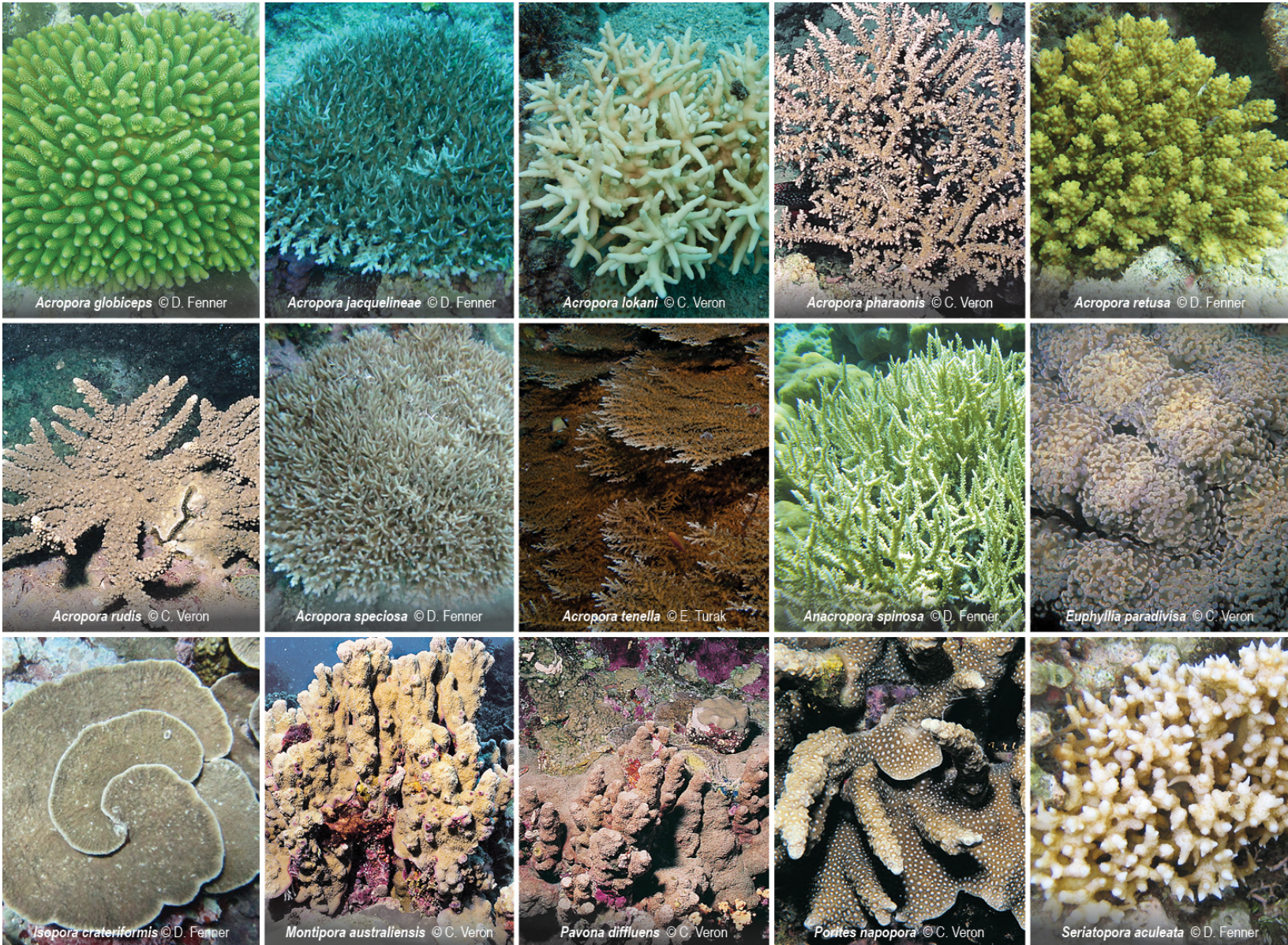




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# U.S. ESA-listed Indo-Pacific Corals Recovery Planning Workshop · May 2021

## Workshop Summary





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## DOCUMENT PREPARED BY

The “U.S. ESA-listed Indo-Pacific Corals Recovery Planning Workshop Summary” was prepared by the National Marine Fisheries Service Pacific Islands Regional Office and Lynker Technologies (ProTech Fisheries Domain Task Order# 1305M319FNFFT0244).



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## GLOSSARY OF COMMON ABBREVIATIONS

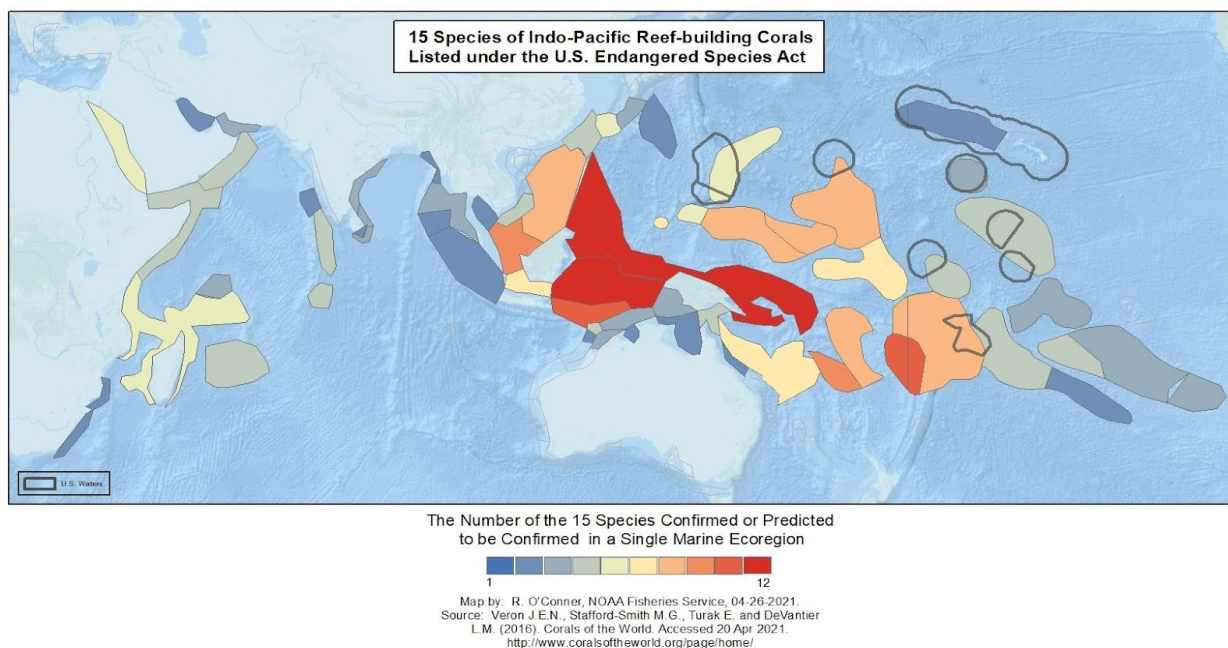
AI	Artificial Intelligence
BECQ	Bureau of Environmental and Coastal Quality
BOEM	Bureau of Ocean Energy Management
BOG	Break Out Group
CITIES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNMI	Commonwealth of the Northern Mariana Islands
COTS	Crown-of-Thorns Starfish
CRAG	Coral Reef Advisory Group
CRW	Coral Reef Watch
CT	Coral Triangle
DHW	Degree Heating Weeks
DLNR	Department of Land and Natural Resources
DPS	Distinct Population Segment
eDNA	Environmental Deoxyribonucleic Acid (DNA)
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GCRMN	Global Coral Reef Monitoring Network
GHG	Greenhouse Gas
GMST	Global Mean Surface Temperature
HFC	Hydrofluorocarbon
HST	Hawaii Standard Time
IUCN	International Union for Conservation of Nature
LBSP	Land Based Source of Pollution
MPA	Marine Protected Area
MU	Management Unit
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OA	Ocean Acidification
PIMPAC	Pacific Islands Managed and Protected Areas Community
PRD	Protected Resources Division
PVA	Population Viability Analysis
SeaBSP	Sea Based Sources of Pollution
SSTa	Sea Surface Temperature Anomaly
SST	Sea Surface Temperature
TMDL	Total Maximum Daily Load
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	U.S. Department of Agriculture
WRI	World Resources Institute

## 1.0 Purpose and Overview

The National Oceanic and Atmospheric Administration’s (NOAA) National Marine Fisheries Service (NMFS) is developing a recovery plan, pursuant to the United States’ (U.S.) Endangered Species Act (ESA) section 4(f), for 15 species of Indo-Pacific reef corals listed as threatened under the ESA in 2014 (herein referred to as the “15 listed corals”). The purpose of a recovery plan, a guidance document, is to provide a roadmap for the species recovery, with the goal of improving its status and managing threats to the point at which protections under the ESA are no longer needed.

Seven (7) of the 15 listed corals are known to occur in U.S. waters: *Acropora globiceps*, *A. jacquelineae*, *A. retusa*, *A. speciosa*, *Euphyllia paradivisa*, *Isopora crateriformis*, and *Seriatopora aculeata*. Five (5) of the 15 listed corals occur in the non-U.S. Pacific Ocean: *A. lokani*, *A. tenella*, *Porites napopora*, *Anacropora spinosa*, and *Montipora australiensis*. Three (3) of the 15 listed corals occur in the Indian Ocean: *Pavona diffluens*, *Acropora pharaonis* and *A. rudis*. Figure 1.0-1 illustrates the collective ranges of the 15 listed corals across the Indo-Pacific.

**Table 1.0-1.** Collective ranges of the 15 ESA-listed Indo-Pacific Corals across the Indo-Pacific. Grey polygons indicate U.S. waters.



NMFS held an invitational virtual workshop in May 2021 connecting stakeholders and experts from a range of relevant disciplines to harness their collective expertise, creativity, and ingenuity to help inform NMFS' development of an effective and practical recovery plan for the 15 listed corals. The workshop was announced in the U.S. Federal Register on March 24, 2021 (86 FR 15650), and was open to the public.

The goal of the workshop was to gain information and informed, creative ideas to help further the development of: (a) recovery approaches that address the challenges relevant to recovery of the 15 listed corals; (b) recovery criteria that need to be met to delist each of the species; and (c) recovery actions to reduce and/or ameliorate threats to the 15 listed corals.

Workshop outcomes include:

- Participants informed and able to engage in coral recovery planning discussions;
- A draft list of options for determining management units;
- A draft list of recovery criteria concepts; and
- A draft list of recovery actions and priority ranking of actions.

This Workshop Summary report provides a basic summary, rather than in-depth synthesis or analysis, of key discussion points raised by the participants and expert opinions shared during the workshop. The workshop was not a consensus-seeking meeting; rather, participants were asked to freely provide their ideas and expert opinion. Many comments and questions represent the input of just one or a few participants. Therefore, the opinions and any recommendations summarized in this Workshop Summary are not the consensus opinion of the participants, nor the opinion of NMFS.

NMFS will use input gained from the workshop to inform additional conversations with experts, and the development of the recovery strategy, recovery criteria, and recovery actions for the 15 listed corals within the Recovery Plan. Although this Workshop Summary is intended to be inclusive of the conversations at the workshop, the Recovery Plan may not reflect all of the ideas raised during the workshop. NMFS will seek public comment on the Draft Recovery Plan.

## 2.0 Schedule

NMFS held the workshop over the course of four 3-hour virtual sessions in May 2021. Duplicate meetings for each session's discussion points were held to accommodate participants from different time zones as listed below in Hawaii Standard Time (HST).



### **Week 1- Session I: Recovery Introduction**

- Option/Group A: Wednesday May 5, 8 - 11 a.m.
- Option/Group B: Thursday May 6, 2 - 5 p.m.

### **Week 2- Session II: Recovery Approaches**

- Option/Group A: Wednesday May 12, 8 - 11 a.m.
- Option/Group B: Thursday May 13, 2 - 5 p.m.

### **Week 3- Session III: Recovery Criteria**

- Option/Group A: Wednesday May 19, 8 - 11 a.m.
- Option/Group B: Thursday May 20, 2 - 5 p.m.

### **Week 4- Session IV: Recovery Actions**

- Option/Group A: Wednesday May 26, 8 - 11 a.m.
- Option/Group B: Thursday May 27, 2 - 5 p.m.

Attachment A provides an overview of the workshop agenda.

## **3.0 Participants**

Sixty-five (65) experts from the United States and the Indo-Pacific attended all or parts of the workshop. Participants represented a variety of areas of expertise from a range of relevant disciplines, including the listed coral species' biology/ecology, threats to the species, the species' habitat and ecosystem, recovery planning, and coral reef conservation and management. Attachment B provides the names of the participants.

The meeting was facilitated by Gabrielle Johnston, Lynker Technologies, LLC. The NMFS technical leads- Danielle Jayewardene, Lance Smith, and Chelsey Young- provided brief overview presentations of session topics, and facilitated small break out group (BOG) discussions. In addition, other NMFS and Lynker staff supporting the workshop, and members of the public were present for one or more sessions throughout the workshop.

## **4.0 Expert Input**

The participants' input provided during the workshop was gathered through different methods as described below. The collective input is presented in this Workshop Summary in the same manner.

**Pulse-checks-** throughout the workshop NMFS posed questions via online polls, using the software "Slido", related to items discussed during presentation overviews and/or group

discussions. These “pulse-checks” were primarily opportunities for expert engagement. Participants were provided only a few minutes to provide their anonymous feedback, were not expected to provide responses based on a comprehensive understanding or in-depth analysis related to the particular topics but rather their initial impressions, and were able to view a projection of the poll results while the poll was still open. Given the purpose and method of polling, results are not an unbiased, formal quantitative metric of expert opinion.

