and then use this additional input to develop our 12-month finding.

- All public submission of additional information or comments should be submitted by July 31, 2102. Information on how to submit information is available on the web at http://www.nmfs.noaa.gov/stories/2012/04/4_13_12corals_petition.html.

Overview of Status Review Report as Prepared by the Biological Review Team

NOAA Fisheries established a team of federal scientists (the Biological Review Team) to prepare the Status Review Report that examined the status of 82 candidate coral species and evaluate extinction risk for each of them. The team chose to evaluate extinction risk as the likelihood of a species status falling below a Critical Risk Threshold by the year 2100. The team was comprised of: Russell E. Brainard (NOAA), Charles Birkeland (USGS), C. Mark Eakin (NOAA), Paul McElhany (NOAA), Margaret W. Miller (NOAA), Matt Patterson (NPS), and Gregory A. Piniak (NOAA). The Status Review Report was independently peer reviewed by the Center for Independent Experts.

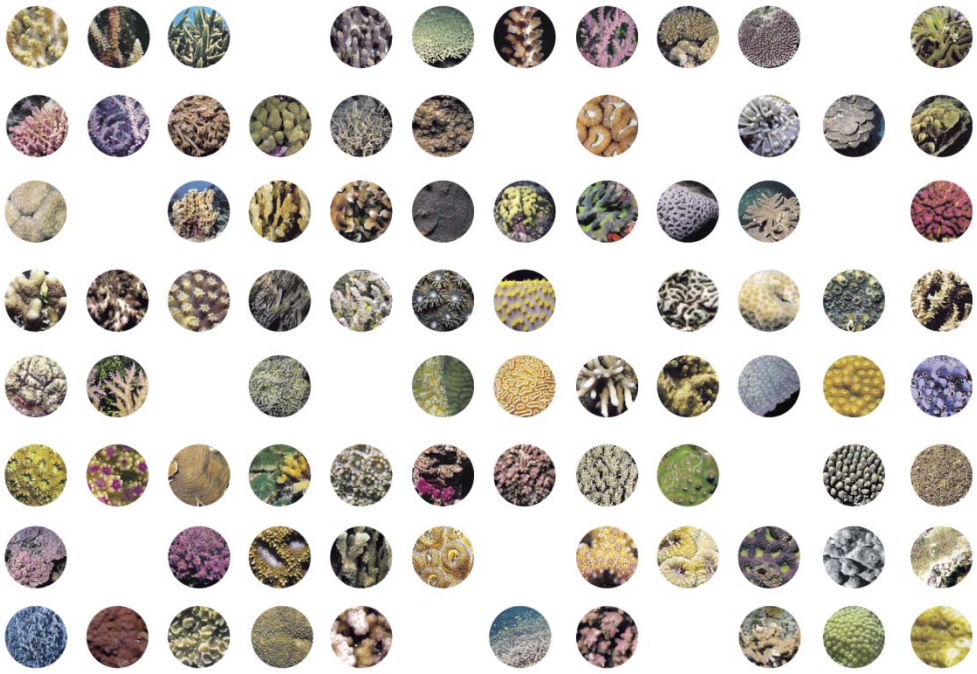
Normally, the information contained a Status Review would include a 'Management Report'. In the instance of corals, however, the team did not feel it had the expertise to compile and review regulatory mechanisms. Therefore, others experts within NOAA Fisheries prepared a draft Management Report as a separate document. Collectively these two reports constitute the best available scientific and commercial information that we have compiled to date.

Please note that releasing these documents is not a part of the normal rulemaking process – it is only an engagement process that allows us to be transparent and open in our decision making. Should NOAA Fisheries determine that a listing is warranted, it will publish a proposed rule in December 2012 for additional public comment.

NOAA Technical Memorandum NMFS-PIFSC-27

September 2011

Status Review Report of 82 Candidate Coral Species Petitioned Under the U.S. Endangered Species Act



Russell E. Brainard, Charles Birkeland, C. Mark Eakin,
Paul McElhany, Margaret W. Miller, Matt Patterson,
and Gregory A. Piniak

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

About this document

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to understand and predict changes in the Earth's environment and to conserve and manage coastal and oceanic marine resources and habitats to help meet our Nation's economic, social, and environmental needs. As a NOAA line office, the National Marine Fisheries Service (NMFS) conducts or sponsors research and monitoring programs to improve the scientific basis for conservation and management decisions. The NMFS strives to make information about the purpose, methods, and results of its scientific studies widely available.

NMFS' Pacific Islands Fisheries Science Center (PIFSC) uses the **NOAA Technical Memorandum NMFS** series to achieve timely dissemination of scientific and technical information that is of high quality but inappropriate for publication in the formal peer-reviewed literature. The contents are of broad scope, including technical workshop proceedings, large data compilations, status reports and reviews, lengthy scientific or statistical monographs, and more. NOAA Technical Memoranda published by the PIFSC, although informal, are subjected to extensive review and editing and reflect sound professional work. Accordingly, they may be referenced in the formal scientific and technical literature.

A **NOAA Technical Memorandum NMFS** issued by the PIFSC may be cited using the following format:

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Cover: Photographs courtesy of JEN Veron and MG Stafford-Smith, Coral ID 2002.

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Status Review Report of 82 Candidate Coral Species Petitioned Under the U.S. Endangered Species Act

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NOAA Technical Memorandum NMFS-PIFSC-27

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for several weeks during Matt and Mariska's absence. Kathryn Dennis (UH JIMAR-CRED) assisted with editing and formatting of the final document.

