Endangered Species Act – Section 7 Consultation

Action Agency:	National Marine Fisheries Service, Pacific Islands Region,
Activity:	Mesophotic Coral Ecosystems of American Samoa Re-initiation
Consulting Agency:	National Marine Fisheries Service, Pacific Islands Region, Protected Resources Division
NMFS File No. (PCTS):	PIR-2019-02647
PIRO Reference No.:	I-PI-18-1774-AG

Approved By: ______________________________

Michael D. Tosatto
Regional Administrator, Pacific Islands Region

Date Issued: ______________________________

Contents

1 INTRODUCTION

Section 7(a)(2) of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1536(a)(2)) requires each Federal agency to insure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. To "jeopardize the continued existence" means to "engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). A Federal agency is required to consult formally with the National Marine Fisheries Service (NMFS) for marine species or their designated critical habitat or with the United States Fish and Wildlife Service (USFWS) for terrestrial and freshwater species or their designated critical habitat when that agency's action "may affect" an ESA-listed species. Federal agencies are exempt from the requirement for formal consultation if they have received from the NMFS or the USFWS written concurrence with their determination that an action "may affect, but is not likely to adversely affect" ESA-listed species or their designated critical habitat (50 CFR 402.14(b)).

Updates to the regulations governing interagency consultations (50 CFR part 402) will become effective on September 26, 2019 [84 FR 44976]. Because this consultation was pending and will be completed prior to that time, we are applying the previous regulations to the consultation. However, as the preamble to the final rule adopting the new regulations noted, "[t]his final rule does not lower or raise the bar on section 7 consultations, and it does not alter what is required or analyzed during a consultation. Instead, it improves clarity and consistency, streamlines consultations, and codifies existing practice." Thus, the updated regulations would not be expected to alter our analysis.

For the actions described in this document, the action agency is the National Center for Coastal Ocean Science (NCCOS) which proposes to fund the 2019 Mesophotic Coral Ecosystems of American Samoa under Contract #NA19NOS4780196. The consulting agency for this proposal is NMFS' Pacific Islands Regional Office, Protected Resources Division. This document represents NMFS' final biological opinion on the effects of the proposed action on endangered and threatened species that has been designated for those species.

This document represents the NMFS' biological opinion (opinion) of the effects on marine species protected under the ESA under NMFS jurisdiction that may result from actions under the Mesophotic Coral Ecosystems of America Samoa. This opinion has been prepared in accordance with the requirements of section 7 of the ESA, implementing regulations (50 CFR 402), agency policy, and guidance and is based on information contained in the initial Biological Evaluation (BE) submitted in 2015, published and unpublished scientific information on the biology and ecology of threatened and endangered marine species of concern in the action area, monitoring reports and research in the region, similar nursery activities and their effects on corals and other listed species in other regions of the world, and other relevant scientific and grey literature (see Literature Cited).

1.1 Consultation History

On April 30, 2015, the NMFS Pacific Islands Regional Office (PIRO) received a request from the Coral Reef Conservation Program (CRCP; CRCP 2015) to initiate a formal consultation for the proposed directed-take of listed corals research that CRCP was proposing to fund. In submitting its request for consultation, the CRCP determined that the proposed directed-take research may adversely affect the ESA-listed coral species *Acropora globiceps*, *Acropora jacquelineae*, *Acropora retusa*, *Acropora speciosa*, *Euphyllia paradivisa*, and *Isopora crateriformis*. While a no take prohibition existed for those coral species, CRCP had the obligation to insure that the proposed research would not jeopardize those species. Based on the information contained in the BE provided by the CRCP, and available scientific literature, PIRO determined there was sufficient information to initiate a consultation on May 4, 2015. On July 25, 2015, PIRO issued an opinion (PIRO 2015) in which our office determined that the proposed directed-take of listed corals through the Mesophotic Coral Ecosystem of American Samoa research would not jeopardize the ESA-listed corals *Acropora globiceps*, *Acropora jacquelineae*, *Acropora retusa*, *Acropora speciosa*, *Euphyllia paradivisa*, and *Isopora crateriformis*.

In June of 2019, the NCCOS contacted PIRO to request technical assistance concerning consultation requirements for a second research project of the Mesophotic Coral Ecosystems of America Samoa that NCCOS was proposing to fund. Based on the consultation history previously described, PIRO determined that the proposed activities constituted a modification to the action in a manner causing effects to ESA-listed species not previously considered, and instructed NCCOS to request a re-initiation of the 2015 Mesophotic Coral Ecosystems of America Samoa consultation.

ESA Consultation must be reinitiated if: 1) Take occurs to an endangered species, or to a threatened species for which NMFS has issued regulations prohibiting take under section 4(d) of the ESA.; 2) new information reveals effects of the action that may affect ESA-listed species or designated critical habitat in a manner or to an extent not previously considered; or 3) the identified action is subsequently modified in a manner causing effects to ESA-listed species or designated critical habitat not previously considered. On July 30, 2019, NMFS PIRO received the NCCOS request (NCCOS 2019) to re-initiate formal consultation. PIRO determined that we had enough information to initiate, and formal consultation was initiated on that date.

2 DESCRIPTION OF THE PROPOSED ACTION

The 2019 Mesophotic Coral Ecosystem of American Samoa research builds on the 2015 research activities by attempting to characterize the mesophotic coral ecosystem habitat and compare it to what is known about shallow coral reefs in American Samoa, quantify the contribution of mesophotic coral ecosystems to the biodiversity and functional role of the entire coral reef environment, and identify processes that regulate mesophotic coral ecosystems.

The research conducted under the original consultation began in August 2015, and lasted approximately 18 months. The study collected data and samples from mesophotic reef areas using closed-circuit SCUBA rebreathers and mixed gases. Divers worked in tandem, with one diver recording video of the habitat, while the second diver took photographs and collected samples.

Best Management Practices (BMP) for the 2015 research were primarily directed towards limiting the extent of samples taking from any one colony and limiting them to those necessary to determine statistical significance. Collections were limited to:

- coral pieces of less than 10 cm in length or diameter, but never more than 20 % of the colony
- no more than 5 samples per species (or unique coral morphology/ form) were to be collected per dive location;
    - with the possibility of 10 dive locations and maximum of 5 samples per species, a maximum of 50 samples per coral species/unique form were to be taken.

The 2019 research proposes to use photo documentation and limited sampling to further determine the presence and extent of listed corals in American Samoa. Rapid Ecological Assessments would be conducted at discrete dive locations around Tutuila, and if possible around the Manu'a, Aunu'u, and Swain's Islands, and Rose Atoll. At each dive location, assessments would be conducted at 40, 60, 80 and 100-meter depths. Genetic analysis would be applied to the samples collected across the various depths to assist in providing information on the morphological diversity and depth ranges for listed corals throughout the study area.

The same BMPs (sampling protocols) that were used in the 2015 research would be adhered to for the proposed research. The proposed sampling efforts for the 2019 research are listed in Table 1 below.

2019 Mesophotic Ecosystems of American Samoa		
Taxon	Number of Specimens	Total Size of Specimen Tissue Area
Acropora globiceps	50	1,650 cm^2
Acropora jacquelineae	50	1,650 cm^2
Acropora retusa	50	1,650 cm^2
Acropora speciosa	50	1,650 cm^2
Euphyllia paradivisa	50	628 cm^2
Isopora crateriformis	50	3,925 cm^2
Pavona diffluens	50	5,338 cm^2
Totals	350	16,311 cm2

Table 1: 2019 Mesophotic Coral Ecosystems of America Samoa proposed collection totals.

3 APPROACH TO THE ASSESSMENT

3.1 Overview of NMFS Assessment Framework

NMFS approaches its section 7 analyses through a series of sequential steps. The first step of this sequence identifies those physical, chemical, or biotic aspects of proposed actions that are known or are likely to have individual, interactive, or cumulative direct and indirect effects on the environment (we use the term "potential stressors" for these aspects of an action). As part of this step, we identify the spatial extent of any potential stressors and recognize that the spatial extent of those stressors may change with time. The area that results from this step is the *Action Area* for consultation.

The second step of our analyses identifies the listed species (collectively, listed resources) that are likely to co-occur with these potential stressors in space and time. If we conclude that such co-occurrence is likely, we then try to estimate the nature of that co-occurrence (these represent our *exposure analyses*); that is, the intensity of the stressors we expect listed species to be exposed to and the duration and frequency of any exposure. In this step of our analyses, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent.

If applicable, our exposure analyses also identifies the physical or biological features of critical habitat, including any physical or biological features ("essential features") of critical habitat or areas that require special management consideration or protection such as sites for breeding and rearing, food, water, space for growth and normal behavior, and cover and shelter; and we identify the number, age or life stage, and gender of the individuals that are likely to be exposed to an action's effects and the populations or subpopulations those individuals represent. This information is represented in the *Status of Listed Resources*. In this section we review the species' legal status, trends, and the threats that led to this status as well as those that may be impeding the species' chances of recovery. We also assess the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat, and ecosystem. We present this information in the *Environmental Baseline*. The environmental baseline is designed to assess the condition of the habitat and the species within the action area. The information in the *Environmental Baseline* with the *Status of Listed Resources* forms the foundation of our analyses and determining the risk a proposed action poses a particular species or their designated critical habitat.

Once we identify the listed resources that are likely to be exposed to an action's effects and the nature of that exposure, we examine the scientific and commercial data available to determine whether and how those listed resources are likely to respond given their exposure (these represent our *response analyses*).

3.2 Risk Analyses for Endangered and Threatened Species

Our jeopardy analyses ask whether an action agency has *insured* that its action *is not likel*y to jeopardize the continued existence of endangered or threatened species. To assess whether an action agency has complied with this standard, our jeopardy analyses ask if the evidence available allows us to conclude that the agency has *insured* that any reductions in *numbers*, *reproduction*, or the *distribution* of endangered or threatened species that are likely to result from its proposed action are likely to be inconsequential for these species (50 CFR §402.02). This standard specifically focuses on endangered or threatened species as those "species" have been listed, which can include a biological species, a subspecies, or distinct population segments of vertebrate species.

Few federal actions affect every member of endangered and threatened species that occur in marine or coastal ecosystems. Instead, the overwhelming majority of federal actions affect some members of some populations of these listed species. To determine whether an action that affects individuals is likely to affect the listed species those individuals belong to, we rely on the relationship between species, populations, and individuals. The viability of listed species (their probability of extinction or probability of persistence) depends on the viability of the populations that comprise the species while the viability of populations are determined by the fate of the individuals that comprise them: populations grow or decline as the individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our risk analyses reflect these relationships between listed species and the populations that comprise them, and the individuals that comprise those populations. Our risk analyses begin by identifying the probable risks actions pose to listed individuals that are likely to be exposed to an action's effects. Our analyses then integrate those individuals' risks to identify consequences to the populations they represent and next we determine the consequences of population-level effects on the species as listed.

