EXTERNAL INDEPENDENT PEER REVIEW OF THE STATUS REVIEW OF 82 CORAL SPECIES UNDER THE ENDANGERED SPECIES ACT

COMPLETED FOR THE CENTER FOR INDEPENDENT EXPERTS

EXECUTED BY DR. BERNHARD RIEGL, NOVEMBER 1-12, 2010

Executive summary

A report produced by *Brainard et al.* for the NFMS in response to a petition by the Center for Biological Diversity to list 83 species of coral under the U.S. Endangered Species Act was reviewed.

The report was authored by seven scientists from NOAA (NMFS, NOS, CRCP), the National Parks Service and the USGS. It contains five chapters on general background information on the biology and threats facing coral reefs and corals in general, the way threats were assessed and how their severity was polled. A sixth chapter gives details of the biology and threats to each of 82 coral species that the authors chose to include from the original list of 83 proposed species (*Oculina varicosa* was excluded from the analysis). A seventh chapter provides an overview and synthesis. An appendix details the hydrocoral species *Millepora boschmai*.

After a thorough review of the material, it was concluded that:

- The Status Review includes and cites the best scientific and commercial information available on the species, their biology, stock structure, habitats, threats and risks of extinction
- Methods used are valid and appropriate
- Scientific conclusions are factually supported, sound and logical
- Opposing scientific studies or theories were acknowledged and discussed
- Uncertainties were assessed and clearly stated
- The Extinction Risk Analysis was indeed supported by the information presented

The reviewed document presents a complete and thoroughly executed review of the near-totality of knowledge that is presently available with regards to the 82 discussed species. Any omissions are trivial and do not take away from the overall excellent quality of this report.

Background

On October 20, 2009, the Center for Biological Diversity petitioned the National Marine Fisheries Service (NMFS) to list 83 coral species as endangered or threatened under the U.S. Endangered Species Act. The petition was based on a postulated predicted decline in available habitat for the species, with anthropogenic climate change and ocean acidification as the primary factors among the various stressors responsible. After original review of the document, NMFS identified 82 of the species as candidates, finding that the petition provided substantive information for a potential listing of these species. NMFS then established a Biological Review Team (BRT) to assess the status of the candidate species. A Status Review Report was produced that examines the status of and provides an estimate of extinction risk for each of the 82 candidate coral species. This document makes no recommendations for listing, which will be done in a separate evaluation to be conducted by NMFS, but is a review of the known pertinent information regarding the 82 coral species in question and the threats they are facing.

The present review concerns this report, authored by *Brainard et al. "Status Review Report of 82 Species of Corals under the U.S. Endangered Species Act"*.

Description of the Individual Reviewer's Role in the Review Activities

This review was solicited by Northern Taiga Ventures, Inc (NTVI), the organization that administers independent peer reviews for the NMFS Office of Science and Technology. Solicited was an independent peer review to be submitted to the CIE and to be approved by the CIE steering committee. Content requirements were given that pertain to the evaluation of scientific accuracy of the findings, the clarity and logic of presentation, and the foundedness in fact of the conclusions. Terms of Reference were given for the peer review, which were followed and addressed under the "Summary and findings for each TOR" section in the present report.

The following tasks were stipulated:

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than 19 November 2010, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts,". Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Summary and finding for each TOR

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, their biology, stock structure, habitats, threats and risks of extinction?

Overall Assessment. Yes, in all cases.

Scientific information: The Status Review contains several detailed and up-to-date citation lists. A thorough review of what information regarding the 82 coral species is available in the scientific literature has been conducted by obvious specialists in their field (the authors of the report). This is seen by the types of literature used, and its supplementation by inquiries where literature was found to be ambiguous. For example, where information regarding the status of sibling species of *Montastraea* in Bermuda was unclear, respected scientists at the Bermuda Biological Station were asked for their opinion (S.de Putron, T. Murdoch). Similarly, the published information, in particular in the genus *Acropora*, was critically evaluated and supplemented by information from experts in the field (most notably in the Pacific region). The scientists cited in personnel communication are respected and well-published authorities in the systematics, taxonomy and biogeography of these corals (D. Fenner, J. Maragos, R. Randall). The cited literature is up to date and contains many articles that have only just appeared or are still in print, or even under review. This shows that the authors have indeed used all material available and a more thorough review would, in my opinion, not be possible.
Evaluation: Scientific information has been adequately and appropriately used and described.

Commercial information: This pertains only to the trading status of the 82 coral species. The information is up to date and accurate and, as far I could discern, the best available data have been used. The information presented here is the most complete compilation on a species-by-species basis that I have yet come across.
Evaluation: Commercial information has been adequately and appropriately used and described.

