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

NOAA Technical Memorandum NMFS-F/SPO-211
December 2020

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Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, Ph.D., Acting NOAA Administrator

National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

Recommended citation:

M. D. Lettrich, D. M. Dick, C. C. Fahy, R. B. Griffis, H. L Haas, T. T. Jones, I. K. Kelly, D. Klemm, A. M. Lauritsen, C. R. Sasso, B. Schroeder, J. A. Seminoff, and C. M. Upite. 2020. A Method for Assessing the Vulnerability of Sea Turtles to a Changing Climate. NOAA Tech. Memo. NMFS-F/SPO-211, 82 p.

Copies of this report may be obtained from:

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Executive Summary

The National Marine Fisheries Service (NMFS), together with the U.S. Fish and Wildlife Service (USFWS), have mandates to protect and recover sea turtle species listed under the Endangered Species Act (ESA). Climate change and environmental variability are key stressors affecting sea turtle conservation. Sea turtle populations are expected to respond to climate change and environmental variability in a variety of ways that may manifest as shifts in distribution, population structure, abundance, and/or phenology. However, there is a lack of specific information on climate-related impacts for many populations, and there are few methods specifically designed to assess the vulnerability of sea turtle populations. Vulnerability assessments can help provide that climate-related information, and the NMFS Climate Science Strategy[1] and Regional Action Plans[2] recommend conducting vulnerability assessments for living marine resources, including sea turtles. Therefore NMFS, with input from USFWS, developed a method to simultaneously assess the climate vulnerability of multiple sea turtle populations to help fill critical information gaps and identify candidate populations for targeted climate-related research.

The method described in this study follows the model of the NMFS methods for Marine Fish and Shellfish Climate Vulnerability Assessments[3] and the Marine Mammal Climate Vulnerability Assessments[4]. It uses existing information and expert elicitation to assess sea turtle populations' exposure, sensitivity, and adaptive capacity to climate change and variability. Exposure to climate change is assessed by scoring projected changes in climate conditions within a population's current distribution. Sensitivity and adaptive capacity to climate change are assessed based on current understanding of a population's life history traits.

An expert working group identified relevant climate exposure factors and life history traits. A separate working group defined scoring criteria for each climate exposure factor and life history trait to differentiate between sea turtle populations. The assessment method was first pilot-tested with sea turtle populations occurring within the Pacific Ocean. We revised and updated the final approach used in this study based on input received during the pilot test.

Prior to the full assessment, we acquired maps showing the projected change in the climate exposure factors and overlaid current population distribution data. We assembled background narratives summarizing the existing literature available for the life history traits for each population.

A team of sea turtle experts individually scored climate exposure as a function of the magnitude of projected climate change within the current distribution using a four-point scale. The team members then individually scored sensitivity (combined with adaptive capacity) using the provided background information and their own knowledge using a similar four-point scale. Team members also assessed the quality of the underlying data used to score each factor and attribute. After compiling individual scores, the team met to discuss differences in scoring and individually revised scores as necessary. The team identified potential differences in the

[1] https://www.fisheries.noaa.gov/national/climate/noaa-fisheries-climate-science-strategy
[2] https://www.fisheries.noaa.gov/national/climate/climate-science-strategy-regional-action-plans
[3] https://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/TM%20OSF3.pdf
[4] https://spo.nmfs.noaa.gov/sites/default/files/TMSPO196_508.pdf

interpretation of available information to ensure a common understanding of each attribute and factor but did not work toward consensus.

We then aggregated the scores and calculated a weighted mean score for each life history trait and climate exposure factor for each population. We combined these weighted mean scores of climate exposure factors and life history traits into an overall exposure score and an overall sensitivity score, respectively, using a logic model. Finally, we calculated a climate vulnerability score for each population by combining a population's climate exposure score and climate sensitivity score using a vulnerability matrix.

The assessment method was applied to sea turtle populations defined as Distinct Population Segments[5] (DPSs) under the ESA or Regional Management Units (RMUs) as identified in Wallace et al. (2010), where DPSs are not designated. The assessment produced a list of populations ranked by vulnerability to climate change. Each population received a vulnerability profile that summarized the distribution of expert scores for each life history attribute and climate exposure factor, and identified variables that contribute the most to the population's vulnerability. The resulting population-specific profiles will support management decision-making by identifying populations most vulnerable to climate change and the underlying causes of that vulnerability. Similarly, researchers could use assessment results to prioritize research toward specific populations, regions, or attributes to expand our understanding of sea turtle population responses to climate change and the consequences to the broader marine ecosystem. This document details the method we used to conduct the climate vulnerability assessment. We will endeavor to publish the global and population-specific results in a separate, peer-reviewed journal article.

[5] https://www.federalregister.gov/d/96-2639

1 Background

Climate change and environmental variability are impacting species inhabiting coastal and marine environments, resulting in range shifts, changes in local abundance, and variation in timing of life history events (Pinsky et al. 2013, Poloczanska et al. 2013, Brown et al. 2016, Staudinger et al. 2019). Sea turtle populations have been, and will continue to be, affected by changing climate conditions (Hawkes et al. 2009, Hamann et al. 2013, Butler 2019). Some sea turtle populations have shown climate-related shifts in distribution (Hays et al. 2001, Hamann et al. 2007, Maffucci et al. 2016), changes in nesting phenology (Weishampel et al. 2004, Pike et al. 2006, Pike 2009, Weishampel et al. 2010, Lamont and Fujisaki 2014, Neeman et al. 2015), and changes in reproductive rates (Stokes 2014). Projected climate change effects on sea turtles include the alteration of nesting phenology and distribution, reproductive success, hatchling (i.e. primary) sex-ratios, foraging distribution, foraging success, and increased cold-stunning (Fish et al. 2005, Hawkes et al. 2007, Hawkes et al. 2009, Fuentes et al. 2011, Wyneken and Lolavar 2015, Griffin et al. 2019). Some populations have been predicted to change in distribution (Willis-Norton et al. 2015, Wyneken and Lolavar 2015), breeding phenology (Almpanidou et al. 2016, Patel et al. 2016), and abundance (Saba et al. 2012, Montero et al. 2018).

The National Marine Fisheries Service (NMFS), together with the U.S. Fish and Wildlife Service (USFWS), are mandated to protect and recover sea turtle species listed under the Endangered Species Act (ESA). These mandates include the issuance of scientific research permits and take authorizations, interagency Section 7 consultations, recovery planning and implementation, species listings and delistings, critical habitat designations, and status reviews. Consideration of impacts from all possible natural and human-caused stressors on population viability, which is required in ESA-mandated activities, would be incomplete without also considering potential climate change effects (McClure et al. 2013, NMFS 2016). An improved understanding of species responses to changing climate and ocean conditions, including the magnitude and direction of the effect, will help inform and refine management efforts.

Climate vulnerability assessments (CVAs) provide a rapid, general approach to identifying species that may be most vulnerable to climate change and the potential factors contributing to their vulnerability. Typically, CVAs follow a similar framework or structure that combines exposure to a threat, sensitivity to a threat, and capacity to adapt to a threat (i.e. adaptive capacity) (Schneider et al. 2007, Glick et al. 2011, Foden and Young 2016, Foden et al. 2018). To optimize their utility, many CVAs also quantify or qualify the uncertainty associated with the respective assessment effort (Foden et al. 2018).

There have been numerous CVA studies of terrestrial species since the 1990s (e.g., Herman and Scott 1994, Staudinger et al. 2015, Böhm et al. 2016) but relatively few CVAs for species inhabiting marine ecosystems (Pacifici et al. 2015). In the marine environment, fish have been the most common subjects of CVAs to date (e.g., Chin et al. 2010, Johnson and Welch 2010, Foden et al. 2013, Pecl et al. 2014, Hare et al. 2016a), while CVAs for non-fish species have been limited in number and scope (e.g., Hamann et al. 2007, Lawler et al. 2007, Laidre et al. 2008, Fuentes et al. 2011, Sousa et al. 2019, Lettrich et al. 2019).

Other types of studies (e.g., modeling) can offer insight into potential species-specific responses to climate change. However, these approaches are generally resource- and data-intensive and impractical to perform for multiple species concurrently. In light of these resource constraints, CVAs may be used to identify priority species for modeling initiatives (Silber et al. 2017).

The NMFS Climate Science Strategy (Link et al. 2015) and other strategies (e.g., NFWPCAP 2012) call for vulnerability assessments as a first step in assessing risks and developing climate adaptation strategies for natural resources. CVAs were identified in all NMFS Regional Action Plans (Hare et al. 2016b, Lovett et al. 2016, NOAA NW/SW Fisheries Science Centers 2016, Polovina et al. 2016, Sigler et al. 2016) designed to implement the NMFS Climate Science Strategy (Link et al. 2015).

To provide relevant climate-related information for protected species managers, a team of NMFS and USFWS representatives developed a targeted methodology to assess the vulnerability of sea turtles to climate change. Using a similar development process and framework as the Marine Fish and Shellfish Climate Vulnerability Assessment (FCVA) (Morrison et al. 2015, Hare et al. 2016a) and Marine Mammal Climate Vulnerability Assessment (MMCVA) (Lettrich et al. 2019), we adapted the assessment components and scoring criteria to reflect the life histories of sea turtles for the Sea Turtle Climate Vulnerability Assessment (STCVA). Here we present the method and describe its application.

2 Assessment Methodology

2.1 Framework overview and development

The STCVA was designed using a structure and expert-based scoring approach similar to the FCVA and MMCVA and the same nomenclature (i.e., climate exposure factors, sensitivity and adaptive capacity attributes) described by Chin et al. (2010). Our method scored multiple features for two separate components: 1) *exposure to climate change* and 2) *sensitivity to climate change (with adaptive capacity)*. The framework then combined those separate component scores into a *relative vulnerability score* (Fig. 1).

2.1.1 Exposure Component

We defined climate exposure factors as measures of the magnitude of climate change a population is expected to experience. We scored climate exposure factors as a function of the degree of change expected for that factor in areas that overlap with the population's current distribution. For those climate exposure factors that could be modeled spatially, exposure was scored by overlaying current range maps of each population onto the projected climate exposure factor.

Future climate projections are based on scenarios of greenhouse gas emissions. Climate projections use representative concentration pathways (RCPs) to characterize possible greenhouse gas emissions through the end of the 21st century using different scenarios of human population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy (Moss et al. 2010, van Vuuren et al. 2011). They are named using numbers that represent different values of radiative forcing in watts per square meter by 2100 — 2.6, 4.5, 6, and 8.5. RCP 8.5 represents a 'business-as-usual' scenario and assumes that the fewest greenhouse gas mitigation measures will be implemented (Riahi et al. 2011).