We measure risks to listed individuals using the individual's "fitness," which are changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success as a result of their exposure to a stressor. In particular, we examine the scientific and commercial data available to determine if an individual's probable responses to an action's effect on the environment (which we identify during our response analyses) are likely to have consequences for the individual's fitness. When individual listed animals are expected to experience reductions in fitness, we would expect those reductions to also reduce the abundance, reproduction rates, or growth rates (or increase variance in one or more of these rates) of the populations those individuals represent (see Stearns 1992). A reduction in one or more of these variables (or one of the variables we derive from them) is a *necessary* condition for reductions in a population's viability, which itself is a *necessary* condition for reductions in a species' viability. On the other hand, when listed animals exposed to an action's effects are not expected to experience reductions in fitness, we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise (for example, see Anderson 2000; Mills and Beatty 1979; Stearns 1992). If we conclude that listed animals are not likely to experience reductions in their fitness we would conclude our assessment.

If, however, we conclude that listed animals are likely to experience reductions in their fitness, our assessment tries to determine if those reductions are likely to be sufficient to reduce the viability of the populations those individuals represent (measured using changes in the population' abundance, reproduction, spatial structure and connectivity, growth rates, genetic health, or variance in these measures to make inferences about the population's extinction risks). In this step of our analyses, we use the population's base condition (established in the *Environmental Baseline* and *Status of Listed Resources* sections of this biological opinion) as our point of reference.

Finally, our assessment tries to determine if changes in population viability are likely to be sufficient to reduce the viability of the species those populations comprise. That is, our assessment tries to determine if the action agency can insure that changes in the populations are not likely to reduce the viability of the species those populations comprise. In this step of our analyses, we use the species' status (established in the *Status of Listed Resources* and informed by the *Environmental Baseline* sections of this opinion) as our point of reference. The primary advantage of this approach is that it considers the consequences of the response of endangered and threatened species in terms of fitness costs. Individual-level effects can then be translated into changes in demographic parameters of populations, thus allowing for an assessment of the biological significance of particular human disturbances.

Biological opinions, then, distinguish among different kinds of "significance". First, we focus on potential physical, chemical, or biotic stressors that are "significant" or most important (also, salient), and distinct from ambient or background. We then ask if (a) exposing individuals to those potential stressors is likely to represent a "significant" adverse experience in the life of individuals that have been exposed; (b) exposing individuals to those potential stressors is likely to cause the individuals to experience "significant" physical, chemical, or biotic responses; and (c) any "significant" physical, chemical, or biotic responses are likely to have "significant" consequence for the fitness of the individual animal. In the latter two cases, (items (b) and (c)), the term "significant" means "clinically or biotically significant" rather than statistically significant.

For populations (or sub-populations, demes, etc.), we are concerned about whether the number of individuals that experience "significant" reductions in fitness and the nature of any fitness reductions are likely to have a "significant" consequence for the viability (i.e. probability of demographic, ecological, or genetic extinction) of the populations(s) those individuals represent. Here "significant" also means "clinically or biotically significant" rather than statistically significant.

For "species" (the entity listed as threatened or endangered, which may not be the biological species), we are concerned about whether the number of populations that experience "significant" reductions in viability (that is, increases their extinction probabilities) and the nature of any reductions in viability are likely to have "significant" consequences for the viability (the probability of demographic, ecological, or genetic extinction) of the listed species those populations comprise. Here again, "significant" also means "clinically or biotically significant" rather than statistically significant.

In this step, we also ask whether or to what degree the agency has insured that probable reductions in a species' viability are not likely to have significant consequences for the viability of the listed species those populations comprise. The answer to this question informs our conclusion about whether an agency has insured that any reductions in numbers, reproduction, or the distribution of threatened or endangered species that are likely to result from its proposed action are likely to be inconsequential for these species (50 CFR §402.02).

3.3 Evidence Available for this Consultation

To conduct our analyses, we considered lines of evidence available through published and unpublished sources that represent evidence of adverse consequence or the absence of such consequences. In particular, we considered information contained in NMFS's final ruling to list 20 coral species as threatened under the ESA (79 FR 53851), status of corals reports, manuals, and taxonomic listings (Veron 2014, Veron 2000, Wallace 1999), and coral resilience studies (Maynard et al. 2012, Maynard et al 2015).

We supplemented this information by conducting electronic searches of literature published in English or with English abstracts using research platforms in the Science Direct, Google Scholar, Google, Bing Academia, and Bing. These platforms allowed us to cross search multiple databases for journals, open access resources, books, proceedings, web sites, for literature on the biological, ecological, and fisheries sciences.

For our literature searches, we used paired combinations of the keywords such as *Acropora*, wound healing, coral breakage, coral breakage survival, coral regeneration, regeneration rates, coral disease, climate change, and many others to search these electronic databases. Electronic searches have important limitations, however. First, often they only contain articles from a limited time span. Second, electronic databases commonly do not include articles published in small or obscure journals or magazines. Third, electronic databases do not include unpublished reports from government agencies, consulting firms, and non-governmental organizations. To overcome these limitations, we identified additional papers that had not been captured in our electronic searches and searched their literature cited sections and bibliographies. We acquired references that, based on a reading of their titles and abstracts, appeared to comply with our keywords. If a references' title did not allow us to eliminate it as irrelevant to this inquiry, we acquired the reference.

3.4 Application of this Approach in this Consultation

We begin by deconstructing the proposed action into its constituent parts. This step allows us to distinguish the effects of related activities on listed resources. NMFS identified the following potential stressors (or subsidies) associated with the proposed action. These stressors are:

1. Direct physical impact
2. Hazardous chemicals and materials
3. Disease, parasites, and nuisance and invasive species
4. Turbidity

In this step of our analysis, we evaluate available evidence to determine the likelihood of listed species or critical habitat being exposed to these potential stressors. Our analysis assumed that these stressors pose no risk to listed species or critical habitat if these stressors do not co-occur, in space or time, with the: (a) individuals of endangered or threatened species, or areas designated as critical habitat for threatened or endangered species; (b) species that are food for endangered or threatened species; or (c) species that prey on or compete with endangered or threatened species.

3.4.1 Exposure Analyses

Our challenge in this step is to identify: what populations, life history forms or stages of listed species are exposed to the proposed action; the number of individuals that are exposed; the pathways of their exposure; the timing and duration of their exposure; the frequency and severity of the exposure; and how exposure might vary depending upon the characteristic of the environment and individual behavior. Typically, in this step of our analysis we would identify how many individuals are likely to be exposed, which populations the individuals represent, where and when the exposure would occur, how long the exposure would occur, the frequency of the exposure, and any other particular details that help characterize the exposure. To do this we require knowledge of a species' population structure and distribution, life history strategy, and abundance.

For our exposure analyses, we use data on species occurrence in the action area and the extent, duration, frequency, and severity of each stressor. For data gaps, we may use information on surrogate species, and information on similar actions in other locations which may be impacting individuals of other populations. We may also query experts to formulate opinions or estimates of exposure.

Managing and analyzing coral within the context of the ESA is unusual since the term "individual" that we use for coral is not necessarily one individual animal like we consider individual sea turtles or whales. While it has properly been assumed for listed vertebrate species that physical contact of equipment or humans with an individual constitutes an adverse effect due to high potential for harm or harassment, the same assumption does not hold for listed corals due to two key biological characteristics:

- All corals are simple, sessile invertebrate animals that rely on their stinging nematocysts for defense, rather than predator avoidance via flight response. So whereas it is logical to assume that physical contact with a vertebrate individual results in stress that constitutes harm and/or harassment, the same does not apply to corals because they have no flight response;
- Most reef-building corals, including all the listed species, are colonial organisms, such that a single larva settles and develops into the primary polyp, which then multiplies into a colony of hundreds to thousands of genetically-identical polyps that are seamlessly connected through tissue and skeleton. Colony growth is achieved mainly through the addition of more polyps, and colony growth is indeterminate.

The colony can continue to exist even if numerous polyps die, or if the colony is broken apart or otherwise damaged. The individual of these listed species is defined as the colony, not the polyp, in the final coral listing rule (79 FR 53852). Thus, affecting some polyps of a colony does not necessarily constitute harm to the individual.

For the purposes of this consultation, we consider effects to each colony as individuals within a local population, within a regional, and global population.

3.4.2 Response Analyses

As discussed in the introduction to this section of this biological opinion, we use the best scientific and commercial data available to identify the intended and unintended consequences that are likely to result from the different activities that comprise the proposed action. These analyses identify the probable direct and indirect consequences of exposing listed resources to those activities for listed individuals, populations, and species, and designated critical habitat; these analyses represent the "response analyses" and "risk analyses" of our consultations. Our "response analyses" review the scientific and commercial data available to determine whether, how, and to what degree listed resources are likely to respond given their exposure to the intended and unintended consequences of classes of activities. Because the response of animals to a potential stressor are influenced by the animal's pre-existing physical, physiological, or behavioral state, our response analyses consider the *Status of Listed Resources* and the impacts of the *Environmental Baseline*.

3.4.3 Risk Analyses

Our "risk analyses" begin by identifying the probable consequences of those responses for the "performance" of listed individuals, and then they identify the consequences of changes in individual performance on the viability of the populations those individual represent. Our "risk analyses" conclude by determining the consequences of changing the viability of the populations, and the species those populations comprise. We ask: (a) what is likely to happen to different individuals; and (b) what is likely to happen to the populations or species those individuals comprise?

When individual, listed animals are expected to experience reductions in fitness, we would expect those reductions to also reduce the abundance, reproduction rates, or growth rates (or increase variance in one or more of these rates) of the populations those individuals represent (see Stearns 1992). If we conclude that listed animals are not likely to experience reductions in their fitness then we would conclude our assessment.

Our risk analyses reflect these relationships between listed species and the populations that comprise them, and the individuals that comprise those populations. Our risk analyses begin by identifying the probable risks actions posted to listed individuals that are likely to be exposed to an action's effects. Our analyses then integrate those individual risks to determine if the number of individuals that experience reduced fitness (or the magnitude of any reductions) is likely to be sufficient to reduce the viability of the populations those individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, or variance in these measures to make inferences about the population's probability of becoming demographically, ecologically, or genetically extinct in 25, 50, or 100 years). In this step of our analyses, we use the population's base condition (established in the *Environmental Baseline* and *Status of Listed Resources* sections of this opinion) as our point of reference.

Our risk analyses conclude by determining whether changes in the viability of one or more population is or is not likely to be sufficient to reduce the viability of the species (measured using probability of demographic, ecological, or genetic extinction in 25, 50, or 100 years) those populations comprise. For these analyses, we combine our knowledge of the patterns that accompanied the decline, collapse, or extinction of populations and species that are known to have declined, collapsed, or become extinct in the past.

