NOAA Technical Memorandum NMFS-PIFSC-27

September 2011

Status Review Report of 82 Species of Corals Under the U.S. Endangered Species Act

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National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Highlights

- Biological Review Team (BRT) established May 2010.
  - 7 members, 2 external to NOAA (USGS & NPS)
  - Charged with evaluating extinction risk for 82 coral species
- Draft Status Review Report reviewed by Center for Independent Experts (and NMFS mgmt/GC) in Nov. 2010
  - Draft revised taking into consideration reviewer comments
  - NOAA Technical Memorandum NMFS-PIFSC-27 published Sep. '11
- Status Review Report includes:
  - Synopses for each of the 82+ candidate coral species
  - Information on potential threats to their existence
  - Estimates of their risk of extinction by 2100
- Ocean warming, disease, and ocean acidification, all directly or indirectly related to greenhouse gas emissions, were considered to pose greatest extinction risk to 82 candidate corals

Biological Review Team

Member	Affiliation	Expertise
Dr. Rusty Brainard, chair	NOAA-PIFSC	Coral reef ecosystem monitoring in Pacific, oceanography, ocean acidification
Dr. Margaret Miller	NOAA-SEFSC	Coral biology/ecology, focus on W. Atlantic/Caribbean
Dr. Paul McElhany	NOAA-NWFSC	Population viability analysis, risk assessment models, ocean acidification
Dr. Mark Eakin	NOAA-NESDIS CRW	Coral ecology, coral bleaching, satellite remote sensing, climate prediction
Dr. Greg Piniak	NOAA-NCCOS	Coral reef ecology, near shore processes, land-based sources of pollution
Dr. Chuck Birkeland	USGS-HCFU	Coral reef biology/ecology in Pacific
Mr. Matt Patterson	NPS-IMFCN	Coral reef monitoring in W Atlantic/Caribbean

Status Review Report: Contents

Chapter 1 – Introduction

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- Status/Ecological History of E. Pacific Reefs