NMFS policy guidance states RCP 8.5 be used when considering the treatment of climate change in ESA activities (NMFS 2016) and the STCVA therefore used RCP 8.5 for climate change projections to maximize the utility of the information produced for management purposes.

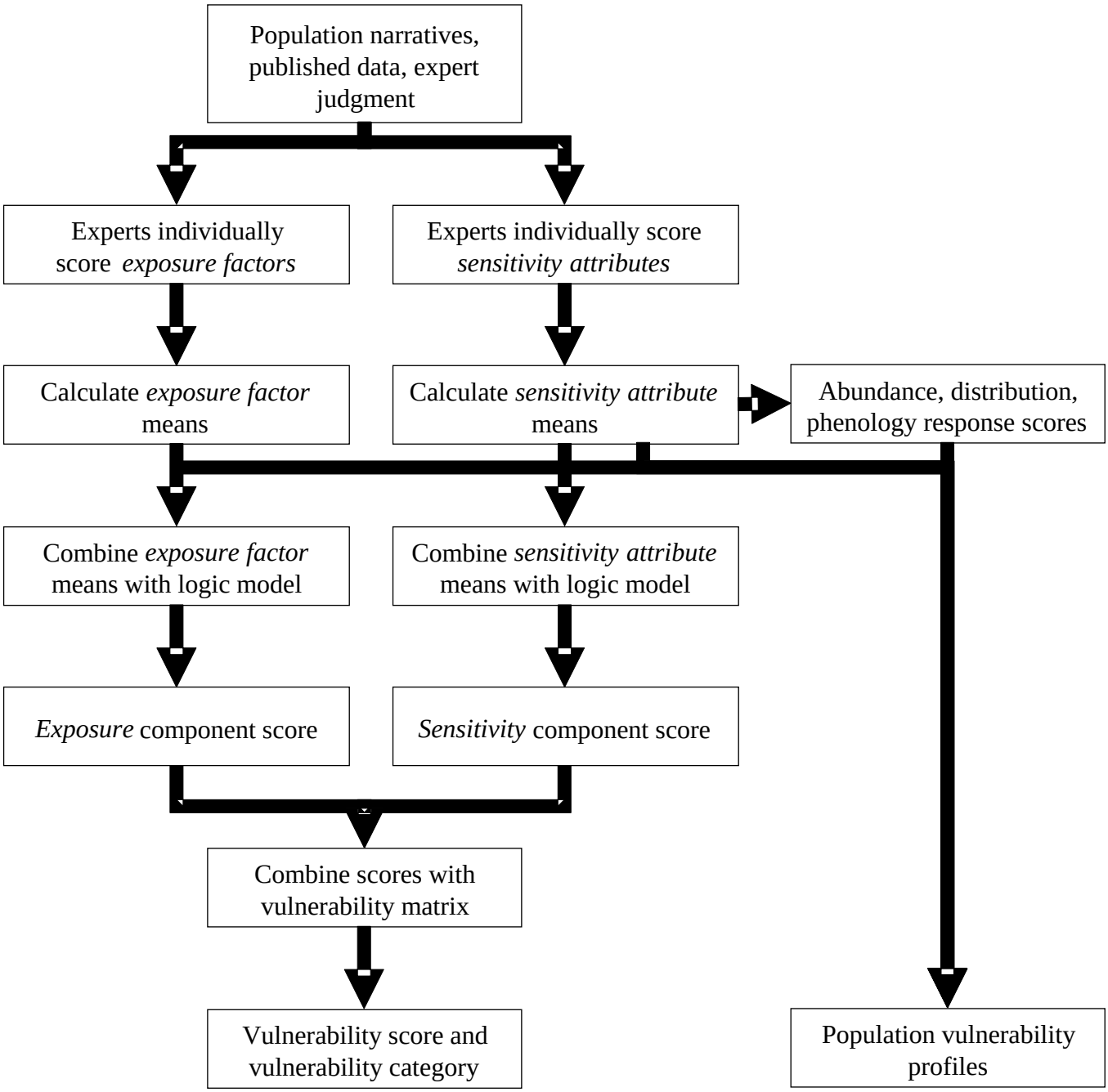

Figure 1. Climate vulnerability assessment process from information gathering to final products (adapted from Lettrich et al. 2019).

2.1.2 Sensitivity and Adaptive Capacity Component

We defined *sensitivity* as the degree to which a population is likely to be affected by climate-driven changes in environmental conditions and *adaptive capacity* as the ability of a population to modify intrinsic characteristics (e.g., behavior, physiology, habitat use) to cope with climate-driven changes in environmental conditions (Glick et al. 2011). Tolerance of a condition and adaptation to a condition exist along a spectrum of possible responses to that condition. With simple changes in wording, an attribute could be categorized as relating to either sensitivity or adaptive capacity (Williams et al. 2008, Hare et al. 2016a). For example, a population with a specialist diet could be considered sensitive to climate change due to its reliance on specific prey or forage species. Also, it could be considered to have a low capacity to adapt to climate-driven changes in the availability of its preferred prey or forage species. Therefore, we combined sensitivity and adaptive capacity into a single component, hereafter referred to as the "sensitivity component," and the attributes within it referred to as "sensitivity attributes."

We considered whether each sensitivity attribute related to potential responses in population abundance, geographic distribution, and phenology. Some attributes influenced all three response categories, while other attributes only influenced one or two response categories. Potential responses of sensitivity included: 1) changes in abundance resulting in declines or increases in population size, 2) changes in distribution resulting in climate-driven changes in geographic ranges, including range expansion, contraction, or shift, and 3) changes in phenology resulting in seasonal shifts (earlier or later in the year) or changes in duration (prolonged or shortened) of life history events such as breeding or migration.

2.1.3 Method Development: Identifying Climate Exposure Factors and Sensitivity Attributes and Establishing Scoring Criteria

We convened an expert workshop with representatives from NOAA and USFWS, other governmental agencies, non-governmental organizations (NGOs), and academia to inform the selection of relevant climate exposure factors and sensitivity attributes (based on sea turtle life history traits). These experts used existing CVA frameworks and approaches (e.g., Thomas et al. 2011, Pecl et al. 2014, Hare et al. 2016a) as models and sourced attributes from prior syntheses of climate impacts on sea turtles (e.g., Hamann et al. 2007, Hawkes et al. 2009, Poloczanska et al. 2009, Fuentes et al. 2011).

We identified eight climate exposure factors to be used to score climate exposure (Table 1). These were the same climate exposure factors used in the FCVA and MMCVA, with the exception of sea ice extent since it is not a feature that sea turtles encounter. The selected climate exposure factors are variables that are likely to directly affect sea turtles and also sea turtle prey or habitat. Many of these variables have been used in other sea turtle climate-related studies (Hamann et al. 2007, Hawkes et al. 2009, Poloczanska et al. 2009, Fuentes et al. 2011, Hamann et al. 2013).

We identified 14 life history attributes that could be influenced by climate change to score sensitivity (Table 2). We assessed each attribute independently of the other attributes. For example, when considering two nearly identical populations for which the only attribute that differed was the number of offspring produced, the population that produced more offspring was considered to have a lower sensitivity (and higher adaptive capacity) to climate change. Although many of these attributes are correlated, we made efforts to reduce "double counting" by describing those situations in which an attribute overlapped with another attribute. Our final

set of attributes minimized overlap between attributes. For example, we did not include conservation status (e.g., ESA, IUCN Red List) because population abundance and trend were already considered during the status determination.

We established criteria to guide the scoring using four bins for each factor (Appendix A) and attribute (Appendix B). The criteria used to score exposure are suitable for cross-taxa assessment within the geographic scope. The specific criteria used to score each sensitivity attribute were selected based on the unique life histories of sea turtles and are not appropriate for cross-taxa assessment.

Table 1. Climate exposure factors included in the STCVA.

Climate Exposure Factor	**Description**
Sea Surface Temperature	The temperature of the upper water column (the mixed layer) may have direct physiological effects on sea turtles and/or prey.
Air Temperature	The near-surface air temperature may have direct physiological effects on sea turtles, nests, eggs, and/or prey. Air temperature serves as a useful proxy for estuarine and shallow water temperature.
Precipitation	Rain, snow, and ice that affects salinity and serves as a delivery mechanism for pollutants and contaminants. Rain can affect nesting habitat.
Salinity	Surface salt content that can affect sea turtle health and/or prey.
Ocean Acidification	The ongoing decrease in the ocean's pH that may affect sea turtle prey and habitat.
Dissolved Oxygen	The amount of oxygen in surface waters, which may affect sea turtle prey.
Circulation	The movement of water masses, which may affect sea turtle movement and/or prey.
Sea Level Rise	The relative change in sea level, which may affect sea turtle and/or prey habitat.

Table 2. List of sensitivity attributes included in the STCVA.

Sensitivity Attribute	Description
Prey/Diet Specificity	The breadth of a population's diet and the ability of individuals to shift foraging strategy and/or diet under changing conditions.
Habitat Specificity (in-water)	The breadth of habitat used by a population and underlying vulnerability of that habitat.
Nesting Beach Type	The type of beach individuals of a population use, a proxy for nesting habitat vulnerability.
Geographic Extent of Nesting	The geographic extent and spatial density of a population's nesting activity.
Nesting Site Fidelity	The degree to which individuals of a population use the same locations in successive nesting seasons.
Lifetime Reproductive Potential	The ability of an individual (and by extension, population) to produce offspring that facilitate population growth and avoid declines in abundance.
Length of Nesting Season	The peak timing and duration of female nesting as a proxy for the ability of a population to adapt its reproductive timing to changing conditions.
Adult Physiological Sensitivity to Temperature	The influence of temperature on physiological processes of nesting females.
Nest/Egg Sensitivity to Temperature	The effect of temperature on the nests and eggs of a population based on critical temperature thresholds.
Migration	The migratory patterns and pathways of a population.
Foraging Home Range	The spatial extent of the foraging range of individuals within a population.
Population Abundance	The current abundance estimate of nesting females in a population.
Population Abundance Trend	The change in a population's abundance through time.
Cumulative Stressors	The level to which a population is impacted by non-climate stressors.