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EXECUTIVE SUMMARY

On October 20, 2009, the Center for Biological Diversity petitioned the National Marine Fisheries Service (NMFS) to list 83 coral species as threatened or endangered under the U.S. Endangered Species Act. The petition was based on a predicted decline in available habitat for the species, citing anthropogenic climate change and ocean acidification as the lead factors among the various stressors responsible for the potential decline. The NMFS identified 82 of the corals as candidate species, finding that the petition provided substantive information for a potential listing of these species. The NMFS established a Biological Review Team (BRT) to prepare this Status Review Report that examines the status of these 82 candidate coral species and evaluates extinction risk for each of them. This document makes no recommendations for listing, as that is a separate evaluation to be conducted by the NMFS.

The BRT considered two major factors in conducting this review. The first factor was the interaction of natural phenomena and anthropogenic stressors that could potentially contribute to coral extinction. 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. Threats of local origin but having widespread impact, such as sedimentation, nutrient enrichment, and fishing, were considered of medium importance in determining extinction risks. It is acknowledged that many other threats (e.g., physical damage from storms or ship groundings, invasive species or predator outbreaks, collection and trade) also negatively affect corals, often acutely and dramatically, but generally at relatively small local scales. These local threats were considered to be of limited scope and not deemed to contribute appreciably to the risk of species extinction, except in those special cases where species have restricted geographic or habitat ranges or species have already undergone precipitous population declines such that these local threats further contribute to depensatory processes that can magnify extinction risks (e.g., feedback-loops whereby individual survival decreases with smaller population size). The BRT acknowledges that local and global threats operate on different time scales and, though there is high confidence in the general progression of some key global threats, such as ocean warming and ocean acidification, there is much less certainty in the timing and spatial patterns of these threats. There is also substantial uncertainty in the abilities of the 82 candidate coral species to tolerate or adapt to each of the threats examined, as well as uncertainty in the dynamics of multiple simultaneous stresses. The BRT specifically identified increasing human population levels and the intensity of their collective human consumption as the root drivers of almost all global and local threats to coral species. In evaluating future threat impacts, the BRT attempted to project current trends, without assumptions of future policy changes or technological advances that could potentially alter the projections used in this analysis.

The second major factor was the fundamental ecological character of each candidate coral species—particularly life history, taxonomy, and abundance. Corals have complex life cycles and a taxonomy based on variable skeletal morphologies. Both of these complicate assessment of species status and extinction risk. Planktonic larval phases, cryptic settlement, long post-settlement periods with high mortality, and external fertilization are characteristics of many coral species. A lack of adequate data on many aspects of life history makes it difficult to determine the population dynamics of corals throughout their ranges with confidence. In addition, the increasing availability of genetic analyses of coral populations in many cases calls into question the morphology-based classifications traditionally used to separate nominal coral species. Even if species are assumed to be identifiable in the field, it is often difficult to distinguish separate colonies, and there is no way to distinguish genetic individuals in the field (i.e., many colonies may be genetically identical clones). These limitations make it challenging to assess accurate population demographics for most species. Coral reef monitoring data offer some insights, but are often reported at the genus level or are not optimized for relatively rare species. As a result of these demographic and monitoring limitations, species-level abundance and trend data were virtually non-existent for most of the 82 candidate coral species under consideration.

In the absence of species-specific abundance and trend information, BRT members relied heavily upon the best available information on the spatial extent of the species ranges and on their understanding of the likely impacts of the suite of threats on each of the individual coral populations over the period until 2100. The lack of adequate information on complex coral ecology and interactions between threats made the assessment of extinction risk for each of the 82 nominal coral species extremely challenging and uncertain.

The BRT chose to evaluate extinction risk as the likelihood of a species status falling below a Critical Risk Threshold by the year 2100, a time frame over which climate projections are readily available and have been sufficiently vetted through extensive scientific peer review to be deemed to have reasonable reliability. The Critical Risk Threshold

describes a condition where the species is of such low abundance, or so spatially fragmented, or at such reduced genetic and/or genotypic diversity that extinction is extremely likely. Assessment of the Critical Risk Threshold took into consideration depensatory processes, environmental stochasticity, and catastrophic events. Following extensive discussion about each candidate coral species, the likelihood of the status of the species falling below the Critical Risk Threshold by 2100 was anonymously estimated by each BRT member assigning ten points to eight "risk likelihood categories" linked to probabilities; points were summed across the seven BRT members for each risk likelihood category. After further discussion and a second round of anonymous voting for each of the 82 candidate coral species, the likelihood of the species status falling below the Critical Risk Threshold was expressed as a histogram of the percentage of likelihood points for each risk category and an estimate of the mean likelihood was calculated (Fig. ES-1). After completing at least two rounds of separate voting for each of the 82 candidate coral species, the BRT discussed the relative rankings of the species in a comparative sense to identify potential outliers that needed further consideration and an additional closed vote was taken when warranted by this analysis or discovery of new information.