**Targeted brainstorming-** during sessions II, III and IV, NMFS facilitated group discussions to generate ideas and input related to targeted topics. The input was recorded on a virtual collaborative white-board, using the software “Mural”, where text could be added by each participant. Participants were also invited during these discussions to share comments and questions verbally or via virtual chats, which were captured, as appropriate and possible, by the workshop support staff on the virtual white-boards.

**General conversation-** throughout the workshop, participants were encouraged to ask questions and make comments (verbally or via chat) in response to presentations, and during the targeted brainstorming discussions. These comments and questions were captured via detailed meeting minutes, and key points summarized.

**Public comment-** opportunities for public comment were provided at the end of each session. However, no public comments were made during these times during the workshop.

## 4.1 Session I: Recovery Planning Introduction

Session I set the stage for Sessions II, III, and IV with NMFS providing three presentations: (1) a brief overview of the 2014 ESA coral listing, and an introduction to ESA recovery planning; (2) an overview of the threats evaluation of the 15 listed corals from the 2021 draft Recovery Status Review; and (3) an overview of the several challenges for recovery planning for the listed corals, and a working draft recovery vision, recovery goals, and recovery objectives to help frame the recovery planning discussions. Attachment C provides a PDF summary of the presentation slides provided.

### 4.1.1 ESA Recovery Planning

#### **General conversation**

Following NMFS’ brief overview of ESA recovery planning (presentation 1), participants were invited to ask questions and share comments. Points raised by participants during several discussions on this topic include:

- Recovery plans should be developed based on best available science, i.e. not influenced by political pressures.
- Recovery plans need to be practical and effective with a mechanism to re-evaluate and assess the outcome of the work; 5 year reviews have an important role.
- Review various recovery plans that may be helpful for developing the recovery planning strategy, goals, objectives, criteria etc. (E.g. the Caribbean *Acropora*- [NMFS 2015], Steller sea lion- [NMFS 2008], Puget Sound chinook salmon- [NMFS 2007], Island Fox- [USFWS 2015], Desert tortoise- [USFWS 2011], and Quino checkerspot butterfly-recovery plans [USFWS 2000]).
- NMFS recovery efforts generally integrate with ESA section 7(a)(2) consultations; consultations reference recovery plans in undertaking jeopardy analyses and for outlining Reasonable and Prudent Measures, Terms and Conditions, and Conservation Recommendations.
- Non-U.S. entities can implement recovery actions, and can receive NOAA funding to do so; the recovery plan helps NOAA fund recovery actions internationally if actions are identified within the plan.
- The recovery plan can adopt and support other countries' or international efforts that facilitate recovery, and can help facilitate international collaboration and leverage funding across regions and countries.
- Collaborate with the U.S. Agency for International Development (USAID) and the U.S. State Department, both key players in non-U.S. waters. USAID has major marine projects in several Coral Triangle countries. In addition, the U.S. Department of Agriculture (USDA) commonly provides technical assistance to help foreign countries manage soils, forests, and nutrient flows.
- A resilient reef hearing at the U.S. House of Representatives ([HR160](#)) was held in May 2021; it has the potential to result in increased funding for coral reef conservation.

#### 4.1.2 Threats Evaluation

##### Pulse-checks

Following NMFS' overview of the threats evaluation (presentation 2), participants were invited to provide their respective initial opinions via a brief poll, on the ranking of the importance of eight threats to the listed corals as outlined by NMFS. Forty-six (46) participants provided responses as summarized in Table 4.1.2-1. The highest ranked threat to the 15 listed corals was considered to be ocean warming, followed by land-based sources of pollution, ocean acidification and coral disease.

**Table 4.1.2-1.** Participants' opinion on the ranking of importance of the eight NMFS presented threats to the listed corals, ranked from highest to lowest importance (combined for group A and B, and weighted to reflect input per participant).

Threats to the 15 listed corals	Weighted Ranking Score
Ocean warming	8.0
Land-based sources of pollution	6.4
Ocean acidification	5.8
Coral disease	5.4
Fishing	4.4
Predation	3.0
Sea-level rise	1.6
Collection and trade	1.4

### General conversation

Points raised by participants during the threats evaluation discussion include:

- All 15 listed corals are included under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).
- While there is limited species-specific information available on the 15 listed corals, overall trends indicate that they have declined in abundance over several decades; this may not be the case for some parts of the ranges of any given species.
- Specific links to erosion, fragmentation, or shifts in the geographic distribution of the 15 listed corals are largely undetermined.
- While a formal threats ranking is not required for recovery planning, threats need to be prioritized during the recovery planning process.
- The estimated timeline for a species to recover can be different from that of the timeline used for evaluating threats to the species; as a hypothetical example, an estimated species recovery timeline may be 20 years, alternatively 200 years, while the reasonable timeline for the threats evaluation for the species is 50 years.
- Consequences of ocean acidification on corals such as reduced calcification and reduced fertilization are harder to document than ocean warming effects.
- Unlike the ESA-listed endangered *Cantharellus noumeae*, *Siderastrea glynni*, and *Tubastraea floreana* corals, the population status of the 15 listed species are driven primarily by climate change threats rather than local threats.
- Non-climate threat regimes, which are important, are different across countries and regions, potentially requiring tailored recovery actions.
- While recovery criteria describe the conditions that must be met in order to delist a species, meeting the criteria is not a de facto qualification to delist the species. NMFS must still undergo an ESA 5-factor analysis to delist species (NMFS 2021). This can be interpreted as the criteria being “necessary” but not “sufficient” for delisting.



### 4.1.3 Recovery Challenges

Following NMFS’ overview of the several challenges faced in recovering the 15 listed corals (presentation 3), 59 participants shared their perspective, via a poll, on the main challenge we face as summarized in Table 4.1.3-1. Global climate change was considered to pose the greatest challenge for recovery planning for the 15 listed corals. Additional obstacles identified by many participants include the scale of the recovery effort, political inaction, data deficiency, changing taxonomy, limited time, and lacking funding/resources.

**Table 4.1.3-1.** Participants' opinions synthesized and combined for Group A and B, on the main challenge we face in recovering the 15 listed corals (listed in approximately descending order starting with the most frequently identified challenge).

Challenges for recovering the 15 listed corals
Climate change (GHG emission, global change, global warming)
Politics/political inaction
Ocean acidification
International/broad scale and scope
Resources/funding
Taxonomy
Data deficiency (incl. on species and distribution)
Time/urgency
Partnerships/collaboration/coordination/international cooperation and integration
Local management/local action/local government
Tractable solutions
Institutional inertia
Effective MPAs
Population growth
Economic incentives
Economic growth and consumption
Human behavior
Marine heatwaves
Public apathy
Assessing if recovery needed
Environmental conditions
Ignorance
Viability
Meaningful interventions
Industrial outfalls
Reduction (population)

## General conversation

Points raised by participants during the discussion on recovery challenges, and the draft recovery vision, goals and objectives, include:

- Review and learn from other recovery plans and efforts, including importantly the Caribbean *Acropora* coral recovery plan (NMFS 2015).
- Consider developing “implementation plans” to accompany the recovery plan, which outline how other entities can implement recovery actions within their jurisdiction and articulate how this contributes to the recovery goal. See as an example the Kirtland’s Warbler recovery plan (USFWS 1985) and associated implementation plans.
- Reference a recent paper titled “Designing a Blueprint for Coral Reef Survival” (Kleypas et al. 2021) in developing the recovery strategy.
- In the draft recovery goal, delete “as possible” in the language “throughout as much of the species’ geographic and ecological ranges as possible” as it could mean zero.
- Consider including “increasing” the population size and mitigating species’ threats in the recovery goal (assuming species’ abundance has declined compared to the baseline).
- Consider a process-based goal for long-term success: maintain existing genetic diversity and preserve evolutionary and ecological processes necessary for the perpetuation of the species into the indefinite future.
- Note that “no longer meeting the definition of threatened” does not necessarily mean the species has been “conserved”.
- Since many of the 15 listed corals are naturally rare, recovery objectives (not just recovery criteria) may need to be tailored for each species. Only some, not all species may realistically be able to be brought to the point where they become self-sustaining/ self-regulating/ resilient.
- Consider criteria that spell out not only if species are moving closer to being “conserved”, but also moving closer to extinction.

## 4.2 Session II: Recovery Approaches

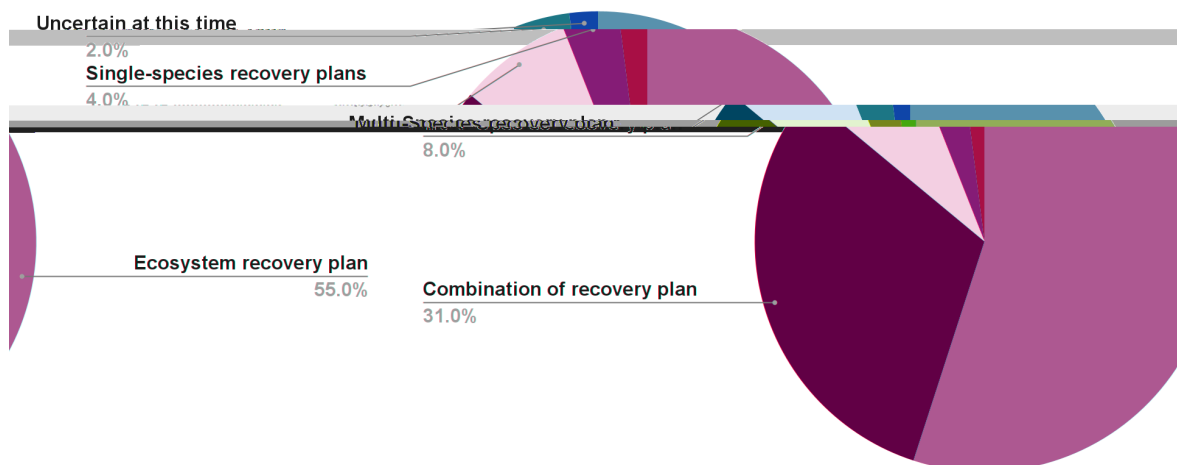
In Session II NMFS provided an overview of four proposed approaches for addressing the challenges for recovery planning for the 15 listed corals: (1) developing an ecosystem recovery plan, which is appropriate if several listed species in a shared biotic community rely on protection and/or restoration of their ecosystem to reach recovery; (2) undertaking a two-pronged approach to recovery actions, where the first prong involves large-scale global level recovery actions to mitigate climate change effects to facilitate recovery, and the second prong involves smaller-scale local recovery actions to promote the survival and resilience of the corals in the interim; (3) building off existing research, management and conservation efforts wherever appropriate and practicable; and (4) defining management

units (MUs), a tool that can be used when threats, management authority, and/or population viability may differ across geographic areas requiring tailored management programs. Attachment C provides a PDF summary of the presentation slides provided.

### 4.2.1 Ecosystem Recovery Plan

#### Pulse-check

Following NMFS' brief overview of types of recovery plans that can be developed, and NMFS' proposed idea to develop one ecosystem recovery plan for the 15 listed corals, 51 participants provided their respective initial opinions via a poll, on the type of recovery plan that might be most appropriate, as summarized in Figure 4.2.1-1. A majority of participants felt that an ecosystem recovery plan might be most appropriate, followed by many selecting the option of developing a combination of recovery plan types for the 15 listed corals.



**Figure 4.2.1-1.** Participants' vote, summarized and combined for Group A and B, on the recovery plan approach that may be most appropriate to develop for each of the 15 listed corals.

#### General conversation

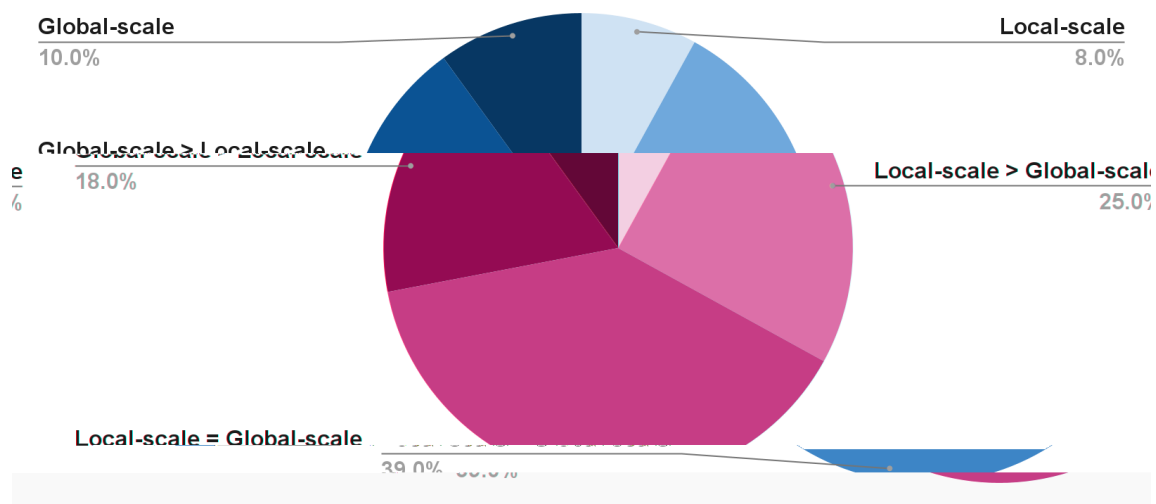
Points raised by participants during the discussion on recovery plan approaches/types include:

- A potential advantage of an ecosystem recovery planning approach is the potential prevention of decline and listing of other species in the same reef ecosystem.
- Community-level metrics may help achieve the larger objective of a recovery plan.

