5. METHODS

5.1 Overview

In evaluating the 82 candidate coral species, the BRT first assessed whether the taxonomic units in the candidate list were, in fact, "species" as described in the U.S. Endangered Species Act. Next, to estimate extinction risk for each of the candidate species, the BRT relied on a data review and expert evaluation. The data review included an evaluation of the relevant aspects of the biology and ecology of the species and an evaluation of the threats as documented in the published literature. The expert evaluation involved BRT members considering the likelihood that the species status will fall below the Critical Risk Threshold by the year 2100. The key information used and determinations made by the BRT are included in the individual species assessments in Chapters 6 and 7.

The Critical Risk Threshold describes a condition where a species is of such low abundance, or so spatially fragmented, or at such reduced diversity, that extinction is extremely likely. The reasons for evaluating Critical Risk Threshold rather than risk of absolute extinction are discussed below and in Chapter 4. The BRT used a voting process to assess the likelihood that the status of a species would fall below the Critical Risk Threshold. The voting process captured the uncertainty in the mind of each team member about the true likelihood. Each member judged the plausibility of a discrete set of likelihood levels and allocated votes or "likelihood points" to each possible level based on a weighing of the best available science. After several rounds of anonymous voting and discussion, votes of the members were combined to reach a final BRT determination on extinction risk.

5.2 The Species Question

The BRT first examined the taxonomy of each of the 82 candidate coral "species." In many cases, the taxonomic boundaries for the species on the candidate list were unclear. For each "species" on the list, the BRT selected one of the following options:

1. Accept the nominal species designation as listed in the petition,
2. Describe alternative potential species designations and provide the risk evaluation on each of the alternatives along with an indication of the species designation deemed most likely by the BRT, or
3. Accept an alternative species designation based on the best available information and provide the risk evaluation on that new designation.

The default was to select option 1 and accept the species designation in the petition. This option does not necessarily imply strong support for the species designation; it was simply selected in the absence of compelling contradictory information. Recent molecular analyses have suggested substantial revisions are necessary for many of the coral species designations that have been based on traditional morphology-based taxonomy (see Section 2.1.2 and description of taxonomic issues in the individual species accounts in Chapters 6 and 7 for additional discussion). It is anticipated that future research will likely result in taxonomic reclassifications of some of the candidate coral species considered in the Status Review Report.

5.3 Data Review

The evaluation of extinction risk was based on a compilation of the best available information on the biology and ecology of and the threats to both corals in general (Chapters 2–4) and the candidate species or related species in particular (Chapters 6 and 7). As part of the data collection effort, the NMFS solicited and received public comments about published and unpublished data that were useful in augmenting the BRT's examination of Critical Risk Threshold. The species-level biological data collection effort included information related to taxonomy of the candidate species, life history characteristics relevant to extinction risk (e.g., growth form, mode of reproduction, preferred habitat, depth range), geographic range of the species, trends in abundance or percent cover, vulnerability to threats, evolutionary and geologic history, and other relevant factors. Much of the desired species-specific information was largely unavailable for the majority of the candidate species. When biologically justified, the BRT extrapolated characteristics of the genus, related taxa, or taxa with similar physiological or habitat characteristics. This extrapolation introduced additional uncertainty into the analyses, as there are numerous examples in the literature in which ecological or physiological traits are not consistent across species within a genus. In some cases, essentially no species-specific information was available other than the taxonomic species description and some questionable geographic range maps.

The threat information provided generally in Chapter 3 and specifically for each of the 82 candidate coral species in Chapters 6 and 7 addressed both the current trajectories of the threats and consequences of the threats on the species. In terms of extinction risk, the top three threats identified by the BRT were ocean warming, disease, and ocean

acidification—although other, usually local, factors (e.g., fishing, land-based sources of pollution, sera-level rise, predation, trade) were also important in many instances. As with the species-level biological information, in most cases there was no species-level information on how the individual threats would affect particular candidate coral species. The BRT evaluated how these threats would affect corals in general, focusing on studies of taxa related to those on the list of candidate species.