When we conduct these analyses, our assessment is designed to establish that a decline, collapse, or extinction of an endangered or threatened species is not likely; we do not conduct these analyses to establish that such an outcome is likely. In this step of our analyses, we use the species' status (established in the *Status of the Listed Resources* section of this opinion) as our point of reference.

3.5 Action Area

The action area consists of dives sites between 40 – 100 m depth at randomly selected sites around the American Samoan islands of Tutuila, Aunu'u, Manu’a (around Ofu, Olosega, and Tau), and Swain’s and Rose Atoll. The research is expected to start in the fall of 2019, and continue for four years. The field efforts will consist of seven 14-day trips spread across the four years from 2019 – 2023.

4 STATUS OF THE SPECIES

4.1 Species Likely to be Adversely Affected

The Mesophotic Coral Ecosystems of American Samoa concerns the collection of voucher specimens from several ESA-listed corals. The collection of specimens from ESA-threatened species would be for morphometric, genetic, histological, and physiological studies. This part of the proposed research involves “take” as defined by the ESA, and is considered “likely to adversely affect” the species listed in Table 2, and that action and its potential effect on those species are considered further in this opinion.

Species	Scientific Name	ESA Status	Effective Listing Date	Federal Register Reference
Corals	*Acropora globiceps*	Threatened	9/10/2014	79 FR 53852
	Acropora jacquelineae	Threatened	9/10/2014	79 FR 53852
	Acropora retusa	Threatened	9/10/2014	79 FR 53852
	Acropora speciosa	Threatened	9/10/2014	79 FR 53852
	Euphyllia paradivisa	Threatened	9/10/2014	79 FR 53852
	Isopora crateriformis	Threatened	9/10/2014	79 FR 53852
	Pavona diffluens	Threatened	9/10/2014	79 FR 53852

Table 2: ESA-listed corals species determined likely to be adversely affected by directed take of voucher specimens during the Mesophotic Coral Ecosystems of America Samoa.

4.1.1. Acropora globiceps

4.1.1.1 Distribution and Abundance

Acropora globiceps has been reported from the central Indo-Pacific, the oceanic west Pacific, and the central Pacific (IUCN, 2010). It has been reported as common and relatively widespread in the north-south direction, but somewhat restricted in the east-west direction and has a narrow depth range (Richards 2009). Richards (2009) estimates the range of the species at 5 million km^2, and within its range can be found on upper reef slopes, reef flats, and adjacent habitats in depth ranging from 0 to 8 m. Based on Richards *et al.* (2008) and Veron (2014), the absolute abundance of this species is likely at least tens of millions of colonies.

4.1.1.2 Biological Characteristics

Colonies of this species are usually small and digitate, with the size and shape dependent on the amount of wave action that a colony is exposed to. Colonies are uniform blue or cream in color (Veron, 2000). It appears similar to *Acropora gemmifera*, but in strong wave action is similar to *Acropora monticulosa*. The species is a hermaphroditic spawner with lecithotrophic (yolk-sac) larvae.

4.1.1.3 Threats to the Species

The biggest threat to this coral species is global climate change due to the increase of CO_2 emissions from the burning of fossil fuels. The impact of increased atmospheric CO_2 on the world's oceans is to increase water temperatures and lower pH. Increasing ocean temperatures are directly responsible for bleaching events around the world that have led to significant coral mortalities; while increasing temperatures may work in tandem with coral diseases to reduce coral health and survivorship (Bruno *et al*., 2007). As the oceans warm it is likely that there will also be a greater stratification of ocean water, which will decrease vertical mixing of nutrient-rich waters resulting in nutrient-poor surface waters (Behrenfeld *et al*., 2006).

Acidification of the world's ocean (lower pH) will potentially impact corals by reducing calcification rates, increasing erosion, and affecting reproduction. Reduced calcification rates may force corals to respond in one of three ways: corals may grow slower; corals may grow at the same rate, at the cost of reducing skeletal density; or corals may divert energy from other processes (such as reproduction) to maintain the same growth rate (Hoegh-Guldberg *et al.*, 2007). An increasingly acidic ocean may cause corals to calcify more slowly and become more fragile, this would impede reef growth and decrease the ability of corals to recover from habitat damage resulting from disturbances such as hurricanes, vessel groundings, and anchoring (Brainard *et al*., 2011). Although research has been inconclusive, acidification may impact development and physiology, fertilization and settlement success of coral larvae (Portner et al., 2004, Albright et al., 2008, Albright et al., 2010).

There is very little information on threats to the species specific to *A. globiceps,* so the information for the genus *Acropora* is provided. *Acropora* are among the most susceptible corals to bleaching (Marshall and Baird, 2000; McClanahan *et. al*. 2007; McClanahan *et. al*., 2005). Experiments have shown that acidification has had negative effects on calcification, productivity, and has impaired the fertilization and settlement of *Acropora* species (Anthony *et al*., 2008; Marubini *et al*., 2003; Reneger and Riegel, 2005; Schneider and Erez, 2006; Anthony *et al*., 2008; Crawley *et al*., 2010; Albright *et al*., 2010). Available information indicates that species of the genus are moderately to highly susceptible to disease (Aronson and Precht, 2001; Bruckner and Hill, 2009).

4.1.1.4 Conservation of the Species

Records confirm that *A. globiceps* occurs in 22 Indo-Pacific ecoregions[1] that encompass the following countries' EEZs: Australia, Federated States of Micronesia, Fiji, French Pacific Island Territories, Indonesia, Japan, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, Pitcarin Islands, the Commonwealth of the Northern Mariana Islands, Guam, American Samoa, and Vietnam (79 FR 53851).

The scope of regulatory mechanisms in the countries where the species is found varies in terms of those that utilize them and the extent to which those regulatory mechanisms are applied, but the most common regulations in place for this species are those regarding reef fishing, area management for protection and conservation, and collection laws (79 FR 53851).

4.1.2 Acropora jacquelineae

4.1.2.1 Distribution and Abundance

Acropora jacquelineae has been reported from the central Indo-Pacific (IUCN, 2010), and has been found in Indonesia and Papua New Guinea (Richards *et al.*, 2008b). Richards (2009) calculated the geographic range of the species at 2 million km^2, and within its range has been reported as uncommon (Veron 2000). The species occurs in numerous habitats including, lower reef slopes, walls and ledges, mid-slopes, and upper reef slopes protected from wave action, and is found in depths ranging from 10 to 35 m. Based on Richards et al. (2008) and Veron (2014), the absolute abundance of the species is likely at least a million colonies.

4.1.2.2 Biological Characteristics

Colonies of *A. jacquelineae* are flat plates up to 1 m in diameter (Brainard *et al*., 2011). Viewed from above, plates are covered with a mass of fine delicately-curved axial corallites giving an almost moss-like appearance. Colonies are uniform grey-brown or pinkish in color (Veron 2000). The species is a hermaphroditic spawner with lecithotrophic (yolk-sac) larvae.

4.1.2.3 Threats to the Species

See the general information in the paragraphs describing climate change under *A. globiceps*.

There is very little information on threats to the species specific to *A. jacquelineae,* see genus information provided under *A. globiceps*.

4.1.2.4 Conservation of the Species

Acropora jacquelineae occurs in 12 Indo-Pacific ecoregions that encompass five countries' EEZs including: Federated States of Micronesia, Indonesia, Papua New Guinea, Solomon Islands, and Timor-Leste (79 FR 53851).

The scope of regulatory mechanisms in the countries where this species is found varies in terms of those that utilize them and in the extent to which those regulatory mechanisms are applied, but

[1] Ecoregion used throughout this opinion are based on Veron (2014). See Reference section for citation.

the most common regulations in place for this species are those regarding reef fishing, and area management for protection and conservation (79 FR 53851).

4.1.3 Acropora retusa

4.1.3.1 Distribution and Abundance

Acropora retusa occurs across a wide range globally, having been reported in the Red Sea, Madagascar, South Africa, and Chagos in the Indian Ocean, the Solomon Islands and the central Pacific (Veron 2000, Veron and Wallace, 1984). The species has been reported as common in South Africa, and uncommon throughout the rest of its range (Veron 2000; Veron and Wallace, 1984). Richards (2009) estimated the species range at 68 million km^2, and within its range occupies several shallow depth habitats (1 to 5 m) including reef slopes and back-reef areas, such as upper reef slopes, reef flats, and lagoons. Based on Richards *et al*. (2008) and Veron (2014), the absolute abundance of the species is likely at least 1 million colonies.

4.1.3.2 Biological Characteristics

A. retusa are typically seen as flat plates with short thick digitate branches (Brainard *et al*., 2011), and is similar in appearance to *Acropora branchi*, *Acropora gemmifera*, and *Acropora monticulosa*. Colonies are brown in color (Veron 2000; Veron and Wallace, 1984). The species is a hermaphroditic spawner with lecithotrophic (yolk-sac) larvae.

4.1.3.3 Threats to the Species

See the general information in the paragraphs describing climate change under *A. globiceps*.

There is very little information on threats to the species specific to *A. retusa,* see the genus information provided under *A. globiceps*.

4.1.3.4 Conservation of the Species

Records confirm that *A. retusa* occurs in 23 Indo-Pacific ecoregions that encompass many countries' EEZs including: Brunei, Federated States of Micronesia, Fiji, the French Pacific Islands Territories, India, Indonesia, Japan, Kenya, Madagascar, Malaysia, Mauritius, Mozambique, Cook Islands, Tokelau, Niue, Palau, Papua New Guinea, Samoa, Seychelles, Solomon Islands, South Africa, Sri Lanka, Tanzania, Tonga, Tuvalu, Tuvalu, the Commonwealth of the Northern Mariana Islands, Guam, American Samoa, and Vietnam (79 FR 53851).

The scope of regulatory mechanisms in the countries where this species is found varies in terms of those that utilize them and the extent to which those regulatory mechanisms are applied, but the most common regulations in place for this species are those regarding reef fishing, and area management for protection and conservation (79 FR 53851).

4.1.4 Acropora speciosa

4.1.4.1 Distribution and Abundance

Acropora speciosa is reported to have a moderately broad range (Richards 2009), and has been reported in Fiji, Indonesia, Papua New Guinea, Australia, the Philippines, Polynesia, and Micronesia (Brainard *et al*, 2011). Richards (2009) estimated its range at 20 million km^2, and within its range occupies lower reef slopes and walls, especially those with clear waters. The species is found in depths ranging from 20 to 40 m, and has even been found in "mesophotic habitats" (40 – 150 m). Using an area correction for the population estimate made in Richards *et al.* (2008), the total population size for *A. speciosa* has been estimated at over 10 million colonies, with and an effective population size of at least 1 million colonies.