2.2 Preparing to Implement the Assessment

2.2.1 Scale and Scope

We designed the STCVA for application to sea turtle Distinct Population Segments (DPSs) (50 CFR § 223.102, 50 CFR § 224.101) and Regional Management Units (RMUs) (Wallace et al. 2010). These units are subsequently referred to in this document as "populations." The assessment considered the entire life cycle and known geographic ranges of each population. We used climate exposure factors projected to the year 2055, a sufficient timeframe for climate projections to capture climate trends and decadal variability, yet near-term enough to provide management-relevant information (based on scoping interviews with NMFS and USFWS managers).

Other CVAs and frameworks have included a weighting factor to account for attributes that are disproportionately impactful for a species or population (e.g., Thomas et al. 2011, Reece and Noss 2014); however, we omitted a weighting factor in the STCVA to reduce complexity (e.g., Hare et al. 2016a, Lettrich et al. 2019).

2.2.2 Exposure Maps

Climate exposure factors have been projected and presented in a variety of studies and formats (IPCC 2013, Hayhoe et al. 2017). We obtained climate projections for each climate exposure factor across the entire geographic scope of the assessment from the Earth Systems Research Laboratory (ESRL) web portal (ESRL 2014), following the established approach used in the FCVA. The ESRL web portal provided projections for many of the climate exposure factors scored in the assessment (see Appendix A, Climate Exposure Factors). Using the ESRL projections maximized the number of climate exposure factors in the assessment that were modeled using the same climate models, timeframe, and spatial resolution. Sea level rise and circulation projections were not available through the ESRL web portal.

We obtained customized ESRL web portal projections using the average of all climate models, the RCP 8.5 experiment, the entire year seasonal period, and the 21st century time period of 2006-2055 (Table 3). The ESRL portal produced projection maps for each climate exposure factor (sea surface temperature shown as example in Fig. 2). The projected standard anomaly (Z) (Fig. 2a) was calculated using the equation:

$$Z = \frac{\bar{X}_F - \bar{X}_P}{\sigma_P}$$

where $\bar{X}_F$ is the mean of the climate exposure factor during the period 2006–2055, $\bar{X}_P$ is the mean of the climate exposure factor during the period 1955–2005, and σ_P is the standard deviation of the climate exposure factor during the period 1955–2005. The projected change in variability (F) (Fig. 2b) was calculated using the equation:

$$F = \frac{V_F}{V_P}$$

where V_F is the variance of the climate exposure factor during the period 2006–2055 and V_P is the variance of the climate exposure factor during the period 1955–2005.

The geographic range of the maps can be adjusted to the specific basin or region being assessed to provide greater resolution.

Table 3. Settings used for ESRL Climate Change Web Portal for each climate exposure factor.

ESRL Field	Value
Experiment	RCP 8.5
Model	Average of All Models
Variable	[Based on climate exposure factor]
Statistic	Standard Anom (avg historical)
Season	Entire year
21st Century Period	2006–2055
Region	Scaled to fit entire population distribution

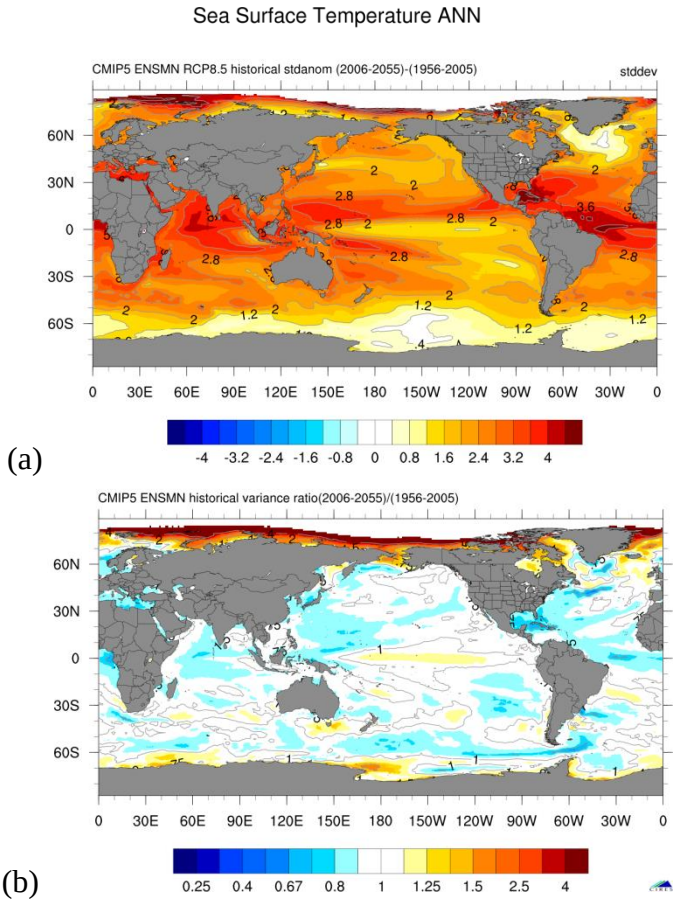

Figure 2. Sample output from ESRL Climate Change Web Portal showing annual sea surface temperature projection a) change in mean, top and b) change in variability, bottom. This figure uses the following settings: experiment = RCP 8.5, model = average of all models, variable = sea surface temperature, statistic = standard anom (avg historical), season = entire year, 21st century period = 2006–2055, region = global. The projections are based on the Coupled Model Intercomparison Project 5 (CMIP5) ensemble mean (ENSMN) of climate models. (http://www.esrl.noaa.gov/psd/ipcc/ocn/)

The ESRL output maps could be used as-is; however, we downloaded and reclassified the legend to match the criteria of scoring bins. Doing so presented the exposure maps categorized by scoring bin and eliminated the need for experts to interpret the climate exposure factor and the scoring criteria simultaneously.

Projections obtained from downscaled models or peer-reviewed studies are useful, but the same projections for each individual climate exposure factor must be used for all populations that are assessed. Finer resolution models are difficult to generate, and are not necessary for a CVA conducted at broad geographic scales such as the STCVA.

We supplemented the exposure maps with additional information, such as population range boundaries, sighting data, and density estimates. Range maps were obtained from a variety of sources such as recovery plans (NMFS and USFWS 1991, 1992, 1993, 1998a, 1998b, 1998c, 1998d, 1998e, 1998f, 2008, 2016, NMFS et al. 2011), status reviews (NMFS and USFWS 2007, 2013a, 2013b, 2014, 2015, Conant et al. 2009, Seminoff et al. 2015), OBIS SEAMAP (Halpin et al. 2009), the International Union for the Conservation of Nature's Red List (IUCN 2016), and Wallace et al. (2010).

2.2.3 Population Background Narratives

We assembled information about each population's life history attributes, distribution, and references to climate change to ensure a common baseline of available information for all scorers. We organized this information as population narratives, similar to other CVAs (e.g., Chin et al. 2010, Pecl et al. 2014, Hare et al. 2016a, Lettrich et al. 2019). The background narratives included information describing the current state of knowledge about each assessed life history attribute. When available, the background narratives also highlighted studies documenting populations' responses to changing climate conditions. For poorly studied populations, we included life history information from related populations or species. For example, if information was lacking for a central Pacific population, information from an eastern Pacific population may have been included to help inform experts' scores.

2.2.4 Expert Selection

For each subpopulation we selected subject matter experts with field or other relevant research experience to score the STCVA. While expertise about any given population was valuable, having experts that could score a variety of populations allowed us to compare scores across populations and avoid scorer bias. If each expert only scored one population, we would have had difficulty attributing scores to the population instead of the scorer. We included experts from NMFS and USFWS, other governmental agencies, NGOs, and academia.

2.3 The Expert Scoring Process

Each climate exposure factor and sensitivity attribute was scored individually by each member of the group of experts for each population. Expert elicitation is an accepted technique with established protocols (EPA 2009) that has been utilized by NMFS in ESA activities and climate assessment efforts (e.g., Good et al. 2005, Brainard et al. 2011, Hare et al. 2016a, Lettrich et al. 2019). The optimal number of scorers depends on multiple factors such as breadth of individual expertise, breadth of group expertise, and availability (Linstone and Turoff 1975, Hsu and Sandford 2007, Mukherjee et al. 2015). To ensure a sufficient number of reviews for each

population while maintaining a reasonable workload for the expert scorers, a minimum of three experts scored each population.

Experts scored each climate exposure factor and sensitivity attribute by allocating five points across four scoring bins (i.e., low, moderate, high, and very high) according to the respective scoring criteria for that factor or attribute. Criteria for "Bin 1 – Low" correlated to low exposure, low sensitivity, and high adaptive capacity whereas criteria for "Bin 4 – Very High" correlated to high exposure, high sensitivity, and low adaptive capacity.

2.3.1 Scoring Climate Exposure Factors

Experts compared the range maps of each population to the projected exposure level for each factor. They then scored each factor by allocating five points across four bins according to the magnitude of exposure projected across the entirety of the population's current distribution (see Appendix A, Climate Exposure Factors). For example, if the magnitude of exposure within an entire population's distribution matched the criteria for "Bin 4 – Very High", all five points were placed in "Bin 4". If the magnitude of exposure in part of a population's distribution matched the criteria for "Bin 4" and part matched the criteria for "Bin 3 – High", experts placed points according to the proportion of the distribution that matched each bin.

Some factors did not have modeled projection maps (e.g., circulation and sea level rise), and experts scored these factors using expert judgement based on peer-reviewed and grey literature about projected impacts.

2.3.2 Scoring Sensitivity Attributes

Experts used their knowledge and population-specific experience combined with the population narratives to place their five points into each attribute's four bins based on the bin criteria described in Appendix B (Climate Sensitivity Attributes). For example, if all supporting evidence for a population matched the criteria in "Bin 4 – Very High", the experts placed all five points in "Bin 4 – Very High." If evidence for a population ranged across several bins, experts could spread their points across multiple bins based on the supporting evidence; the most points were placed in the bin with greatest support from the literature or based on the expert's knowledge of and experience with the population. Alternatively, if data quality was low, points could be spread across multiple bins, which would reflect uncertainty for the respective factor/attribute. For attributes with multiple criteria, experts used their best judgement to place primary emphasis on those metrics with higher quality data and secondary emphasis on other metrics less supported by data. Appendix B provides definitions, background, and scoring criteria for each attribute, as well as the relationships between each attribute and the response in abundance, distribution, and phenology.

2.3.3 Assessing Data Quality

Similar to the FCVA and MMCVA, experts provided a data quality score for each factor and attribute. The data quality score represents how much evidence supports the placement of the points. Naturally, factor/attribute scores that are associated with higher data quality yield results with higher confidence.