Biology: A thorough and well-founded review of the biology of all 82 species is given. Despite significant shortcomings in our collective knowledge of many of the treated species, the authors have used published information about closely-related species to supplement in areas of deficiency. Where this was done, it is clearly stated, thus no mis-information can occur. The key factors of reproduction and most common mortality factors (where known) have received detailed treatment and thus the biology of all 82 treated species has been adequately described to allow estimation of their status as potentially threatened or not.
Evaluation: Biology in general and for each of the 82 species in particular has been adequately and appropriately described.

Stock structure: Very little information about stock structure in corals is available but where it exists, it has been used in this report. Trends in stock structure in *Montastraea* and Caribbean *Acropora* are well illustrated and allow the clear depiction of trends. Linkages between stock structure and known reproductive features of the corals are clearly outlined and put into perspective.

Evaluation: Stock structure in general and for each of the 82 species in particular has been adequately and appropriately described, wherever this was possible.

Habitats: Habitats in general have been described in the first section of the report, and their value for the species and threats has been discussed in sufficient detail. For each of the 82 species, as much information about preferred habitat within reefs is given as can be obtained from the literature. This information is up to date and where it is incomplete or suffers any shortcomings, this has been clearly stated in the report. The report does as good a job in describing habitats of the 82 species as is possible given the knowledge available in the literature. Global and local (within U.S.A.) distributions are clearly shown, which is important to judge the overall level of rarity, isolation, etc, of a species. Where unclear or doubtful records exist, these have been clearly outlined and discussed.
Evaluation: habitats in general and for each of the 82 species in particular have been adequately and appropriately described.

Threats: Threats are clearly outlined and differentiated into the most important man-made local (land-based sources of pollution), medium-scale natural (predator outbreaks, diseases) and large-scale climate-change driven (thermal stress, acidification) threats to population status. The categories are well-chosen and realistic. The global context of these threats and how exactly each threat factor interferes with coral biology is clearly outlined in chapter 3, and then the relevant information is repeated and/or applied to each of the 82 listed species.
Evaluation: threats in general and for each of the 82 species in particular have been adequately and appropriately described.

Risk of extinction: Given the limited information on demographics and population status in their usually wide (mostly ocean-basin-scale) distribution, the estimation of risk of extinction for the 82 selected coral species is a somewhat arbitrary process. The authors of the report have made a good effort of outlining the problems with the process, listing the strong and the weak sides of their approach. Chapter 4 of the report provides a very good outline of the process, as well as a realistic evaluation of the problems. Potential shortcomings are clearly listed and the process was presented in a transparent way.
Evaluation: Risk of Extinction has been adequately and appropriately evaluated.

2. Are methods used valid and appropriate?

Overall Assessment. Yes, in all cases.

The primary methods of this assessment are literature review and Risk of Extinction estimation by voting by the members of the BRT. The literature review was excellently and expertly executed and all relevant information required to draw up an overview of status and threats of the 82 coral species in question was obtained. Based on this information, the BRT then proceeded to rank threat as perceived by the individual specialist members of that team. The mean of these rankings was then calculated as the final vote regarding the threat status and the likelihood of each species to fall under a critical risk threshold, considered to be a point of no return for a long-term viable population. This method has apparently been used before in the context of

evaluation of population viability for the Endangered Species Act. This is described and examples from previous applications are listed. Based on that information, the method is valid and appropriate.

3. Are the scientific conclusions factually supported, sound and logical?

Overall Assessment: For the purpose of this assessment, yes.

The primary scientific conclusions in this report pertain to the threat status of 82 corals with regards to them falling below a postulated critical risk threshold. While the execution of the work that has lead to the scientific conclusions with regards to threats to each of the 82 species is clear, logical, well-documented and unbiased, I am hesitant to call it truly factually supported. There are several points with which issues remain, including:

Threats: the weighting of threats, whether high or low, is not based on any quantification, but on consensus based on a review of the pertinent literature. The difference is subtle, but important. The threat weighting presented is a qualitative judgment. To be quantitative and fully based in measurable fact, it would have had to have been drawn up by censussing some statistic, such as maybe the relative area of reef already lost to each threat. That notwithstanding, the listing and weighting of threats are based on facts as derived from the literature and can therefore be considered as factually supported by what is known in the literature.