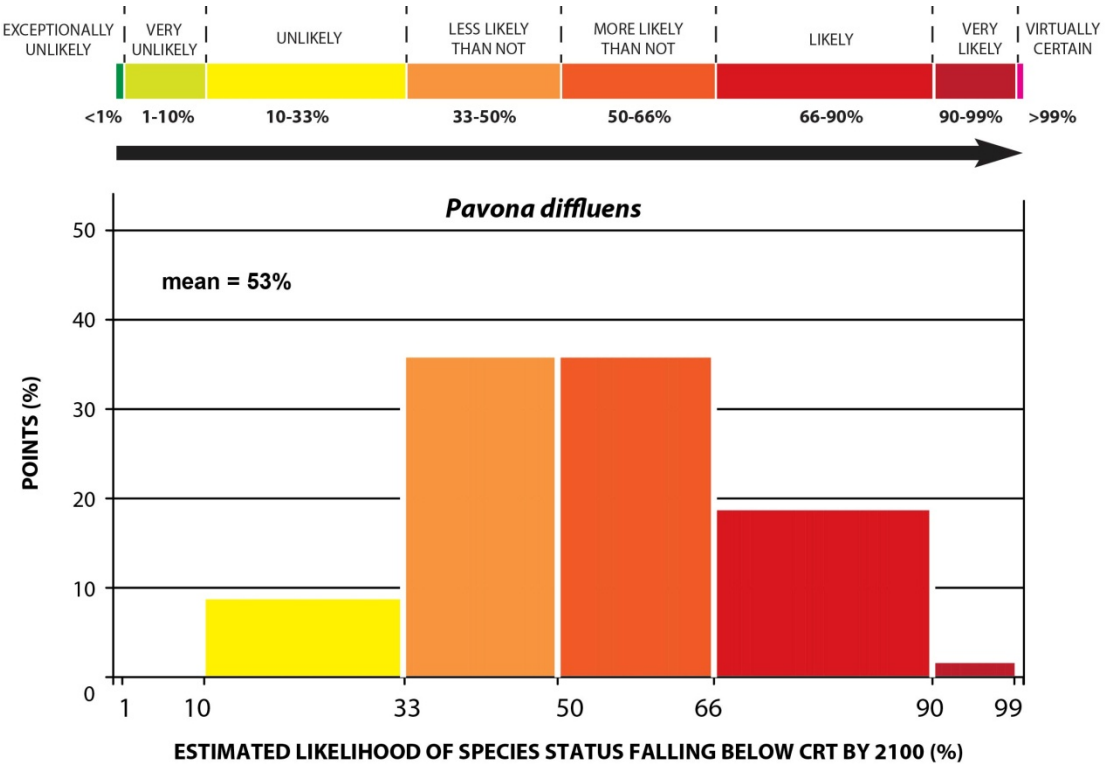

Figure ES-1. Example histogram showing the distribution of points to estimate the likelihood that the status of *Pavona diffluens* will fall below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

This process yielded a list of the 82 candidate coral species ranked by the mean likelihood of falling below the Critical Risk Threshold by 2100 (Fig. ES-2, Table ES-1). Given the myriad uncertainties described above, this list must be understood as a qualitative ranking, not supporting fine parsing among species whose mean scores differ by only a few points. While the mean likelihood of a species status falling below the Critical Risk Threshold by 2100 is an important indicator of the extinction risk, the broad distribution of points in these histograms highlights the high level of uncertainty in these estimates of Critical Risk Threshold likelihood by the BRT members. Both the mean likelihood scores and the uncertainty should be considered in the application of these estimates.

That said, certain patterns in the Critical Risk Threshold likelihood estimates are notable. Caribbean species were estimated to have relatively high likelihoods of falling below their Critical Risk Thresholds by 2100, with five of the seven candidate species from that region ranked in the top seven overall. This reflects the relatively small and restricted geographic extent of these species, pervasive and demonstrated impacts of both local and global threats, and the significant, well-documented declines of corals throughout the Caribbean region. Other candidate species determined by

Figure ES-2. Summary of votes tallied across Critical Risk Threshold likelihood categories for all 82 candidate coral species ranked by mean likelihood. The x-axis indicates the percent likelihood of a species status falling below the Critical Risk Threshold. Darkness of color scales to the proportion of votes in each risk category for each species. Red text is used for Caribbean species names and black text is used for Indo-Pacific species names. See the Individual Species Accounts (chapters 6 and 7) for the distribution of votes in each likelihood category.

Table ES-1. Summary of votes tallied in each risk likelihood category (colored columns), mean (and standard error, SE) likelihood of falling below the Critical Risk Threshold by 2100, and mean likelihood range for each of the 82 candidate coral species ranked by mean likelihood as determined by the BRT. The SE was calculated by taking the standard deviation of the seven mean voting scores of the BRT members. Mean likelihood range is the mean range of the likelihood estimates of the seven BRT voters. For example, an individual voter spreading votes in categories between "unlikely" and "more likely than not" would have an individual range of 56%. Three voters with a 33% range, one with a 56% range, and three with a 66% range would produce an average likelihood range of 50.4%. Red text is used for Caribbean species names and black text is used for Indo-Pacific species names. Species listed in parentheses were not petitioned per se, but were incorporated based on best available taxonomic information (see Sections 7.3.2, 7.8, 7.10.4 for discussions of taxonomic issues within Pocillopora, Montipora, and Porites respectively).