Data quality was scored a "3" if there were observed, modeled, or measured data to support the placement of points. Data quality was scored a "2" if the score was based on a nearby subpopulation or different species, or if conflicts existed in the supporting information that

complicated the ability to assign scores. Data quality was scored a "1" if the expert's knowledge of, and experience with, the population was the sole basis for the score. Data quality was scored a "0" if there was no data on which to score, and the expert's familiarity with that aspect of the population was only sufficient to provide a marginally informed opinion. Experts scored data quality for climate exposure factors based on the underlying information about the population distribution. Sea turtle experts were not asked to assess the data quality of the climate models or exposure maps. Experts scored data quality for sensitivity attributes based on their own knowledge and on the data provided in the population background narratives.

2.4 Calculating Scores

2.4.1 Climate Exposure Factor and Sensitivity Attribute Means

We computed mean scores for each climate exposure factor and sensitivity attribute through a three-step process.

First, we combined the points from all experts to produce weighted mean scores for each climate exposure factor and each sensitivity attribute. Here, the weighting is for the bins within a factor or attribute and does not refer to individual factor or attribute weighting as discussed above (Section 2.1.3 Method Development: Identifying Climate Exposure Factors and Sensitivity Attributes and Establishing Scoring Criteria). Within each factor and attribute, bins are weighted according to how the criteria for the bin influence the factor or attribute. We calculated weighted mean scores with bin weights corresponding to bin number, using the following equation:

$$Factor\ or\ Attribute\ Weighted\ Mean\ = \frac{((B_1\ *\ 1) + (B_2\ *\ 2) + (B_3\ *\ 3) + (B_4\ *\ 4))}{(B_1 + B_2 + B_3 + B_4)}$$

where B_n is the number of points in bin n.

Second, for the climate exposure factors that included both change in variability and change in mean (i.e., all factors except circulation and sea level rise), we used the greater of the two means as the score for that factor.

Third, we placed mean sensitivity attribute scores with the response categories (abundance, distribution, and phenology) identified as relevant to that attribute. For example, if a given attribute had influence over all three response categories, then the mean attribute score applied to each response category. Alternatively, if a given attribute only had influence over abundance, the mean attribute score was applied to abundance, but not to distribution and phenology for that attribute. The three response categories remained independent of one another and separate from the mean sensitivity attribute score.

2.4.2 Exposure and Sensitivity Component Scores

We determined exposure and sensitivity component scores using the logic model from the FCVA (Table 4) and the factor and attribute mean scores for each population. We used a logic model to avoid discounting situations in which most factors or attributes scored low while a few factors or attributes scored highly and would have a disproportionate effect on the population's exposure or sensitivity.

Table 4. Logic model used to determine exposure component score and sensitivity component score.

Component Score	Criteria
Very High (4)	3 or more attribute or factor mean scores ≥ 3.5
High (3)	2 or more attribute or factor mean scores ≥ 3.0, but does not meet threshold for "Very High"
Moderate (2)	2 or more attribute or factor mean scores ≥ 2.5, but does not meet threshold for "High" or "Very High"
Low (1)	Less than 2 attribute or factor mean scores ≥ 2.5

2.4.3 Overall Vulnerability

We determined the overall vulnerability for a population by multiplying exposure component scores and sensitivity component scores to generate a vulnerability rank and place each population into a vulnerability category. Higher scores reflected expert opinion depicting greater vulnerability. Populations were placed into vulnerability categories using the exposure component score and sensitivity component score cross-referenced with a vulnerability matrix derived from the FCVA (Fig. 3).

2.4.4 Response Category Score

Within the sensitivity component, the three response categories provide additional information about anticipated responses. We calculated each population's response category score using the same approach as overall sensitivity, using the weighted means of the individual attribute scores for that population while ignoring values of "N/A". As different attributes influence abundance, distribution, and phenology, comparisons were not made across response categories within a population.

3 Conclusion and Next Steps

Sea turtle populations are expected to respond to changing climate conditions in a variety of ways including range shifts and/or phenological shifts, which may ultimately lead to changes in abundance. Climate-related information can help inform management activities under the ESA, and CVAs can identify those species and populations most vulnerable to climate change and the underlying drivers of that vulnerability. Our method is an early step in evolving efforts to inform management measures under changing climate conditions. Here we applied the STCVA method at the population level to identify vulnerable populations and describe drivers of climate vulnerability on a management-relevant scale. However, this method may be modified to operate on differing spatial and temporal scales as needed. Similar to the FCVA, the STCVA was designed to be repeated at regular intervals to incorporate updated climate projections from new IPCC reports and National Climate Assessments. As additional information becomes available on sea turtle responses to other climate variables (Appendix A), additional climate exposure factors can be added to the process. Likewise, additional sensitivity attributes (Appendix B) may be added to future iterations of the assessment as necessary. The results of the STCVA can highlight data gaps and help prioritize research needs. As population-specific biological information improves, additional information can be incorporated into future assessments to

continue to refine our understanding of sea turtle biology, strengthen the CVAs, and support climate-informed management decisions.

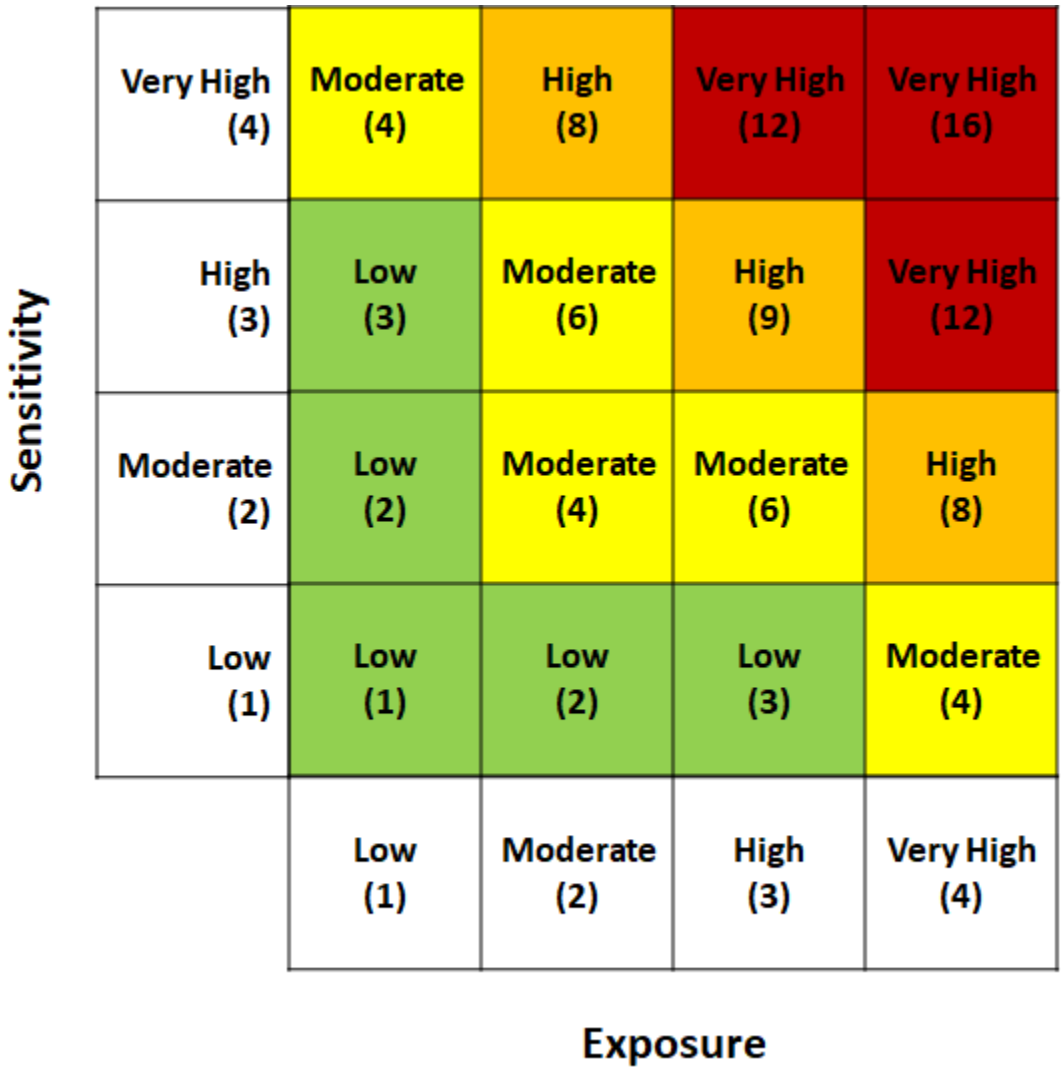

Figure 3. Vulnerability matrix derived from FCVA used to combine sensitivity category component score and exposure component score to determine overall vulnerability category. Numbers in parentheses represent the factors and product of multiplying sensitivity and exposure. Low vulnerability (1-3), moderate vulnerability (4-6), high vulnerability (8-9), and very high vulnerability (12-16) can result from multiple combinations of sensitivity and exposure.

3.1 Global Implementation

With the method developed and tested, we applied the STCVA method to sea turtle DPSs and RMUs. The outputs from this global application will include a ranked vulnerability index, response category scores, and population-specific vulnerability profiles. Populations will be categorized and ranked by overall vulnerability to support management needs and inform decision making and research directions. Each population will have its own graphical representation of sensitivity and exposure scores. Corresponding profiles will describe the attributes and factors contributing to vulnerability and identify data gaps such as attributes and factors with weak supporting evidence. Researchers can use the vulnerability profiles to target research toward specific attributes that may be driving the vulnerability of a given population and to explore responses to varying magnitudes of change in that driver. Managers can use the vulnerability profiles to identify the attributes that contribute most to population sensitivity and the types of climate change impacts expected to most affect a population. This information can be used to design science-based management strategies and focus efforts on attributes and factors that could most reduce vulnerability. We will endeavor to publish the global and population-specific results in a separate, peer-reviewed journal article.

3.2 Interfacing with Other CVAs

We encourage future iterations of this assessment to interface with other CVAs that characterize the vulnerability of protected species as well as their prey and habitat. The STCVA could be strengthened by including the results of regional applications of the FCVA and habitat climate vulnerability assessments as input to the STCVA's prey/diet specificity and habitat specificity attributes. Developing a plan to integrate the results of the different CVAs will help to describe the interconnected and cascading effects of climate change.