4.1.5.2 Biological Characteristics

Colonies of *A. spe*ciosa form thick cushions or brush-like branches, and can be elongate, radial, or tubular in shape (Brainard 2011), and is similar in appearance to *A. echinata* and *A. granulosa*. Colonies usually appear cream in color and have colored branched tips (Veron 2000). Based on information from other *Acropora* species, *A. speciosa* is most likely a hermaphroditic spawner with lecithotrophic (yolk-sac) larvae.

4.1.4.3 Threats to the Species

See the general information in the paragraphs describing climate change under *A. globiceps*.

There is very little information on threats to the species specific to *A. speciosa,* see the genus information provided under *A. globiceps*.

4.1.4.4 Conservation of the Species

Records confirm that *A. speciosa* occurs in 26 Indo-Pacific ecoregions and several countries' EEZs including: Australia, Brunei, China, Federated States of Micronesia, the French Pacific Island Territories, Indonesia, Malaysia, Maldives, Marshall Islands, Palau, Papua New Guinea, Philippines, Solomon Islands, Taiwan, Timor-Leste, the Pacific Remote Islands Areas, and Vietnam (79 FR 53851).

The scope of regulatory mechanisms in the countries where this species is found varies in terms of those that utilize them and the extent to which those regulatory mechanisms are applied, but the most common regulations in place for this species are those regarding reef fishing, and area management for protection and conservation (79 FR 53851).

4.1.5 Euphyllia paradivisa

4.1.5.1 Distribution and Abundance

Euphyllia paradivisa has a restricted range, being found only in the Coral Triangle Region (Brainard *et al*., 2011). The species inhabits environments protected from wave action on upper reefs slopes, mid-slope terraces, and lagoons in depths from 2 to 25 m. Based on Richards *et al.* (2008) and Veron (2014), the absolute abundance of the species is likely at least tens of millions of colonies.

4.1.5.2 Biological Characteristics

Colonies of *E. paradivisa* are made up of branching separate corallites (Brainard *et al*., 2011). The taxonomy was described as having no taxonomic issues but having tentacles similar to *E. divisa* and skeleton that is the same as *E. glabrescens*, *E. paraglabrescens*, and *E. paraancora*. Colonies are pale greenish-grey in color with lighter colored tips (Veron 2000).

4.1.5.3 Threats to the Species

See the general information in the paragraphs describing climate change under *A. globiceps*.

Due to its limited distribution, there is a lack of information on the susceptibility of *E. paradivisa* to many of the threats that corals face at this time. The species experienced high bleaching levels during the event that occurred in Palau (Bruno *et al*., 2001) during the 1997-98 incident, but its susceptibility to acidification, disease, and predation are largely unknown (Brainard *et al*., 2011). Species of the genus *Euphyllia* are major contributors in the aquarium trade, but due to the similarity in appearance among the species, the nature of the specific threat is unknown (Brainard *et al*., 2011). The major concern with the species would appear to be its limited distribution, especially since the area of its distribution is highly disturbed, and its apparent uncommon occurrence throughout its range (Brainard *et al*., 2011).

4.1.5.4 Conservation of the Species

Records confirm that *E. paradivisa* occurs in 8 Indo-Pacific ecoregions, and in numerous countries' EEZs including: Brunei, Fiji, the French Pacific Island Territories, Indonesia, Malaysia, Tokelau, Niue, Papua New Guinea, Philippines, Samoa, Timor-Leste, Tonga, Tuvalu, American Samoa, and Vietnam (79 FR 53851).

The scope of regulatory mechanisms in the countries where this species is found varies in terms of those that utilize them and the extent to which those regulatory mechanisms are applied, but the most common regulations in place for this species are those regarding reef fishing, and area management for protection and conservation (79 FR 53851).

4.1.6 Isopora crateriformis

4.1.6.1 Distribution and Abundance

Although there are some questions regarding the distribution due to similarity in *Isopora* species, *Isopora crateriformis* has been reported to occur from Sumatra to American Samoa (Wallace 1999; Veron 2000). The species is found primarily in reef flats and upper reef slopes most commonly in shallow, high-wave energy environments, from low tide to at least 12 m depth, and has been reported from mesophotic depths. Richards (2009) calculated the geographic range of the species at about 11 million km^2. Based on the results from Richards *et al.* (2008) and Veron (2014), the absolute abundance of the species is likely at least millions of colonies.

4.1.6.2 Biological Characteristics

Colonies of *I. crateriformis* are typically flat encrusting plates (Brainard *et al*., 2011). Based on its encrusting morphology, the species is not prone to asexual reproduction via fragmentation. Colonies of the species are generally brown in color (Veron 2000).

4.1.6.3 Threats to the Species

See the general information in the paragraphs describing climate change under *A. globiceps*.

Although there is little species specific information, *I. crateriformis* has been reported to tolerate high temperatures better than other species at the family level in both the American Samoa and Fiji bleaching events from past years (Craig *et al*., 2001; Lovell 2000). With scant information on the species with regard to acidification, disease, and predation; *I. crateriformis* is considered to have similar susceptibility to these threats as other members of the family *Acroporidae* (Brainard *et al*., 2011).

4.1.6.4 Conservation of the Species

Records confirm that *I. crateriformis* occurs in 13 Indo-Pacific ecoregions that encompass several countries' EEZs including: Australia, Brunei, Fiji, French Pacific Island Territories, Indonesia, Kiribati, Malaysia, Tokelau, Niue, Papua New Guinea, Philippines, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and American Samoa.

The scope of regulatory mechanisms in the countries where this species is found varies in terms of those that utilize them and the extent to which those regulatory mechanisms are applied, but the most common regulations in place for this species are those regarding reef fishing, and area management for protection and conservation (79 FR 53851).

4.1.7 Pavona diffluens

4.1.7.1 Distribution and Abundance

Pavona diffluens is restricted in both its east-west and north-south distribution, occurring in the Red Sea and the Arabian Gulf (Veron 2000), although it has been recently reported in the Northern Marianas and American Samoa (Carpenter *et al*., 2008). Its habitats include at least upper reef slopes, mid-slopes, lower reef crests, reef flats, and lagoons, in depths of 5 to 20 m. Based on results from Richards *et al*. (2008) and Veron (2014), the absolute abundance of the species is likely at least millions of colonies.

4.1.7.2 Biological Characteristics

Colonies of *P. diffluens* are boulder or rounder in shape with deep corallites (Brianard *et al*., 2011), and is similar in appearance to *P. gigantea* and *P. explanulata*. Colonies are typically tan in color (Veron 2000). The reproductive characteristics of the species have not been determined, but six other species in the genus are known to be gonochoric broadcast spawners.

4.1.7.3 Threats to the Species

See the general information in the paragraphs describing climate change under *A. globiceps*.

Little information specific to the species is available, but members of the genus *Pavona* have proven to be highly susceptible to bleaching in the eastern Pacific (Glynn *et al*., 2001; Mate 2003). Additionally, members of the genus show a diverse range of response to acidification; while one species shows slowed calcification under conditions of reduced levels of aragonite (Marubini *et al*., 2003), another species in the genus has shown no growth rate change over the past several decades in the eastern Pacific (Manzello 2010). No specific information is available on the susceptibility of *P. diffluens* to disease and predation, and again within the genus there is a range from more to less susceptible.

4.1.7.4 Conservation of the Species

Records confirm that *P. diffluens* occurs in five Indo-Pacific ecoregions that encompass numerous countries' EEZs including: Djibouti, Egypt, Eritrea, French Pacific Island Territories, Iran, Israel, Jordan, Madagascar, Oman, Pakistan, Saudi Arabia, Sudan, United Arab Emirates, and Yemen.

The scope of regulatory mechanisms in the countries where this species is found varies in terms of those that utilize them and the extent to which those regulatory mechanisms are applied, but the most common regulations in place for this species are those regarding reef fishing, and area management for protection and conservation (79 FR 53851).

5 ENVIRONMENTAL BASELINE

The environmental baseline for a biological opinion includes past and present impacts of all state, federal or private actions and other human activities in the action area, anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02). The Consultation Handbook further clarifies that the environmental baseline is "an analysis of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat (including designated critical habitat), and ecosystem, within the action area." (USFWS and NMFS 1998). The purpose of describing the environmental baseline in this manner in a biological opinion is to provide context for effects of the proposed action on listed species.

The past and present impacts of human and natural factors leading to the status of the species addressed by this opinion within the action area include fishery interactions, vessel groundings, pollution, marine debris, and climate change. The environmental baseline for the ESA-listed marine species addressed by this opinion are described below.

As previously described, this opinion considers the proposed action of NCCOS funding of the Mesophotic Coral Ecosystems of American Samoa. The proposed research would be a continuation of research done in 2015, and has the goal of comparing and contrasting the biological diversity of the American Samoa shallow coral reef environments to the mesophotic coral reef environments. The 2015 research met with very limited success, with only three samples taken from the listed coral species *Acropora speciosa*. The sample sizes taken were 7, 10, and 10 cm^2, for a total of 27 cm^2.

American Samoa consists of five main islands and two coral atolls. The largest and most populous island is Tutuila, with the Manu’a, Aunu’u, and Swian’s Islands, and Rose Atoll, also included in the territory. The work to be conducted by the Mesophotic Coral Ecosystems of America Samoa will be within the areas designated as the National Marine Sanctuary of American Samoa (NMSAS) and the Rose Atoll Marine National Monument (RAMNM).

Originally established as the Fagatele Bay National Marine Sanctuary, on July 26, 2012, the Sanctuary was expanded to include five other units, and the name was changed to the National Marine Sanctuary of American Samoa (FR 77 43942). The additions included: the bay area of Fagalua/Fogama, and the waters around part of Aunu’u, Ta’u, and Swain’s Island and Rose Atoll. These additions increase the size of the Sanctuary from 0.25 square miles to 13,581 square miles, of which 99 % was from the addition of the RAMNM.

The regulations established for the NMSAS included general prohibitions that include, discharging any material or other matter within the Sanctuary; disturbing the benthic community by dredging, filling, dynamiting or otherwise altering the seabed; and anchoring. Fishing prohibitions established include, the use of poisons or explosives, any type of fixed net, and the use of a bottom trawl. Also, the take of live rock or coral is prohibited (take was already prohibited in territorial waters less than 60 under ASCA 24.0927 (a) and in federal waters under 50 CFR 665.125(c)). Prior to the establishment of these regulations, the ESA-listed corals considered in this opinion were at potential risk from many of these activities, mostly around Tutuila where the majority of the population of American Samoa resides; since their enactment, the ESA-listed corals at are minimal risk from local anthropogenic impacts. Although these same regulations apply to Rose Atoll, the atoll’s distance from the major population centers in American Samoa has always prevented impacts to ESA-listed corals from locally derived human-caused impacts.