SPECIES	# OF VOTES IN EACH RISK LIKELIHOOD CATEGORY								MEAN LIKELIHOOD (%)	SE OF BRT MEANS (%)	MEAN LIKELIHOOD RANGE (%)
	<1	1-10	10-33	33-50	50-66	66-90	90-99	>99			
Montastraea annularis	0	0	0	0	19	29	22	0	78	6.9	45.4
Montastraea faveolata	0	0	0	0	19	29	22	0	78	6.9	45.4
Acropora lokani	0	0	0	1	17	34	18	0	77	8.1	50.1
Acropora jacquelineae	0	0	0	1	17	37	15	0	76	7.3	50.1
Dendrogyra cylindrus	0	0	0	1	22	33	14	0	74	6.6	48.9
Montastraea franksi	0	0	0	3	25	24	18	0	74	9	47.9
Mycetophyllia ferox	0	0	0	5	26	30	9	0	70	8.2	50
Acropora rudis	0	0	0	9	19	34	8	0	70	11.2	49
Acropora dendrum	0	0	0	4	30	29	7	0	69	5.6	55
Pocillopora elegans (E Pacific)	0	0	3	7	25	26	9	0	67	13	53.4
Montipora patula (verrilli)	0	0	0	11	28	24	7	0	66	9.9	50.1
Acropora donei	0	0	0	13	28	26	3	0	64	8.2	52.6
Acropora pharaonis	0	0	0	15	27	23	5	0	64	8.9	55
Euphyllia paradivisa	0	0	0	15	28	22	5	0	63	9.6	50.3
Millepora foveolata	0	0	0	16	26	25	3	0	63	9.8	50.3
Millepora tuberosa	0	0	0	17	25	25	3	0	63	10.1	50.3
Euphyllia paraancora	0	0	0	17	27	21	5	0	63	10.4	50.3
Isopora cuneata	0	0	0	15	29	24	2	0	62	8.5	51.3
Euphyllia cristata	0	0	0	19	26	21	4	0	62	10.5	50.3
Montipora dilatata/flabellata (turgescens)	0	0	0	17	30	20	3	0	61	7.3	56.1
Agaricia lamarcki	0	0	0	17	29	23	1	0	61	6.3	54.9
Anacropora spinosa	0	0	0	22	27	19	2	0	59	7.5	54.9
Dichocoenia stokesi	0	0	0	19	33	17	1	0	59	5.1	58.3
Acropora microclados	0	0	3	19	27	19	2	0	58	11	60.3
Montipora lobulata	0	0	3	23	22	18	4	0	58	11.9	57.1
Acropora striata	0	0	2	21	27	19	1	0	58	8.4	58.1
Acropora listeri	0	0	3	18	31	17	1	0	58	6.7	64.9
Acropora globiceps	0	0	2	21	29	17	1	0	57	8.1	58.1
Pachyseris rugosa	0	0	3	23	24	18	2	0	57	10.8	57.1
Alveopora fenestrata	0	0	0	28	23	18	1	0	57	8.5	52.6
Alveopora allingi	0	0	0	27	25	17	1	0	57	8.7	52.6
Montipora australiensis	0	0	3	25	22	17	3	0	57	12	53.7
Anacropora puertogalerae	0	0	2	24	26	16	2	0	57	8.1	60.1
Acropora tenella	0	0	2	22	28	18	0	0	57	7.7	58.1
Montipora angulata	0	0	3	26	21	17	3	0	57	11.9	53.7
Isopora crateriformis	0	1	4	20	24	20	1	0	57	14.2	51.3
Montipora caliculata	0	0	3	25	23	16	3	0	57	11.6	53.7
Alveopora verrilliana	0	0	0	29	24	16	1	0	56	9	49.1
Montipora calcarea	0	0	3	26	23	15	3	0	56	11.6	53.7
Caulastrea echinulata	0	0	5	21	28	13	3	0	56	9.6	62.6
Seriatopora aculeata	0	0	4	25	25	15	1	0	55	10.3	59.1