4 Acknowledgements

We thank the many contributors and supporters throughout the development and application of the STCVA. The members of the Protected Species Climate Vulnerability Assessment steering committee guided the initiation of this project: Gregory Balogh, David Gouveia, Jonathan Hare, T. Todd Jones, Nathan Mantua, Eric Shott, Gregory Silber, Michael Simpkins, Christopher Toole, Carrie Upite, and Kyle Van Houtan. Expert workshop participants provided input on assessment framework and initial attribute lists: Robyn Angliss, Jason Baker, Gregory Balogh, Steven Bograd, Charlotte Boyd, Erica Fleishman, Mariana Fuentes, Kathy Goodin, John M. Halley, Jonathan Hare, Dennis Heinemann, Nathan Mantua, Wendy Morrison, Mark Nelson, Aaron Poe, Vincent Saba, Gregory Silber, Michael Simpkins, Mridula Srinivasan, Michelle Staudinger, Christopher Toole, and Kyle Van Houtan. Mariana Fuentes, Joanne Braun McNeill, and Kyle Van Houtan helped develop initial attribute lists. Jeanette Davis and Laura Ferguson tested the framework. Camryn Allen, Summer Martin, Irene Kelly, T.Todd Jones, and Yonat Swimmer participated in the Pacific Islands pilot test. Stephen K. Brown, Richard Merrick, Kenric Osgood, Mridula Srinivasan, and Donna Wieting provided critical support throughout the project. Brian Stacy, Kristin Laidre, and Michelle Staudinger reviewed individual attributes. The Protected Resources Board provided feedback and support. The STCVA scoring team revised attribute definitions and scoring criteria: Camryn Allen, Paolo Casale, Mariana Fuentes, Alexander Gaos, Mark Hamann, Lauren Kurpita, Mike Liles, Summer Martin, Susanna Piovano, Earl Possardt, Vincent Saba, Yonat Swimmer, Manjula Tiwari, Jeanette Wyneken, and Thane Wibbels. Erin McMichael reviewed this Technical Memorandum. Kate O'Dell provided technical edits.

This project was funded by NOAA Fisheries Office of Science and Technology. The views expressed herein are the authors' and do not necessarily reflect the views of NOAA or any of its sub-agencies.

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Appendix A Climate Exposure Factors

A.1 Sea Surface Temperature

Background: Sea surface temperature (SST) is measured using a variety of methods and corresponding depths. For the purpose of this assessment, SST refers to the temperature of the upper water column, or the mixed layer (ESRL 2014). Sea turtles spend significant time in this depth zone when surfacing to breathe and to help regulate their body temperature. Species distributions have been correlated with SST (Polovina et al. 2004). Prey abundance and distribution also have been correlated with SST (Rutherford et al. 1999). Water temperature affects physiology and has implications for survival (Schwartz 1978, Witherington and Ehrhart 1989).

Scoring:

	Projected change in mean (Standard Anomaly)	Projected change in variability (Variance Ratio)
Bin 1:	$\|x\| < 0.5$ std dev	<1.15
Bin 2:	0.5 std dev $\leq \|x\| <$ 1.5 std dev	$1.15 \leq x < 1.54$
Bin 3:	1.5 std dev $\leq \|x\| <$ 2.0 std dev	$1.54 \leq x < 1.78$
Bin 4:	$\|x\| \geq$ 2.0 std dev	≥ 1.78

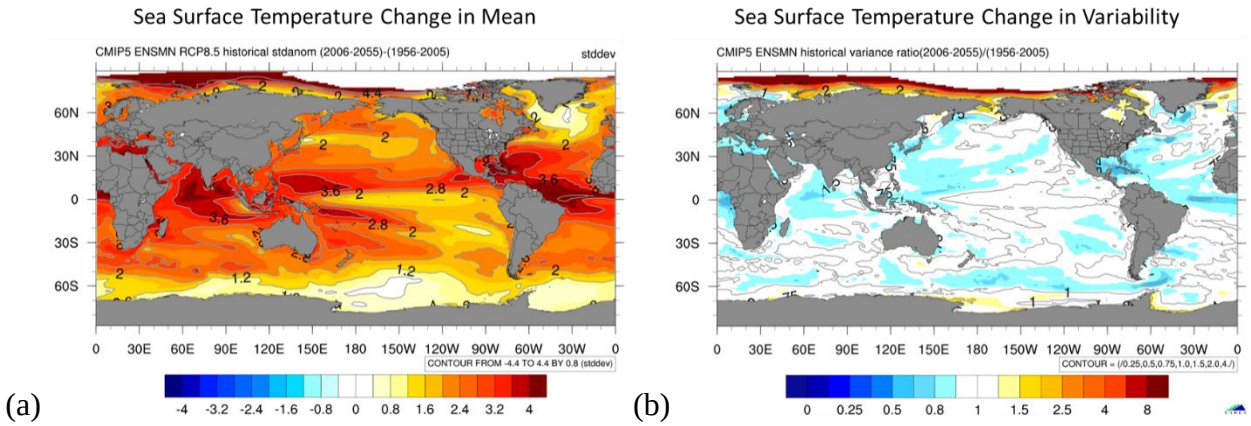

Figure A-1. a) Projected future sea surface temperature (in 2055) compared to historical conditions calculated by subtracting the historical mean from the mean of the future and then dividing the difference by the historical standard deviation. b) Projected change in sea surface temperature variability, calculated as future variance (in 2055) divided by past variance. (source: Earth Systems Research Laboratory 2014)

A.2 Air Temperature

Background: Near-surface air temperature has been shown to have physiological impacts on sea turtles (Sato 2014, Dudley et al. 2016). Near-surface air temperature has been correlated with sand temperature (Hays et al. 2003, Laloë et al. 2014, Esteban et al. 2016), which affects sea turtle nests and eggs.

Scoring:

	Projected change in mean (Standard Anomaly)	Projected change in variability (Variance Ratio)
Bin 1:	$\|x\| < 0.5$ std dev	<1.15
Bin 2:	0.5 std dev $\leq \|x\| <$ 1.5 std dev	$1.15 \leq x < 1.54$
Bin 3:	1.5 std dev $\leq \|x\| <$ 2.0 std dev	$1.54 \leq x < 1.78$
Bin 4:	$\|x\| \geq$ 2.0 std dev	≥ 1.78

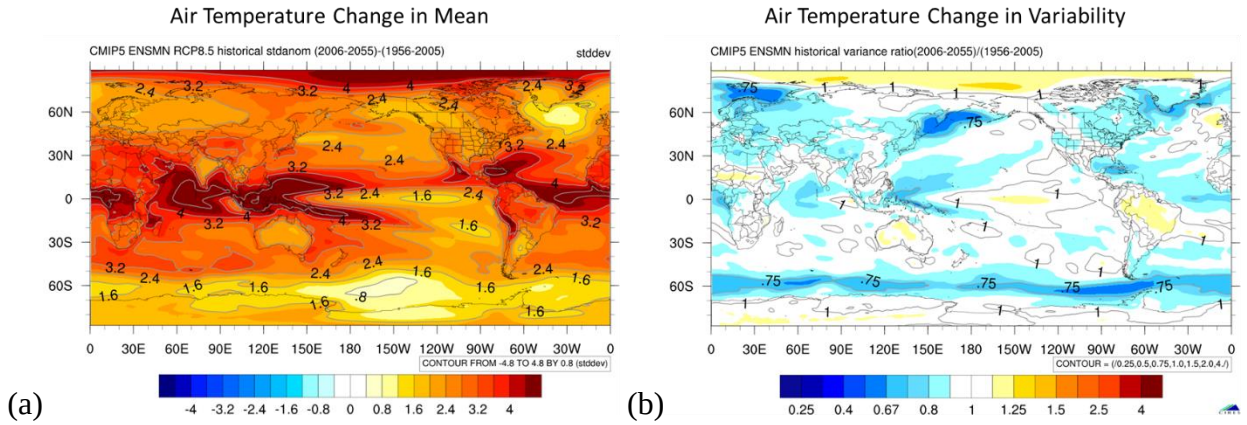

Figure A-2. a) Projected future air temperature (in 2055) compared to historical conditions calculated by subtracting the historical mean from the mean of the future and then dividing the difference by the historical standard deviation. b) Projected change in air temperature variability, calculated as future variance (in 2055) divided by past variance. (source: Earth Systems Research Laboratory 2014)

A.3 Precipitation

Background: Precipitation affects surface salinity in the open ocean and coastal areas. It serves as a delivery mechanism for pollutants and debris from land-based sources, particularly in coastal areas. Precipitation serves as a mediating effect on sand temperatures, and therefore nest temperatures, and influences moisture conditions within nests (Matsuzawa et al. 2002, Houghton et al. 2007, Lolavar and Wyneken 2015, Wyneken and Lolavar 2015).

Scoring:

	Projected change in mean (Standard Anomaly)	Projected change in variability (Variance Ratio)
Bin 1:	$\|x\| < 0.5$ std dev	<1.15
Bin 2:	0.5 std dev $\leq \|x\| <$ 1.5 std dev	1.15 $\leq$ x <1.54
Bin 3:	1.5 std dev $\leq \|x\| <$ 2.0 std dev	1.54 $\leq$ x < 1.78
Bin 4:	$\|x\| \geq$ 2.0 std dev	$\geq$ 1.78

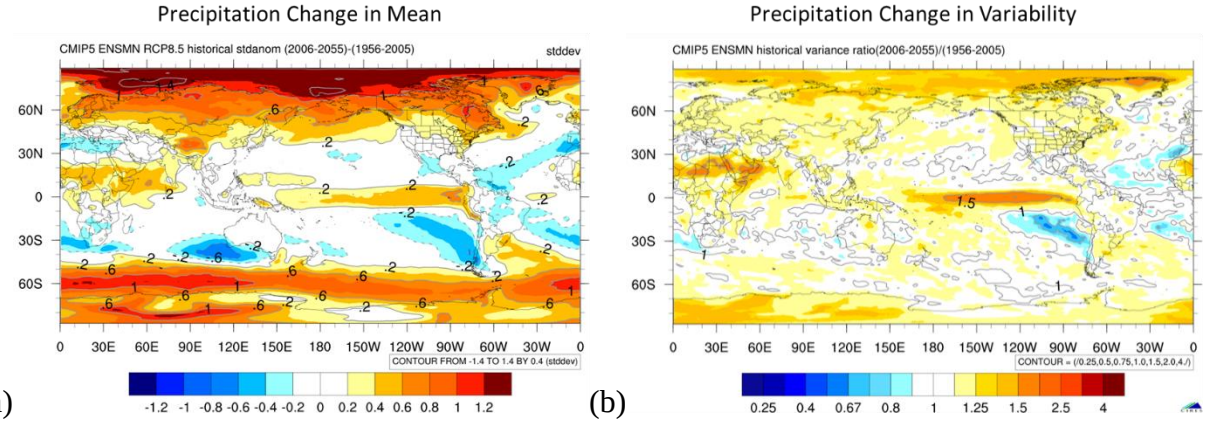

Figure A-3. a) Projected future precipitation (in 2055) compared to historical conditions calculated by subtracting the historical mean from the mean of the future and then dividing the difference by the historical standard deviation. b) Projected change in precipitation variability, calculated as future variance (in 2055) divided by past variance. (source: Earth Systems Research Laboratory 2014)

A.4 Sea Surface Salinity

Background: Surface salinity is a dynamic property that affects circulation. Salinity has been hypothesized as a factor in sea turtle nest site selection (Foley et al. 2006) and hatchling success (Wood and Bjorndal 2000), however a conclusive link remains elusive. Salinity may also influence sea turtle prey species.