Although their isolation provides some level of protection from local stressors, the islands and atolls of the NMSAS and RAMNM are not immune to the impacts from the global phenomenon of climate change. The global mean temperature has risen by 0.76^{o} C over the last 150 years, and much of that increase has occurred over the past 50 years (Solomon *et al*., 2007). This temperature change is due largely to the increased levels of the greenhouse gas carbon dioxide (CO_2) which has steadily increased from approximately 280 ppm at the start of the Industrial Revolution to over 390 ppm by 2009 (WDCGG 2010).

Increased levels of CO_2 are due primarily to the burning of fossil fuels and human development that has resulted in deforestation around the world. The major impacts to the world’s oceans have been the increase in water temperatures as the earth warms, acidification (lower pH) from the increased CO_2 absorbed by the oceans, and rising sea levels due to glacial melt from the increasing global temperatures.

Globally, climate change is adversely affecting many coral species. Increasing water temperatures has been linked to widespread and accelerated bleaching and mass mortalities of corals around the world over the past 25 years (Brainard *et al.*, 2011). Ocean acidification, which changes the calcium carbonate saturation state of seawater, may affect fertilization and larval settlement in corals, and could decrease growth and calcification rates (Brainard *et al*., 2012).

Corals are generally slow growing organisms that often have a narrow depth range preference that is optimum for the symbiotic algae that produces much of the food corals survive on; if sea levels rise faster than corals are able to keep pace with, the wavelengths of light that reach them may not be useable by the algae they rely on.

The incidence of climate-related events to the corals within the RAMNM, and the NMSAS, have been minimal compared to many areas around the world. This could be primarily due to relative stability of the Pacific waters in these areas and the general lack of other locally caused anthropogenic stressors that many corals closer to inhabited areas face, or may be an artifact of the overall lack of monitoring of these areas due to their isolation.

6 EFFECTS OF THE ACTION

In this section of a biological opinion, NMFS assesses the probable effects of the proposed action on threatened and endangered species. Of the seven coral species that may be adversely affected by the proposed action, the exposure and risks are expected to be similar. Addressing the species individually would have no discernible improvement in the evaluation. Therefore, all seven corals species are referred to together as “corals”.

‘Effects of the action’ refer to direct and indirect effects of the action on a species or critical habitat, together with the effects of other activities that are interrelated and interdependent with that action that would be added to the environmental baseline. “Direct effects” are caused by exposure to the action related stressors that occur at the time of the action. “Indirect effects” are those that are likely to occur later in time (50 CFR 402.02). The ‘effects of the action’ are considered within the context of the ‘Status of the Species,’ together with the ‘Environmental Baseline’ and ‘Cumulative Effects’ to determine if the proposed action can be expected to have direct or indirect effects on a species that appreciably reduces its likelihood to survive and recover in the wild by reducing its reproduction, number, or distribution (50 CFR 402.02), otherwise known as the jeopardy determination. Since no critical habitat has been designated in the action area, impacts on critical habitat are not considered in this opinion.

Approach. NMFS determines the effects of the action using a sequence of steps. The first step identifies stressors (or benefits) associated with the proposed action with regard to listed species. The second step identifies the magnitude of stressors (e.g., how many individuals of a listed species will be exposed to the stressors; *exposure analysis*). In this step of our analysis, we try to identify the number, age (or life stage), and gender of the individuals that are likely to be exposed to a proposed action's effects, and the populations or subpopulations those individuals represent. The third step describes how the exposed individuals are likely to respond to these stressors (e.g., the mortality rate of exposed individuals; *response analysis*).

The final step in determining the effects of the action is establishing the risks those responses pose to listed resources (*risk analysis*). The risk analysis is different for listed species and designated critical habitat. Our jeopardy determinations must be based on an action's effects on the continued existence of threatened or endangered species as those species have been listed, which can include true biological species, subspecies, or distinct population segments of vertebrate species. Because the continued existence of listed species depends on the fate of populations that comprise them, viability (probability of extinction or probability of persistence) of listed species depends on viability of their populations. Similarly, the continued existence of populations are determined by the fate of individuals that comprise them; populations grow or decline as individuals that comprise the population live, die, grow, mature, migrate, and reproduce (or fail to do so).

Our risk analyses reflect these relationships between listed species and the populations that comprise them, and the individuals that comprise those populations. We begin by identifying the probable risks the action poses to listed individuals that are likely to be exposed to an action's direct and indirect effects. Our analyses then integrates those individuals' risks to identify consequences to the populations those individuals represent. Our analyses conclude by determining the consequences of those population-level risks to the species those populations comprise.

We measure risks to listed individuals using the individual's "fitness," which are changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success. In particular, we examine the scientific and commercial data available to determine if an individual's probable responses to an action's effects on the environment (which we identify during our response analyses) are likely to have consequences for the individual's fitness.

When individually listed animals are expected to experience reductions in fitness, we would expect those reductions to also reduce the abundance, reproduction rates, or growth rates (or increase variance in one or more of these rates) of the populations those individuals represent. Reductions in one or more of these variables (or one of the variables we derive from them) is a *necessary* condition for reductions in a population's viability, which is itself a *necessary* condition for reductions in a species' viability. On the other hand, when listed animals exposed to an action's effects are *not* expected to experience reductions in fitness, we would not expect the action to have adverse consequences on the viability of the populations those individuals represent or the species those populations comprise. If we conclude that listed animals are *not* likely to experience reductions in their fitness, we would conclude our assessment.

If, however, we conclude that listed animals are likely to experience reductions in their fitness, our assessment tries to determine if those fitness reductions are likely to be sufficient to reduce the viability of the populations those individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, or variance in these measures to make inferences about the population's extinction risks). In this step of our analyses, we use the population's base condition (established in the 'Status of Listed Species', 'Environmental Baseline', and 'Cumulative Effects' sections of this opinion) as our point of reference. Finally, our assessment tries to determine if changes in population viability are likely to be sufficient to reduce the viability of the species those populations comprise.

This introduction summarizes stressors and interactions resulting from the proposed action. It is included here to set the stage for the following sections.

NMFS has determined that the stressors associated with the proposed action includes the "take" of polyps from a coral colony, and the resulting stresses associated with the removal of this coral tissue that is collected. When NMFS listed the coral species considered in this opinion, it used the concept of the ''physiological colony'' as the entity that can be considered an individual. I.e., the final rule (Final Rule 79 FR 53982) considers the ''individual'' for each of the listed species to be the colony, polyps are not considered individuals, sexually- and asexually-produced colonies are considered individuals.

This stressor is the same for all the coral species listed in Table 2. The following sections will focus on the exposure, response and risk to each individual species from the collection of voucher specimens.

6.1 Potential Stressors

The potential stressors associated with this action include:

- Direct physical impacts
- Hazardous chemicals and materials
- Disease, parasites, and nuisance and invasive species
- Turbidity

6.2 Exposure Analysis

6.2.1 Direct physical impacts

All of the ESA-listed corals in Table 2 will potentially be affected by the stressors listed above. The most likely and severe effect is direct physical harvest when divers cut fragments off of a colony. The directed take of voucher specimens of corals as proposed for the Mesophotic Coral Ecosystems of America Samoa would result in, at the most, 50 specimens of each species. A. globiceps, *A. jacquelineae*, *A. retusa*, and *A. speciosa* would have a total specimen tissue area removed of 1,650 cm^2 each. *E. paradivisa* would have a total specimen tissue area removed of 628 cm^2, *I. crateriformis* would have a total specimen tissue area removed of 3,925 cm^2, and *Pavona diffluens* would have a total specimen tissue area removed of 5,338 cm^2. A total specimen tissue area of up to 16,311 cm^2 would be removed for all species combined. None of the individual specimens will constitute a complete colony. As these species are uncommon in the action area, and this represents a maximum number samples that would be collected.

6.2.2 Hazardous chemicals and materials

Any foreign material added to the aquatic environment could affect corals in the action area. These include oil or other chemicals associated with vessels, and chemicals or materials used in collection or preservation of specimens. The applicant is committed to using vessels with engines that are in proper working order which will reduce the likelihood of catastrophic spill. Most oil and hydrocarbons associated with fuel floats on water, and eventually evaporates, but would not sink to the bottom where coral live.

6.2.3 Disease, parasites, and nuisance and invasive species

Coral colonies are affected by diseases, parasites, and nuisance and invasive species[2]. Sampling from one colony to another, and across one area to another, could result in cross contamination. To prevent the spread of disease, parasites, and nuisance and invasive species; the researchers will avoid sampling from colonies that are diseased, and sterilize equipment between collection sites.

6.2.4 Turbidity

The activities during collection could cause temporary plumes of turbidity where suspended sediments could smother colonies or settle onto their skeletons which could stress colonies at various levels, resulting in a range of effects from benign nuisance to reduced survival or death. The proposed research will use scuba divers to collect coral samples who will take precautions to minimally disturb the bottom or surrounding substrate, thus minimizing the amount of sediment displaced.

6.3 Response Analysis

6.3.1 Direct physical impacts

Hard corals occasionally break naturally due to wave action or other factors, and depending on the severity of the break or the age and condition of the colony, the injuries could heal completely, could cause the colonies to become stressed for a period of time, or die.

Loss of tissue and subsequent regrowth of coral tissues has energetic costs that could slow other growth and reproduction, exposed areas of coral skeleton are prone to bioerosion and overgrowth by algae and certain sponges, and damaged and stressed tissue may be more susceptible to infection by coral diseases that may hinder or prevent healing to the point that the colony dies.

[2] Nuisance and invasive species are species that either prey on or compete with coral colonies. They also are noted to have "infestations" that can overwhelm other species and disrupt the ecological stability of the habitat. Nuisance species are native or indigenous to the area while non-native species are labeled as invasive species.

However, colonies can continue to exist even if numerous polyps die, or if the colony is broken apart or otherwise damaged. The sampling described in this opinion would potentially injure and negatively affect colony polyps, but given the small sample size (and associated sampling protocol), and the colonial nature of corals, no significant injury would occur to any colony, and the proposed specimen samples are not expected to represent a serious threat to the health or survival of the colony sampled.

As fragments are snipped or broken off from a colony, wounds are exposed to the surrounding aquatic environment. Wounds often heal naturally but can subject the colony to reduced fitness in three ways. First, regeneration requires energy so that resources may be diverted from growth and reproduction (e.g., Kobayashi, 1984; Rinkevich and Loya, 1989; Meesters et al., 1994; Van Veghel and Bak, 1994). Secondly, colony survival may be hindered because injuries provide sites for the entry of pathogens and bioeroders and space for the settlement of other organisms such as algae, sponges, and other corals (Bak et al., 1977). Third, injuries reduce the surface area available for feeding, photosynthesis and reproduction (e.g. Jackson and Palumbi, 1979; Wahle, 1983; Hughes and Jackson, 1985).