5.4 Defining Extinction Risk

Another key issue was the definition of "risk" used for the evaluation. Predicting risk of absolute extinction (i.e., when there will be zero living members of a species) is notoriously challenging (Coulson et al., 2001). Especially in typically-clonal organisms like corals, where colonies can be very long-lived (many hundreds of years), a species may be functionally unviable long before the last colony dies. As discussed in Chapter 4, problems associated with low density may render a species at severely elevated risk well before extinction. Rather than try to predict risk of absolute extinction, the BRT estimated the likelihood that a population would fall below a Critical Risk Threshold within a specified period of time. The Critical Risk Threshold was not quantitatively defined. Rather, the BRT defined the Critical Risk Threshold as a condition where a species is of such low abundance, or so spatially disrupted, or at such reduced diversity, that the species was at extremely high risk of extinction with little chance for recovery. See Chapter 4 for a discussion of the factors that contribute to defining the Critical Risk Threshold. Uncertainty about the population level at which the Critical Risk Threshold would be reached contributed to the overall uncertainty of the analysis.

There is no formal definition in the U.S. Endangered Species Act for the term "foreseeable future" as used in the legal description of "threatened". However, agency policy guidance recommends linking the time horizon for the risk evaluation to the timeframe over which it is possible to scientifically predict the impact of the threats (U.S. Department of Interior, 2009). Both the petition and the BRT determined that climate change and ocean acidification probably pose significant extinction risk threat to corals. The year 2100 was used as the time horizon for this risk evaluation because this century was the timeframe over which the BRT had access to reasonable, scientifically vetted predictions of key threats and their impacts (see Chapter 3). In particular, the BRT determined that the Intergovernmental Panel on Climate Change (IPCC) collection of CO_2 emissions scenarios and climate models provided projections with adequate confidence to the year 2100 to reasonably support their use in evaluating Critical Risk Thresholds for the candidate coral species. Much of the scientific information available on the potential impacts of ocean acidification on corals has likewise been based on IPCC CO_2 emission scenarios and model projections.

5.5 Assessing the Critical Risk Threshold

The BRT evaluated the likelihood of each candidate coral species falling below the Critical Risk Threshold by the year 2100. Likelihood was defined using a 0%–100% scale divided into the following eight qualitative categories: exceptionally unlikely (< 1%), very unlikely (1%–10%), unlikely (10%–33%), less likely than not (33%–50%), more likely than not (50%–66%), likely (66%–90%), very likely (90%–99%), and virtually certain (> 99%) (Fig. 5.5.1). These category boundaries and labels are based on those used by the IPCC for summarizing conclusions about climate change research (IPCC, 2007b; Pew Center on Global Climate Change, 2007). This system of qualitative categories was used in the evaluation to emphasize the lack of precision in the analysis—the BRT had no quantitative way to distinguish between, for example, a 58% and 59% likelihood and did not intend to imply more precision than existed. The BRT described this as evaluating the "likelihood" of the risk hypothesis because the category labels are in terms of whether something is qualitatively likely. The BRT is not using the term "likelihood" to denote a quantitative statistical probability, but rather in a common, colloquial sense. Although these category labels (e.g., "less likely than not") provide a reasonable description of the **likelihood** of some event, it is critical to emphasize that the labels do not describe what risk is **acceptable**.

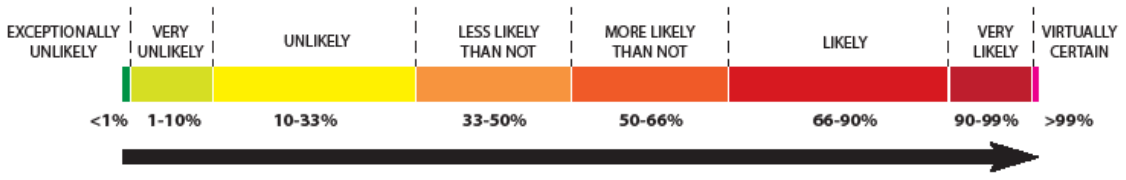

Figure 5.5.1. Scale and categories used by the BRT to evaluate risk hypotheses.