Scoring:

	Projected change in mean (Standard Anomaly)	Projected change in variability
Bin 1:	$\|x\| < 0.5$ std dev	<1.15
Bin 2:	0.5 std dev $\leq \|x\| <$ 1.5 std dev	$1.15 \leq x < 1.54$
Bin 3:	1.5 std dev $\leq \|x\| <$ 2.0 std dev	$1.54 \leq x < 1.78$
Bin 4:	$\|x\| \geq$ 2.0 std dev	≥ 1.78

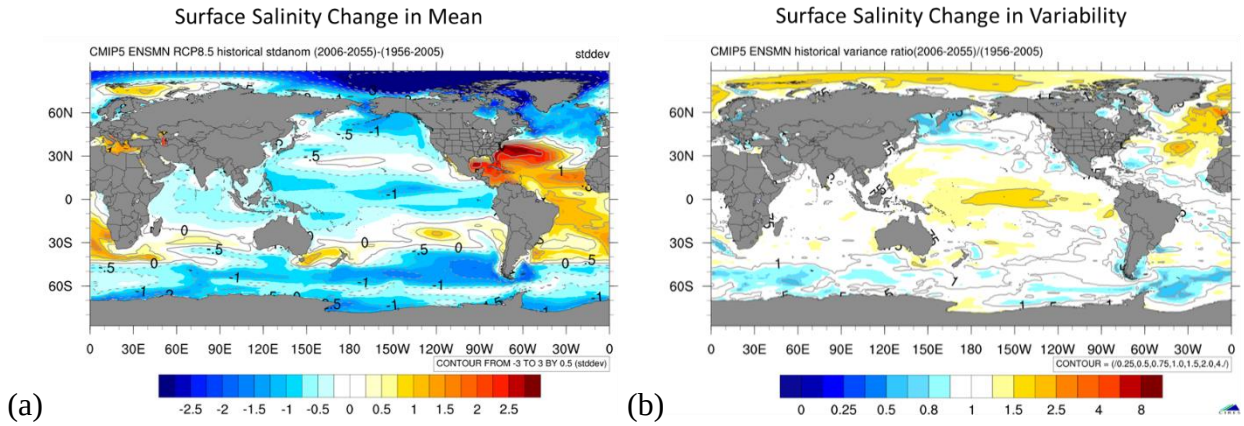

Figure A-4. a) Projected future salinity (in 2055) compared to historical conditions calculated by subtracting the historical mean from the mean of the future and then dividing the difference by the historical standard deviation. b) Projected change in salinity variability, calculated as future variance (in 2055) divided by past variance. (source: Earth Systems Research Laboratory 2014)

A.5 Ocean pH

Background: Ocean acidification refers to the decreasing of the ocean's pH through chemical reactions resulting from increased atmospheric carbon dioxide. While no direct physiological effects of pH have been documented for sea turtles, pH has been shown to impact habitats (e.g., coral reefs) and prey species (Langdon and Atkinson 2005, Fabry et al. 2008).

Scoring:

	Projected change in mean (Standard Anomaly)	Projected change in variability (Variance Ratio)
Bin 1:	$\|x\| < 0.5$ std dev	<1.15
Bin 2:	0.5 std dev $\leq \|x\| <$ 1.5 std dev	1.15 $\leq$ x <1.54
Bin 3:	1.5 std dev $\leq \|x\| <$ 2.0 std dev	1.54 $\leq$ x < 1.78
Bin 4:	$\|x\| \geq$ 2.0 std dev	$\geq$ 1.78

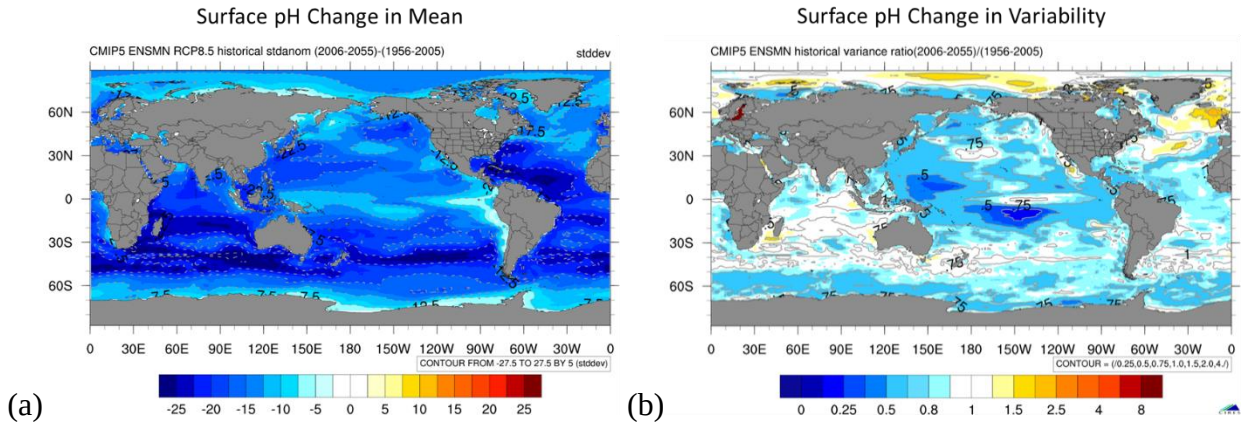

Figure A-5. a) Projected future sea surface pH (in 2055) compared to historical conditions calculated by subtracting the historical mean from the mean of the future and then dividing the difference by the historical standard deviation. b) Projected change in sea surface pH variability, calculated as future variance (in 2055) divided by past variance. (source: Earth Systems Research Laboratory 2014)

A.6 Dissolved Oxygen

Background: Dissolved oxygen in the surface water varies with temperature and usage by biotic elements of the marine ecosystem. While no physiological effects of dissolved oxygen have been observed for sea turtles, dissolved oxygen impacts prey species (Craig et al. 2001).

Scoring:

	Projected change in mean (Standard Anomaly)	Projected change in variability (Variance Ratio)
Bin 1:	$\|x\| < 0.5$ std dev	<1.15
Bin 2:	0.5 std dev $\leq \|x\| <$ 1.5 std dev	$1.15 \leq x < 1.54$
Bin 3:	1.5 std dev $\leq \|x\| <$ 2.0 std dev	$1.54 \leq x < 1.78$
Bin 4:	$\|x\| \geq$ 2.0 std dev	≥ 1.78

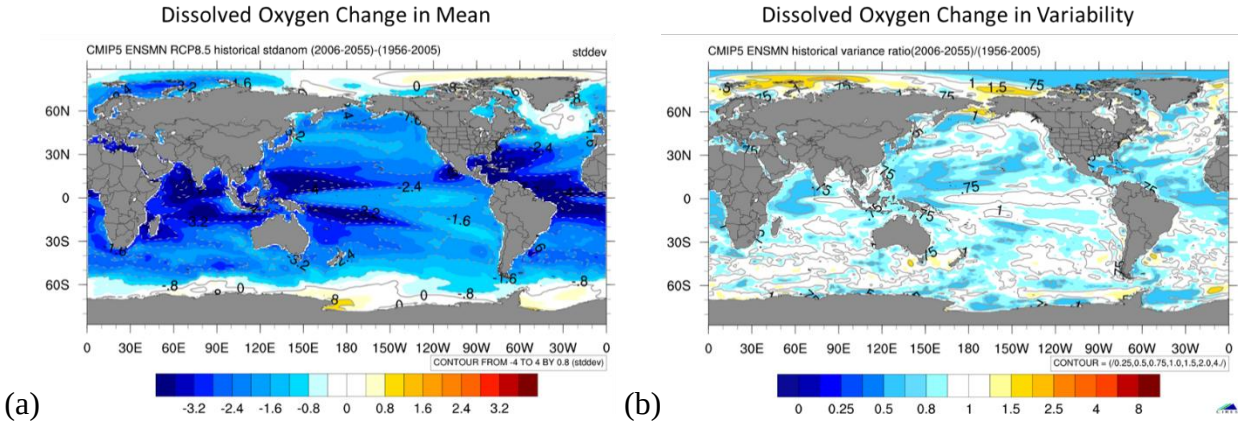

Figure A-6. a) Projected future dissolved oxygen (in 2055) compared to historical conditions calculated by subtracting the historical mean from the mean of the future and then dividing the difference by the historical standard deviation. b) Projected change in dissolved oxygen variability, calculated as future variance (in 2055) divided by past variance. (source: Earth Systems Research Laboratory 2014)

A.7 Circulation

Background: Circulation refers to the movement of water masses. It occurs on the scale from major currents to estuarine mixing and includes processes such as upwelling, Ekman transport, and eddies. Circulation contributes to the dispersal of post-hatchling sea turtles (Hays et al. 2010, Putman et al. 2012, Briscoe et al. 2016, Chambault 2017) and may aid migration of juveniles and adults (Luschi et al. 2003) and aggregation of prey species. Circulation is difficult to project, and therefore we use a qualitative approach similar to the Fish Stock Climate Vulnerability Assessment (Morrison et al. 2015, Hare et al. 2016).