## 4.2.2 Two-pronged Approach to Recovery Actions

### Pulse-check

Following NMFS' brief overview of the proposed idea to take a two-pronged approach to recovery actions, 51 participants provided their respective initial opinions via a poll, on the level of emphasis that should be placed on each "prong" in implementing recovery actions for the 15 listed corals as summarized in Figure 4.2.2-1. A plurality of participants favored a balanced portfolio of large-scale global-level recovery actions in combination with smaller-scale, local-based recovery actions. The second most popular option was more emphasis on smaller local-scale recovery actions, and the third most popular option was more emphasis on global scale recovery actions.



**Figure 4.2.2-1.** Participants' opinions on the level of emphasis that should be placed on local, smaller scale recovery actions to promote survival and resilience of listed corals, versus global, large-scale recovery actions to mitigate climate change threats. Percentages are averaged between groups A and B.

### General conversation

Points raised by participants during the discussion on the two-pronged approach to recovery actions include:

- All long-term recovery actions will not necessarily be large-scale addressing climate change threats; there are smaller scale coral survival and resilience actions that will require longer term planning and rollout, and likewise climate change mitigation efforts that need to be addressed immediately.



- Consider ex-situ conservation (could fit into both prongs, or be a third prong) for the most threatened species, but note that this can raise a host of new problems. Refer to NMFS’ experience with Pacific salmon.
- All the interventions listed in the 2019 National Academies of Sciences, Engineering, and Medicine Report “A Research Review of Interventions to Increase the Persistence and Resilience of Coral Reefs” (NASEM 2019), and active reef restoration in general, can be considered in recovery planning for the 15 listed corals, i.e. actions are not restricted to NOAA implementable actions.

### 4.2.3 Building off Existing Efforts

#### Pulse-check

Following NMFS’ brief overview of the proposed approach to build off existing research, management and conservation efforts wherever appropriate and practicable for implementation of recovery actions for the 15 listed corals, 37 participants provided their respective initial inputs via a poll on key existing efforts for NMFS to be aware of in developing a recovery plan; numerous efforts were highlighted as summarized in Table 4.2.3-1.

**Table 4.2.3-1.** Participants' input summarized and combined for Group A and B, on efforts to be aware of in recovery planning for corals.

Existing Research, Management and Conservation Efforts to Build On
Marine Protected Areas and area-based management from across the Indo-Pacific
Various aspects of restoration efforts from different regions
Coral resilience and vulnerability assessments
National Academy of Sciences Interventions Report
Caribbean <i>Acropora</i> recovery plan
The Coral Reef Conservation Program
Project Phoenix/taxonomic revisions
Paris Agreement/ Biden’s GHG reduction efforts/ U.S. climate initiative
Australian colleagues’ experience
Great Barrier Reef Efforts (incl. coral rehab and growth)
Fishery Management Plans (U.S. federal and local)
Terrestrial restoration/management plans
Monitoring, including citizen science
Sedimentation and herbivore management efforts
American Samoa Ocean Plan
Approaches to managing ecosystem transitions (resist, accept, direct)
Pacific jurisdiction/Territorial restoration plans
Tracking populations trends
Everglades Restoration project

## Existing Research, Management and Conservation Efforts to Build On

Species location, abundance and distribution information
Research on optimizing restoration tracking of population trends
Coral Restoration Consortium
Advances in restoration methods for resilience
Hawaii State effort to identify key habitat areas of 300+ terrestrial species on Maui
Increasing community sustainability and resilience
Reducing sedimentation and overexploitation of herbivores
Citizen science monitoring of reefs in the Philippines
Natural resource management plans from CNMI, Guam and Kwajalein Atoll
Spatial data on variability in coral stress
Range shifts

### General conversation

Points raised by participants during the discussion on building on existing efforts include:

- While working across other agencies/entities to mitigate GHGs and other threats, focus on NMFS' strengths and abilities in implementing recovery actions.
- Review and learn from the Caribbean *Acropora* recovery plan (NMFS 2015) and any relevant Great Barrier Reef (GBR) recovery efforts. The GBR management monthly updates are found at: <https://www.gbrmpa.gov.au/the-reef/reef-health>
- Insights from the Caribbean *Acropora* related recovery efforts include:
  - It is challenging to conduct qualitative assessments; trends are unclear, threats continue to occur.
  - Success has occurred with propagation; mainly assisted reproduction.
  - It is not easy to break into and coordinate with international networks; requires extensive labor, time and resources.
- The recovery plan will need to identify and recognize local efforts and legal structures in other countries, with recovery actions adopted and tailored accordingly.

### 4.2.4 Management Units (MUs)

#### Targeted brainstorming

Following NMFS overview of MUs, workshop participants were divided into small break-out groups (BOGs) and asked to provide input on the pros, cons, and considerations for the development of MUs using three different options: Ecoregion-based MUs, Population-based MUs, and Exclusive Economic Zones (EEZs)-based Mus. Participants were also asked to identify other MU options and considerations. A summary of the input combined across BOGs, and Group A and B is provided below:

### **Ecoregion-based MUs:**

#### Pros:

- Biologically based and defensible.
- The system is known, stable, and there are data to support it.
- Threats to species within an ecoregion are likely similar, including climate change driven threat effects.
- Promotes collaboration of knowledge and problem solving between cross-jurisdictional partnerships.
- Manageable unit of size and number of units.

#### Cons:

- Scale of management, jurisdiction, and action are not the same within an ecoregion. Monitoring across governments and political boundaries is complex.
- Not inclusive of species, archipelagos, or EEZs. Some new ecoregions would have to be developed.
- Not dynamic; boundaries would have to change over time, and would require updating.
- Too large to properly manage.
- The population structure of the species within is unknown; species pools hard to identify.

#### Considerations:

- Could work if subdivided to fit the needs of recovery actions and responses (political, funding, agreements, etc.).
- Would need to design around the scale of threats, responses, and recovery as these may differ within current ecoregions.

### **Population-based MUs:**

#### Pros:

- A population-level management approach is needed.
- Easily measurable.
- Most flexible approach and can be tailored as we acquire new information.
- Can be tailored to species.

#### Cons:

- Population envelopes may be different (and probably poorly known) for different species.
- Populations are not well defined, and there is dispute about how to define.
- There are many populations, therefore particularly challenging to create MUs around these.
- Research on population distributions and ranges would be needed.

#### Considerations:

- ESA does not allow invertebrate species to be listed/delisted at a population

- level, but nothing prevents management at sub specific scales.
- Populations can differ in threats/vulnerabilities.

### **EEZ-based MUs:**

#### Pros:

- Aligns with laws, regulations, and funding at local scales that may be implemented to protect species.
- Easily understood and would be relatively easy to work with if grouped appropriately by pressures and management opportunities.
- Actions could be tailored to resources/capacity of each country/jurisdiction.
- Management approaches will likely follow political boundaries.

#### Cons:

- No physical/biological basis, and would be prone to fragmented MUs.
- Reef systems are exposed to completely different threat regimes, and species pools are subdivided.
- An impractical number of EEZs results in the need to collapse/combine MUs, thus defeating the usefulness of jurisdictional boundaries.
- Organisms and ecosystems do not observe political boundaries.
- U.S. EEZ covers about four different archipelagoes and could limit the agency of individual territories that are part of a larger EEZ network.

#### Considerations:

- A modified EEZ boundary could be an option—grouping EEZs into similar management frameworks.
- MUs are going to be the most helpful when tailoring actions to address threats to EEZs or some other relevant socio-political boundaries.

### **Other MU options:**

- Combine biologically based ecoregions and politically bound EEZs.
- Develop based on Archipelago boundaries.
- Design around threat regimes, using appropriate scale, requiring common responses; reference reef-at-risk regions from the 2011 mapping initiative.
- Develop by species using species distributions, risks, and accessibility.
- Locate in the U.S. only.
- Locate in relation to where there is potential for action, e.g., within the USAID program.
- Develop based around existing political relationships on the ground.
- U.S. versus International-based, as actions might be different (e.g., rely on existing local efforts in the U.S. vs. prioritize building collaboration in international waters).
- Use heat-maps, i.e. based on areas according to frequency of species occurrence.
- Use ecoregions or EEZ and provide a matrix to show map of the species per both axes.



- Align with Marine Protected Areas (MPAs) that contain the species of concern.
- EEZs combined with recovery areas based on refugia or focused recovery actions.
- Divide by reef type or location.
- Overlay existing U.S. efforts for land-based sources of pollution within 15-species ranges.
- Develop around populations that are doing well, since corals do not occur in all locations across their range.
- Avoid developing MUs; there may not be great benefit in doing so.

### Pulse-check

Following the group discussions, 50 participants shared their initial opinions via a poll on the most suitable options, of those discussed jointly, for defining MUs to facilitate recovery planning for the 15 listed corals as summarized in Table 4.2.4-1. The sense was that MUs might best be determined using a hybrid of several options such as an overlay of ecological (e.g. ecoregions) and political boundaries (e.g. EEZs). Using either the ecoregion-, threat classification-, or EEZ-based option also ranked relatively high.

**Table 4.2.4-1.** Participants’ opinion of the most suitable options for defining MUs, ranked from the most to least suitable option (combined for group A and B, and weighted to reflect input per participant).

Management Unit Options	Weighted Ranking*
Combination Eco-Political / Hybrid of options	5.5
Ecoregions	4.2
Threats classification/mapping	4.0
EEZs or EEZ groupings	4.0
Populations	2.5
Archipelagos	2.3
Based on opportunities for actions	1.9
Regional body groupings	1.8
Subunits—reef type or location, etc.	1.7
U.S. vs. international	1.0
Focus on populations doing well	1.0
MUs based on species by species	0.8
Align with MPAs that contain sp of concern	0.7
No MUs	0.7
MUs for some, not others	0.5

## **General conversation**

Points raised by participants during the discussion on MUs include:

- It is challenging to discuss options for determining MUs without full insight and discussion on recovery criteria and actions.
- ESA does not preclude defining MUs based on species populations simply because corals are invertebrates.
- Note that an MU differs from a “recovery unit” (a recovery unit is a population unit of the listed entity that is geographically or otherwise identifiable and is essential to the recovery of the entire listed entity).
- MUs would ideally encompass the entire range of the 15 listed corals, involve the same set of MUs for all species, and have the ability to be applied to potential future listed corals (or coral-associated species) for management practicability.
- MUs need to be determined using the best available information, there is no perfect option (or recovery plan).
- Many listed species will be in locations and countries with limited financial resources and capacity for management; MUs may help prioritize which species and populations to focus on.
- MUs can add complexity, given criteria would need to be considered for each MU.
- Poor biological knowledge challenges the idea of tailoring recovery criteria by MU; likely more relevant to tailor recovery actions by MU.
- Recovery criteria and actions can occur at multiple scales; some potentially tailored to specific MUs, some same across many MUs, with some same for all MUs.
- Consider if species have conflicting ecological requirements; ensure enhancing/restoring one species does not incur cost to another.
- Consider any concerns of splitting U.S. jurisdiction across different MUs.
- Recognize individual countries' jurisdictions; countries will use their own political input regardless of the MU option chosen.

### **4.3 Session III: Recovery Criteria**

In session III, NMFS provided a brief introduction to ESA recovery criteria, which spell out the anticipated conditions for the species to achieve recovery, and serve as the structuring element of a recovery plan guiding the development of recovery actions. Attachment C provides a PDF summary of the presentations provided.

## **Targeted brainstorming**

Following NMFS brief overview of criteria, workshop participants were asked to provide input, via large group discussions, on the pros, cons and considerations for a range of

different concepts for (i) demographic criteria; (ii) ecosystem criteria; (iii) climate change threats-based criteria; and (iv) local threats-based criteria. NMFS offered a few criteria concepts to facilitate brainstorming, and participants were encouraged to suggest additional recovery criteria concepts. A summary of expert input for each criteria type, recorded across groups and combined for Group A and B, cross referenced for common themes, is provided in the sections below.

### 4.3.1 Demographic-Based Criteria Concepts

Note: demographic criteria need to be developed species by species for each of the 15 listed corals, i.e. they need to be species-specific.

#### **Population Viability Analysis (PVA) Based Thresholds and Risk:**

Pros:

- Provides the most accurate and modifiable value.
- Quantitative: PVA provides objective, measurable, and scientifically justifiable information.
- Relates to recovery planning and gets at the root of what ESA listings intend.
- Forces acknowledgement of how much risk is acceptable, and what probability of extinction is acceptable for recovery.

Cons:

- The scale of the Pacific adds complexity; PVA does not scale well unless you have a sampling program that allows you to scale it up.
- Not enough data: PVA requires good population abundance data over time. Only a handful of these populations have been identified, let alone tracking vital rates necessary to develop PVA models.
- Requires assumptions, there is uncertainty in parameterization and extinction risk estimation, and challenges in species identification may prohibit species-specific demographic analyses.
- Data-intensive: would require finding, identifying, and following many remote populations.

Considerations:

- The best viability criteria clearly tie a modeling or analysis approach to feasible monitoring methods.
- PVA is a tool that was developed specifically for the ESA; but should base the criteria on what data are available now and what we expect in the future.

#### **Abundance:**

Pros:

- Essential; abundance is a core element of recovery.

- Straightforward to measure, and trends in abundance are likely associated with population size.
- Provides information on the status at a given time.
- Included in the coral health-monitoring program.

Cons:

- Not sufficient to protect species from climate change and related threats.
- Extensive data collection would be needed. Data is currently lacking, and it is uncertain we would ever have these throughout the range.
- Unknown baselines; do not know what the abundance of any of these species was before human impact to reefs.
- Does not account for trends in population.

Species and/or MU Differences:

- Target abundance would likely be different across reef systems; the larger the MU, the more likely a single target value could not be identified.
- Need species-level abundances and trends for these species and all the rest in the Indo-Pacific.
- Need baseline data, and it is a massive effort with low feasibility.

Considerations:

- Target abundances could be quite difficult to identify because of the lack of baseline data for many, if not all, species.