SPECIES	# OF VOTES IN EACH RISK LIKELIHOOD CATEGORY								MEAN LIKELIHOOD (%)	SE OF BRT MEANS (%)	MEAN LIKELIHOOD RANGE (%)
	<1	1-10	10-33	33-50	50-66	66-90	90-99	>99			
Acropora speciosa	0	0	4	25	25	16	0	0	55	10.1	54.4
Acropora verweyi	0	0	7	21	25	16	1	0	54	11.5	59.1
Acropora retusa	0	0	6	25	22	15	2	0	54	13.2	55.7
Pocillopora danae	0	0	8	20	28	11	3	0	54	13.7	52.3
Pavona diffluens	0	0	6	25	25	13	1	0	53	12	61.4
Acropora paniculata	0	0	5	26	26	12	1	0	53	9.4	49.9
Acropora polystoma	0	0	6	26	25	12	1	0	53	9.9	61.3
Acropora vaughani	0	0	8	24	24	13	1	0	52	11.2	61.3
Astreopora cucullata	0	0	8	25	24	11	2	0	52	9.2	59
Barabattoia laddi	0	0	4	28	29	8	1	0	52	12.6	51.1
Acropora palmerae	0	0	7	24	28	11	0	0	52	8.8	60
Acropora horrida	0	0	5	27	29	9	0	0	52	6.8	56.7
Physogyra lichtensteini	0	0	10	25	22	12	1	0	51	11.4	62.3
Porites horizontalata	0	0	10	25	22	12	1	0	51	11.7	62.3
Pocillopora elegans (W Pacific)	0	2	9	23	23	12	1	0	50	14.6	56.9
Porites napopora	0	0	8	27	27	8	0	0	50	9.1	57.7
Acanthastrea brevis	0	0	8	28	26	7	1	0	50	9.1	57.7
Acanthastrea hemprichii	0	0	8	28	26	7	1	0	50	9.1	57.7
Acanthastrea ishigakiensis	0	0	8	28	26	7	1	0	50	7	59.9
Porites nigrescens	0	0	8	29	25	7	1	0	50	8.9	57.7
Acropora acuminata	0	0	9	25	30	6	0	0	49	8.5	56.6
Acropora aculeus	0	0	11	22	30	7	0	0	49	11.8	51
Pectinia alcicornis	0	0	16	22	20	10	2	0	48	15.6	58.9
Acropora aspera	0	1	9	24	31	5	0	0	48	9.3	57.9
Pavona bipartita	0	0	10	28	26	6	0	0	48	10.9	47.4
Acanthastrea regularis	0	3	8	26	25	8	0	0	48	15	46.6
Pavona cactus	0	0	12	27	24	7	0	0	47	10.7	47.4
Pavona decussata	0	0	11	28	25	6	0	0	47	10.7	50.7
Pavona venosa	0	0	11	28	25	6	0	0	47	12	48.3
Cyphastrea agassizi	0	0	15	22	25	8	0	0	47	13.8	51.7
Cyphastrea ocellina	0	0	15	23	24	8	0	0	47	13.7	51.7
Turbinaria stellulata	0	0	8	33	29	0	0	0	46	5.9	40.6
Galaxea astreata	0	1	9	34	24	2	0	0	45	7.5	51.9
Psammacora stellata	0	2	18	30	18	2	0	0	41	9.2	58.4
Leptoseris incrustans	0	6	17	27	17	3	0	0	39	10.3	61.1
Leptoseris yabei	0	6	18	25	19	2	0	0	39	11.1	57.7
Turbinaria mesenterina	0	3	19	36	12	0	0	0	37	9.5	45.1
Turbinaria peltata	0	3	19	36	12	0	0	0	37	9.5	45.1
Turbinaria reniformis	0	3	19	36	12	0	0	0	37	9.5	45.1
Heliopora coerulea	0	4	24	28	11	3	0	0	37	11.1	54.1
Porites (Clade 1 forma *pukoensis**)	0	30	25	14	1	0	0	0	19	8.3	43.1
all votes summed	0	65	494	1750	1981	1209	241	0			
frequency of species per likelihood bin	0	13	57	80	82	77	57	0			
percentage of species per likelihood bin (%)	0	16	70	98	100	94	70	0			
mean likelihood score frequency	0	0	1	25	46	10	0	0			

* see species account *Porites pukoensis* for details

the BRT to have relatively high extinction risk also tended to have highly restricted geographic ranges, documented declines in abundance or low population sizes, and/or were extremely vulnerable to one or more threats. In contrast, lower risk candidate coral species tended to have wide geographic and habitat distributions, tolerance to marginal environmental conditions, and/or known tolerance of important threats. Among the 82 candidate coral species, the mean estimated likelihood of a species status falling below the Critical Risk Threshold by 2100 ranged from 78% ("likely" to fall below the Critical Risk Threshold by 2100) to 19% ("unlikely" to fall below the Critical Risk Threshold by 2100). The overall mean likelihood of falling below the Critical Risk Threshold by 2100 was 55% across all 82 candidate coral species, thereby falling into the "more likely than not (50%–66%)" risk likelihood category (the mode was also in this category). The distribution of mean likelihood scores across the 8 risk likelihood categoies for all 82 candidate coral species (Fig. ES-3) shows that the mean likelihood scores for 26 of the 82 species were in the 'less likely than not' (25) or 'unlikely' (1) risk likelihood categories and 56 of the 82 species were in the 'more likely than not' (46) and 'likely' (10) risk likelihood categories. The overall uncertainty was high with the mean range of votes for all 82 of the candidate coral species spanning 53.75% (SD 12.73) of the total likelihood range. In simplified terms, the BRT concluded, albeit with high uncertainty, that the status of most of the 82 candidate coral species are "more likely than not" to fall below the Critical Risk Threshold by 2100 under the assumption of status quo policies and technologies.