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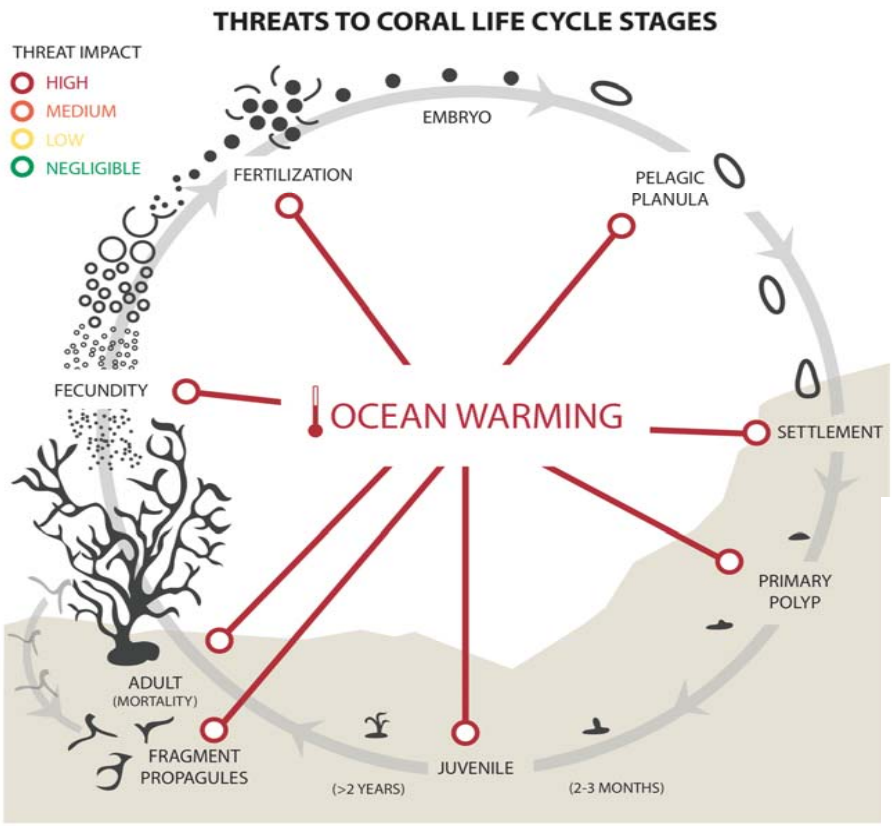
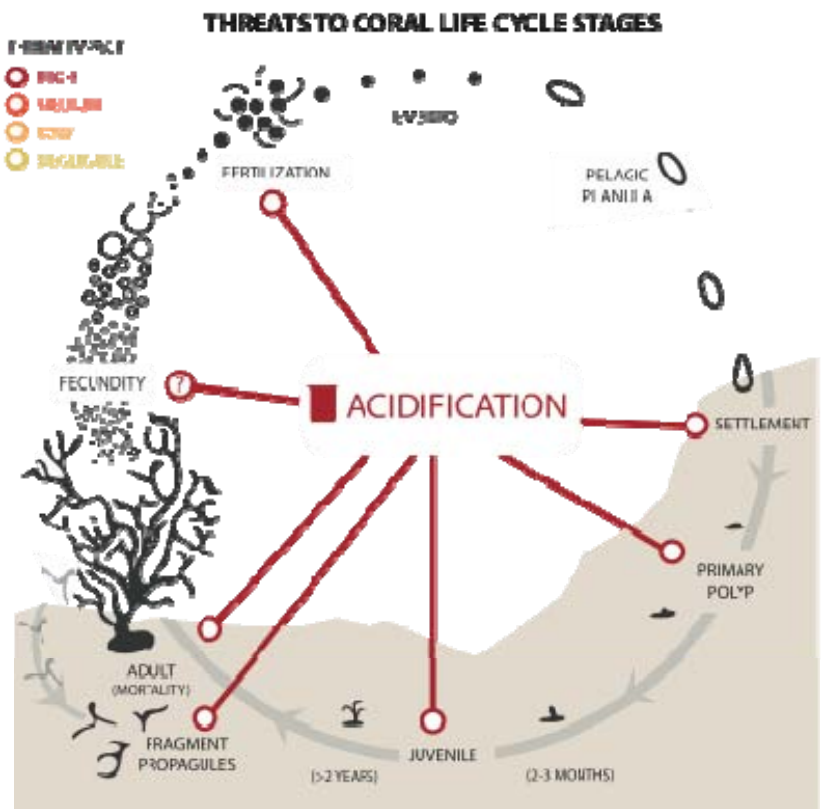
Evaluation of Extinction Threats

Section 4(a)(1) Factors	Threat	Importance
5	Ocean warming	high
3	Disease	high
5	Ocean acidification	med-high
1	Fishing- trophic effects	medium
1, 5	Sea-level rise	low-medium
1	Sedimentation	low-medium
1	Nutrients	low-medium
5	Changing circulation	low
1	Changing storms	low
3	Predation	low
1	Fishing - destructive practices	low
1	Physical damage - storms	low
1	Coastal construction	low
2	Aquarium and curio trade	low
5	Toxins*	not neglibile
5	Invasive species	neglible-low
5	Insolation*	probably negligible
5	Salinity	negligble
5	Dust	negligible
1	Physical damage - debris	negligible
1	Physical damage - tourism/divers	negligible
1	Physical damage - vessels	negligible

Threats to Coral Life Cycle Stages





Interactive & Unmeasureable (?)