**Distribution:**

Pros:

- Most reliable type of information we currently have. Range and distribution data are currently quite incomplete but probably the best data throughout the range for all species.
- Important because we cannot separate the listing status of invertebrate populations by Distinct Population Segments (DPSs) under the ESA.
- Allows us to think ahead, with vectors of climate change.
- Helps in regionally prioritizing recovery actions.

Cons:

- Insufficient for recovery.
- Do not have evidence of loss of range in any of these species. These species are poorly known and are likely to be found in the future in places where they were not known before. This would only be an expansion of our knowledge, not of their biological range.
- Using as a percentage of MUs is not very good in that there may be a weaker link to viability.
- It is not feasible to anticipate resurveying distribution over time to evaluate this as a criterion.

Considerations:

- The number of replicate populations can provide insight into redundancy, an aspect of "resilience."
- A species may have a highly restricted distribution in a given location.

**Genetic Diversity:**

Pros:

- Preserving future evolutionary flexibility is critical for maintaining these species into the future.
- Quantitative and necessary for adaptive variation.
- May help identify connected or isolated populations, or source/sinks of larvae, which could help prioritize recovery actions to certain areas.
- Prioritizing the research required to assess all field-based criteria would inform conservation efforts in countries outside the U.S. that might otherwise lack resources to study these.

Cons:

- No obvious link to extinction risk or recovery.
- Important but extremely challenging in terms of data, and likely different goals for each species.
- Diversity alone is not sufficient.
- Do not have accurate ranges or abundances for these species. How would we reach genetic diversity throughout the range?
- No baseline.

Species and/or MU Differences:

- Essential for resilience.
- Obligate outcrossing needs genetic diversity for successful reproduction, which informs restoration actions and recovery criteria.

Considerations:

- Genetic diversity of *Symbiodinium* and microbiome might be as relevant as that of the coral. Need to take a holobiont perspective.
- Baseline; do not yet know anything about the genetic diversity of any of these species.

**Demographics- Size Class/Reproductive Size:**

Pros:

- Demographics of 100 fist-sized colonies are not equivalent to that of 100 car-sized colonies.
- If repetitive photography is possible, growth rates may be very good indicators of the direction of population change.

Cons:

- Requires more information than abundance, but it is not much more difficult, especially with video monitoring.

**Other demographic criteria concepts:**

- Connectivity/ Gene-flow
- Colony density
- Bleaching resistance over successive bleaching events

**Pulse-check**

Following the group discussion, 35 participants provided their initial opinions via a poll, on the most suitable demographic-based criteria concepts to develop further, of those identified jointly, as summarized in Table 4.3.1-1. Note that ecosystem-based criteria concepts were addressed in the same discussion-round, and therefore included in the same poll and table (in *italics*, grey cells), but the summary of the input will be presented in the next section of this Workshop Summary. The demographic criteria concepts selected at first glance by a majority of participants were distribution, abundance, and PVA based thresholds and risks. Additionally, genetic diversity and coral vulnerability/resilience were selected by many.

**Table 4.3.1-1.** Participants’ combined opinion on the most suitable demographic-based criteria concepts to develop further, listed in order of those concepts selected most frequently by participants (participants selected all that applied).

<b>Demographic and <i>Ecosystem</i>-Based Criteria Options</b>	<b>Frequency selected</b>
Distribution (species-specific)	77%
Abundance (species-specific)	69%
PVA based thresholds and risks (species-specific)	60%
<i>Live coral cover</i>	46%
Genetic diversity (species-specific)	43%
Coral vulnerability/resilience (species-specific)	37%
<i>Habitat- e.g. rugosity, complexity</i>	34%
<i>Community diversity, species richness/abundance</i>	32%
Demographic- size-class/reproductive size (species-specific)	29%
Connectivity/genetic flow (species-specific)	23%
<i>Abiotic conditions- water quality</i>	17%
<i>Reef extent</i>	15%
<i>Algal cover- macroalgae and turf</i>	11%
<i>Conditions that favor listed species of interest</i>	11%
<i>Herbivore diversity/density</i>	9%
<i>Function-based criteria: carbon-fixation, etc.</i>	6%
<i>Critical areas for herbivores’ life history/biology</i>	3%



## General conversation

Points raised by participants during the discussion on demographic criteria include:

- Base the criteria on what data are available now and what is expected in the future.
- There is limited species-specific information, therefore it is difficult to develop demographic criteria, which would need to be built on a research program collecting necessary information.
- Interim recovery criteria, as included in the Caribbean *Acropora* recovery plan (NMFS 2015), can be developed where there are no or very limited data. However, note that little progress has been made in the Caribbean in developing these interim criteria in the ~7 years since the Recovery Plan was adopted (higher priorities to be pursued).
- PVA is the gold standard, especially for ESA, but assumes access to robust data.
- An advantage of a viability criteria is that it can be stipulated that the risk of quasi-extinction must be low into the future, conditional on improving knowledge of current and future threats (e.g., carbon emissions). Also, the 'quasi-extinction' threshold can be set high enough to indicate a functioning population, not just a non-extinct one.
- The challenge with PVA is the need to have many identified corals that are studied well enough to get vital rates and are studied over time. Currently only a handful of corals have been identified, and not monitored well.
- There are only a few ongoing monitoring programs in the Indo-Pacific; most focus on genus level and higher, not species-level.
- NMFS has a large-scale "Large Area Imaging" aka "Structure from Motion Photogrammetry" (large is relative, ~100 m<sup>2</sup>) monitoring effort in the Pacific that allows tracking assuming positive species identifications, but it will take a first round of discovery, and the species identification challenges are real.
- The Indo-Pacific area is 2/3 around the earth; the scale discussed for application of the "structure for motion" sampling makes it difficult, or impossible, to determine population distribution. Sampling 20 different patches is not equivalent to sampling populations across the Pacific.
- A baseline does not really exist to compare abundance and trends in genetic diversity; but perhaps not needed for measurement.
- Instead of looking at all areas in the Indo-Pacific, consider looking at a few areas where species are viable; a population can be reproductive if you have 3-4 colonies per 100m<sup>2</sup> (i.e. species viability driven by reaching a certain density).
- Consider using the recovery plan to play an action-forcing role by highlighting how necessary demographic data are, leading to prioritization of funding for research that gains necessary information. However, this raises the question on where to invest limited resources, on monitoring or abating threats.

- Not having demographic criteria does not preclude actions directed at increasing populations. With millions of square miles to cover, and since demographic criteria are not required, consider leaning on threat-based criteria, which if structured correctly can provide information on the listed species. E.g., implement a monitoring program that helps identify if species are responding to threats-based recovery actions, and a propagation program to increase abundance and demographic factors without reaching a specific threshold to say it is recovered.
- Consider relative trends as a criterion, and/or criteria based on threats being abated to a point that they are not going in a particular direction.

### 4.3.2 Ecosystem-Based Criteria Concepts

#### **Live Coral Cover:**

Pros:

- Easiest parameter to measure.
- Data on coral cover in Indo-Pacific countries is common.
- Indicates the overall health of the ecosystem for the listed corals' survival.
- Since zooxanthellate coral species have much in common, such as similar upper thermal thresholds for bleaching, measuring ecosystem features like coral cover can tell you about individual species.

Cons:

- These particular threatened species are/were not the dominant species on Indo-Pacific reefs, so their status may not be captured by a change in live cover, rugosity, etc.
- Increase in cover in general may not benefit the listed species (i.e., spatial composition). Stable or even increasing total live coral cover can mask declines in even relatively common genera.
- Given most of the 15 species are rare, it is possible that live cover of the reef could recover while the listed species become extinct.
- Coral cover provides very limited information. Important to have diversity and demographic information.

Considerations:

- A hysteresis analysis could indicate the role of, and criteria for, coral cover.
- Ecosystem criteria are attractive in indicating improved coral reef status and function, but none of them ensures the recovery of the listed species themselves.

#### **Habitat (rugosity, complexity):**

Pros:

- Important for ecosystem services/essential fish habitat.
- Easy to measure and compare.

- Vital indicator of biodiversity function.
- Good measure of ecosystem health.

Cons:

- It is not certain how the chosen species contribute to rugosity since they are clearly not ecosystem dominants.
- Unclear if there is a straightforward relationship between rugosity (at a reef scale) and the viability of the listed species.
- Useful but definitely a secondary parameter.

Considerations:

- Need to have a sense of what habitat characteristics are important to the listed species, determining if they are the same for all; the same as for those that are dominant and not listed; and what habitat types support these species primarily.
- Rugosity is important, but not sure how to link it to the recovery of a specific species.

**Reef Extent (e.g. coral reef area):**

Pros:

- Larger reef areas provide a better chance for the species to expand.
- Provides a concept of potential space in which species can exist.
- Good information maps on reef extent exist as a baseline.

Cons:

- Listed species have habitat requirements such as depth and water quality that must be present, making extent alone insufficient.
- Reef extent with relative quality of reef habitat is important.
- Some species might be healthy with viable populations even if small, i.e. may not correlate with reef size.
- Massive areas to assess; may require novel approaches (i.e., remote sensing).

**Community Metrics (Diversity, Richness, Turnover rates, Co-occurring Species):**

Pros:

- Captures more of the ecosystem.

Considerations:

- Species turnover rates: the proportion of species that appear and disappear from the community over time and changes in a species' rank highest to lowest abundance, density, or percent cover (important metrics for rare and imperiled species).

**Function-based Criteria; e.g. Carbon Fixation, Energy Flows, Etc.:**

Considerations:

- Evaluating required criteria (pH, aragonite saturation, temperature, and pollution) for these species might be helpful.

### **Coral Vulnerability and Resilience:**

Pros:

- Would provide some indication of ecosystem status, usually combines a range of parameters.
- Response to heat stress events can provide both species- and community-level data.
- Important to access data with coral reef resilience, which increasingly exists in reef mapping databases for Coral Triangle (CT) countries.

Cons:

- Need to compare across species and sites.

### **Herbivore Diversity and Density:**

Pros:

- If coral/algal competition is relevant to these locations, herbivore diversity tends to best predict herbivory rate and therefore system functioning for coral growth.

Cons:

- More to measure/survey.

### **Algal Cover (Macroalgae and Turf):**

Pros:

- Coral reef ecosystems have many symbiotic feedbacks among non-coral taxa that might be critical to the species.

Cons:

- Difficult for multiple observers to distinguish between macroalgae and turf, which leads to unreliable results.

### **Other ecosystem-based criteria concepts:**

- Species-Specific Preferred Conditions (settlement triggers, predators, etc.)
- Abiotic Conditions (water clarity/quality)

### **Pulse-check**

Following the group discussion on ecosystem-based criteria concepts, participants were asked their initial opinion on the most suitable ecosystem-based criteria concepts to develop further; see Table 4.3.1-1 above. Note that ecosystem-based criteria (in *italics*, grey cells) were included in the same poll as demographic-based criteria concepts. The ecosystem-based criteria selected by many participants were live coral cover, habitat (e.g. rugosity, complexity), and/or community diversity (species richness/abundance).

## General conversation

Points raised by participants during the discussion on ecosystem criteria include:

- It is challenging to identify if a species trend is going up or down without measurement. The size of the Indo-Pacific makes the task of tracking and measuring the listed corals trends daunting; there are currently no to minimal listed species trend data. Legions of people are needed that can identify most of the species and to determine trend data. Ecosystem criteria provide a potential means to measure this.
- Consider including ecosystem criteria, simply as a proxy, and in conjunction with species-specific criteria.
- Ecosystem criteria could be used to identify reef systems showing exceptional rates of decline or recovery and could help prioritize actions in the case of declining systems and instigate research into the relationship between an improving reef system and the population status of the listed species.
- It is important to note that given the relative rarity of the listed corals, ecosystem recovery as measured by ecosystem criteria may be observed, but may not reflect the recovery of the listed corals. Alternatively, the listed corals could recover without the ecosystem recovering, though the inverse is more likely.
- Ecosystem criteria could be addressed with threat-based criteria, i.e. if threats are fixed, ecosystem criteria would likely be too, therefore carefully consider the benefit of including ecosystem criteria.

### 4.3.3 Climate Change Threats-Based Criteria Concepts

#### **Global Mean Atmospheric Carbon Dioxide Concentrations:**

Pros:

- Already being measured and bleaching threshold is understood (360 ppm).
- Beneficial for coral and other animals' health and recovery.
- ESA provides mechanisms for addressing GHG emissions, which can help address this threat.
- Helps define when and what type of interventions may be most effective.

Cons:

- Politically charged and less proximate to coral impacts.
- ESA listing will not change global mean atmospheric carbon dioxide.
- Criteria for returning to normal will not be met for several hundreds of years.
- Not feasible in the current timeframe of less than a century.
- No authoritative management in place to enforce.

Considerations:

- Should be broadened to GHG-forming emissions.
- Needs to be linked to species-specific needs.

### **Global Mean Surface Temperature (GMST):**

#### Pros:

- Publicly recognized.
- Already being measured and negotiated.
- Models can provide us with GMST equivalents to heat stress metrics, and can examine GMST at the time of the onset of Pacific bleaching and mortality.
- Addresses what is most impactful.

#### Cons:

- Scale is too big to be meaningful.
- Ocean temperature is collected at the surface, not at the benthos or throughout depth ranges.
- Unknown if this is relevant to these taxa. Makes assumptions between GMST and coral population viability.
- Temperature could be within range, yet acidification would still threaten the livelihood of corals.

#### Considerations:

- Local stress experienced is not accounted for in GMST; local changes in Sea Surface Temperature (SST) are site specific.

### **Ocean Warming (Degree Heating Weeks [DHWs], degrees Celsius):**

#### Pros:

- The closest criterion in its effects on corals' survival and recovery status.
- More relevant than GMST.
- Provides a measure of heat stress directly applicable to coral health globally.
- Coral Reef Watch (CRW) is already monitoring this.