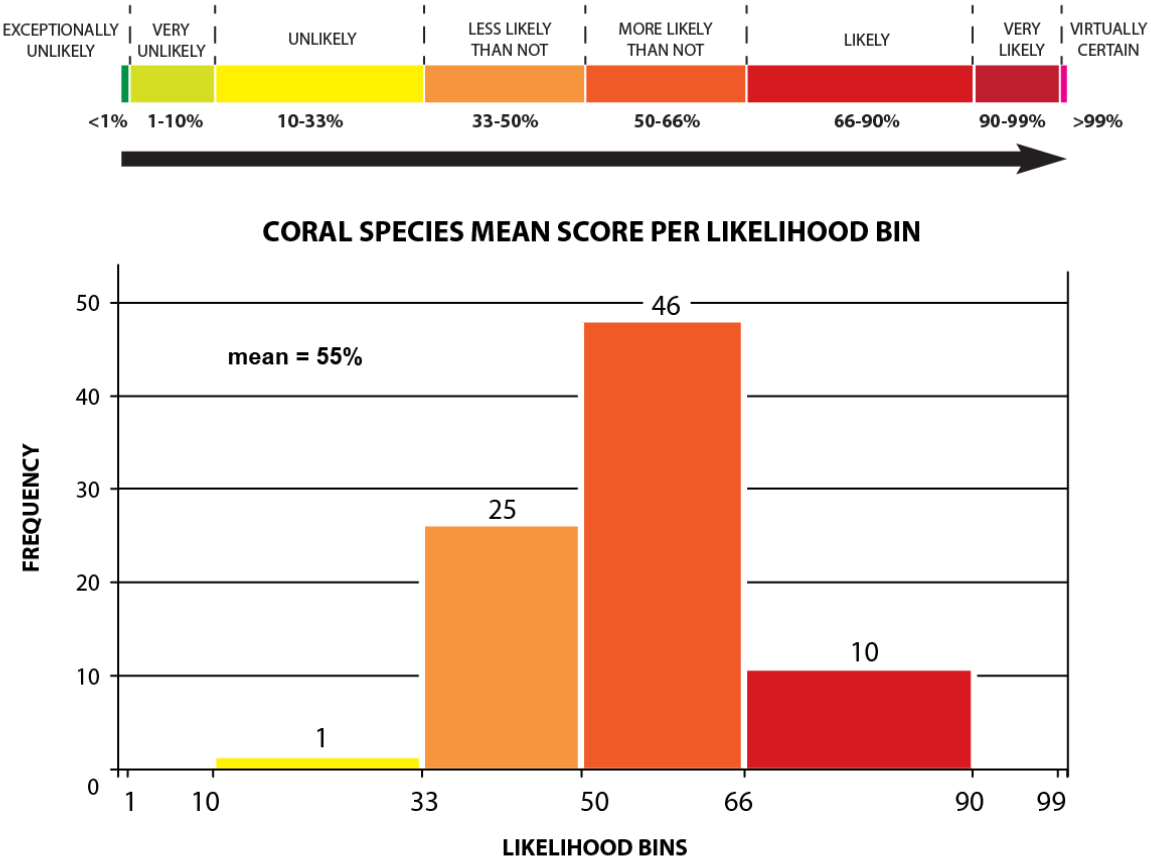

Figure ES-3. Number of coral species mean with likelihood scores (total = 82 scores) in each risk likelihood category. The overall mean of the mean likelihood scores of all 82 species is 55%.

1. INTRODUCTION

On October 20, 2009, the National Marine Fisheries Service (NMFS) received a petition from the Center for Biological Diversity (CBD) to list 83 species of coral as either threatened or endangered under the U.S. Endangered Species Act. Eight of these species are found in the western Atlantic/Caribbean (indicated by (C) in the list below), and the remaining 75 species are found in the Pacific and Indian Oceans (Indo-Pacific). In alphabetical order, the 83 species included in the petition (using Cairns et al (1999) for the spelling of the species names) are:

Acanthastrea brevis
Acanthastrea hemprichii
Acanthastrea ishigakiensis
Acanthastrea regularis

Acropora aculeus
Acropora acuminata
Acropora aspera
Acropora dendrum
Acropora donei
Acropora globiceps
Acropora horrida
Acropora jacquelineae
Acropora listeri
Acropora lokani
Acropora microclados
Acropora palmerae
Acropora paniculata
Acropora pharaonis
Acropora polystoma
Acropora retusa
Acropora rudis
Acropora speciosa
Acropora striata
Acropora tenella
Acropora vaughani
Acropora verweyi

Agaricia lamarcki (C)

Alveopora allingi
Alveopora fenestrata
Alveopora verrilliana

Anacropora puertogalerae
Anacropora spinosa

Astreopora cucullata
Barabattoia laddi

Caulastrea echinulata

Cyphastrea agassizi
Cyphastrea ocellina

Dendrogyra cylindrus (C)

Dichocoenia stokesi (C)

Euphyllia cristata
Euphyllia paraancora
Euphyllia paradivisa

Galaxea astreata

Heliopora coerulea

Isopora crateriformis
Isopora cuneata

Leptoseris incrustans
Leptoseris yabei

Millepora foveolata
Millepora tuberosa

Montastraea annularis (C)
Montastraea faveolata (C)
Montastraea franksi (C)

Montipora angulata
Montipora australiensis
Montipora calcarea
Montipora caliculata
Montipora dilatata
Montipora flabellata
Montipora lobulata
Montipora patula

Mycetophyllia ferox (C)

Oculina varicosa (C)

Pachyseris rugosa

Pavona bipartita
Pavona cactus
Pavona decussata
Pavona diffluens
Pavona venosa

Pectinia alcicornis

Physogyra lichtensteini

Pocillopora danae
Pocillopora elegans

Porites horizontalata
Porites napopora
Porites nigrescens
Porites pukoensis

Psammocora stellata

Seriatopora aculeata

Turbinaria mesenterina
Turbinaria peltata
Turbinaria reniformis
Turbinaria stellula

The petition states that all of these species are classified as vulnerable (76 species), endangered (6 species: *Acropora rudis*, *Anacropora spinosa*, *Montipora dilatata*, *Montastraea annularis*, *M. faveolata*, *Millepora tuberosa*) or critically endangered (1 species: *Porites pukoensis*) by the International Union for Conservation of Nature (IUCN). *Montipora dilatata* and *Oculina varicosa* are also on the NMFS Species of Concern list. The petition also purports that all of these species occur in U.S. waters.

The NMFS issued a 90-day finding (National Marine Fisheries Service, 2010), wherein the petition was determined to contain substantial information for all of the petitioned species except *Oculina varicosa* (see the 90-day finding for information included in the petition). Thus, the NMFS initiated a status review of the remaining 82 species of corals; *O. varicosa* will not be considered further. The NMFS Pacific Islands Regional Office (PIRO) and the Southeast Regional Office (SERO) requested that the NMFS Pacific Islands Fisheries Science Center (PIFSC) and the Southeast Fisheries Science Center (SEFSC) form a Biological Review Team (BRT) to review the status of the 82 candidate coral species. The PIFSC and SEFSC Directors then issued invitations for participation on the BRT.