Critic threat threshold: This was not quantified but defined as "when the species was at extremely high extinction risk with limited chance for recovery". Chapters 4.5, 4.6, and 4.7 describe what this threshold means and how it should be understood and applied; however, this provides no quantitative guide as to where and when the threshold could be reached or what could be done to avoid reaching it. That said, even if a quantification based on a sound understanding of coral population processes had been developed, it would be extremely difficult or indeed impossible to apply it to the vast majority of the 82 species that needed to be assessed. Satisfactory stock and recruitment information is available only for a minority of these species (maybe the *Montastraea* and some Caribbean *Acropora* populations – and that is presented in the report), thus much guesswork would still be required. Given these constraints, the development and formulation of the critical risk threshold is sufficiently based on fact and is sound and logical.

Risk hypothesis: See above. Although the risk of reaching the critical threat threshold was ranked along a scale of 0-100, the basis of this ranking was founded more on opinion than fact.

Evaluation of risk hypothesis: This was done by each member of the Biological Review Team being polled as to his/her assessment of the scaled likelihood of a species falling under the critical risk threshold based on the findings given in the species-specific reviews of biology and threats as well as the global review of reef biology and threats. Thus, this is more a qualitative than quantitative assessment. However, it is firmly based in fact inasmuch as all presented scientific background was taken into account to evaluate the polling. Such a process has been previously used by NOAA for the evaluation of risk to salmon populations and is also

comparable to the way the Intergovernmental Panel on Climate Change (IPCC) comes to final conclusions about climate change research – something with a similar amount of unknowns as the assessment of 82 coral species. While not without inherent weaknesses – that have been outlined by the report authors themselves – one can accept the evaluation of the risk hypothesis as sufficiently grounded in scientific fact. The evaluations and their presentation are sound and logical.

4. Where available, are opposing scientific studies or theories acknowledged and discussed?

Overall Assessment: For the purpose of this assessment, yes.

Given the relative novelty of this process, there are no obvious opposing scientific studies that could invalidate how the general conclusions of this report were obtained. Where opposition to used scientific publications exists, this is noted as much as is practicable. The report accepts the findings of the 7th IPCC report, which is vehemently opposed by some, and other papers that in general support the premise that climate change is indeed occurring. The entire process of this threat evaluation and the proposed listing of 82 coral species builds on the premise that observable global climate change is a demonstrated fact. The report does not explicitly state that some significant opposition exists to this line of thought but this is not necessary in the present context since opposition is not based on scientific findings.

There are no studies that provide any data that allow opposing the notion of serious coral reef degradation occurring on a world-wide scale and that the threats outlined in this report are real.

5. Are uncertainties assessed and clearly stated?

Overall Assessment: For the purpose of this assessment, yes.

Uncertainties exist at several levels. Firstly, uncertainty exists within the literature as to the effects of climate change. These uncertainties are discussed in the literature itself and not reiterated here. Where the most uncertainty existed (ex., effects of ocean acidification, insolation, cloudiness, toxins on coral reefs, ice-sheet reaction to global warming as a driver of sea level change, changes in thermohaline circulation, changes in hurricane frequency, etc.), this was explicitly taken into account in the report and so stated. This was done, for example, at the level of the stress weightings, where threats with particularly unclear status (i.e. uncertainty about the effects) were rather down- than up-weighted. Uncertainties in the projection of certain key variables on coral stress (such as human population growth predictions, climate predictions, etc.) were expressed in the presentation of different forecast scenarios, which were then explicitly taken into account.

Uncertainties were also detected and discussed in the report with regards to abundance estimates for most corals. These were acknowledged and usefulness of the data including the uncertainties was discussed (for example, on p. 74 it states that “the data are useful in helping to distinguish among the different species of *Acropora*, particularly given the limitations in coral cover data that could show trends”; many other citations along these lines exist).

A valid and important point is outlined in the following quote: “There was considerable uncertainty and skepticism amongst the BRT regarding some of the reported species distributions. Much of this uncertainty arose from basic taxonomic uncertainty among the corals (discussed in Section 2.1) and the difficulty in identifying species in the field. Where questions arose, they are discussed in the individual species accounts (Chapter 6).” (p. 75). Overall species distribution was an important factor in evaluating threat levels to the species and also, if species do not occur in U.S. territorial waters, their protection under the ESA is difficult and possibly of dubious benefit. Within the discussion for each species, these distributional uncertainties were discussed and addressed by adding literature or expert opinion to further define distributional records.

Much uncertainty exists about the effective population size of corals and its effect on the critical threat threshold. This is important and discussed on pp. 75-76.

The evaluation of the critical risk threshold itself is fraught with uncertainties, which was addressed by the voting process within the Biological Review Team. The uncertainties involved are discussed at length in chapters 5.5, 5.6 and 5.7. Thus they are, if not removed, at least clearly stated.