The Species Question

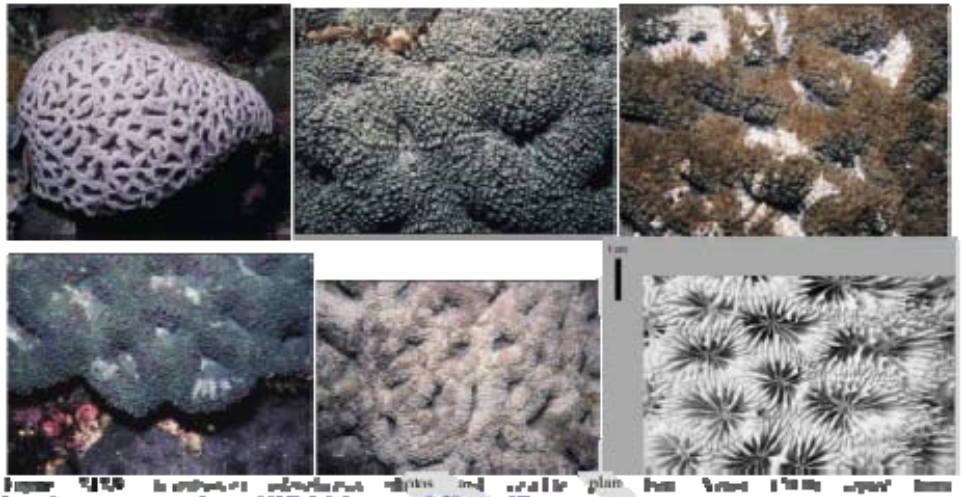
Is each candidate coral is a "species" under the ESA (a group of organisms that 'interbreed when mature' and are reproductively isolated from other such groups [common gene pool is separate and distinct from others]?

- Most corals 'species' have been described by classical taxonomy relying on similarities and differences in morphology. Corals are especially plastic in their morphology depending on the environmental conditions under which they live.
- The degree of environmental versus genetic determination of morphological characteristics determines the degree to which morphologically-classified species designations accurately reflect 'true' biological species (i.e. interbreeding and reproductively isolated groups).
- Genetic studies have shown that morphological taxonomies poorly reflect the genetic species status within many coral genera.
- Evolutionary history of corals is marked by reticulate processes – individual lineages have repeated cycles of divergence and convergence.

The BRT used solid genetics information when it existed, but defaulted to morphological descriptions when genetic studies were not available (e.g. for most of the 82 candidate species).