#### Cons:

- Need to evaluate at multiple depths (i.e., depth refugia).
- Corals adapt, but so far most adaptation has been mortality of vulnerable individuals and subpopulations.
- DHW does not account for fine-scale (local or site) differences; too large of a scale to capture localized temperature regimes.
- Could be met while not addressing Ocean Acidification (OA).
- Differences in bleaching thresholds are not well understood (even within species).

#### Species and/or MU Differences:

- Define with a rolling window approach to look at differences in adaptation timescale.

#### Considerations:

- CRW has made adjustments to original baselines.
- Could utilize other thermal stress anomaly statistics (i.e., Sea Surface



Temperature anomaly [SSTa], step).

- Light, flow, etc. all modify bleaching risk beyond just DHWs and can vary locally and temporally. How do you incorporate these factors?
- Need to decide whether to use a fixed or moving window for DHW calculation.

### **Ocean Acidification (aragonite saturation state levels):**

Pros:

- Applicable globally.
- Objective, measurable, and ecologically relevant.
- Should set this for the listed species and relate it to global conditions.

Cons:

- Limited information on required aragonite saturation state for these species.
- Less critical than heat stress.
- Limited data of relevant scale.
- Uncertainties about coral adaptation capacities.

Considerations:

- Outcome-changing species-specific interactions between warming and OA make it impossible to predict the relationships for unstudied species.
- Need to consider pH, productivity, calcification, total alkalinity, etc.

### **Global Conditions Criteria:**

Considerations:

- As current patterns change, so will population and genetic connectivity.

### **Identifying Areas of Refuge:**

Pros:

- Would lead to increased understanding of climate–species relationships or identification of resilient phenotypes.

Cons:

- Requires higher resolution climate modeling to resolve why these areas are refugia.
- Could justify ignoring declining trends in distribution or genetic diversity.

Considerations:

- Need to identify colonies of the threatened species that are showing recovery in the face of climate threats. Survival and recovery shows adaptation to changing conditions.

### **Other Climate-change threats-based criteria concepts:**

- Local Sea Surface Temperature to focus on local scales.
- Increasing Extreme Weather Events with Climate Change

## Pulse-check

Following the group discussion on climate change threats-based criteria concepts, 32 participants provided their respective initial thoughts via a poll, on the most suitable concepts of those jointly identified to develop further as summarized in Table 4.3.3-1. The concept selected by a large proportion of participants was ocean warming (DHWs, °C). Also selected by many participants was global mean atmospheric CO<sub>2</sub> concentration (ppm) and ocean acidification (aragonite saturation state levels).

**Table 4.3.3-1.** Participants’ combined opinion on the most suitable climate change threats-based criteria concepts to develop further, listed in order of those concepts selected most frequently by participants (participants selected all that applied).

Climate Change Threats-Based criteria concepts	Frequency selected
Ocean warming (DHWs, °C)	88%
Global mean atmospheric CO <sub>2</sub> concentration (ppm)	48%
Ocean acidification (aragonite saturation state levels)	42%
Global Mean Surface Temperature (GMST)	33%
Locations where species are doing well/climate refugia	30%
Localized based on coral range/distribution	12%
Global conditions	3%

## General conversation

Points raised by participants during the discussion on climate change threats-based criteria include:

- A global-conditions based criterion would be interesting and forward-looking, consistent with the conversations in the workshop thus far.
- Consider different criteria (e.g., ocean temps) for different recovery areas/ MUs.
- “Site specific” recovery actions to address climate change entails identifying the scale of the action, which could be broad, e.g. regional, basin-wide or global.
- Consider the challenge related to setting climate-change related metrics/ thresholds that seem unlikely to be met.
- Since the 15 listed corals are at risk, the question is whether the climate related criteria have to specify conditions lower than conditions today.
- Given that an ESA "threatened" species is considered likely to become endangered within the *foreseeable future*, unlike an ESA “endangered” species that is *currently* in danger of extinction throughout all or a significant portion of its range, it may not be necessary to stipulate a threats condition better than today for a threatened species.

- It is different to say that future viability should be assessed accounting for changing conditions (due to climate change) vs making a criteria that is a stipulation of some climate threshold being met for recovery.
- There are great satellite based data, and the threshold of what corals need today and how they adapt is known, but it won't be known in the future; it is challenging to identify temperature criteria for future decades because much will change.
- There are many corals adapted to the temperature constraint, thus considering how to construct "normal" is important.
- Consider using rolling climatology and setting an anomaly; work has shown that letting the threshold shift over a long timescale improves modelling input for degree heating weeks (DHW).
- DHW are not immutable; calculated on historical climatology. It is recalculated to include all the new data but centered on data from the 80s when baseline was set.
- Ideally, we would be shooting for species-specific DHW thresholds, but DHW can vary significantly over small spatial scales therefore does not account for fine-scale differences, and we're dealing with 15 under-studied taxa whose thresholds we don't currently know even in a single place (again except *Isopora* (maybe)).
- Setting a regional threat level below a certain level is reasonable unless the corals have now all evolved to deal with that stress. Across the Main Hawaiian Islands, a driver analysis explains around 25% of bleaching and can indicate if it is in a bleaching condition, but doing this at the scale of 100 meters is not very predictable.
- Climate threats in general are more applicable at a species level as we know how different species respond to bleaching events, increased SST, etc.
- We have no information on the phylogenetic relatedness of the 15 listed corals to more commonly studied species.
- It is hard to do species-level eDNA, and difficult to get funding.
- There is ongoing work to review benthic cover and colony-level datasets at multiple shallow exposed reef sites around Guam during and between several bleaching events between 2013 and 2017, which will allow some measure of the effects of thermal/light stress events on *A. globiceps*. Preliminary analysis suggests a 50% decline is likely, but certain assumptions are made.

#### 4.3.4 Local Threats-Based Criteria Concepts

##### **Land Based Sources of Pollution (LBSP); Measurable Contaminant Thresholds:**

Pros:

- Important for establishing threshold for mortality, sub-lethal effects, and impact on reproductive capacity.
- Important given rising sea levels and increasing human populations.

- Can be measured in-situ and using remote sensing; ongoing in many places.
- Quick, cheap, easy, low-tech way of measuring this is visibility.

Cons:

- Thresholds for these species are unknown.
- Existing water quality standards are not designed for coral reef protection.
- Thresholds will need to consider baselines and duration of exposure.
- Not easy to assess across the entire range.
- Not practical to routinely measure; however rare events are very important.

Species and/or MU Differences:

- Varies with species.
- Varies with life stage; gametes and larvae can be more vulnerable.

Considerations:

- Need to develop species-specific thresholds.
- Freshwater influence is generally overlooked as a threat.
- A lot of nitrogen enrichment in water comes from the air; if nutrients are included, measuring them in-water might integrate water and airborne sources.
- Define MU by degree of management coordination for water quality management, fishing management, etc. Determine if network mapping of governance coordination in this region has been done.

**Local Water Quality, Turbidity, Contaminants, and Nutrients:**

Pros:

- Mechanistic connection to photosynthesis.
- Visibility/turbidity are easy to measure.

Cons:

- Water quality thresholds are difficult to establish based on observational data alone.

Species and/or MU Differences:

- Coral morphology may affect susceptibility to stressors like sediment.
- Life history stages will respond differently to water quality (e.g., larvae will not settle on sediment-laden surfaces).

Considerations:

- Thresholds need to account for not only survivability but also ecosystem services.
- Nutrients have many direct and indirect effects, including macroalgae, disease, and recovery.

**L BSP: Minimum Proportion of Ranges Well-Protected:**

Pros:

- Easy to establish and efficient way of controlling local threats in each region.
- Achievable and timely as infrastructure investments increase.

- Build on Reefs at Risk analysis of World Resources Institute (WRI).

Cons:

- Most "protection" does not address LBSP.
- Unenforceable.
- Limited knowledge of the breadth of contaminant effects.

**LBSP; Sufficient Evidence Not Impeding Recovery:**

Pros:

- Given global threats (which are difficult to control), it makes sense to have a criterion that puts limits on LBSP.

**Disease; Minimum Prevalence:**

Pros:

- Captured in many monitoring protocols.
- Relevant to what is happening in the Atlantic.
- Critical information.
- Highly relevant and fast acting.

Cons:

- Would have to be very specific in order to use as a criterion.
- Difficult to measure and monitor prevalence of disease.
- No way of determining if disease is a local or global threat.
- Too many unknowns; do not know what the diseases are, the causes, or how to control them.

Species and/or MU Differences:

- Varies by coral species and disease type.

Considerations:

- Criteria related to outbreak conditions, number of outbreaks, or mortality levels per outbreak, rather than average prevalence.

**Fishing Effects; Minimum Proportion of Ranges Well-Protected:**

Pros:

- Can be obtained from effective MPAs where fishing is not allowed.
- Six Coral Triangle countries have an MPA management effectiveness system.
- Local fishing is important to monitor as many reefs are impacted.
- Protected areas can buffer against bleaching effects and other disturbances, but it takes a specific set of criteria; long-established, well-enforced, noticeable difference of human impacts outside versus inside.

Cons:

- No threshold for what level of fisheries management is required to maintain coral reef health.

- Varies for different habitat types.
- Difficult to assess MPA enforcement across all countries.
- Lack of data to define areas for protection from fishing to support coral recovery.

Species and/or MU Differences:

- The roles that fisheries play in influencing the health of different coral species is unknown.

Considerations:

- MPA status is not enough; need management strategies that will improve recovery.
- No clear information on the status of fisheries stocks.
- Unable to define fisheries sustainability or linkage to a healthy ecosystem.
- Evaluate fishing methods used (e.g., dynamite, gill net, cyanide).
- Define "well-protected"; might need a checklist, e.g. effect management, gear management, degree of enforcement, etc.
- Determine how much evidence is there to directly link herbivore diversity and the health of the listed species.
- Balance between fish take and reef health is necessary.

### **Invasive species:**

Pros:

- Many include diseases such as the spread of stony coral tissue loss disease.

Cons:

- Occurrence of invasive species would be very area specific. May be more relevant for a few MUs.

Considerations:

- Consider a recovery plan action identifying what local protections or laws would help protect identified climate refugia of super rare species.

### **Collection and Trade:**

Pros:

- Monitoring for occurrence and abundance would be able to quantify mortality from collection.
- More manageable threat.
- Must look at national policies pertaining to trade and U.S. import rules.

Species and/or MU Differences:

- Only important in some jurisdictions.

Considerations:

- Should include at least one criterion related to trade in the recovery plan.
- Important to address the current loophole in CITES that allows trade in species identified only by genus.



### **Predators:**

#### Pros:

- Presence of crown-of-thorns starfish (COTS), *Acanthaster*, could be very important.
- COTS may increase due to high nutrients.

#### Cons:

- Carrying capacity for predation is likely unknown and difficult to determine.

#### Considerations:

- Listed species may have a difficult time recovering if they are hit hard by predators like COTS.
- Predation is a natural process; humans have accelerated it by overfishing and contributing to poor water quality, place measures on those threats.
- Aside from temperature stress, COTs are likely the largest source of mortality in *Acropora globiceps* on Guam's reefs. COTS removal is not a perfect management measure, and it requires a reasonable amount of capacity and diligence if undertaken late during the outbreak, but the effects are immediate in protecting the dwindling number of remaining colonies.

### **Storm Damage:**

#### Pros:

- Could be a climate change impact.

#### Considerations:

- Capacity to respond.
- Capacity for recovery actions.
- Consider natural resistance to breakage from storms. May be an issue with OA and weaker skeletons.

### **Other local threats-based criteria concepts:**

- Presence/Extent of Hypoxic Zones
- User Capacity in terms of Tourists Visiting Reef Areas
- Social indicators such as poverty, which ultimately is a key threat (i.e., unemployment rate in coastal regions, diversity of economies).
- Natural resistance to breakage from storms and recovery from storms, built around the capacity to respond since we cannot control natural events (e.g. adequate response triage)
- Appropriate and effective regulatory, response, restoration, and enforcement mechanisms are in place domestically and internationally for both planned and unplanned impacts.
- Quantitative recovery criteria acknowledging the information does not yet exist.
- Oil extraction areas.

- Integrate threat analysis by geography or MU to determine areas of minimal stress/threat.
- Sea-based sources of pollution (SeaBSP) like dredging, in-water development, etc.

**Pulse-check**

Following the group discussion on local threats-based criteria, 36 participants provided their respective initial opinions via a poll, on the most suitable local threats-based criteria concepts of those jointly identified to develop further as summarized in Table 4.3.4-1. The concepts at the top of the list were Fishing effects- minimum proportion of ranges well protected; Disease- minimum prevalence; and LBSP- measurable contaminant thresholds and/or minimum proportion of ranges well protected.

**Table 4.3.4-1.** Participants’ opinions on the most suitable concept for local threats-based criteria to develop further, listed in order of those concepts selected most frequently by participants (participants selected all that applied).

Local Threats-Based criteria concepts	Frequency selected*
Fishing effects- Minimum proportion of ranges well-protected	69%
LBSP- Measurable contaminant thresholds	58%
Disease- Minimum prevalence	56%
LBSP- Minimum proportion of ranges well-protected	50%
Local water quality	42%
LBSP- Sufficient evidence not impeding	31%
Predation/COTS	25%
Invasive species presence/absence	22%
Reclamation/coastal construction/other physical damage	20%
Collection and trade	19%
Storm damage/breakage	8%
Presence/extent of hypoxic zones	6%
Mining/oil extraction	3%

\* Average % value for groups A and B combined.