Thus, uncertainties were both clearly stated, assessed and, where possible, addressed or incorporated in a way that a balanced and credible decision process was still possible. A balanced and unbiased approach was taken in their evaluation.

6. Are the results in the Extinction Risk Analysis supported by the information presented?

Overall Assessment: For the purpose of this assessment, yes.

The report clearly outlines the threats faced by each of the treated 82 species, presents the polling for the risk analysis, and provides a justification for the polling. Thus the results are clearly presented and justified. Care was taken by the authors to support the polling results by outlining the relative weight put onto the threat factors and which had been considered to have the greatest weight for the decision. Therefore, the Extinction Risk Analysis is supported as much as is possible by the information.

It would have been preferable if the analysis could have been based on quantitative rather than the mostly qualitative indicators. However, the absence of detailed (and in many species even general) species-specific information precluded this. Given these severe data constraints, the analyses are as thorough as they could possibly have been.

Conclusions and Recommendations

After a thorough review of the material, it was concluded that:

- The Status Review includes and cites the best scientific and commercial information available on the species, their biology, stock structure, habitats, threats and risks of extinction.
- Methods used are valid and appropriate.
- Scientific conclusions are factually supported, sound and logical.
- Opposing scientific studies or theories were acknowledged and discussed.
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- The Extinction Risk Analysis was indeed supported by the information presented.

The reviewed document presents a complete and thoroughly executed review of the near-totality of knowledge that is presently available with regards to the 82 discussed species. Any omissions are trivial and do not take away from the overall excellent quality of this report.

Specific comments:

Found here are comments other than formatting issues that are shown in yellow highlighting in an accompanying annotated pdf file.

p.ii: "Photographs…by Charles Veron". His name is actually John Edward Norwood, Charlie is the nickname (supposedly dating back to his very early childhood days).

Executive summary: provides a succinct overview of rationale and process

Chapter 1
Provides a satisfactory background for the reasons behind the document and about the structure and rationale outlined by the petition, as well as the Endangered Species Act.

Chapter 2:
Section 2.1.1. Taxonomy and morphology of scleractinian corals: This is a brief but accurate overview of what a coral is and how it functions. I could not detect any major issues.

p.5, 2.1.1., para 2: "The Scleractinia have diversified into multiple families, all of which exploit the ability to form complex colonies." The Fungiidae are actually mostly solitary.

Section 2.1.2 Species delineation and uncertainty in corals: This is a well-written section that outlines the species problem, in particular where it is relevant for the ESA. I could not detect any major problems or difficulties.

Section 2.1.3 Evolutionary History: A brief, but sufficiently informative section for the present purpose. There are no major shortcomings, but one comment:

p.7, 2.1.3. Evolutionary history: The reef-less interval at the beginning of the Cenozoic is exaggerated by Veron (2008) and this is echoed here. Reefs were present, albeit not widely distributed, already in the Danian, which immediately follows the K/T event. It is, in fact, possible that in some areas (Paris basin) some Cretaceous taxa may have actually survived into the Dania. Be it as it may, coral reefs were alive and kicking already in the Paleocene (many well-developed reefs particularly in North Africa and the Middle East) and not only in the Eocene. This should be corrected, since p.202 of the report correctly states that *Acropora* arose in the Paleocene. So, here's a contradiction: if there were no reefs in the Paleocene, where would this genus have arisen (it could have arisen in non-reef habitats, but that's not the fact)?
What we do have, however, is an approximately 10 million year reefless period in the lower Triassic, following the Permo-Triassic extinction of the Paleozoic corals.

Section 2.2. Biology: This is a well-written and clear section. I could not find any major deficiencies

p.8: “Edinger and Risk (1995) speculated that this pattern in the Atlantic was driven by lower rates of extinction of brooders relative to broadcast spawners during the Caribbean Oligocene-Miocene extinction event” True, but Glynn (2009) has taken exception to that (Glynn PW (2009). Survival of brooding and broadcasting reef corals following large scale disturbances: is there any hope for broadcasting species during global warming? Proc 11th Int Coral Reef Sym, 368-37 (see text in last paragraph on p.371)).

p.8, last para: an explicit mortality schedule for a scleractinian is given by Harriott (Harriott VJ (1985). Mortality rates of scleractinian corals before and during a mass bleaching event. MEPS 21:81-88).

p.10, three lines from bottom: Sentence incomplete. “Fragmentation is a common…” insert “process” or “accurrance” or delete “a”.

p.11, 2.2.4 Clonality and genetics “If there is low genotypic diversity within individual stands and/or across the region, it might suggest that a clonal species’ status is under much greater extinction risk than would be judged from its overall abundance.”: the term “extinction debt” (Tilman D et al. 1994. Habitat destruction and the extinction debt. Nature 371:65-66) could be introduced here, since this is really what is being referred to.