Scoring:

Bin	Criteria
Bin 1:	Distribution overlaps almost exclusively with large boundary currents or tidal currents
Bin 2:	Much of distribution overlaps with large boundary currents or tidal currents
Bin 3:	Much of distribution overlaps with currents that are expected to have a high magnitude of change such as estuarine circulation, and/or nearshore density- and wind-driven currents
Bin 4:	Distribution overlaps almost exclusively with currents that are expected to have a high magnitude of change such as estuarine circulation, and/or nearshore density- and wind-driven currents

A.8 Sea Level Rise

Background: Sea level rise (SLR) refers to the relative change in sea level and has both a local and a global component. Sea level rise comprises thermal expansion of sea water, addition of water volume from melting of land-based glaciers, and local changes in land elevation due to processes such as subsidence and isostatic rebound. Sea level rise can effectively eliminate some shoreline habitat over time and has the potential to exacerbate coastal flooding during storms and spring tides. Because sea turtles must interact with terrestrial habitat during hatching and nesting, sea level rise will impact all species. We modify the approach of the Fish Stock Climate Vulnerability Assessment (Morrison et al. 2015, Hare et al. 2016) to include finer resolution for low and moderate exposure. We further modify the FCVA to assess change in sea level rather than the rate of sea level rise.

Other assessments of nesting beach vulnerability to sea level rise have taken the approach of examining the loss of habitat under varying sea level rise scenarios (Daniels et al. 1993, Fish et al. 2005, Baker et al. 2006, Fish et al. 2008, Fuentes et al. 2010, Reece et al. 2013, Garcia et al. 2015). Habitat loss is a function of local beach characteristics and relative sea level rise. Modeling habitat loss of all nesting beaches is beyond the scope of this project. We considered the approximate loss in habitat associated with various amounts of sea level rise reported in those other assessments to establish our bin breaks.

If local relative sea level rise projections for mid-century using RCP 8.5 were unavailable, we used projections from Jackson and Jevrejeva (2016, Figure 2e). The 'Intermediate' scenario from Sweet et al. (2017), which aligns with recent SLR studies using RCP 8.5, may be used for nesting beaches in the United States.

Scoring:

Bin	Criteria
Bin 1:	Relative sea level within nesting habitat is expected to increase less than 10 cm by mid-century
Bin 2:	Relative sea level within nesting habitat is expected to increase 10-20 cm by mid-century
Bin 3:	Relative sea level within nesting habitat is expected to increase 20-45 cm by mid-century
Bin 4:	Relative sea level within nesting habitat is expected to increase more than 45 cm by mid-century.

A.9 Appendix A References

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Appendix B Climate Sensitivity Attributes

B.1 Prey/Diet Specificity

Goal: To estimate the breadth of a population's diet and the ability of individuals to shift foraging strategy and/or diet under changing conditions.

Background: The foraging behaviors, target prey species, and habitat preferences of a species or population depends on a number of variables and differs widely between species and populations (Bjorndal 1997, Polovina et al. 2004). In some cases, foraging behaviors and diet vary widely between individuals within a single species or population (Polovina et al. 2004, Hawkes et al. 2006). The diet specificity of a species is described by the diversity of prey the species typically consumes. We assess the ability to switch prey by considering the variety of prey types historically consumed.

Variability exists among other frameworks as to what constitutes a diet specialist. Laidre et al. (2008) used a threshold of one prey type comprising 20% or more of a species' diet as criteria for the most sensitive marine mammal species. Other frameworks (e.g., Cabrelli et al. 2014, Young et al. 2015) use a threshold of a prey type comprising 90% or more of a species' diet to define a diet specialist. The differences in the definition of 'prey type' each framework uses may account for some of this variation and highlights the necessity for consistent usage of terminology among scorers.

We consider the number of prey types and the size of prey as primary factors in prey diversity. Prey types are considered in terms of broad taxonomic groups (e.g., decapods, bivalves, cephalopods, gelatinous zooplankton, grasses, algae, small schooling fish, flatfish). Here, diet specialists are species that consume a narrow selection of prey, with a single genus or family constituting a majority of the diet. Diet generalists are species that consume a wide variety of prey types and sizes. Generalist foragers that can target a variety of prey species and prey sizes, utilizing multiple foraging locations, seasons, and/or strategies are more adaptive and resilient to direct and indirect impacts from climatic changes (Clavel et al. 2011, Young et al. 2015, Beever et al. 2016).

A species or population that consumes a broad assortment of prey species is more adaptive to climate-driven shifts in prey availability because it should be able to more easily switch among prey (ZSL 2010), particularly if any one of its prey species is impacted by climate change (Laidre et al. 2008). Prey specialists that consume only a single prey species or only a small assortment of prey species and prey sizes would likely struggle to find new sources of nourishment if any of its prey are impacted by climate change.

The duration over which the species or population overlaps in space and time with the prey species also impacts the sensitivity of the species or population. If a predatory species or population and its forage species overlap for only a short duration in time and space, climate impacts may create a mismatch and increased vulnerability of the predator species to climate-driven impacts is expected.

Species targeting abundant and widespread prey are more resilient to climate impacts as the prey species itself is likely to be more resilient to environmental changes (Morrison et al. 2015). While not formalized here, we encourage future iterations of this assessment to interface with vulnerability assessments that score the vulnerability of prey species to climate change.

If a species undergoes a shift in diet between life stages or life history stages, experts score the stage that has the most constrained diet.

Relationship to abundance: Individuals of a population with a more specialized diet are more likely to experience declines in abundance due to climate-driven shifts in prey

Relationship to distribution: Individuals of a population with a more specialized diet are more likely to experience shifts in distribution due to climate-driven shifts in prey

Relationship to phenology: Individuals of a population with a more specialized diet are more likely to experience shifts in phenology due to climate-driven shifts in prey

Prey/Diet Specificity Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Generalist; feeds on a wide range of prey types and sizes
Bin 2 (moderate sensitivity)	Generalist; feeds on a limited number of prey types, but a wide variety of species within those types
Bin 3 (high sensitivity)	Specialist; exhibits strong preference for one prey type but is capable of switching when necessary
Bin 4 (very high sensitivity)	Specialist; reliant on one prey type and unable to switch to other prey types

B.2 Habitat Specificity (in-water)

Goal: To determine the breadth of habitat used by a population and the underlying vulnerability of that habitat.

Background: Sea turtles rely on habitat for shelter, foraging, and breeding throughout various life stages. Species that rely on few or highly specific physical and biological features are more likely to be sensitive to climate change (Laidre et al. 2008, Chin et al. 2010), especially if the features are vulnerable to climate-driven changes (ZSL 2010, Case et al. 2015, Morrison et al. 2015). Reliance on different types of features is expected to result in different levels of sensitivity.

For the purpose of this assessment, we consider three types of habitat – physical habitat expected to be resilient to changing climate conditions, physical habitat expected to be vulnerable to changing climate conditions, and biogenic habitat.

Physical features such as depth, bathymetry, submarine canyons and rocky reefs are expected to be resilient to climate change and therefore would result in lower sensitivity for those species that rely on those types of habitat. Other physical features that are more vulnerable to climate changes (e.g., coastal slope) will result in greater impacts to species that rely on those types of features.

Biogenic habitat – habitat created by or consisting of organisms or organism remains – may undergo the greatest changes from a changing climate, as both the ecosystem engineers and underlying physical conditions may be impacted by changing conditions (e.g., Nelson 2009, Doney et al. 2012, Harley et al. 2012). Examples of biogenic habitat include kelp forests, mangroves, salt marshes, coral reefs, and seagrass beds (Teck et al. 2010, Okey et al. 2015). Thus, species that depend on biogenic habitats are likely more vulnerable to climate change.

While the presence of suitable prey plays a key role in defining a species' habitat, we consider the prey and diet specificity of the species in a separate attribute.

Similar to the prey/diet specificity attribute, we encourage future iterations of this assessment to interface with vulnerability assessments that score the vulnerability of habitat to climate change.

For the purposes of this assessment nesting, incubating, and hatching are not considered here.

Relationship to abundance: A population with greater habitat specificity is more likely to experience declines in abundance due to climate-driven habitat alterations

Relationship to distribution: A population with greater habitat specificity is more likely to experience shifts in distribution due to climate-driven habitat alterations

Relationship to phenology: A population with greater habitat specificity is more likely to experience shifts in phenology due to climate-driven habitat alterations

Habitat Specificity Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Population mostly utilizes physical features resilient to climate conditions
Bin 2 (moderate sensitivity)	Population mostly utilizes biogenic features or physical features vulnerable to climate conditions
Bin 3 (high sensitivity)	Population relies on biogenic features or physical features vulnerable to climate conditions for critical life stages or events
Bin 4 (very high sensitivity)	Population relies on biogenic features or physical features vulnerable to climate conditions throughout its entire life

B.3 Nesting Beach Type

Goal: To assess the type of beach individuals of a population utilize and generalize the underlying vulnerability of the nesting habitat.

Background: Sea turtle nesting beaches have characteristics that, while not intrinsic to sea turtles, are linked to sea turtle sensitivity to climate change. Sea turtles show preference for a variety of beach characteristics such as slope, sediment size and color, and vegetation (Kamel and Mrosovsky 2004, Kamel and Mrosovsky 2005, Santidrián Tomillo et al. 2015). Different beach locations may have different perceived stability due to geography, topography, and underlying geological conditions. This is separate from climate exposure because it is more related to the turtles' preference for a particular type of geologic feature.

Fuentes et al. (2011) identified increased sand temperatures, sea level rise, and cyclonic activity as primary drivers of nesting beach vulnerability (see Hawkes et al. 2009, Poloczanska et al. 2009, Witt et al. 2010) and developed a framework to assess nesting beach vulnerability to climate change. Applying the Fuentes et al. (2011) methodology to each individual nesting beach may result in double-counting climate exposure factors and is beyond the scope of this assessment, though the approach would be worthwhile for finer-scale assessments in the future. We use an approach that combines the general topographic and geographic characteristics of the nesting beaches to score this attribute.

Beaches along continents or high-elevation oceanic islands and on the fringes of volcanic islands should be generally more resilient. Low-lying oceanic islands (e.g., atolls) and continental islands (e.g., barrier islands) are more vulnerable to climate change and sea level rise (Forbes et al. 2013, Lorenzo-Trueba and Ashton 2014), and the species or populations that nest there may have additional sensitivity due to the consequences of exposure to climate change, sea level rise, and natural hazards such as coarse woody debris (e.g., fallen trees, stumps) (Fujisaki and Lamont 2016). Atolls may undergo significant changes with rising sea levels (Woodroffe 2008, Webb and Kench 2010). Geographic isolation of an island increases sensitivity since there are no nearby suitable areas for nesting, effectively eliminating the possibility to shift nesting locations.