**General conversation**

Points raised by participants during the discussion on local threats-based criteria include:

- Consider the usefulness of social indicators (e.g. unemployment rate in coastal regions, or diversity of economies), if consider poverty as an ultimate driver.
- Consider vulnerability to disease and cold water events when making corals heat tolerant; need to protect genetic diversity.

- Consider collection and trade. The U.S. is the world’s major importer of corals, importing approximately 70 percent of all live corals and 90 percent of all Scleractinia species documented in trade. The significant trade in stony corals poses a threat to the listed species, with *Acropora* and *Euphyllia* comprising the top two genera imported “live.” While all stony corals are listed under CITES, data documenting the species and volume of stony corals in trade remains limited as a loophole exists in CITES that allows substantial trade in these species; specifically, parties to CITES have agreed to allow nations to trade in stony corals while documenting only a coral’s genus making it difficult to ascertain which species of coral are traded and at what volume.
- Consider effects from the predation by crown-of-thorns starfish (COTS) on a restoration project (i.e. nursery); particularly if selectively breeding corals for resistance to high temperature.
- Aside from temperature stress, COTS are likely the largest source of mortality in *Acropora globiceps* on Guam's reefs. COTS removal is not a perfect management measure, and it requires a reasonable amount of capacity and diligence, but the effects are immediate in protecting the dwindling number of remaining colonies.
- COTS has been a major concern in parts of the Philippines.
- There is evidence from the Caribbean linking herbivore abundance or other biometrics with the two listed species of coral species health. There are papers from the Indian and Pacific Ocean that document the indirect effects of fishing on corals and are referenced in the draft Recovery Status Review.
- Invasive species have not been a major issue to date for the listed corals, but may play a larger role in the future.
- Consider identifying how many of the listed species and their abundances are within MPAs, especially MPAs that are functional (not paper parks).
- Consider the trend occurring around the world of people moving from rural to urban, which might allow some relaxation of some pressures in more remote places, while pressures increase in urban locations.
- Consider impacts related to deep sea mining, oil extraction, and physical damage (ship groundings, coastal construction and more); significant impacts can occur locally.
- Consider maintaining herbivory as a key strategy in prevention and recovery of corals.
- Consider couching fishing effects as an 'ecosystem' criterion, as this obviates the need to demonstrate linkage to recovery potential of an individual species.

#### 4.4 Session IV: Recovery Actions

In Session IV NMFS provided a brief introduction to ESA recovery actions, i.e. the steps to take to achieve recovery. Attachment C provides a PDF summary of the presentations provided.

## Targeted brainstorming

Following NMFS overview of recovery actions, workshop participants were asked to identify recovery actions to facilitate the listed corals' ability to achieve (i) demographic and ecosystem criteria, (ii) climate change threats-based criteria, and (iii) local threats-based criteria during three rounds of group discussions. Participants were also invited to identify the actual on-the-ground specific activities necessary to complete the recovery actions, and various considerations. NMFS provided some ideas for actions to facilitate brainstorming. A summary of the input (combined for Group A and B) recorded across groups, cross referenced for common themes, is provided in the following sections.

### 4.4.1 Actions to Address Climate Change Threats

#### **Implement U.S. and international measures to reduce greenhouse gas emissions to limit atmospheric CO<sub>2</sub> concentrations to the level needed for coral recovery.**

Activities:

- Any federal agency triggering ESA section 7 (a)(2) consultation for the listed coral species shall not receive an incidental take statement unless that agency has in place a section 7(a)(1) coral conservation program.
- Implement federal actions to reduce GHG (renewable energy, fossil fuel reduction) and develop funding programs to encourage state and local action to reduce GHG.
- Fully implement the Paris Agreement and subsequent United Nations Framework Convention on Climate Change (UNFCCC) agreements to limit warming to 1.5°C.

Considerations:

- Consider focusing on things over which NOAA has some significant influence, e.g., fuel for ships, siting offshore energy (shared with Federal Energy Regulatory Commission [FERC]/Bureau of Ocean Energy Management [BOEM])
- Revisit Reefs at Risk for the Pacific and Coral Triangle for primary threats of sedimentation, pollution, and destructive fishing to begin to set priority geographies.

#### **Develop and implement measures to reduce ocean warming and OA.**

Activities:

- Align cultivation and sequestering efforts at local scales with sustainable development efforts in coastal communities Pacific-wide.
- Establish a task force between NOAA and the Bureau of Ocean Energy Management (BOEM) on deep-sea sequestration and permitting for those efforts.

- Implement the 30 x 30 terrestrial and marine protection goals in the U.S. and encourage other countries to do the same (i.e., enhance carbon sequestration through ecosystem protection and restoration)

Considerations:

- Expand beyond the typical NOAA partnership. Work with innovators that are leading the way in new technologies.
- Recommend separating out the thermal/ocean warming actions and not merging them as one thing—they are very different issues, mechanisms, and science.
- Geoengineering seems out of reach with the cost and ability to scale up to be beneficial for a reef system.
- Work on reducing methane emissions of livestock like cattle and sheep by feeding them things that reduce emissions (e.g., probiotics).

**Implement U.S. and international measures to sequester carbon so CO<sub>2</sub> concentrations can be reduced to the level needed for coral recovery.**

Activities:

- Implement large-scale tree-planting programs to sequester CO<sub>2</sub>.
- Develop and implement industrial-scale atmospheric CO<sub>2</sub> capture and sequestration.
- Implement large-scale replanting and maintenance of mangrove and seagrass communities along coastlines.

Considerations:

- This is needed in parallel with reducing emissions.

**Understand and manipulate, if possible and reasonable, feedback loops, cascading effects, and the many things that are associated with rising CO<sub>2</sub> that exacerbate the system.**

Activities:

- Encourage protection and restoration of mangroves, seagrasses, wetlands, forests.

**Research, develop, and implement interventions to use local geoengineering to increase the persistence and resilience of reef-building corals and coral reefs to climate change threats.**

Activities:

- Work with Australian colleagues to implement practical local geoengineering actions to reduce heat and light stress on coral reefs.
- Develop best-practices for implementing local practices to reduce health and light stress on U.S. coral reefs.

**Research, develop, and implement interventions to increase the persistence and resilience of reef-building corals and coral reefs to climate change threats.**

Activities:

- Research on relative resilience in reef areas across the Pacific range of the corals and effective mitigation strategies.
- Develop coral restoration plans to address the specific goal of coral resilience to climate change.
- Develop a collaborative network and centralized reporting mechanism for those engaging in resistance/resilience/persistence interventions throughout the Indo-Pacific to allow different locations in this vast region to learn from each other.

Considerations:

- Ensure that restoration efforts are robust against the physical stresses posed by climate change (e.g., more intense storms).
- Species and genotype specific differences require work on the ESA corals themselves rather than applying inference from other studies—focused research targeting these species can become its own impact.

**Conduct strategic research to better understand the impacts of thermal stress and acidification on listed corals.**

Activities:

- Identify habitats most and least vulnerable to these threats.
- Assess the ability of listed corals to migrate to climate refugia, including investigation of changing currents, larval sources and sinks.
- Consider studying/preserving habitat outside of the current temperature ranges of corals in the expectation that ranges may expand poleward.

Considerations:

- Separate out thermal stress and acidification.
- Prioritize researching actions to reduce warming and acidification impacts. There is already a good understanding that these are major threats to recovery.

**Implement outreach and education strategies to raise awareness on the importance of controlling climate change for listed corals.**

Activities:

- Engage experts in the psychology of behavior change to design campaigns that promote climate friendly behaviors (e.g., lower energy consumption).
- Highlight both the cultural and economic valuation of coral reefs and the diversity they support.
- Highlight the “infrastructure” flood protection functions of coral reefs in light of the likely increase in storm frequency, flooding, etc.



Considerations:

- Any outreach/education activities should be done in partnership with social/behavioral scientists.
- From a behavioral science perspective, connecting these types of large climate concepts to corals via outreach is generally ineffective. A more targeted outreach done as an activity under certain recovery actions might be a better approach.

**Review and consider the Resist-Accept-Direct<sup>1</sup> (RAD) concept (led by NPS).**

Considerations:

- Challenges arise in that ESA Section 7 consultations only address the level of species jeopardy, and it is rather unlikely that an individual action (e.g. power plant) would raise to the level of species jeopardy.

**Other actions identified to address climate change threats:**

- Determine health and population growth effects of climate warming and ocean acidification.
- Identify and address key interactions with local stressors.
- Change our economic modeling and goals from growth to sustainability.
- Identify genotypes and populations with inherent resistance and resilience.
- Add the requirement in section 7 that for each action there must be a "green alternative" included.
- Establish legal protections in all regions/countries to allow control of GHG and limit other threats. Provide suggested parameters of protections that are needed.
- Undertake a review of federal actions that generate GHG and suggested reduction targets.
- Identify socio-economic barriers (e.g., misinformation, lack of information, lack of political will, corruption, etc.) to the implementation of actions and develop strategies to account for them to the extent possible, engage our social science/political genius colleagues in this process.
- Undertake coral species banking (aka. seed banking).

**General conversation**

Points raised by participants during the discussion on recovery actions addressing climate-change threats include:

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<sup>1</sup> A tool that encompasses the entire decision space for responding to ecosystems facing the potential for rapid, irreversible ecological change.

- Consider U.S. current administration and climate goals, and think broadly, beyond outreach and education. Focus on specific actions that will translate to policy.
- Most actions to reduce ocean warming will also reduce acidification and sea level rise, with the exception of solar radiation.
- Recommend treating the different climate-change related phenomena separately; increasing coral persistence and resilience in the face of warming, acidification, sea level rise, reductions in ocean oxygen levels, etc. involve different issues, mechanisms, and science and may require completely different actions.
- Target GHG emission mitigation on the largest emissions sectors.
- While 80% of GHGs are carbon dioxide based, especially also methane, from example leakage from “natural” gas extraction, distribution and use is important to address.
- Consider calling out protection of the tundra ecosystem as a recovery action to prevent the methane stored in the permafrost from being released.
- If we consider recommending prevention of permafrost from melting, we need to consider actions such as reducing cattle farming or beef consumption. Since this is challenging in a recovery plan, perhaps address by implementing outreach, education and policy to encourage the general public to reduce their carbon footprint.
- Target Greenhouse initiative to help liaison among different federal agencies to increase the pressure from NOAA coral programs to help move the needle on national initiatives.
- Separate out interventions related to coral themselves versus geo-engineering based interventions, they are completely different actions.
- Cloud brightening is a good idea; as is carbon sequestration, but recommend finding a better way to phrase geoengineering as it is broad.
- Monitor mitigation in the islands as per the Climate Science Strategy Regional Action Plans.
- Consider NMFS 'ability to address actions driving climate change effects to protected species pursuant to ESA section 7(a)(2) consultations. Consider an activity to withdraw the existing 2008 memorandum that prohibits NMFS from addressing these actions. The memo is currently in review with the Biden Administration in response to a letter to revoke the memorandum.
- While there are many ways to find a nexus with many federal actions triggering ESA section 7(a)(2) consultations, they typically focus on preventing things from getting worse. ESA section 7(a)(2) consultations are most influential when there is species jeopardy; however, the effect of an individual action (e.g. power plant) may not rise to the level of species jeopardy.
- ESA section 7(a)(1) compared to ESA section (a)(2) is a better tool for promoting species recovery as it is more effective at changing the dialog with agencies responsible for actions.

#### 4.4.2 Actions to Address Local Threats

##### **Develop and implement watershed/land use management plans to control the effects of land-based sources of pollution on the listed species.**

Activities:

- Support implementation of local tropical 'coral' watershed plans (NOAA); developed with island capacity considerations for management and use of locally available resources for management.
- Mapping LBSP across coastlines to identify priority areas that will benefit most from upland management (e.g., cover crops, riparian buffers, terraces)

Considerations:

- Take stock of plans that have been made but not implemented.
- Prioritize nutrients based on severity of direct and indirect effects.

##### **Address sewage discharges throughout the species' ranges.**

Activities:

- Identify high-priority geographic regions and coordinate/fund efforts to reduce discharges that impact coral.
- Encourage programs that develop and implement practical solutions to sanitary waste management in small islands.
- Convert cesspools and septic systems and subsidize conversion.

Considerations:

- Expensive and challenging to coordinate conversion of private waste systems.

##### **Work with the local government to further adjust Total Maximum Daily Load for discharge permits from municipal and industrial facilities.**

Activities:

- Review discharge permits and see where contaminants can be eliminated and reduced from these processes.

Considerations:

- Some facilities are not up to date in their processes/equipment.
- Reduction of contaminant releases can be costly for municipalities, industry, and equipment.
- Some local municipalities may not have the funds to upgrade their processes quickly, rather it would be changes over a period of time.

##### **Study organismal response to nutrients and contaminants and implement appropriate remedies.**

Activities:

- Start with literature review to determine potential thresholds; refine; local monitoring consideration.

Considerations:

- Important for developing appropriate criteria and legal standards.

**Implement measures to reduce direct and indirect effects of fishing on listed corals.**

Activities:

- Support monitoring and implementation of laws and regulations to control/stop destructive fishing.
- Develop carrying capacity for fisheries in countries across the regions for the 15 listed corals.
- Continue to increase both the number and spatial extent of MPAs/MMAs.

Considerations:

- Take into consideration that there is a lot of fishing that is legitimate but also causes a lot of damage to habitats.

**Expand marine protected areas to address indirect impacts from fisheries.**

Activities:

- Provide support to states and local communities to implement protected areas.

Considerations:

- Many communities outside of the U.S. rely on fishing for their livelihoods, and is part of their culture, therefore, feasibility of this approach outside of the U.S. may be limited.

**Respond to, control, and minimize effects of coral disease events on listed corals.**

Activities:

- Develop disease intervention strategies for outbreaks, and conduct training.

Considerations:

- Research to identify what are the causes and how to prevent the occurrence of diseases.
- The Global Coral Reef Monitoring Network (GCRMN) could play a part in disease monitoring.