Individual Species Accounts

Species Names

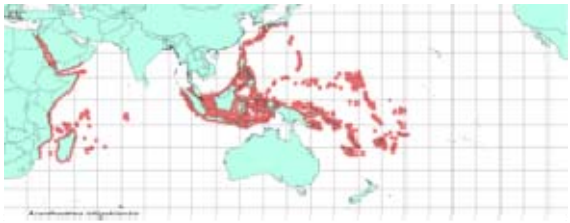


Characteristics

Taxonomy

Evolutionary History

Distribution



Habitat/Depth

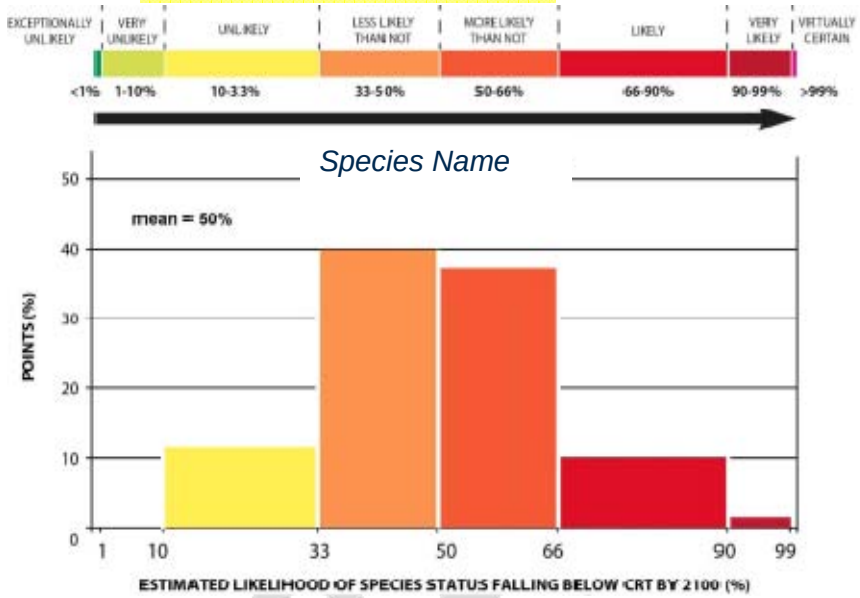
Individual Species Accounts

Abundance Abundance

Life History Life History

Threats Threats

Risk Assessment Risk Assessment



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Extinction Risk Analysis

- Critical Risk Threshold was defined by the BRT as a condition where a species is of such low abundance, so spatially fragmented, or at such reduced genetic and genotypic diversity that extinction is extremely likely
  - Based on consideration of:
    - depensatory processes (e.g., declining reproductive output due to low population density of sessile broadcast spawners),
    - environmental stochasticity, and
    - catastrophic events.
- Likelihood of a species population falling below a Critical Risk Threshold by the year 2100,
  - a time frame where climate projections are readily available and sufficiently scientifically-vetted (IPCC AR4).

- BRT followed approaches used in the following:

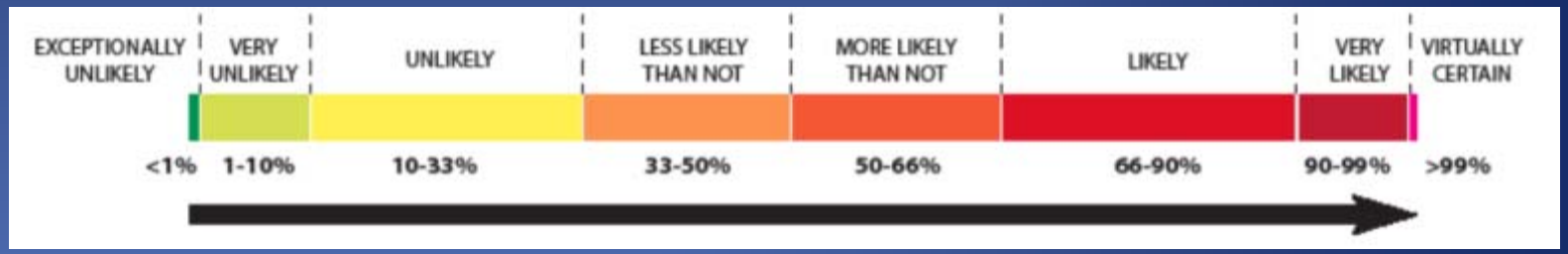
- Good, T. P., Waples R. S., Adams P., and (eds). 2001. Updated status of federally listed ESUs of West Coast salmon and steelhead. NMFS-NWFSC-66. NOAA Tech. Memo. NMFS-NWFSC-66 598 p. U.S. Dept. Commerce, 598 p.
- IPCC. 2001. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (R. K. Pachauri, and A. Reisinger, eds.), 104 p. Intergovernmental Panel on Climate Change, Geneva, Switzerland.
- Pew Center on Global Climate Change. 2007. Highlights from Climate Change 2007 Synthesis Report of the IPCC Fourth Assessment Report: Summary for Policy Makers.

General Risk Principles: 'All other things being equal. . .'

- Smaller geographic range → higher risk
  - Likely smaller population size (demographic risk)
  - Higher vulnerability to local stressors and catastrophes
- Broad habitat range → lower risk
  - Higher tolerance to stressors
- Presence in marginal habitats (e.g. mesophotic, extremely shallow, high turbidity, etc) → lower risk
  - Higher tolerance to stressors
  - Mesophotic: possibly buffered from land-based threats