The NMFS requested the BRT to assess the status of each candidate coral species and the degree of threat to each of the species with regard to the factors listed under Section 4 of the U.S. Endangered Species Act of 1973 (16 *United States* Code 1531-1544, 87 Statute 884), without making recommendations about whether any of the 82 candidate coral species should be listed as threatened or endangered. 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.

1.1 Scope and Intent of 82 Corals Status Review Report

In May 2010, the NMFS convened the 82-Corals BRT, including experts in the fields of coral biology and ecology, physical oceanography, climate change, and population dynamics to prepare a Status Review Report of the 82 candidate coral species as mandated by the U.S. Endangered Species Act. This Status Review Report includes a determination of the risk of extinction for each of the 82 candidate coral species out to the year 2100 based on an evaluation of the best available information and data including the following topics: (1) long-term trends in abundance throughout the species' ranges; (2) potential factors for any declines of the species throughout their ranges (human population and consumption, climate change, ocean acidification, overharvesting, natural predation, disease, habitat loss, etc.); (3) historical and current range, distribution, and habitat use of the species; (4) historical and current estimates of the species' population sizes and available habitats; and (5) knowledge of various life history parameters (size/age at maturity, fecundity, length of larval stage, larval dispersal dynamics, etc.). In evaluating the risks of extinction, the BRT did not make any assumptions about future policy changes or technological advances that could potentially alter the projections used in this analysis.

1.1.1 Background on the Endangered Species Act

The purposes of the U.S. Endangered Species Act are to provide a means to conserve ecosystems on which endangered species and threatened species depend, to provide a program for the conservation of endangered and threatened species, and to take appropriate steps to recover a species. The U.S. Fish and Wildlife Service (USFWS) and the NMFS share responsibility for administering the Endangered Species Act; the NMFS is responsible for determining whether marine, estuarine or anadromous species, subspecies or distinct population segments are threatened or endangered under the Endangered Species Act. To be considered for listing under the Endangered Species Act, a group of organisms must constitute a "species."

The U.S. Endangered Species Act and a 1996 joint USFWS-NMFS policy (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 1996) provide the following definitions and criteria for designation of a population or group of populations:

> *"the term **species** includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature."*
>
> *"**endangered species** is defined as "any species which is in danger of extinction throughout all or a significant portion of its range."*
>
> *"**threatened species** is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."*

The NMFS must base its determinations on whether to list species solely on the best available scientific and commercial information. The status of each species is evaluated by estimating the risk of extinction and determining whether the species is an endangered species or a threatened species based on any of the following factors in Section 4(a)(1) of the U.S. Endangered Species Act:

A. The present or threatened destruction, modification or curtailment of its habitat or range;
B. Overutilization for commercial, recreational, scientific or educational purposes;
C. Disease or predation;
D. Inadequacy of existing regulatory mechanisms; or
E. Other natural or manmade factors affecting the continued existence of the species.

The purpose of this Status Review Report is to provide important information about the status and risk of extinction for each of the 82 candidate coral species for use in making these listing determinations. This Status Review Report does not assess the inadequacy of existing regulatory mechanisms (listing factor D above).

1.1.2 Candidate species/Species of Concern listing

Each of the 82 coral species included in this Status Review Report are considered to be candidate species under the U.S. Endangered Species Act. "Candidate species" refers to (1) species that are the subject of a petition to list and for which the NMFS has determined that listing may be warranted pursuant to Endangered Species Act Section 4(b)(3)(A), and (2) species for which the NMFS has determined, following a status review, that listing is warranted (whether or not they are the subject of a petition). Further, of the 82 candidate coral species considered in this Status Review Report, only *Montipora dilatata* has previously been identified as a Species of Concern under the Endangered Species Act (National Marine Fisheries Service, 2004). A "species of concern" identifies species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act. For example, *Montipora dilatata* was identified as a Species of Concern in 2004 based on the species being very rare, endemic to a small geographic area (Hawai`i), and subject to the following factors for decline: (1) vulnerability to coral bleaching; (2) fresh water kills and exposure at extreme low tide; (3) habitat degradation and modification as a result of sedimentation, pollution, and alien alga invasion; and (4) damage by anchors, fish pots, swimmers, and divers.

1.1.3 The "species" question

When conducting Status Review Reports, BRTs need to determine whether the nominal candidate species in question are in fact "species" as defined by the U.S. Endangered Species Act. Corals are marine invertebrates, not vertebrate species; therefore, individual coral species may not be subdivided into distinct population segments for the purposes of the Endangered Species Act (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 1996). Although scientists have begun using genetic tools to reexamine coral taxonomic issues and identify coral populations, these data are still relatively sparse and generally do not exist across the full geographic ranges for any coral species. For each of the 82 candidate corals considered in this Status Review Report, the status of each species must be considered throughout their entire ranges when evaluating extinction risks. The best available literature relevant to each of the candidate coral species in this petition is examined in Chapter 2 and within the individual species accounts (Chapters 6 and 7).

1.2 The Petition

The purpose of this Status Review Report is to provide important information about the status and risk of extinction for each of the 82 candidate coral species for use by the NMFS in making listing determinations under the U.S. Endangered Species Act. ***The purpose of this Status Review Report is not to evaluate the validity of the specific assertions in the Petition or to provide alternative recommendations for other coral species to be considered for listing.*** However, a brief summary of the Petition is provided here for context.