**Develop guidelines for COTS removal actions, and undertake COTS removal actions in appropriate sites.**

Activities:

- Coordinate efforts with Australia and others on COTS removal, conduct virtual workshops.

Considerations:

- Genetic comparisons showed that Central Pacific outbreaks were fueled from local parents - likely results from local nutrient impacts fueling high reproductive success.
- What is the practicality if we don't know the listed coral location?

**Evaluate risk and benefit of potential removal strategies for other corallivores.**

Activities:

- Identify corallivores that represent the greatest threats in each location.

Considerations:

- Corallivores are part of the natural system and outbreaks are a symptom - need to address the underlying cause of imbalance rather than responding to a symptom of another issue.
- Not all corallivores are bad.

**Develop and implement measures to reduce the effects of coral collection and trade on listed corals.**

Activities:

- Consumer education to reduce demand.
- Research on the 15 listed corals and other vulnerable species for ex-situ culture. These can then be provided to the aquarium industry and reduce/ stop the wild collection.

Considerations:

- Listing the species increases pressure from research even more than trade. Getting them into culture may reduce the need for wild harvest to address many of the research questions listed.

**Implement biosecurity controls such as ballast water and hull fouling regulations to prevent invasive species and disease transfer between jurisdictions.**

Activities:

- Develop 'omics (the collective characterization and quantification of pools of biological molecules) approaches to disease and invasive species detection (ballast water or harbor sampling).

**Develop emergency response alternatives for post-event impacts, storms, groundings, or other events.**

Activities:

- Assessing coral damage and prioritizing areas to restore and re-attach dislodged corals.
- Marine debris removal after a storm event.
- Support development and implementation of response plans at the state and local level.
- Encourage government agencies to use existing regulations more effectively to address response.
- See work by Peter Mumby on coral rubble stabilization methods post-bleaching and storm damage.

Considerations:

- Current funding (such as FEMA) that addresses storm damage is for manmade infrastructure and is difficult to get funding for reef recovery.

**Enforce existing or develop new regulations to mitigate local threats to listed corals.**

Activities:

- Determine predominant local threats to corals; identify enforcement shortcomings and gaps requiring new regulations.
- Develop Clean Water Act water-quality criteria for coral health.

Considerations:

- University of Hawaii, and Pacific Islands Managed and Protected Areas Community (PIMPAC) have been highly successful with improving regulations through their Legal Fellows program.
- Temporal regulations, such as during coral spawning or bleaching periods.

**Increase Regional Coordination Plans, including local through federal or international groups.**

Activities:

- Train local monitoring teams to identify corals to species to acquire better data on trends of listed species and other species that may be listed in the future.
- Establish integrated land to sea management (e.g. pair pollution mitigation with MPA establishment).

Considerations:

- This is not an immediate threat and seems minor in the face of more imminent climate related issues.

**Establish legal protections in all regions/countries to allow control of key threats other than GHG emissions.**

Activities:

- Propose a 4(d) rule that would allow for Section 9 prohibitions, as well as Section 7. Change Section 7 regulations to apply to federal actions that occur outside of U.S. jurisdiction, for example USAID actions.

**Implement outreach and education strategies on the importance of controlling local threats for listed corals.**

Activities:

- Develop citizen science programs to help evaluate actions, and work with USAID.
- Specific outreach for fishermen for initiatives to manage herbivorous fish.

Considerations:

- Use peer-to-peer learning networks that match managers in different countries who face similar challenges to build capacity.

### **Other actions provided to address local threats:**

- Restoration of Coral (e.g., raising and growing coral).
- Determine what species are best for carbon sequestration, to replace mangroves in Hawaii.
- Implement measures to reduce pollution and contaminants of materials (e.g. plastics, groundwater) already in the ocean.
- Determine the vertical distribution of species across regions to highlight local stressors for individual species.
- Implement citizen science programs to help identify large local threat events (e.g. bleaching, disease outbreaks, predators, etc.).
- Prevent introduction, rapidly respond to, and minimize impacts of alien invasive species.

### **General conversation**

Points raised by participants during the discussion on recovery actions addressing local threats include:

- Need precise and concrete actions beyond outreach and education to prevent decline of reef ecosystems across the Indo-Pacific range. Need to leverage existing efforts, working with non-governmental organizations (NGOs) or other entities.
- Prioritize areas; the U.S. has resources but a small coral footprint (area-wise), while the Philippines for example have less resources and a huge coral footprint.
- Need to identify which federal agencies have a dog in the fight to use leverage.
- Explore the status and applicability of coral vaccines.
- Consider including the 15 listed corals under CITES appendix I to advocate for protection; any species collected have to be “sustainable” and any country shipping them have to prove they are not susceptible to extinction. It can be done to show that trade/country can be regulated through CITES if trade is not sustainable.
- Global analysis shows that local management has a large impact on coral survival success after coral bleaching treatment.
- Watershed management is very hard, not a silver bullet. There are many watershed projects where the problem was identified, but over time the threats that were thought to be the most predominant ones are not. Success depends on where these watershed plans are being developed, i.e. the backdrop culturally and environmentally. American Samoa is a good example where watershed management has had positive results on the marine environment.
- The exacerbation of ocean acidification and incremental improvements are important.



- Consider addressing legacy contaminants that are already in the water/ environment beyond reducing additional discharges.
- Managing disease is labor intensive. Some success with epoxy mixed with antibiotics.
- Consider preventing disease via transport (ex. Ballast water discharge).
- There are citizen-monitoring programs in Hawaii, Guam, and the Marianas that include disease observations and response, but generally need improved advertising and sufficient funding to implement response strategies.
- Funding for episodic response needs to be taken into consideration for long term monitoring and long-term actions/strategies. Consider bundling developing strategies for a few response types: disease, invasive species, bleaching and COTS outbreaks.
- Develop local action, or specific working groups to help with coordinated efforts during an emergency. Look to models of emergency response in a climate emergency, and models in federal fishery disaster declaration.
- Look to Conservationevidence.com, which is used for small scale projects that come from community driven reporting. Having centralized reporting available for local managers that is accessible can be powerful.
- Address wastewater management in coastal communities in foreign nations, consider working with USAID. Wastewater is not just a “nitrogen effect”, far worse.

#### **4.4.3 Actions to Address Species Demographic and Ecosystems Factors**

##### **Develop coral reef mapping/inventory tools.**

Activities:

- Focus on eDNA.

Considerations:

- If lacking tools and expertise, before developing new tools, take stock of what exists to avoid duplication of effort.

##### **Develop and support monitoring programs to collect data on the demographic factors of listed species, and on their coral reef ecosystems.**

Activities:

- Invest in strategies to survey species routinely and at scale. Genetic technologies seem promising (e.g., Environmental DNA [eDNA]).
- Develop artificial intelligence (AI) tools to recognize listed corals.

Considerations:

- Partner with key countries, considering local capacity.
- Centralized way to report monitoring data as open-access data to share and coordinate efforts across regions.

**Based on monitoring results, conduct appropriate population enhancement of listed species.**

Activities:

- Focus population enhancement on heat tolerant genetics.
- Restore herbivores, remove invasive algae.

Considerations:

- Implement heat tolerance screening.
- Enhance settlement substrate.

**Restore, protect, and enhance ecosystem integrity and function.**

Activities:

- Focus on ecosystem functions where local and global threats interact.

Considerations:

- Review all the MPAs that are designed to protect and enhance reef ecosystems' integrity and function.

**Conduct strategic research on species' biology/ecology.**

Activities:

- Level of resistance to climate change among listed species.
- Research on how different life history strategies (e.g., brooding versus broadcast spawning) confer greater or lesser vulnerability to climate change threats.

Considerations:

- Perhaps seek to create categories of similarly behaving species so as to reduce monitoring burden.

**Establish range-wide gene banking or cryopreservation for each species.**

Activities:

- Implement ex-situ conservation, which seems an important component for these rare species.
- Should be structured as a 'permanent' archive and a collection that is used for intervention research.
- Both the Coral Restoration Consortium (CRC) ad hoc working group (Virginia Weiss chair) and Caribbean *Acropora* Recovery Team have developed strategies ([http://crc.reefresilience.org/wp-content/uploads/2020/01/ARIT-GeneticBanking-WG-Report\\_FINAL.pdf](http://crc.reefresilience.org/wp-content/uploads/2020/01/ARIT-GeneticBanking-WG-Report_FINAL.pdf)).

Considerations:

- Live and cryo-banks are both important; live-banks might experience drift in the gene pool over time, whereas cryo-banks will preserve 'original' genes. Different in cost.
- Huge need for a federal repository for listed coral cryo-archive, but it is challenging to find a central federal repository.

- Consider if climate ever will reach the condition where such species can survive in the natural reef environment; and what would be adequate.
- Capacity to freeze larvae is close; eggs not a top priority now due to challenges of preservation.

**Identify and protect likely climate refugia areas.**

Considerations:

- How do we identify climate refugia? Areas of slower climate velocity in projections of future climate models? Areas with stable coral cover under previous bleaching events? Some combination?
- A counterpart to climate refugia might be identification of potential new habitat as temperatures change in areas that are currently cool.
- Look at future suitable areas and consider those for translocation of climate resilient populations.

**Coordinate recovery implementation.**

Activities:

- Develop a tiered system of common monitoring protocols, including citizen science-based methods.
- Develop Pacific-wide consortium for developing and outplanting coral.

**Other Recovery Actions to address demographic and ecosystem factors, ETC.:**

- Improve species identification/develop new identification tools.
- Encourage research partnerships between U.S. and non-U.S. academic and government institutions.
- Develop monitoring plans to allow estimation of impacts of threats on abundance and demographic rates.

**General conversation**

Points raised by participants during the discussion on demographic and ecosystem recovery actions include:

- Recovery actions can satisfy both threat-based and demographic criteria.
- Because the 15 listed species are generally rare, it is difficult to track them for population viability analysis.
- There are three layers of sampling, diver survey, eDNA, and automated imaging.
- eDNA is quite good at getting coral cover, but to get to species level is hard.
- Instead of sending out new teams and training them, which is expensive, train those that are already surveying to be able to identify and include listed species in surveys.

- There are ongoing monitoring programs in 8 countries. E.g. Peter Houk has been working with his group in the Marshall Islands. A little bit of training goes a long way.
- Develop color cards of the 15 listed corals and train citizen scientists, tourists and the dive industry, even locally trained community conservation groups. Citizen science enhances local buy-in and local scientific capacity, particularly effective when it can synergize social and monitoring goals.
- Many of the listed species have small populations that are important to monitor and these locations can only be mapped through a diver-based survey, e.g. *Acropora rudis* in Sri Lanka.
- Given names are assigned to morphology not the genes, a step is needed to go from gene to morphology in recording genetics.
- For the Caribbean *Acropora* recovery program some of the most positive strides are related to demographic actions, particularly propagation.
- Interventions can increase adaptation.
- Need to consider live/gene banking and cryopreservation given the scale of climate impacts. Can use spawning from cryobank and replenish the bank as they grow.
- Sperm can be frozen, eggs are tough, and larvae pretty close (needs to be more scalable).
- Even if SST rises beyond corals' ability to survive through repopulation from banks/archives, implement it as a back-up as it is better to have it than not.
- Learn from Caribbean *Acropora* efforts and leverage efforts between regions.
- Two groups that are doing Arcs in Hawaii include the Hawaii Institute of Marine Biology (HIMB) and the Maui Ocean Aquarium; they are both trying to get all the rare corals they have.

#### 4.4.4 Summary List of Recovery Actions

##### Pulse-check

Following the group discussions on recovery actions, 43 participants provided their initial perspective via a poll on the recovery actions of highest priority for implementation to facilitate recovery of the 15 listed corals, of those identified during the discussions, as summarized in Table 4.4.3-1. Note that the participants were provided very limited time to provide their responses (a few minutes), therefore may not have reviewed the entire list of actions nor pondered their answers in any detail. Additionally, the table lists a few recovery actions that overlap, and in some cases lists specific activities rather than high-level recovery actions.

**Table 4.4.3-1.** Provides participants’ combined opinions on the priority level of recovery actions for implementation to facilitate coral recovery, listed in order of those actions selected most frequently by participants (participants selected all that applied).