5.6 BRT Voting

To estimate the likelihood of each of the 82 candidate coral species status falling below the Critical Risk Threshold by 2100, the BRT used a voting process that incorporated uncertainty within and among the seven BRT members. Each BRT member was allotted ten "likelihood points" to allocate among the eight risk categories. Each member's anonymous allocation of likelihood points reflected their perceptions of the status of projected population trends and threats to a given species, and the uncertainty therein, for each particular candidate coral species. These allocations indicated the member's judgment of the plausibility of each risk category. If BRT members were highly certain that the likelihood fell within a specific category (e.g., "likely"), they could place all ten points in that category. If the BRT members were less certain, they could distribute the ten likelihood points among multiple risk categories. For example, two points on "unlikely," three points on "less likely than not," three points on "more likely than not" and two points on "likely" would indicate high uncertainty about the risk likelihood in the mind of the BRT member. Points could be distributed asymmetrically (e.g., eight point on "more likely than not" and two points on "likely") or among many risk categories. To summarize results, the points from all seven BRT members were summed in each category and presented in a histogram for each species (e.g., Fig. 5.6.1). The cumulative point distributions were used to estimate the mean likelihoods (%). This type of voting approach has been used by other BRTs evaluating extinction risk (Good et al., 2005).

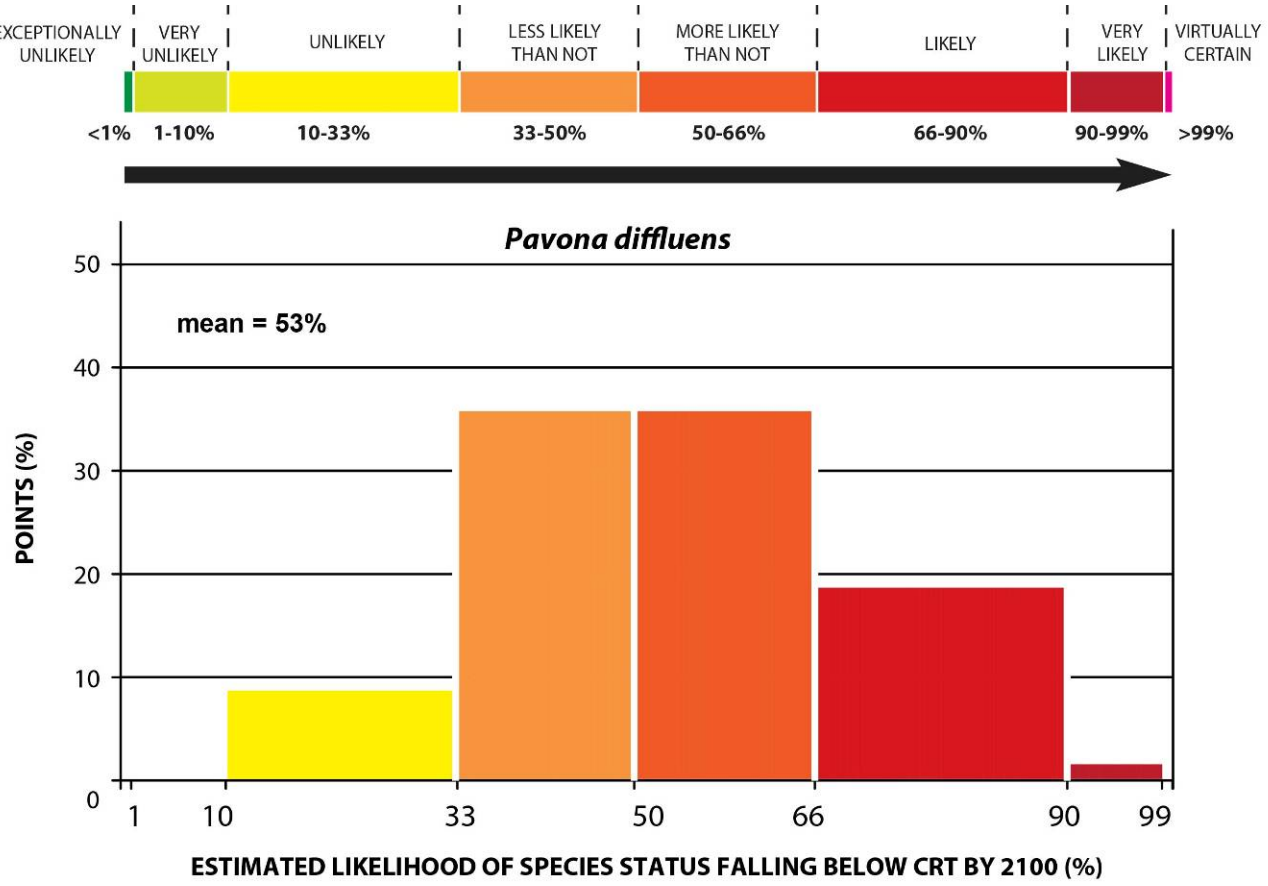

Figure 5.6.1. Example histogram showing distribution of points to estimate the likelihood that the status of *Pavona diffluens* will fall below the Critical Risk Threshold (the species is of such low abundance, or so spatially fragmented, or at such reduced diversity that extinction is extremely likely) by 2100.