Coral species vary in their ability to heal, depending on their growth form, their surrounding environment, their competition within the reef, and severity of the wound. To minimize stress to any colony, and to maximize wound healing and survival; the researchers are proposing to limit collection of fragments to colonies that are large enough to withstand an injury, and to ensure that no more than 20 % of any colony would be collected.

6.3.2 Hazardous chemicals and materials

While exposure to hazardous chemicals and materials can potentially harm coral colonies, we expect the probability of exposure of oil or other hazardous chemicals associated with vessels to be extremely low. By ensuring that all small vessels used will be in proper working condition, the applicant will avoid the most likely source of contamination of the marine environment associated with the proposed research. In addition, no hazardous chemicals or materials would be required during the sampling of any coral colony. Therefore, we expect the risks of exposure to any hazardous chemicals or materials associated with this proposed research to be discountable.

Disease, parasites, and nuisance and invasive species

No samples will be collected from coral colonies that have visible signs of disease. In addition, adherence to the sampling and sterilization protocols will further avoid the likelihood of spreading diseases between coral colonies, and the transfer of parasites, and nuisance and invasive species. Therefore, we have determined that the likelihood of the spread of disease, parasites, and nuisance and invasive species from the proposed research activities are discountable.

6.2.3 Turbidity

All of the researchers participating in this research are skilled divers, and have considerable experience in performing the proposed research activities. The researchers will employ diving practices that will avoid or minimally disturb sediments, and are therefore not likely to create plumes that are severe enough to significantly change the likelihood of survival of any listed coral colony in the action area in any meaningful way. We have therefore determined that the effects from turbidity would be insignificant.

6.4 Risk Analysis

In the last part of our analysis, we consider the stressors the species are likely to be exposed to, their likely response, and finally the risk of the project's effects to the species. We do not expect the ESA-listed coral species in Table 2 to be affected by the hazardous chemicals and materials, diseases and parasites, or turbidity. The only stressor we expect these species to be affected by is direct contact or breakage of fragments from a colony. With the implementation of conservation measures described in the BE and this opinion, we expect the majority of the wounds from the colonies to heal, and most colonies to survive fragment breakage. However, although extremely unlikely, it is possible that some colonies may experience reduced survival or reproductive success, and some may die.

NMFS believes that the magnitude and intensity of the impact from the directed take of voucher coral specimens from would be mitigated by the following factors: 1) The small number of colonies from which specimen material would be collected compared to the estimated abundance of the species; 2) The use of random sample design (REA sites are randomly chosen so revisiting the same site and repeatedly harming the same colony or local population is unlikely); and 3) The strict adherence to Best Management Practices for sampling coral species which includes: sampling no more than one specimen of the target taxa present at any of the survey sites and not sampling if it is judged that collection may inhibit the capacity of the colony to replenish itself.

The proposed sampling protocol would result in a fraction of a colony being collected (never more than 20 %), and as the research previously mentioned has shown, this may result in temporary loss of fitness (reduction of reproductive or growth potential), the colony should recover over time. Also, although the risk of the colony succumbing to disease exists, research described above has shown that the likelihood is low. We therefore conclude that the proposed action presents negligible risk to the overall species. NMFS considers the risk negligible that project-related effects from sampling the coral colonies would appreciably reduce the likelihood of the survival and recovery of the species in the action area, and across their global range.

7 CUMULATIVE EFFECTS

Cumulative effects are limited to the effects of future State, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this opinion (50 CFR 402.02). Cumulative effects, as defined in the ESA, do not include the continuation of actions described under the Environmental Baseline, and future Federal actions that are unrelated to the proposed action are not considered in this section.

The impacts from fisheries, vessel groundings, pollution, and marine debris (as described in the Environmental Baseline section) within the NMSAS and RAMNM are expected to be minimal. The managers of the Sanctuary and the monument are authorized to provide opportunities for research and exploration; but unauthorized access, except for innocent passage or other internationally recognized uses of the seas, is not permitted. This regulatory environment limits the number of vessels and researchers that will have access to these areas, and thereby reduces the risk from groundings, pollution and marine debris.

Anthropogenic release of CO_2 and other greenhouse gases is considered the largest contributor to global climate change, and it is expected that the release of those gases is not only likely to continue, but the rate of their release is expected to increase during the next century (Brainard *et al*. 2011), unless substantial changes are made to lower the emission of greenhouse gases and to slow the pace of deforestation. The earth is committed to a certain level of additional warming because of the level of greenhouse gases already emitted; therefore, global climate change is expected to continue to impact coral species, especially those species that are dependent on shallow coastal reefs and shorelines. There is uncertainty associated with the analysis of potential impacts of climate change on species and ecosystems (Barnett 2001). The effects of climate change will not be globally uniform (Walther *et al.* 2002) and information regarding the magnitude of future climate change is speculative and fraught with uncertainties (Nicholls and Mimura 1988).

In particular, there is no comprehensive assessment of the potential impacts of climate change within the action area. In addition to the uncertainty of the rate, magnitude, and distribution of future climate change and its associated impacts, ecological systems evolve in an ongoing fashion in response to stimuli of all kinds, including climatic stimuli (Smit *et al.*, 2000). Therefore, the 'seriousness' of climate change impacts may be modified by adaptations of various kinds (Tol *et al.*, 1998). However, the adaptability of species and ecosystems are also unknown.

For example, research has indicated that corals may be able to expel less tolerant symbionts, and replace them with those that are more heat tolerant (Baker *et al*., 2004; Oliver and Palumbi, 2010). And, while it is possible that warmer ocean temperatures may extirpate corals from areas they currently occupy, there is also the possibility that some species may be able to colonize areas that are presently uninhabitable due to changes in water temperature, chemistry, or other factors.

Impact assessment models that include adaptation must make assumptions (about when, how, and to what conditions adaptations might occur) based on theoretical principles, inference from observations, and arbitrary selection, speculation, or hypothesis (see review in Smit *et al*, 2000).

The effects of global climate change (the most significant of which for corals are the combined direct and indirect effects of rising sea surface temperatures and ocean acidification) are currently affecting corals on a global scale, particularly in parts of the Caribbean. Thermal stress can induce bleaching (where the coral expels its symbiotic zooxanthellae), which often causes mortality of the affected colony. Increased ocean acidity is thought to adversely affect fertilization, larval settlement, and zooxanthellae acquisition rates for many corals, and for some species it can induce bleaching more so than thermal stress. It also tends to decrease growth and calcification rates. The return frequency of bleaching events at some sites has exceeded the ability of the reefs and coral species to recover there. Brainard *et al*. (2011) report that those effects likely represent the greatest risk of extinction to ESA corals over the next century.

Field observation and models both predict increasing frequency and severity of bleaching events, causing greater coral mortality and allowing less time to recover between events. Therefore, the effects of global climate change could have synergistic effects on impacted corals within the action area. The ability of impacted corals to recover from the effects of the proposed action could be reduced due to the effects of elevated temperatures and increased ocean acidity, and the longer it takes for impacted corals to recover from the effects of the proposed action, the more likely it becomes that the effects of climate change would synergistically impact those corals. However, the degree to which those synergistic impacts may affect corals over the time required for them to recover from project impacts is unknown.

NMFS expects that recovery following the end of sampling activities would be relatively fast, and the possible synergistic impacts of climate change combined with the effects of the proposed action are not expected to be significant for the corals considered in this opinion.

8 INTEGRATION AND SYNTHESIS OF EFFECTS

The purpose of this biological opinion is to determine if the proposed action is likely to have direct or indirect effects on threatened and endangered species that appreciably reduce their likelihood of surviving and recovering in the wild by reducing their reproduction, numbers, or distribution (50 CFR 402.02), otherwise known as the jeopardy determination. This is done by considering the effects of the action within the context of the 'Status of Listed Species' together with the 'Environmental Baseline' and the 'Cumulative Effects', as described in the Approach section (beginning of Section 6 Effects of the Action).

We determine if mortality of individuals of listed species resulting from the proposed action is sufficient to reduce the viability of the populations those individuals represent (measured using changes in the populations' abundance, reproduction, spatial structure and connectivity, growth rates, or variance in these measures to make inferences about the population's extinction risks).

In order to make that determination, we use a population's base condition (established in the Status of Listed Species and Environmental Baseline sections of this opinion) as context for the overall effects of the action on affected populations. Finally, our opinion determines if changes in population viability, based on the Effects of the Action and the Cumulative Effects, are likely to be sufficient to reduce viability of the species those populations comprise. The following discussion summarizes the probable risk the proposed action poses to the coral species identified in Section 3.

As described in the Effects of the Action section, the directed take of voucher specimens of corals as proposed for the Mesophotic Coral Ecosystems of America Samoa would result in, at the most, 50 specimens of each species. *A. globiceps*, *A. jacquelineae*, *A. retusa*, and *A. speciosa* would have a total specimen tissue area removed of 1,650 cm^2 each. *E. paradivisa* would have a total specimen tissue area removed of 628 cm^2, *I. crateriformis* would have a total specimen tissue area removed of 3,925 cm^2, and *Pavona diffluens* would have a total specimen tissue area removed of 5,338 cm^2. A total specimen tissue area of up to 16,311 cm^2 would be removed for all species combined. None of the individual specimens will constitute a complete colony. As these species are uncommon in the action area, and this represents a maximum number samples that would be collected.

No complete colony would be collected, and in no case will specimens be collected from a colony if it is judged that doing so might inhibit the capacity of the colony to replenish itself. Although the removal of a portion of the colony does make the colony more susceptible to disease or algal infection, and there may be some short-term reduction in fitness of the colony, the sample does not represent a significant threat to the health or survival of the colony.

As discussed in the Status of the Species, the ESA-listed coral species listed in Table 2 are distributed throughout much of the Indo-Pacific and have been described as common and relatively widespread in its north-south range.

Acropora globiceps occurs across 22 different ecoregions encompassing 20 different countries and territories, with a range estimate of 5 million km^2. The species abundance has been estimated in the tens of millions of colonies. Although considered common and widespread, the species has been described as restricted in its east-west distribution, and limited in the habitats it occupies. Colonies are generally found on upper reef slopes and reef flats, and within these habitats the species has a limited depth range of 0 – 8 m.

Acropora jacquelineae has been reported across much of the central Indo-Pacific, encompassing 12 ecoregions from 5 countries and territories. Estimates for the species have put its range at approximately 2 million km^2, and its population in the tens of millions, with an effective population size of over 3 million. The species can be found in numerous habitats, and in a wide depth range, but has been reported as uncommon in the habitats that it occupies.

Acropora retusa occurs across a wide range globally, and occurs in 23 Indo-Pacific ecoregions that span more than 30 countries and territories. Estimates have put the species range at 68 million km^2, and its population at over a million colonies. The species reportedly occupies numerous habitats, but has a limited depth range of 1 – 5 m, and although it has been reported as common in South Africa, it has been described as uncommon across the rest of its range.