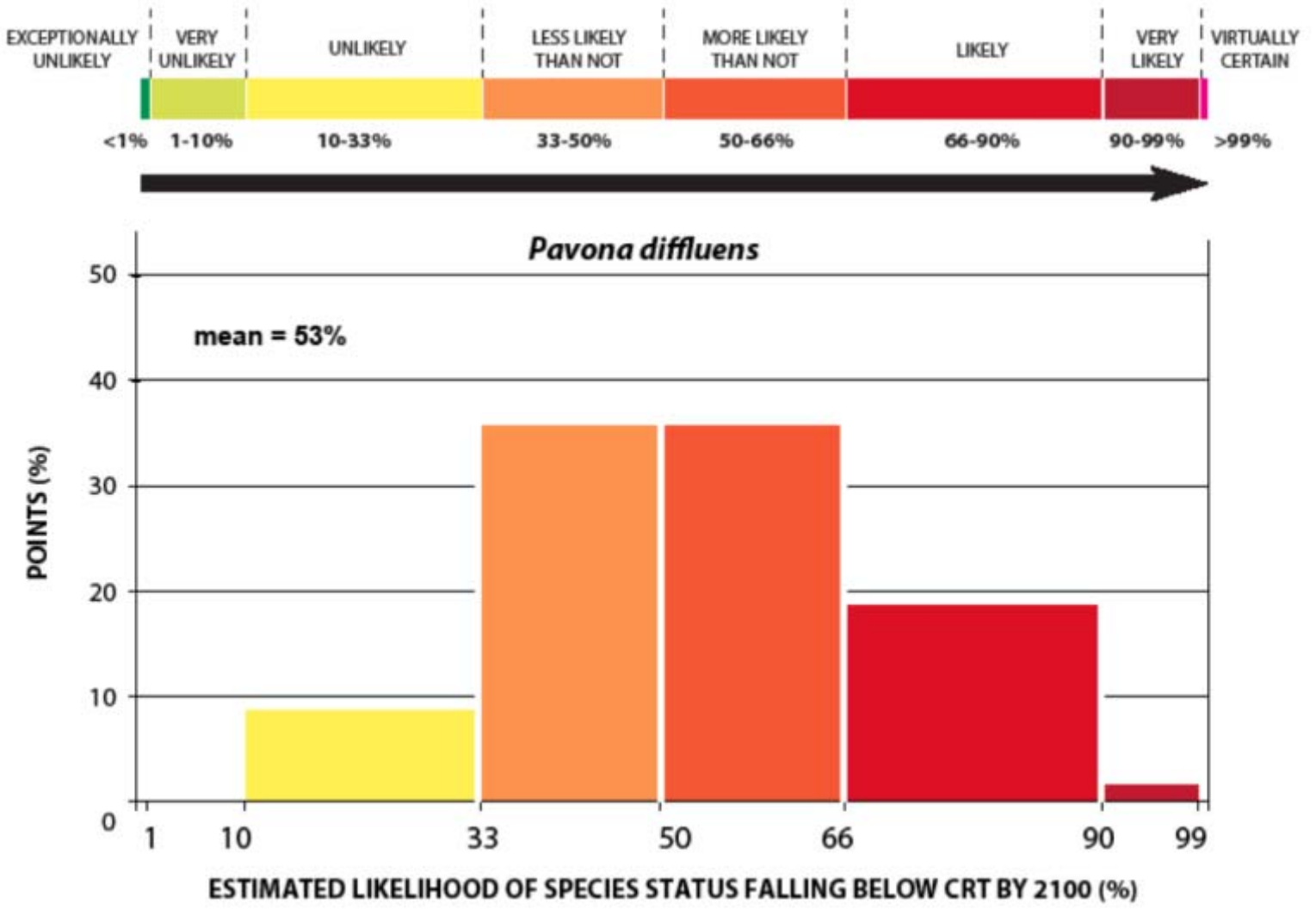
BRT Risk Evaluation Process

- Each BRT member confidentially voted allocating 10 'likelihood' points (similar to False Killer Whale BRT) amongst 8 categories (similar to IPCC) to evaluate: '*Likelihood of a species falling below its Critical Risk Threshold by the year 2100*'



- BRT discussed outcomes of 1st vote, then confidentially voted again.
  - In some cases, particularly when new information was identified in discussion or thereafter, additional votes were made.
- BRT members typically spread their votes across multiple risk categories due to uncertainty based on lack of information.
- This large uncertainty is reflected for both individual species accounts and in means and modes for all species combined.