Section 2.2.3 (p.11). Section calcification and reef building. The report might considering mentioning here that coral skeletons are aragonite, and reef cements aragonite or high-Mg calcite, just to lead easily into the later acidification debate (and just in a sentence).

Section 2.3.2, p.13: Last sentence in the section refers to adaptation of Arabian corals to high temperatures, but the sentences before only refer to adaptation to low temperatures. Coral reefs in the Arabian Gulf are not only selected to withstand some of the lowest temperatures (the lowest temperatures are cited by Veron 1995 for Japan, with 4 deg C, if I remember correctly) but regularly the highest. Also bleaching not only occurred in 2010, but in 1996, 1998, 2002 and 2010. The effects of repetitive mass mortality due to increasing heat, and the temperature adaptation, are described in Riegl and Purkis (Riegl and Purkis (2009). Model of coral population response to accelerated bleaching and mass mortality in a changed climate. Ecol Mod 221: 192-208). Bleaching in the Gulf occurs if temperatures are maintained at >35 or 36 deg C for over 3 weeks (Riegl (2002). Effects of the 1996 and 1998 positive sea-surface temperature anomalies on corals, coral diseases and fish in the Arabian Gulf. Mar Biol 140:29-40.) The bleaching information is reviewed in Baker at al (2008) ECSS, cited in the references. Also corals in American Samoa have been shown to survive to 35 deg C (Craig P et al. 2001. High

temperatures tolerated by a diverse assemblage of shallow water corals in American Samoa. Coral Reefs 20: 185-189.).

Section 2.3.4, p.14, 10 lines from bottom: the Adjani et al (2006) phase-shift reversal has been disputed by Quinn and Kojis (Quinn NJ, and Kojis BL (2008) The recent collapse of a rapid phase-shift reversal on a Jamaican N coast coral reef after the 2005 bleaching event. Revta Biol Trop 56(Suppl 1): 149-159).

Section 2.5.Contrasts between Caribbean and Indo-Pacific Seas: This section is a bit confused. The unique Caribbean fauna is a result of the closure of the Isthmus of Panama and many of the typical taxa arose after the closure (the *Acroporas* for example). The inheritance from the Tethys is less important, since that ocean includes the Pacific. So any inheritance would be on both sides of the isthmus. The story in the Caribbean is one of a slow step-down of the old Indo-Pacific fauna, and a gradual rise of the new Caribbean fauna. The relevant papers are those (many) by Budd and Johnson (ex., Budd AF, Johnson KG (1999). Origination preceding extinction during late Cenozoic turnover of Caribbean reefs. Paleobiology 25:188-200).

Chapter 3: Threats to coral reefs. I note that coastal construction is considered a low threat. In some regions of the world, notably the Arabian, coastal construction is considered the primary threat. And it may well be so in other areas (especially small island states) as well (Sheppard et al (2010). The Persian/Arabian Gulf: A young sea in decline. Mar Pollut Bull 60: 13-38; Sale et al (2010). The growing need for sustainable ecological management of marine communities of the Persian Gulf. Ambio DOI:10.1007/s13280-010-0092-6).

p.26 very first line: "…across each ocean province from Donner (Donner)" . Is this is supposed to mean Donner et al (2005) or Donner (2009)?
p. 26, last paragraph: the bracketing needs to be fixed. Several citations can fit within a single set of brackets.
p. 27, first and second para: the bracketing needs to be fixed. Several citations can fit within a single set of brackets.
p. 28, second para: Negri et al. citation needs the year specified.
p.28, section 3.2.2.3. Suggest renaming to "Changes to water column stratification"; Polovina et al: citation needs year specified.

p.29, first para: another useful citation might be: Silverman J, Lazar B, Cao L, Caldeira K, Erez J (2009). Coral reefs may start dissolving when atmospheric CO2 doubles. Geophys Res Lett 36, L05606, doi:10.1029/2008GL036282, 2009.

p.31: Fig. 3.2.8; Fig. 3.2.9. In both figures, the citations need the year specified The same holds for p. 32 Fig. 3.2.10.

p. 33, para 2: remove double brackets in citation "((Schneider and Erez 2006))"
p.34, para 3, 4: fix citations.
Bottom of p. 34: fix page break to avoid splitting table.