For each of the 82 candidate coral species, all of the pertinent and best available scientific information acquired by the BRT was presented and discussed openly among the BRT members. At the conclusion of each of those discussions about the available information, each BRT member anonymously voted by allocating their ten likelihood points among the eight risk likelihood categories for each candidate coral species. After this initial round of voting, the points were tallied and presented back to the BRT members as a group for discussion about the voting results and the key risk factors that influenced the point distribution for the particular candidate coral species. While the confidentiality of each

individual BRT member's allocations of likelihood points was maintained, the voting results were presented in a manner that allowed the BRT members to observe the spread (uncertainty) of points by identifying each BRT member by a code number. Following these discussions, a second round of anonymous voting was performed for the individual species to allow each BRT member to take into account the key factors expressed by the other BRT members. Although generally only minor adjustments were made between these voting rounds, there were some rare instances where these intervening discussions about voting factors among the BRT members led to substantial revisions in allocations of likelihood points during the second round of voting (e.g., one BRT member had taken into consideration some factor that was not considered by another BRT member). Following the second vote of each individual species, likelihood points were again tallied and presented in aggregate form to the entire BRT for further discussion.

After completing the voting for all of the 82 candidate coral species, the BRT presented and discussed the relative rankings of the species in a comparative sense to identify potential outliers that needed further consideration. If any single BRT member requested another round of voting for a particular species, then additional voting was performed. For the vast majority of the 82 candidate coral species, the BRT agreed that the outcomes of the second vote were final. For a few of the candidate coral species, additional factors or important new information or data that became available in the weeks (or months) following the second vote that the BRT agreed warranted reconsideration. In some cases, this included new information on the taxonomic validity of the species. In those instances, the new information was shared and discussed amongst the BRT members prior to conducting additional anonymous rounds of voting. In each of those instances, BRT members were provided with copies of their prior votes for the species in question. In summary, all voting was always anonymous and each of the 82 candidate coral species were discussed and voted on at least twice.

In addition to voting on the 82 candidate species, the BRT considered the one coral species that has been reported to have potentially gone extinct in recent years. *Millepora boschmai* is a species of hydrocoral potentially limited to the eastern Pacific that may have already gone extinct as a result of thermal-stress induced bleaching. While not a candidate species, the BRT determined that it would provide a valuable test of an extreme case to provide context for interpreting the voting results of the candidate species. An individual species account, including risk assessment voting and discussion of risk factors, for *Millepora boschmai* is provided in the Appendix.

5.7 Strengths and Limitations of the Approach

The BRT recognized that the approaches used in developing this Status Review Report have numerous inherent limitations, many resulting from the exceptional scarcity of species-specific information about the taxonomy, abundance, distribution, life history, and responses to threats of the 82 candidate coral species as reported in Chapters 2–7. In addition, the U.S. Endangered Species Act required an ambitious and challenging timeline for completion of the Status Review Report following submission of the Petition. Some of the limitations and strengths of the process included:

Limitations

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

While the BRT recognized the above limitations to the approach used, the BRT also acknowledged the many noteworthy strengths or advantages of the approach.

Strengths

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

In establishing the approaches used for this Status Review Report, the BRT investigated many other alternatives, including many that have been used in the development of other Status Review Reports for other candidate species. One alternative approach would be to use a more structured method explicitly linking the available information to the final conclusion. This would have involved a combination of quantitative and qualitative scoring with links among them. However, there was a striking paucity of information available for most of the 82 candidate coral species under consideration here and it was difficult to quantitatively (or even qualitatively) capture the interactive and synergistic effects of multiple stressors. A structured, explicit approach such as this one would likely have been less expeditious and was considered unlikely to result in either a better risk evaluation or better incorporation of uncertainty into the risk evaluation.