Example for Estimated Likelihood Of *Pavona diffluens*



Results for all 82 Species

Caribbean species in red

SPECIES	# OF VOTES IN EACH RISK LIKELIHOOD CATEGORY								MEAN LIKELI-HOOD (%)	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	2	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

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	<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			

Results

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Millepora foveolata	0	0	0	16	26	25	3	0	63	9.8	50.3
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Acropora striata	0	0	2	21	27	19	1	0	58	8.4	58.1
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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
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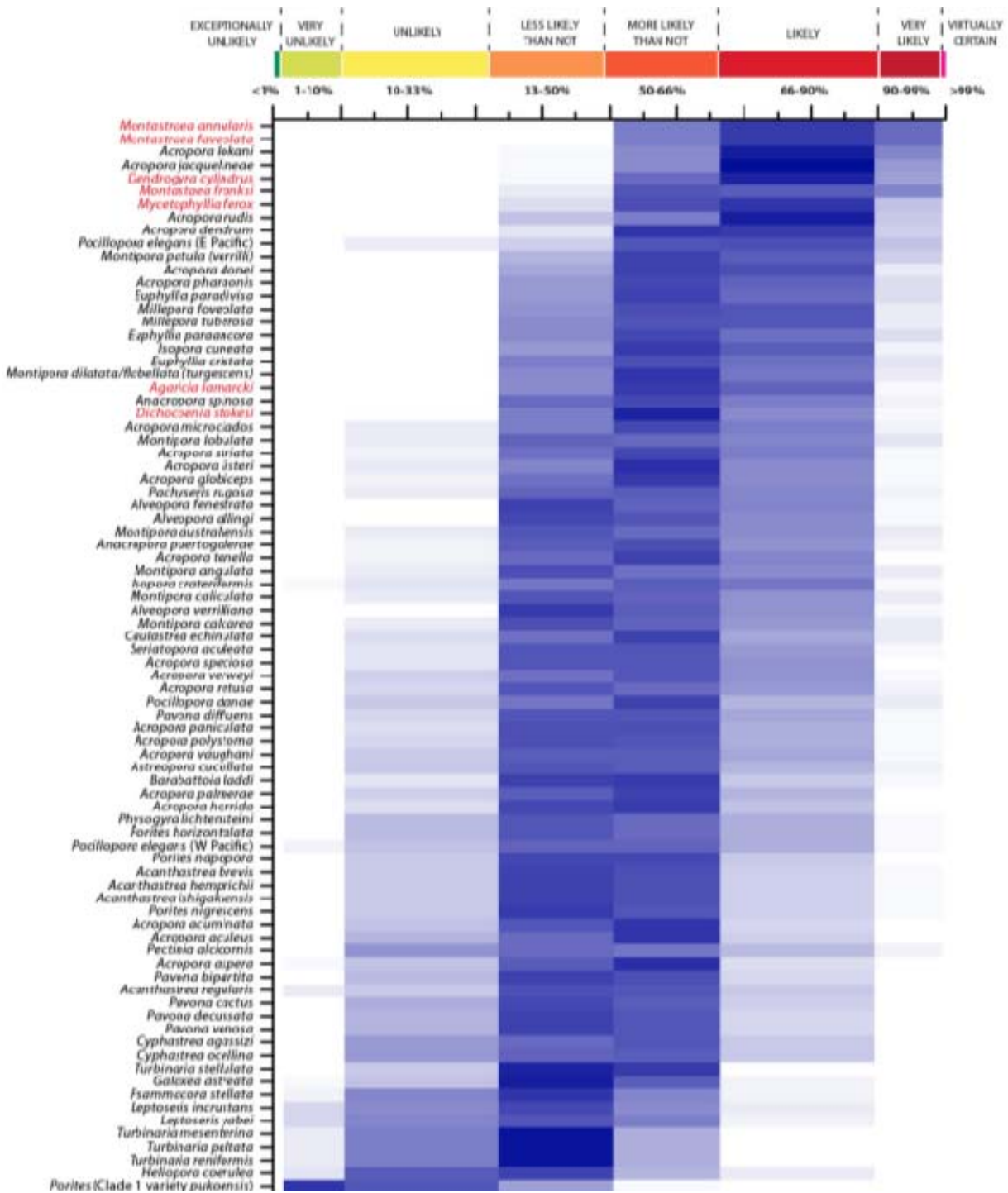
Montipora angulata	0	0	3	26	21	17	3	0	57	11.9	53.7
Isopora crateriformis	0	1	4	20	24	20	1	0	57	14.2	51.3
Montipora caliculata	0	0	3	25	23	16	3	0	57	11.6	53.7
Alveopora verrilliana	0	0	0	29	24	16	1	0	56	9	49.1
Montipora calcarea	0	0	3	26	23	15	3	0	56	11.6	53.7
Caulastrea echinulata	0	0	5	21	28	13	3	0	56	9.6	62.6
Seriatopora aculeata	0	0	4	25	25	15	1	0	55	10.3	59.1