p. 34, para 4: While acidification demonstrably will lead to a decline in crustose coralline algae (CCA) , does it automatically lead to more growth of fleshy algae? This is implied by sentence "(Jokiel et al. 2008) showed dramatic declines (86%) in the growth rate of CCA and other reef organisms (250% decline for rhodoliths), and an increase in the growth of fleshy algae at CO2 levels expected later this century. The decrease in CCA growth, coupled with rapid growth of fleshy algae, will result in less available habitat, and more…" Also, the sentence should not begin with a bracketed term.

p.34, para 4: There is a reference to a figure 3.9, but no such figure exists in the text.

p. 36, 2.3.2. Increased erosion. "The final well-documented impact of ocean acidification (falling carbonate saturation state) is a reduction in the structural stability of corals and reefs, which result both from increases in bioerosion and decreases in secondary cementation." This is an overstatement. The only study that clearly shows less cementation is that of Manzello on reefs that are anything but typical for the tropics. The precipitation of cements is a much more subtle process than is generally given credit for in the biological literature. It is, by the way, the "primary" way of binding reefs together, so "secondary cementation" is a bit of a misnomer. The organisms themselves bind far less than the cements. For an extreme view on this (not subscribed to by all, or even many) use Silverman J,Lazar B, Cao L, Caldeira K, Erez J (2009). Coral reefs may start dissolving when atmospheric CO2 doubles. Geophys Res Lett 36, L05606, doi:10.1029/2008GL036282, 2009.

p.37, first para: (Albright et al. in press 2010). Is this in press or published?

p. 37, para 2: clean up: "Kuffner et al. (Kuffner et al.) and Jokiel et al. (Jokiel et al.) have…"

p. 37, last para: clean up "Blanchon and Shaw ((Blanchon and Shaw 1995)) argued.." Also clean up the last line and consolidate citations with a single bracket.

p. 39, line 3: clean up "… ((Neumann and Macintyre 1985))…"

p. 39, para 3: clean up: "Blanchon et al. (Blanchon et al. 2009).." to Blanchon et al (2009)…

p.40, last para: sentence doesn't make much sense to me "These surface ocean currents are highly variable over a broad range of spatial and temporal scales, most notably seasonal and inter-annual time scales associated with the El Niño-Southern Oscillation (ENSO)." ENSO operates on an approximately 4-5 year scale, but does not affect reefs world wide other than via teleconnections. Reword a bit.

p. 40, last para: clean up: “Vecchi et al. (Knutson et al.) examined changes in tropical Pacific..” and “..it is largely due to anthropogenic climate forcing {Vecchi, 2006 #2248}.”

p. 41, 1st line: clean up: “…In another comparison of climate observations to models, Wentz et al.
(Tissot and Hallacher 2003a) found that..”

p. 41, para 2: highly repetitive text: As for density-driven circulation of the ocean interior, many general circulation models of the coupled ocean–atmosphere system simulate a weakening of Atlantic Thermohaline Circulation in response to enhanced greenhouse warming (Latif et al. 2000). Both surface warming and freshening in high latitudes, the so-called sinking region, contribute to the weakening of the Thermohaline Circulation in these models. Some models even simulate a complete breakdown of the Thermohaline Circulation at sufficiently strong forcing (Canadell 2007).

From p.40, the formatting issues are written into the text and outlined in the accompanying pdf file, so the comments here are sparser.

p. 41, para 4: “Updated research continues to support this IPCC assessment (Ward et al. 2006).” But this citation is older than the IPCC 2007 report by one year. So how can it be "updated research"?

p.42, para 2: “Iron- and clay-rich soils found on many Caribbean…”. Clay forms as detritus when rocks break down. So the clays are mostly locally-formed, but additionally receive input via dust (there is more iron in many Caribbean soils than can be locally produced just by breaking down country rock).

p.45, para 4: “…as well as dark and weakly scattering;…” Note: the stronger the scatter, the less light will be available to the coral - unless all the light gets absorbed, as is the case in dense plumes of fine material. So, I think, it is more the light absorption that matters here.

p. 45, para 5: “…but not advected out of the system…”. Aren't things usually ADvected INTO a system? Maybe better to state "transported out of the system"

p.45, last line: “In highly energetic environments where currents… (Larcombe and Woolfe 1999, Larcombe et al. 2001).” I think that the environments in which these authors worked are not necessarily high-energy....they are just very muddy. For comparison also see the recent papers by Perry et al. in similar environments.

p. 49, para 6: “…with long oceanographic residence time,…” maybe better "water residence time"....but it might be better to change the sentence and make it clearer.

p. 49, para 6: “…For example, other stresses…”. Stresses like what exactly?