The petition included descriptions of the morphology, life history, habitat, distribution, and loss estimates over 30 years (20 years into the past and 10 years into the future) for each of 83 petitioned coral species, threats facing each species, and descriptions of the status of coral reef ecosystems of the western Atlantic/Caribbean and Indo-Pacific areas. The petition asserted that each of the 83 petitioned coral species have suffered population reductions of at least 30% over a 30-year period, relying on information from the IUCN. The petition stated that the majority of coral species included in this petition occur in similar habitats in either the western Atlantic/Caribbean or Indo-Pacific basins and face the same threats. Eight of the petitioned species occur in the western Atlantic/Caribbean, and 75 occur in the Indo-Pacific. The

wider Caribbean, according to the petitioner, had the largest proportion of corals classified as being in one of the high extinction risk categories by the IUCN. The petitioner asserted that the Caribbean region suffered massive losses of corals in response to climate-related bleaching and mortality events of 2005, including a record-breaking series of 26 tropical storms and elevated ocean water temperatures. Further, the petitioner asserted that the U.S. Virgin Islands lost 51.5% of live coral cover, and that Florida, Puerto Rico, the Cayman Islands, St. Maarten, Saba, St. Eustatius, Guadeloupe, Martinique, St. Barthelemy, Barbados, Jamaica, and Cuba suffered bleaching of over 50% of coral colonies, citing Carpenter et al. (2008).

The petition described factors that it asserted have led to the current status of these corals, as well as threats that it asserted the species currently face, categorizing them under the Section 4(a)(1) factors. The petition focused on habitat threats, asserting that the habitats of the 83 petitioned coral species, and indeed all reef-building coral species, are under threat from several processes linked to anthropogenic greenhouse gas emissions, including increasing seawater temperatures, increasing ocean acidification, increasing storm intensities, changes in precipitation, and sea-level rise. The petition also asserted that these global habitat threats are exacerbated by local habitat threats posed by ship traffic, dredging, coastal development, pollution, and agricultural and land-use practices that increase sedimentation and nutrient loading. The petition asserted that this combination of habitat threats has already affected coral reef ecosystems on a global scale, and that these threats are currently accelerating in severity such that the quantity and quality of coral reef ecosystems are likely to be greatly reduced in the next few decades.

The petitioner cited Gardner et al. (2003) in asserting that, over the three decades prior to the 2005 events, Caribbean reefs had already suffered an 80% decline in hard coral cover, from an average of 50% to an average of 10% throughout the region. The abundance and trend information presented by the petitioner for each species was limited to an estimate of the percentage loss of its habitat and/or population over a 30-year period (including 20 years into the past and 10 years into the future), as assessed by the IUCN. However, the petition also asserted that these corals face significant threats. To support this assertion, the petitioner cited Alvarez-Filip et al. (2009) in noting the dramatic decline of the three-dimensional complexity of Caribbean reefs over the past 40 years, resulting in a phase shift from a coral-dominated ecosystem to fleshy macroalgal overgrowth in reef systems across the Caribbean.

The petitioner noted that, in the NMFS (2008) critical habitat designation for elkhorn (*Acropora palmata*) and staghorn (*Acropora cervicornis*) corals in the Atlantic, the NMFS identified chronic overfishing of herbivorous species and the die-off of 95% of the long-spined sea urchins (*Diadema antillarum*) across the region in the early 1980s as primary factors in this ecological shift (National Marine Fisheries Service, 2008). Based on that same critical habitat designation, the petitioner concluded that "in the absence of grazing pressure from herbivorous fish and urchins, fast growing algae, macroalgae, and other epibenthic organisms easily outcompete coral larvae by preempting available space, producing toxic metabolites that inhibit larval settlement, and trapping excess sediment in algal turfs." The petitioner cited Gledhill et al. (2008) in asserting that ocean acidification led to a decrease in mean sea surface aragonite saturation state in the greater Caribbean region between 1996 and 2006. The petitioner stated that Hoegh-Guldberg et al. (2007) found marked reductions in resilience accompanied by increased grazing requirements to facilitate reef recovery after modeling the effects of a 20% decline in coral growth rate in response to ocean acidification on a Caribbean forereef.

The petitioner cited Bruno and Selig (2007) in stating that 75% of the world's coral reefs can be found in the Indo-Pacific, which, as cited in the petition, stretches from the Indonesian island of Sumatra in the west to French Polynesia in the east. Further, the petitioner cited the same source, saying that as recently as 1000 to 100 years ago, this region probably averaged about 50% coral cover, but 20%–50% of that total has been lost since the 1980s. The petitioner asserted, citing again Bruno and Selig (2007), that this reduced coral cover was relatively consistent across 10 subregions of the Indo-Pacific in 2002–2003. The petitioner suggested that although these corals have recovered in the past (Colgan, 1987), anthropogenic stressors are increasing the frequency and intensity of mortality events and interfering with the natural ability of coral communities to recover (McClanahan et al., 2004a; Pandolfi et al., 2003). The petitioner cited Sheppard (2003) in explaining that the future of Indian Ocean reefs was a particular concern because over 90% of corals on many shallow water reefs died in 1998 in response to elevated sea surface temperatures, and because average temperatures in the Indian Ocean are expected to rise above 1998 levels within a few decades. The petitioner cited the same source in concluding that as elevated sea surface temperatures and associated climate-induced mass mortality events occur more frequently, it becomes less likely that there will be enough time between events for Indian Ocean reefs to recover.