<u>High Risk</u>
5 of top 7 highest risk species from Caribbean (shown in red font).

Overall mean across all 82 candidate coral species was 55%

>> 'More likely than not' to fall below Critical Risk Threshold by 2100



Results - Graphic

<u>High Uncertainty</u>
Mean spread (range) of votes for each BRT Member was 53.75%

Mean Standard Error between BRT means for the 82 species was 9.9%

Strengths of BRT Approach

- All available relevant information was considered.
- Approach was relatively expeditious (i.e., tight ESA timeline).
- Approach explicitly considered uncertainty about all information.
- Approach could be applied in cases with limited information.
- Approach did not require consensus (but it was generally reached).
- The result represented an aggregate result of experts with varying perceptions of risk to the species.

Limitations of BRT Approach

- Expert-based approaches are subjective.
- Links between available information and conclusions are not readily transparent.
- "Rules" used by BRT members were not explicit, and hence not repeatable.
- The Federal Advisory Committee Act necessitated BRT consist of Federal experts—the pool of qualified and available individuals was limited.
- The short, ambitious deadline was challenging for evaluation of 82 candidate species with global range and limited data.

Peer-Review Process

Draft report sent to Center for Independent Experts

- Terry P. Hughes, Director, ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD Australia
- John W. McManus, Director, National Center for Caribbean Coral Reef Research and Professor, Division of Marine Biology and Fisheries, Rosenstiel School of Marine & Atmospheric Science, University of Miami, Miami, Florida.
- Bernhard Riegl, Professor and Associate Director of the National Coral Reef Institute, NOVA Southeastern University, Fort Lauderdale-Davie, Florida.

Peer-Review Process

- BRT responded to CIE review comments in a separate (55 page) internal report and revised draft where appropriate
- Draft report submitted to PIFSC internal publications process
  - Internal review by PhD stock assessment biologist and Center director
  - Final draft revised accordingly
- Status review published as NOAA Technical memorandum (held pending listing decision)
  - Report submitted to NMFS Pacific Islands Regional Administrator

Summary

- Comprehensive synopses and extinction risk assessment of 82 species of corals
- Evaluation of a broad range of potential threats, the most important extinction risks were posed by the following global threats:
  - ocean warming,
  - coral disease,
  - ocean acidification, all directly or indirectly related to greenhouse gas emissions
- The mean estimated likelihood of falling below the Critical Risk Threshold by 2100 ranged from 78% ('likely') to 19% ('unlikely') among the 82 candidate coral species.
- The overall mean and the median estimated Critical Risk Threshold across all 82 candidate coral species both exceeded 50% likelihood, thereby falling into the 'more likely than not' category.
- The BRT concluded, with high uncertainty, that most of the 82 candidate coral species are 'more likely than not' to fall below the Critical Risk Threshold by 2100.

Summary (con't)

- Caribbean species were estimated to have relatively high probabilities of falling below the Critical Risk Thresholds by 2100 with 5 of the top 7 candidate species from that region.
  - reflects the small geographic extent,
  - pervasive and demonstrated impacts of both local and global threats,
  - significant and well-documented declines of corals in the Caribbean region.
- Other high-risk species have highly restricted geographic ranges, demonstrated low population sizes, and/or extreme vulnerabilities to one or more threats.
- Lower risk species tended to have wide geographic and habitat distributions, tolerance to marginal environmental conditions, and/or known tolerance of important threats.
- The BRT identified increasing human population and the intensity of their collective consumption as the root drivers of almost all global and local threats to coral species.

Questions?