Acropora speciosa occurs across much of the western Pacific, and has been reported in 26 Indo-Pacific ecoregions that span 16 countries and territories. Estimates have put the species range at 20 million km^2, and its total population at over 10 million colonies, and its effective population size of over a million colonies.

Euphyilla paradivisa has a restricted range, limited only to the Coral Triangle Region. The species range covers 8 ecoregions, across 15 countries and territories. Although limited in range, the species occupies several various habitats and has a moderate depth range of 2 – 25 m. The species absolute abundance has been estimated at tens of millions of colonies.

Isopora crateriformis, but the species appears to range from Sumatra to American Samoa, an area encompassing over 11 million km^2, 13 Indo-Pacific ecoregions, and 18 countries and territories. It is estimated that the species has an absolute abundance of at least a few million colonies.

Pavona diffluens has a restricted distribution, occurring in the Red Sea and the Arabian Gulf, but recently has been reported in the Western Pacific in American Samoa and the Northern Marianas. At a minimum the species range encompasses five Indo-Pacific regions across 14 countries and territories, but may be larger based on recent findings. The species occupies several different habitat types, and a depth range of 5 – 20 m. The absolute abundance of the species is estimated to be at least a few million colonies.

As discussed in the Environmental Baseline and Cumulative Effects sections the effects of fisheries, vessel groundings, pollution and marine debris, although possible, are expected to be minimal due to the regulatory environment in place for the Sanctuary and monument. This is not expected to change significantly in the future, even if the request for access increases, as the managers have protection of the resources as their primary responsibility. Climate change impacts will continue, and likely accelerate, as the world's oceans continue to warm and its chemistry changes. However, the impact and time scale of these effects on the trajectory of the affected coral populations in the action area, and across the species range is currently uncertain, and those impacts are expected to occur on a time scale against which the impacts of the proposed action would be indistinguishable.

We considered to what extent the effects of the action affect survival and recovery of this species. The NMFS and USFWS' ESA Section 7 Handbook (USFWS and NMFS 1998) provides further definitions for *survival* and *recovery*, as they apply to the ESA's jeopardy standard.

Survival means: the species' persistence beyond the conditions leading to its endangerment, with sufficient resilience to allow recovery from endangerment. Said another way, survival is the condition in which a species continues to exist into the future while retaining the potential for recovery. This condition is characterized by a species with a sufficiently large population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, which exists in an environment providing all requirements for completion of the species' entire life cycle, including reproduction, sustenance, and shelter.

Recovery means: improvement in the status of a listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act. Said another way, recovery is the process by which species' ecosystems are restored and/or threats to the species are removed so self-sustaining and self-regulating populations of listed species can be supported as persistent members of native biotic communities.

While there is likely to be a temporary reduction to a sampled colonies reproduction and growth potential, and a small chance of a sampled colony succumbing to disease, the proposed action is expected to have a negligible effect on the species resilience, reproduction, and it is not expected to reduce its numbers, or distribution, or impact its size classes, or genetic heterogeneity.

No recovery plan currently exists for these species against which we can assess the effects of the proposed action on recovery. However, given that impacts from the proposed action are expected to result in minimal injury, with no expected loss of a colony as a result of sampling, the proposed action is not expected to significantly impact reproduction or to impede the recovery of any ESA-listed species in Table 2. We do not expect the proposed action to affect the ability of the overall species' populations to grow and to successfully reproduce. The proposed action is expected to have no appreciable effect on the overall size of the populations. We do not expect the proposed action to negatively affect the species' ability to meet their lifecycle requirements, or their recovery.

In summary, the proposed action is not likely to eliminate any coral species in any sampling area, or appreciably reduce the likelihood of their survival and recovery across the action area. When taken in context with the status of these species, the environmental baseline, cumulative impacts and effects, the proposed action is not expected to cause an appreciable reduction in the likelihood of both the survival and recovery of the species in the wild.

9 CONCLUSION

The purpose of this biological opinion is to determine if the proposed action is likely to jeopardize the continued existence of listed species (i.e., jeopardy determination) or result in destruction or adverse modification of designated critical habitat. "Jeopardize the continued existence of" means "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02).

After reviewing the current status of the coral species *Acropora globiceps*, *Acropora jacquelineae*, *Acropora retusa*, *Acropora speciosa*, *Euphyllia paradivisa*, *Isopora crateriformis*, and *Pavona diffluens*, the environmental baseline for the action area, the effects of the proposed action, and the cumulative effects, it is NMFS' opinion that directed-take of voucher specimens of *Acropora globiceps*, *Acropora jacquelineae*, *Acropora retusa*, *Acropora speciosa*, *Euphyllia paradivisa*, *Isopora crateriformis*, and *Pavona diffluens* as part of the Mesophotic Coral Ecosystems of America Samoa in not likely to jeopardize the continued existence of any of those species considered in this opinion. As described in Section 4 above, no critical habitat has been designated or proposed for designation for any of the coral species analyzed. Therefore, the proposed action would have no effect on designated or proposed critical habitat.

10 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and protective regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species without a special exemption. “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct. “Incidental take” is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the reasonable and prudent measures and terms and conditions of the Incidental Take Statement (ITS).

The proposed action results in the directed take of the listed species (see Table below). Currently there is no take prohibition for any of the species in this table. An ITS is not required to provide an exemption to incidental take, the take is not incidental take. Consistent with the decision in *Center for Biological Diversity v. Salazar*, 695 F.3d 893 (9^{th} Cir. 2012), however, this ITS is included to serve as a check on the no-jeopardy conclusion by providing a re-initiation trigger so the action does not jeopardize the species if the level of take analyzed in the biological opinion is exceeded.

10.1 Anticipated Amount or Extent of Incidental Take

The directed take of voucher specimens of corals as proposed for the Mesophotic Coral Ecosystems of America Samoa would result in, at the most, 50 specimens of each species. A. globiceps, *A. jacquelineae*, *A. retusa*, and *A. speciosa* would have a total specimen tissue area removed of 1,650 cm^2 each. *E. paradivisa* would have a total specimen tissue area removed of 628 cm^2, *I. crateriformis* would have a total specimen tissue area removed of 3,925 cm^2, and *Pavona diffluens* would have a total specimen tissue area removed of 5,338 cm^2. A total specimen tissue area of up to 16,311 cm^2 would be removed for all species combined. Sampling protocols would require that no more than 20 % of any colony sampled be taken, and that no samples be taken from any colony found to be diseased. While the risk of a sampled colony dying exists, NMFS has determined that the risk is low; and therefore, the amount of take will be limited to the samples collected.

10.2 Reasonable and Prudent Measures

In order to ensure the federal action agency is tracking take and is not violating the no jeopardy conclusion of this biological opinion, the federal action agency must follow the reasonable and prudent measure described below, along with terms and conditions found in section 10. 3. These measures are non-discretionary—they must be undertaken by the NCCOS.

1. NCCOS shall collect information documenting the take of coral species during directed research activities.

10.3Terms and Conditions

NCCOS shall undertake and comply with the following term and condition to implement the reasonable and prudent measure identified in Section 9.1 above. This term and condition is non-discretionary, and if NCCOS fails to adhere to this term and condition, the protective coverage of this biological opinion may lapse.

1. NCCOS shall collect data on the exact coral species (including number of colonies) sampled and the total size of specimens sampled during directed coral research. This information will include a summary of observed effects to the coral sampled and the condition of the coral after the sampling was completed. NCCOS will use these data to ensure they have not exceeded the level of take proposed and found in the Description of the Proposed Action and Action Area section of this biological opinion. NCCOS will submit this this information to the Pacific Islands Regional Office Protected Resources Division Section 7 Program within a reasonable time after the research has concluded.

11 CONSERVATION RECOMMENDATIONS

The Protected Resources Division of the NMFS Pacific Islands Regional Office has reviewed the information contained in the BE provided by the NCCOS for the proposed funding of the Mesophotic Coral Ecosystems of American Samoa research, and believe the BMPs already in place for the proposed research do not warrant any further recommendations from our office with regards to this action.

12 RE-INITIATION STATEMENT

This concludes formal consultation on the NCCOS proposed funding for the Mesophotic Coral Ecosystems of America Samoa. As provided in 50 CFR 402.16, re-initiation of formal consultation is required where discretionary Federal agency involvement over the action has been retained or is authorized by law, and if:

1. The amount or extent of anticipated take for any species is exceeded;
2. New information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion;

3. The agency action is subsequently modified in a manner that may affect listed species or critical habitat to an extent in a way not considered in this opinion; or
4. A new species is listed or critical habitat designated that may be affected by the action.

13 LITERATURE CITED

Albright, R., Mason, B., Langdon, C. 2008. Seawater carbonate chemistry, larval settlement and growth rate during experiments with coral *Porites astreoides*, 2008. PANGAEA, https://doi.org/10.1594/PANGAEA.726961

Albright, R., B. Mason, M. Miller, and C. Langdon. 2010. Ocean acidification comprises recruitment of the threatened Caribbean coral, *Acropora palmata*. Proceedings of the National Academy of Sciences 107:20400-20404.

Anderson, J. J. 2000. A vitality-based model relating stressors and environmental properties to organism survival. Ecological Monographs 70(3):445-470.

Anthony, K., D. Kline, G. Diaz-Pulido, S. Dove, and O. Hoegh-Guldberg. 2008. Ocean acidification causes bleaching and productivity loss in coral reef builders. Proceedings of the National Academy of Sciences 1-5:17442-17446.

Aronson, R. and W. Precht. 2001. White-band disease and the changing face of Caribbean coral reefs. Hydrobiologica 460:25-38.

Babcock, R. C., 1991: Comparative demography of three species of scleractinian corals using age- and size-dependent classifications. – Ecol. Monogr. 61: 225–244.

Bak, R. P. M., J. J. W. M. Brouns and F. M. L. Heys, 1977: Regeneration and aspects of spatial competition in the scleractinian corals *Agaricia agaricites* and *Montastrea annularis*. – Proceedings of the Third International Coral Reef Symposium, Miami: 143–148.

Barnett, J. 2001. Adapting to climate change in the Pacific countries: The problem of uncertainty. World Development 29(6):977-993.

Behrenfeld, M., R. O'Malley, D. Siegel, C. McClain, J. Sarimento, G. Feldman, A. Milligan, P. Falkowski, R. Letelier, and E. Boss. 2006. Climate-driven trends in contemporary ocean productivity. Nature 444:752-755.

Bellwood D.R., and J.A. Choat. 1990. A functional analysis of grazing in parrotfishes (family Scaridae): the ecological implications. Environ Biol Fish 28:189–214.