p. 52, para 3: “…reefs and those away from the plume were unaffected)…” There is no plume or river mentioned in that sentence. So…what plume?

p. 58, para 2: “In undisturbed conditions, the distribution of corals is considered the status quo even though the realized niches of the affected corals can be a minor component of their fundamental niches and their realized niches might be in suboptimal environments.” This sentence is unintelligible and should be reworded.

p. 58, entire para 5: Yes, see the parallel in plants. Trees often suffer complete (100%) loss of propagules due to seed predation. Yet, they haven't evolved a defense against seed predators, because as long as the population is maintained, no evolutionary pressure is exerted. Same in *H. coerulea*, ...it's just another "tree". No change to text required…just a thought.

p.72: “All else being equal, a species with high abundance is at less extinction risk than a population at low abundance because small populations are more vulnerable to the negative impacts of environmental fluctuations, genetic problems, catastrophic events, and other issues. Higher productivity is also an indicator of low extinction risk.” This may be true in a majority of cases, but not in species that have a dynamics accruing high extinction debt. There are many examples of common species going precipitously near-extinct (the Caribbean *Acropora* and *Monstastraea* are a fine example), while rare species persist. That said, and given the general paucity of data on most coral species, I believe that the approach taken and the cited argument are acceptable.

p. 73, para 1: “At larger spatial scales, geographic distribution becomes important for “spreading the risk” among multiple populations.” Yes, but only if we assume that the population acts as an open population or a well-connected metapopulation (in the strict Hanski-sense), i.e. one where the sub-populations exchange propagules relatively frequently. As corals show (especially the Caribbean *Acropora* and *Montastraea*), wide distribution and ecological dominance do not necessarily insure against precipitous population decline. If recruitment is mainly local, a high extinction debt ensues that, when due to be paid, can be (near-)catastrophic. Thus, even though it may sound a bit paradoxical, the rare species may have a lower extinction likelihood if its local populations accrue less extinction debt, i.e. if the subpopulations are very well connected. Rarity has been demonstrated a realistic survival mechanism in some plants and animals (the plants being better models for the corals).

p.178, distributional chart: *H. coerulea* definitely does not occur in the Arabian Gulf and the N. Arabian Sea.

p. 182, last para: also note that Glynn et al. (2007) suggest that due to poor description of the types, there is very little reason to separate *P. elegans* from *P. verrucosa* and suggested the two to be likely synonymous.

p. 191, distributional chart: also occurs on Easter island (Glynn et al. 2007).

p. 199: “despite previous records from central Pacific (and wasn’t seen by Wells (Wells 1954)).” I don't understand why this statement is here, given that Wells (1954) is not cited in the previous sentences.

p. 200: Disease: I think it's not only emerging diseases, but diseases in general.

p. 203, para 4: Just for info: Note: Riegl and Purkis (2009) Ecol Mod 220:192-208 calculated the recruitment rates needed to recover such populations. This might be helpful for the discussion of the Critical Threshold.

p. 204, last para: “Lateritic soils are typical of tropical islands.” as long as they are volcanic. Better say "Typical of high tropical islands" or "of volcanic tropical islands".

p. 235: *A. horrida*, bleaching: *A. horrida*, if it ever existed in the Arabian Gulf (it is listed by Riegl 1999) went locally extinct after the 1996 and 1998 bleaching events. Might be useful to evaluate overall threat.

p. 263*, A. pharaonis*, thermal stress: *A. pharaonis* became locally extinct in the SE Arabian Gulf after the combined impacts of the 1996, 1998 bleaching events (Riegl 2002, Mar Biol 140:29-40)> might be useful info to evaluate overall threat.

p. 316: distribution: *I. palifera* exists at Bassas da India and on the SE African mainland until northern KwaZulu/Natal. *I. cuneata* is not proven to exist (source: Riegl B (1995) A revision of the hard coral genus *Acropora* in SE Africa. Zool J Linn Soc 113: 249-288).

p. 317: *I. cuneata*, thermal stress: *I. cuneata* was a common species in the *A, palifera* zone of the Chagos, which got almost completely wiped out in 1998 and has not regenerated (Sheppard et (2002) Erosion versus recovery of coral reefs after 1998 El Nino: Chagos Reefs, Indian Ocean. Ambio 31(1) 40-48).

p. 406, first line: Correct spelling to “*Pachyseris*”

APPENDIX 1:

Bibliography of the material provided:

Brainard, R.E., C. Birkeland, C.M. Eakin, P. McElhany, M.W. Miller, M. Patterson, and G.A. Piniak 2010. Status review of 82 Coral Species under the Endangered Species Act. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-xx, 516 p.+1 Appendix.