Recovery Actions	Frequency selected*
Implement U.S. and international measures to reduce greenhouse gas emissions to limit atmospheric CO <sub>2</sub> concentrations to the level needed for coral recovery	82%
Research, develop, and implement interventions to increase the persistence and resilience of reef-building corals and coral reefs to climate change threats	82%
Develop and implement watershed/land use management plans to control the effects of LBSP on the listed coral species and their reef ecosystem	56%
Develop and implement measures to reduce ocean warming and ocean acidification such as carbon sequestration and geoengineering	56%
Develop and support monitoring programs to collect data on the demographic factors of listed species and on their coral reef ecosystems	47%
Enforce existing or develop new regulations to mitigate local threats to listed corals	47%
Restore, protect, and enhance ecosystem integrity and function	40%
Based on monitoring results, conduct appropriate population enhancement of listed species	39%
Respond to, control, and minimize effects of coral disease events on listed corals	39%
Address sewage discharges throughout the species’ ranges	37%
Implement measures to reduce direct and indirect effects of fishing on listed corals	37%
Conduct strategic research on species’ biology/ecology	35%
Develop coral reef mapping/inventory tools	30%
Identify and protect likely climate refugia areas	30%
Conduct strategic research to better understand the impacts of thermal stress and acidification on listed corals	26%
Implement outreach and education strategies to raise awareness on the importance of controlling climate change for listed corals	26%
Improve understanding of listed species’ distributions within each jurisdiction to help prioritize reef areas for management interventions	25%
Encourage research partnerships between U.S. and non-U.S. academic and government institutions with a focus on capacity-building as much as research outcomes	24%
Coordinate recovery implementation	23%
Establish range-wide gene banking for each species/cryopreservation	23%
Implement outreach and education strategies on the importance of controlling local threats for listed corals	21%
Expand MPAs to address indirect impacts from fisheries (30x30)	21%
Identify and reduce non-climate stressors	21%

Recovery Actions	Frequency selected*
Improve species identification/develop new identification tools	19%
Identify socio-economic barriers (e.g., misinformation, lack of information, lack of political will, corruption, etc.) to the implementation of above actions, and develop strategies to account for them to the extent possible	18%
Restoration of coral (e.g., raising and growing coral)	18%
Conduct research to better understand the mechanisms, vectors, and impacts of diseases on listed corals	18%
Gamete, DNA Storage, nursery, identify genotypes/populations with inherent resistance and resilience	17%
Develop guidelines for COTS removal actions and undertake COTS removal actions in appropriate sites	16%
Implement actions to reduce Hydrofluorocarbons (HFCs) and methane, both of which are strong (i.e. have high Global Warming Potential) GHGs and have short lifetimes, so we can slow global warming starting quickly	16%
Undertake a review of federal actions that generate GHG and suggested reduction targets	16%
Develop emergency response alternatives for post event impacts, storms, groundings, or other events	15%
Study organismal response to nutrients and contaminants, and implement appropriate remedies	14%
Develop and implement measures to reduce the effects of coral collection and trade on listed corals	14%
Increase awareness of wastewater pretreatment programs/legacy pollutant considerations	14%
Build capacity to increase funding and partnerships	12%
Determine what monitoring programs already exist and associated databases	12%
Federal fishery disaster response	12%
Implement biosecurity controls/prevent introduction, rapidly respond to, and minimize impacts of alien invasive species	12%
Develop actions to limit the spread of coral disease to new reefs	10%
Develop monitoring plans to quantify changing coral health	10%
Population and habitat connectivity	10%
Reducing microplastics and marine debris	9%
Support for immediate triage/response after hurricane/typhoons	9%
Work with the State to further adjust total maximum daily load (TMDL) for discharge permits from municipal and industrial facilities	9%
Add requirement in ESA section 7(a)(2) work that for each action there must be a "green alternative" included	7%
Determine the vertical distribution of species across regions to highlight local stressors for individual species, i.e., species that are more common in deeper water may respond differently to threats and will require a different response.	7%

Recovery Actions	Frequency selected*
Establish legal protections in all regions/countries to allow control of key threats other than GHGs	7%
Identify and address key interactions with local stressors	7%
Implement measures to reduce pollution of materials (e.g., plastics) already in the ocean	7%
Implement U.S. and international measures to sequester carbon	7%
Monitor the impacts of these threats on the coral populations	7%
Research, develop, and implement interventions to use local geoengineering to increase the persistence and resilience of reef-building corals and coral reefs to climate change threats	7%
Change economic modeling and goals from growth to sustainability	5%
Conducting research that uses local variation in local threats in order to better rank real impacts of different threats on the listed corals	5%
Evaluate risks and benefits of potential removal strategies for other corallivores	5%
Improve settlement habitat in less vulnerable locations (i.e., provide hard substance)	5%
Map reefs in whole range using quality parameters and overlay with existing protected areas	5%
Remove invasive algae	5%
Try to understand and reduce feedback loops and cascading effects	5%
Review and consider the RAD concept—resist, accept, direct (led by National Park Service [NPS])	3%

## 5.0 Summary and Next Steps

The expert input gained during the workshop as captured in this Workshop Summary will be essential for informing NMFS on the development of a recovery plan for the 15 listed corals. Some points that emerged are listed below. It is important to note that this list is not comprehensive and does not reflect an in-depth evaluation of the input gathered.

- The highest ranked threat to the 15 listed corals is ocean warming, followed by land-based sources of pollutions, ocean acidification and coral disease.
- Global climate change (GHG emission, global change, global warming) poses the greatest challenge for recovery planning for the 15 listed corals, and additional obstacles include the scale of the recovery effort, political inaction, data deficiency, changing taxonomy, limited time, and lacking funding/resources.
- An ecosystem recovery plan for all 15 listed corals or a combination of recovery plan types might be an appropriate recovery plan approach.



- The recovery plan could be most effective if it includes a balanced portfolio of global- and local- scale recovery actions, with slightly more emphasis placed on the implementation of smaller local-scale recovery actions.
- There are numerous key efforts to reference and build on in developing and implementing a recovery plan; see Table 4.2.4-1.
- MUs, if applied, might best be determined using a hybrid of several options such as an overlay of ecological (e.g. ecoregions) and political boundaries (e.g. EEZs), alternatively using the ecoregion-, threat classification-, or EEZ-based options.
- Ecosystem-based criteria are useful to include in the recovery plan, and species-specific demographic recovery criteria important.
- The demographic criteria concepts of importance to explore and develop further relate to species-specific distribution, abundance, and PVA based thresholds and risks.
- The top parameters for developing ecosystem-based criteria include live coral cover, habitat (e.g. rugosity, complexity) and/or community diversity (species richness/abundance).
- Ocean warming (DHWs, °C) might be the primary climate-change threats-based criteria concept to develop further, followed by global mean atmospheric CO<sub>2</sub> concentration (ppm) and ocean acidification (aragonite saturation state levels).
- The most relevant local threats-based criteria concepts to develop further relate to Fishing effects (Minimum proportion of ranges well-protected), Disease (Minimum prevalence), and LBSP (Measurable contaminant thresholds and/or Minimum proportion of ranges well-protected).
- There are a range of recovery actions that can be implemented, including importantly the reduction of GHG emissions to limit atmospheric CO<sub>2</sub> concentrations to the level needed for coral recovery; research interventions to increase the resilience of reef-building corals to climate change threats; the development and implementation of watershed management plans to control the effects of LBSP; and the development and implementation of measures to reduce ocean warming and ocean acidification such as carbon sequestration and geoengineering.

NMFS will continue eliciting expert feedback via targeted working group meetings and ad-hoc consultations over the course of the upcoming several months (informed by results from an engagement survey shared with participant during the workshop). The expert input will be used to inform the development of a recovery plan. Once drafted, the public will be notified of the availability of the draft and will have the opportunity to review and provide comment. NMFS will consider all information presented during the public comment period prior to approval of the recovery plan. Given the urgent need for action to facilitate recovery of the 15 listed species and their coral reef ecosystems, recovery actions and activities will begin to be implemented as soon as possible, as appropriate.

## 6.0 Acknowledgement

NMFS extends deep gratitude to the participants for allocating their valuable time, and for bringing their expertise and experience to the workshop to engage in fruitful, constructive and open exchanges. Special thanks also goes to the Lynker and NMFS staff who provided support to enable implementation of the workshop in a virtual environment.

## 7.0 References

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# Attachment A- Workshop Agenda

<b>Read Ahead:</b> Participants to review Backgrounder and SUMMARY of draft Recovery Status Review prior to Session I
<b>Week 1- Session I: Recovery Planning Introduction</b>
<ul style="list-style-type: none"><li>● Overview of ESA coral species listing and ESA recovery planning</li><li>● Overview of the threats evaluation</li><li>● Overview of challenges to recovery planning of the ESA-listed corals</li></ul> <p><i>Outcome: Participants informed and able to engage in recovery planning discussions in session II, III and IV.</i></p>
<b>By May 10:</b> High level Input on existing corals management/conservation efforts
<b>Week 2- Session II: Recovery Approaches</b>
<ul style="list-style-type: none"><li>● Overview of proposed recovery approaches:<ul style="list-style-type: none"><li>○ Ecosystem-based recovery plan</li><li>○ Two-pronged approach to recovery actions</li><li>○ Building on existing efforts</li><li>○ Determining Management Units</li></ul></li><li>● Discussion on management units</li></ul> <p><i>Outcome: Draft list of options for determining management units.</i></p>
<b>By May 17:</b> Participants to continue to provide input on management units <b>By Session III:</b> Participants review Criteria factsheet and consider options for Recovery Criteria.
<b>Week 3- Session III: Recovery Criteria</b>
<ul style="list-style-type: none"><li>● Introduction to recovery criteria</li><li>● Discussion on recovery criteria concepts</li></ul> <p><i>Outcome: Draft list of recovery criteria concepts.</i></p>
<b>By May 23:</b> Participants to continue to provide input on recovery criteria
<b>Week 4- Session IV: Recovery Actions</b>
<ul style="list-style-type: none"><li>● Introduction to recovery actions</li><li>● Discussion on recovery actions and prioritization of actions</li><li>● Workshop wrap-up and next steps</li></ul> <p><i>Outcome: Draft list of recovery actions.</i></p>
<b>By June 11:</b> Participants to continue to provide input on recovery actions.

## Attachment B- List of Participants

Below is a table with a list of workshop participants who attended all or parts of the workshop, and their affiliations, provided in alphabetical order by name.

Participant Name	Affiliation
Rizya Ardiwijaya	The Nature Conservancy, Indonesia
Rohan Arthur	Nature Conservation Foundation, India
Wawan Awaludinnoer	The Nature Conservancy, Indonesia
Dan Barshis	Old Dominion University, U.S.
Marissa Baskett	University California Davis, U.S.
Brian Beck	NOAA Coral Reef Conservation Program, U.S.
Charles Birkeland	University of Hawai'i (retired), U.S.
Eric Brown	National Park of American Samoa, U.S.
Val Brown	NOAA National Marine Sanctuary of American Samoa, U.S.
John Bruno	University of North Carolina in Chapel Hill, U.S.
Victor Bonito	Reef Explorer Fiji
Kristine Bucchianeri	U.S. All Islands Committee
Dave Burdick	University of Guam Marine Lab, Guam
Kristin Carden	Center for Biological Diversity, U.S.
Patrick Cabaitan	Marine Science Institute, University of the Philippines-Diliman, Philippines
Georgia Coward	Department of Marine and Wildlife Resources CRAG, American Samoa
Kitty Currier	Coral Triangle Center
Gerry Davis	NOAA NMFS Pacific Islands Regional Office, U.S.
Ron Dean	NOAA NMFS Pacific Islands Regional Office, U.S.
Joshua DeMello	Western Pacific Regional Fishery Management Council, U.S.
Dori Dick	Ocean Associates, supporting NOAA NMFS Office of Protected Resources, U.S.
Daniel Doak	University of Colorado, U.S.
Mark Eakin	NOAA Coral Reef Watch (retired), U.S.
Douglas Fenner	NOAA NMFS Pacific Islands Regional Office, U.S.
Scott Frew	NOAA Coral Reef Conservation Program, U.S.
Ann Garrett	NOAA NMFS Pacific Islands Regional Office, U.S.
Roger Griffis	NOAA NMFS Office of Science and Technology, U.S.
Asuka Ishizaki	Western Pacific Regional Fishery Management Council, U.S.
Craig Johnson	Systematic Ecology, U.S.
Lyza Johnston	Johnston Applied Marine Sciences, CNMI
Ryan Kelly	University of Washington, U.S.
Steve Kolinski	NOAA NMFS Pacific Islands Regional Office, U.S.
Al Licuanan	De La Salle University, Manila, Philippines
Kevin Lino	Naval Facilities Engineering Command Pacific, U.S.
Derek Manzello	NOAA Coral Reef Watch, U.S.

<b>Participant Name</b>	<b>Affiliation</b>
Joshua Madin	Hawaii Institute of Marine Biology, U.S.
Jon Martinez	NOAA Papahānaumokuākea Marine National Monument, U.S.
Loyal Mehrhoff	Formerly, U.S. Fish and Wildlife and Center for Biological Diversity , U.S.
Margaret Miller	SCORE International Coral Reef Restoration, U.S.
Tony Montgomery	U.S. Fish and Wildlife Pacific Islands Fish and Wildlife Office, U.S.
Jennifer Moore	NOAA NMFS Southeast Regional Office, U.S.
Peter Mumby	University of Queensland, Australia
Cleto L Nanola Jr.	University of the Philippines Mindanao, Philippines
David Obura	Coastal Oceans Research and Development, Indian Ocean, Kenya
Domingo Ochavillo	Department of Marine and Wildlife Resources, American Samoa
Ryan Okano	DLNR Hawaii Division of Aquatic Resources, U.S.
Thomas Oliver	NOAA NMFS Pacific Islands Fisheries Science Center, U.S.
Manny Pangelinan	DLNR Division of Fish and Wildlife, CNMI
Nishan Perera	Blue Resources Trust, Sri Lanka
Denise Perez	BECQ Division of Coastal Resources Management, CNMI
Arjan Rajasuriya	IUCN Country Office, Sri Lanka
Bob Richmond	University of Hawaii, U.S.
Laurie Raymundo	University of Guam Marine Lab, Guam
AJ Reyes	Naval Facilities Engineering Command/Navy Region Marianas, Guam
Frank Roberto	Division of Aquatic and Wildlife Resources, Guam
George Roff	University of Queensland, Australia
Ryan Rykaczewski	NOAA NMFS Pacific Islands Fisheries Science Center, U.S.
Hudson Slay	Environmental Protection Agency Region 9, U.S.
Michael Tenorio	DLNR, Division of Fish and Wildlife, CNMI
Rob Toonen	Hawaii Institute of Marine Biology, U.S.
Tali Vardi	NOAA NMFS Office of Science and Technology, U.S.
Frank Villagomez	DLNR Division of Fish and Wildlife, CNMI
Lani Watson	NOAA NMFS Restoration Center, U.S.
Jordan West	Environmental Protection Agency, Office of Research and Development, U.S.
Alan White	Tetra Tech Inc., U.S.

## **Attachment C- Presentations**

See PDF titled “Attachment C\_ESA Corals Recovery Workshop Presentations\_May2021”