Brainard, R., C. Birkland, C. Eakin, P. McElhany, M. Miller, M. Patterson, and G. Piniak. 2011. Status review report of 82 candidate coral species petitioned under the U.S. Endangered Species Act. U.S. Dept. Commerce, NOAA Tech. Memo., NOAA-TM-NMFS-AGENCY-27, 530 p. + 1 Appendix.

Brown, B. E., 1994: Solar damage in intertidal corals. – Mar. Ecol. Prog. Ser. 105: 219–230.

Bruckner, A. and R. Hill. 2009. Ten years of change to coral communities off Mona and Desecheo Islands, Puerto Rico, from disease and bleaching. Dis. Aquat. Org. 87:19-31.

Bruno, J., E. Selig, K. Casey, C. Page, B. Willis, C. Harvell, H. Sweatman, and A. Melendy. 2007. Thermal stress and coral cover as drivers of coral disease outbreaks. PLoS Biol. 5:e124.

Carpenter. K., M. Abrar, G. Abey, R. Aronson, S. Banks, A. Bruckner, A. Chiriboga, J. Cortes, J. Delbeek, L. DeVantier, G. Edgar, A. Edwards, D. Fenner, H. Guzman, B. Hoeksema, G. Hodgson, O. Jojan, W. Licuanan, S. Livinstone, E. Lowell, J. Moore, D. Ohura, D. Ochivallo, B. Polidoro, W. Precht, M. Quibilan, C. Reboton, Z. Richards, A. Rogers, j. Sanciangco, A. Sheppard, C. Sheppard, J. Smith, S. Stuart. E. Turak, J. Veron, C. Wallace, E. Weil, and E. Wood. 2008. One-third of reef building corals face elevated extinction risk from climate change and local impacts. Science 321:560-563.

Craig, P. C. Birkeland, and S. Belliveau. 2001. High temperature tolerated by a diverse assemblage of shallow-water corals in American Samoa. Coral Reefs 20:185-189.

Craik, W., R. Kenchington and G. Kelleher, 1990. Coral-Reef Management. In, Ecosystems of the world, coral reefs, edited by Z. Dubinsky, Elsevier Science Publishers, N.Y. pp. 453-467.

Code of Federal Register. 50 CFR Part 223 (Vol. 79, No. 175, September 10, 2014). Endangered and threatened wildlife and plants: final listing determination on proposal to list 66 reef-building coral species and to reclassify elkhorn and staghorn corals, final rule.

CRCP. 2015. Biological Evaluation. Mesophotic threatened coral species study. NOAA Coral Reef Conservation Program. April 30.

Glynn, P. and S. Colley. 2001. A collection of studies on the effects of the 1997-98 El Nino-Southern Oscillation event on corals and coral reefs in the eastern tropical Pacific. Bull. Mar. Sci. 69:1-288.

Hoegh-Guldberg, O., P. Mumby, A. Hooten, R. Steneck, P. Greenfield, E. Gomez, C. Harvell, P. Sale, A. Edwards, K. Caldeira, N. Knowlton, C. Eakin, R. Iglesias-Preito, N. Muthiga, R. Bradbury, A. Dubai, and M. Hatziolos. 2007. Coral reefs under rapid climate change and ocean acidification. Science 318:1737-1742.

Hughes, T. P. and J. B. C. Jackson, 1985: Population dynamics and life histories of foliaceous corals. – Ecol. Monogr. 55: 141–166.

Hughes, T.P., 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean reef. Science, Vol. 265, pp. 1547–1551.

IUCN. 2010. IUCN Red List of Threatened Species. Version 3.1 Page ii + 3pp. Page: http://www.iucnredlist.org/. IUCN Species Survival Commission.

Jackson, J. B. C. and S. R. Palumbi, 1979. Regeneration and partial predation in cryptic coral reef environments: preliminary experiments on sponges and ectoprocts. – In: Levis, C. and N.

Boury-Esnault (Eds.) Biologie des Spongiaires: Colloques Internationaux du Centre National de la Recherche Scientifique 291, Paris, pp. 303–308.

Kobayashi, A., 1984: Regeneration and regrowth of fragmented colonies of the hermatypic coral *Acropora formosa* and *Acropora nasuta*. – Galaxea 3: 13–23.

Lovell, E. 2001 Reef Check description of the 2000 mass coral bleaching event of Fiji with reference to the South Pacific. Unpubl report to the University of Rhode Island.

Mate, J. 2003. Ecological, genetic, and morphological differences among three *Pavona* (Cnidaria: Anthozoa) species from the Pacific coast of Panama. Mar. Biol. 142:427-440.

Manzello, D. 2010. Coral growth with thermal stress and ocean acidification: lessons from the eastern tropical Pacific. Coral Reefs 29:749-758.

Marshall, P. and A. Baird. 2000. Bleaching of corals on the Great Barrier Reef: differential susceptibilities among taxa. Coral Reefs 19:155-163.

Marubini, F., C. Ferrier-Pages and J. Cuif. 2003. Suppression of skeletal growth in scleractinian corals by decreasing ambient carbonate-ion concentration: a cross-family comparison. Proceedings of the Royal Society of London. Series B: Biological Sciences 270:179-184.

Maynard, JA, S. McKagan, S. Johnson, P. Houk, G. Ahmadia, R. van Hooidon, L. Harriman, and E. Mcleod. 2012. Coral reef resilience to climate change in Saipan, CNMI; field-based assessments, and implications for vulnerability and future management. Prepared for CNMI DEQ and NOAA as part of the Northern Mariana Islands Coral Reef Initiative with The Nature Conservancy, Pacific Marine Resources Institute and the CNMI Division of Fish and Wildlife as collaborating agencies. 126 pages.

Maynard, J., S. McKagan, L. Raymundo, S. Johnson, G. Ahmadia, L. Johnston, P. Houk, G. Williams, M. Kendall, S. Heron, R. van Hooidonk, and E. McLeod. 2015. Assessing relative resilience potential of coral reefs to inform management in the Commonwealth of the Northern Mariana Islands. Prepared for CNMI BECQ, NOAA and PICSC of USGS as part of the Northern Mariana Islands Coral Reef Initiative with The Nature Conservancy, Pacific Marine Resources Institute and University of Guam Marine Laboratory as collaborating agencies. 154 pages.

McClanahan, T., M. Ateweberhan, N. Graham, S. Wilson, C. Sebatian, M. Guillaume, and J. Bruggemann. 2007. Western Indian Ocean coral communities: bleaching responses and susceptibility to extinction. Mar. Ecol. Prog. Ser. 337:1-13.

McClanahan, T., J. Maina, R. Moothien-Pillay, and A. Baker. 2005a. Effects of geography, taxa, water flow, and temperature variation on coral bleaching intensity in Mauritius. Mar. Ecol. Prog. Ser. 298:131-142.

Meesters, E. H., M. Noordeloos and R. P. M. Bak, 1994: Damage and regeneration: links to growth in the reef-building coral *Montastrea annularis*. – Mar. Ecol. Prog. Ser. 112: 119–128.

Mills, S. K. and J. H. Beatty. 1979. The propensity interpretation of fitness. Philosophy of Science 46:263-286.

NCCOS. 2019. Biological Evaluation and request to re-initiate the Section 7 consultation for the Mesophotic Coral Ecosystems of American Samoa from Kimberly Puglise (National Centers for Coastal Ocean Sciernce) to Ann Garrett (Protected Resources Division, Pacific Islands Regional Office).

Nicholls, R. and N. Mimura. 1998. Regional issues raised by sea level rise and their policy implications. Climate Research 11:5-18.

PIRO, 2015. Biological Opinion from the National Marine Fisheries (NMFS) Pacific Islands Regional Office to the NMFS Coral Reef Conservation Program for the Mesophotic Coral Ecosystems of America Samoa.

Pörtner, H. O., Langenbuch, M. and Reipschläger, A. (2004). Biological impact of elevated ocean CO^2 concentrations: lessons from animal physiology and earth history. J. Oceanogr. 60, 705-718.

Renegar, D.and B. Riegel. 2005. Effect of nutrient enrichment and elevated CO2 partial pressure on growth rate of Atlantic scleractinian coral *Acropora cervicornis*. Mar. Ecol. Prog. Ser. 293:69-76.

Richards, Z. 2009. Rarity in the coral genus *Acropora*: implications for biodiversity conservation. PhD James Cook University.

Rinkevich, B. and Y. Loya, 1989: Reproduction in regenerating colonies of the coral *Stylophora pistillata*. – In: Spanier, E., Y. Steinberger and M. Luria (Eds.) Environmental Quality and Ecosystem Stability: Vol. IV–B. Environmental Quality Israel Society for Ecology and Environmental Quality Sciences, Jerusalem, pp. 257–265.

Schneider, K. and J. Erez. 2006. The effect of carbonate chemistry on calcification and photosynthesis in the hermatypic coral *Acropora eurystoma*. Limnol. Oceanogr. 51:1284-1293.

Solomon, S., D. Qin, M. Manning, K. Averyt, M. Tignor and H. Miller (eds.) 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Smit, B. I. Burton, R. Klein, and J. Wandel. 2000. An anatomy of adaption to climate change and variability. Climatic Change 45:223-251.

Stearns, S. C. 1992. The evolution of life histories. Oxford University Press, 249p

Tol, R., S. Fankhauser, and J. Smith. 1998. The scope for adaptation to climate change: what can we learn from impact literature? Global Environmental Change 8(2):109-123.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. Endangered Species Consultation Handbook. Procedures for Conducting Consultation and Conference Activities Under Section 7 of the Endangered Species Act. http://www.nmfs.noaa.gov/pr/pdfs/laws/esa_section7_handbook.pdf

Van Veghel, M. L. J. and R. P. M. Bak, 1994: Reproductive characteristics of the polymorphic Caribbean reef building coral *Montastrea annularis*. III. Reproduction in damaged and regenerating colonies. – Mar. Ecol. Prog. Ser. 109: 229–233.

Veron, J., 2000. Corals of the World. Australian Institute of Marine Science. Townsville, Australia 3 volumes.

Veron, J. 2014. Results of an update of the corals of the World Information Base for the listing determination of 66 coral species under the Endangered Species Act (ESA). Report to the Western Pacific Regional Fishery Management Council. Honolulu: Western Pacific Regional Fishery Management Council. 11pp. + Appendices.

Wahle, C. M., 1983. Regeneration of injuries among Jamaican gorgonians: the roles of colony physiology and environment. Biol. Bull. 165: 778–790.

Wallace, C. 1999. Staghorn corals of the world: a revision of the coral genus *Acropora* (Scleractinia; Astrocoeniina; Acroporidae) worldwide, with emphasis on morphology, phylogeny, and biogeography, CSIRO Publishing, Collingwood, Australia.

WDCGG. 2010. World Data Center for Greenhouse Gases. Accessed at http://gaw.kishou.go.jp/wdcgg/.