The appendix of this document provides an overview and the details regarding *Millepora boschmai*.

The following citations are recommended to be consulted:

Budd AF, Johnson KG (1999) Origination preceding extinction during late Cenozoic turnover of Caribbean reefs. Paleobiology 25:188-200

Craig P et al. 2001 High temperatures tolerated by a diverse assemblage of shallow water corals in American Samoa. Coral Reefs 20: 185-189

Glyndwr et al. (2007) Diversity and biogeography of the scleractinian coral fauna of Easter Island (Rapa Nui) Pac. Sci. 61: 67-90

Glynn PW (2009) Survival of brooding and broadcasting reef corals following large scale disturbances: is there any hope for broadcasting species during global warming? Proc 11th Int Coral Reef Sym, 368-372

Harriott VJ (1985) Mortality rates of scleractinian corals before and during a mass bleaching event. MEPS 21:81-88.

Perry CT, Larcombe P (2003) Marginal and non reef building environments. Coral Reefs 22(4): 427-432

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Perry CT, Smithers S, Palmer SE, Larcombe P, Johnson K (2008) 1200 year paleoecological record of coral community development from the terrigenous inner shelf of the Great Barrier Reef. Geology 36: 691-694.

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Riegl B (1995) A revision of the hard coral genus *Acropora* in SE Africa. Zool J Linn Soc 113: 249-288

Riegl and Purkis (2009) Model of coral population response to accelerated bleaching and mass mortality in a changing climate. Ecol Mod 220:192-208

Sale et al (2010) The growing need for sustainable ecological management of marine communities of the Persian Gulf. Ambio DOI:10.1007/s13280-010-0092-6

Sheppard et al (2010) The Persian/Arabian Gulf: A young sea in decline. Mar Pollut Bull 60: 13-38

Sheppard et (2002) Erosion versus recovery of coral reefs after 1998 El Nino: Chagos Reefs, Indian Ocean. Ambio 31(1) 40-48

Silverman J,Lazar B, Cao L, Caldeira K, Erez J (2009) Coral reefs may start dissolving when atmospheric CO2 doubles. Geophys Res Lett 36, L05606, doi:10.1029/2008GL036282, 2009

Tilman D et al. 1994. Habitat destruction and the extinction debt. Nature 371:65-66

APPENDIX 2:

Attachment A: Statement of Work for Dr. Bernhard Riegl
External Independent Peer Review by the Center for Independent Experts
Status Review of 82 Species of Coral

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.com.

Project Description: A Status Review of 82 species of coral was conducted by a team at the Pacific Islands Fisheries Science Center pursuant to a petition for NMFS to list 83 coral species and designate critical habitat for them under the Endangered Species Act. Of the petitioned species, 8 occur in the Atlantic and 75 in the Pacific. NMFS has found that the petitioned action may be warranted for 82 of the 83 species; the status review is for these 82 species. The draft Report of the status review team is the subject of the peer review. For each coral species, the report presents and evaluates information on the species' distribution, biology, abundance trends, natural and anthropogenic threats, and danger of extinction throughout all or a significant portion of its range. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. The combination of required expertise of the CIE reviewers shall include working knowledge and recent experience in the biology and ecology of corals, population dynamics of marine invertebrates, quantitative assessment of extinction risk. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review as a desk review, therefore no travel is required.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation,

country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, and other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Desk Review: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

4) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
5) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
6) No later than 19 November 2010, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

25 October 2010	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
28 October 2010	NMFS Project Contact sends the CIE Reviewers the report and background documents
1-15 November 2010	Each reviewer conducts an independent peer review as a desk review
19 November 2010	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
3 December 2010	CIE submits the CIE independent peer review reports to the COTR
10 December 2010	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) each CIE report shall address each ToR as specified in **Annex 2**,
(3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

Annex 2: Terms of Reference for the Peer Review

Status Review of 82 Species of Coral

Evaluate the adequacy, appropriateness and application of data used in the Status Review document.

1. In general, does the Status Review include and cite the best scientific and commercial information available on the species, its biology, stock structure, habitats, threats, and risks of extinction?
2. Are methods used valid and appropriate?
3. Are the scientific conclusions factually supported, sound, and logical?
4. Where available, are opposing scientific studies or theories acknowledged and discussed?
5. Are uncertainties assessed and clearly stated?

Evaluate the findings made in the Status Review.

1. Are the results of the Extinction Risk Analysis supported by the information presented?

All information associated with the Status Review document is to remain strictly confidential until the Status Review is posted to the PIFSC website and/or the Federal Register by NMFS.