Adjacent development near or on beaches can cause coastal squeeze, decreasing the available habitat for sea turtles to nest (Fish et al. 2005, Fish et al. 2008, Mazaris et al. 2009). This can happen on all beach types and confers increased sensitivity in our scoring scheme. In-water development (e.g., jetties, groins, breakwaters) affects sediment dynamics and limits the ability of the beach to accrete and erode naturally (Nordstrom 2014). These types of structures add additional vulnerability to the nesting habitat and serve as obstacles to nesting (Lutcavage et al. 1997, Matsuzawa 2006). Natural and manmade debris from fallen trees, logging or lost fishing gear could also impede nesting activities (Fujisaki and Lamont 2016).

The orientation of island chains and archipelagos may also influence the sensitivity and adaptive capacity of a population. Island chains (including barrier islands) in an east-west orientation may not afford populations that utilize them the ability to move poleward as temperatures rise and some beaches become unsuitable for nesting. Populations that utilize low-lying isolated islands may have more difficulty locating new suitable nesting habitat if beaches become submerged or otherwise unsuitable.

Relationship to abundance: A population that uses more vulnerable or more low-lying isolated nesting beaches is more likely to experience declines in abundance due to climate-driven changes

Relationship to distribution: A population that uses more vulnerable or more low-lying isolated nesting beaches is more likely to experience shifts in distribution due to climate-driven changes.

Relationship to phenology: N/A. The long-term stability of nesting beaches is not expected to influence the phenology of a population.

Nesting Beach Type Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Species nests primarily on continental beaches without adjacent development
Bin 2 (moderate sensitivity)	Species nests primarily on one of the following: • high islands without adjacent development or • continental beaches with adjacent low-density development
Bin 3 (high sensitivity)	Species nests primarily on one of the following: • non-isolated low-lying islands without adjacent development, • high islands with adjacent development, or • continental beaches with adjacent high-density development
Bin 4 (very high sensitivity)	Species nests primarily on one of the following: • isolated low-lying islands, • non-isolated low-lying islands with adjacent development, • high islands with adjacent development and in-water development, or • continental beaches with adjacent high-density development and in-water development

B.4 Geographic Extent of Nesting

Goal: To estimate the geographic extent and spatial density of the population's nesting activity.

Background:

Sea turtle populations nest on beaches that, depending on the population, can span a few hundred meters to entire coasts (Pike 2013). The geographic extent of nesting and nest density across that area affect the population's vulnerability to climate change.

A small geographic extent is often associated with increased risk (Laidre et al. 2008, Isaac et al. 2009, Chin et al. 2010, Thomas et al. 2011, Pecl et al. 2014, Stortini et al. 2015). Populations that nest across a broad geographic area have greater resilience to climate impacts. Nesting across a broader geographic area confers greater diffuseness of available nesting habitat and implies a greater diversity of nesting habitat. Other nesting areas are likely to be available if any single nesting area becomes unsuitable. In a narrow geographic extent, a change that renders any single nesting area unsuitable is likely to impact a greater proportion of the nesting extent.

The density of sea turtle nesting is variable between and within populations. A uniform density means that the population's nesting activity is evenly spread out over an area, while a non-uniform density shows areas of high local density and clustering. Populations that have a non-uniform density may be more sensitive to stochastic events (e.g., storms, pollutant spills, etc.) that affect localized areas where the population may be clustered (Pike and Stiner 2007). The effect of long-term climatic changes (e.g., increasing temperatures) on populations will have varying responses across the distribution of the density (Jensen et al. 2018). When considering a given geographic area, a non-uniform density population with greater density near climatic tolerance thresholds is likely more sensitive to changes in those conditions (Parmesan 2006, Berry et al. 2008). A non-uniform density population with greater density far from climatic tolerance thresholds in that same area is likely less sensitive to changes in those conditions. A uniform density population in that same area will have equal parts of its population near and far from where the climatic tolerance threshold is being passed. In this case, the risk associated with a general, non-uniform density is greater while the benefit may not be greater than that of a uniform density.

In our scoring, nesting geographic extent plays a greater relative role in sensitivity than nest density. Populations with a broad distribution of nesting and uniform density of nests over that area are likely least sensitive to climate change impacts. Populations with a narrow distribution of nesting and non-uniform density of nests over that area are likely most sensitive to climate change impacts.

Other vulnerability assessment frameworks use discrete areal extents (Thomas et al. 2011, Pecl et al. 2014), latitudinal extents (Chin et al. 2010, Stortini et al. 2015), or longitudinal extents (Laidre et al. 2008) to describe the geographic extent of a population. We use qualitative terms to define the geographic extent of nesting of individuals to gain a sense of their potential connectivity with other suitable nesting habitat.

Nesting site locations for each species of sea turtle, compiled from multiple research efforts and datasets, are reported on the OBIS-SEAMAP/SWOT website (Halpin et al. 2009).

Relationship to abundance: A population with a broader geographic extent of nesting with uniform density is less likely to experience climate-driven declines in abundance because a

variety and extensive use of nesting locations reduces the likelihood that climate impacts will adversely affect the entire population.

Relationship to distribution: A population with a broader geographic extent of nesting is less likely to experience climate-driven shifts in distribution.

Relationship to phenology: N/A. The geographic extent of nesting is not expected to influence the phenology of a population.

Geographic Extent of Nesting Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Broad distribution of nests/uniform density
Bin 2 (moderate sensitivity)	Broad distribution of nests/non-uniform density
Bin 3 (high sensitivity)	Narrow distribution of nests/uniform density
Bin 4 (very high sensitivity)	Narrow distribution of nests/non-uniform density

B.5 Nesting Site Fidelity

Goal: To assess the degree to which individuals of a population utilize the same nesting beach locations in successive nesting seasons.

Background:

Homing in migratory species has been well studied, with individuals returning to natal sites or other established areas (e.g., Dittman and Quinn 1996, Bowen et al. 2004, Lohmann et al. 2008, Matsumura et al. 2011, Lohmann et al. 2013). Some individuals of a species display strong site fidelity by returning to the same nesting complex or foraging grounds year after year, often within a few meters or kilometers (depending on the species and population) of previous years. Once individuals have returned to the nesting region where they were born and subsequently selected a nesting beach, sea turtles will tend to renest in relatively close proximity (0 to 5 km) during subsequent nesting attempts and within a nesting season (Miller 1996). Others may select different nesting beaches within a season but located in a general proximal region (e.g. Santidrián Tomillo et al. 2017) or ranging in distances of a few hundred kilometers (Bjorndal et al. 1983). If a site that individuals return to is impacted by climate change, those individuals are expected to be impacted as well (Laidre et al. 2008). As the proportion of individuals within a species or population exhibiting site fidelity increases, the sensitivity to climate change also increases.

This attribute only considers nesting site fidelity and is not limited to natal nesting site fidelity.

Relationship to abundance: A population with greater nesting site fidelity is more likely to experience declines in abundance due to climate-driven changes.

Relationship to distribution: A population with greater nesting site fidelity is less likely to experience shifts in distribution due to climate-driven changes.

Relationship to phenology: N/A. This attribute considers only geographic parameters and does not consider timing.

Nesting Site Fidelity Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Nesting females display a low degree of site fidelity (nests within ~100 km in successive nesting seasons)
Bin 2 (moderate sensitivity)	Nesting females display a moderate degree of site fidelity (nests within ~50 km in successive nesting seasons)
Bin 3 (high sensitivity)	Nesting females display a high degree of site fidelity (nests within ~10 km in successive nesting seasons)
Bin 4 (very high sensitivity)	Nesting females display extreme site fidelity (nests within 1 km in successive nesting seasons)

B.6 Lifetime Reproductive Potential

Goal: To estimate the ability of an individual (and by extension, population) to produce offspring that reach sexual maturity, thereby facilitating population growth and avoiding population declines.

Background: The ability of a species to maintain or increase its abundance and to recover from disturbance depends on the ability of its individuals to reproduce and replace, through recruitment, those individuals lost to mortality (Lande 1993). Among species with similar reproductive strategies, if an individual of a species has more offspring, there is a greater opportunity to adapt to changes. Species with higher reproductive rates are expected to be less sensitive and more adaptive (ZSL 2010, Hagger et al. 2013, Morrison et al. 2015).

Generally, *recruitment* refers to the addition of individuals to a population (Caley et al. 1996). Here, we consider recruitment to be the number of individual offspring produced by one female over the course of that female's lifetime that reach adulthood. All other factors being equal (e.g., direct and indirect anthropogenic effects such as fisheries impacts, habitat loss), species and populations that have greater recruitment are more buffered to disturbances and more likely to adapt to changing conditions. Therefore, those species and populations with greater recruitment would be expected to be less sensitive to climate change.

Since recruitment estimates are not available for many sea turtle populations, we use the characteristics and processes that determine the number of offspring that an individual of a species produces each year or over its lifetime as proxies for recruitment. These proxies include metrics such as clutch size, clutch frequency, age at sexual maturity, and juvenile survival.

Clutch size refers to the number of eggs a female lays per nest. All other factors being equal, individuals with larger clutch sizes will produce more offspring and would be expected to be less sensitive to climate change.

Clutch frequency refers to the number of nests a female lays within a given nesting season. All other factors being equal, individuals that lay more nests will produce more offspring and would be expected to be less sensitive to climate change. Multiple nests laid over the course of a season provide more resiliency to nest loss from predation, storms, or other causes.

Hatching success refers to the relative proportion of eggs that produce live hatchlings. All other factors being equal, high hatching success would result in low sensitivity to climate change.

Emergence success refers to the relative proportion of eggs that produce live hatchlings that leave the nest. All other factors being equal, high emergence success would result in low sensitivity to climate change.

Juvenile survival refers to the survival rate of a cohort from the juvenile stage to the adult stage. Offspring must reach an age at which they can reproduce in order to effectively contribute to the longevity of the species. All other factors being equal, species with higher survival rates will produce more recruits and would be expected to be less sensitive to climate change.

Remigration interval refers to the number of years between nesting seasons for a female. Species or populations that have a shorter remigration interval and therefore nest more frequently are considered less sensitive to climate change.

Age at sexual maturity refers to the age at which a female first nests. The time for a generation to turn over is shorter for species that reach sexual maturity at a younger age, thereby providing

greater opportunity to adapt to changing conditions. All other factors being equal, individuals that reach sexual maturity at a younger age will produce offspring earlier and would be expected to be less sensitive to climate change.

Reproductive Longevity refers to the fertile years of a female sea turtle. Longevity is directly related to age of sexual maturity and reproductive senescence or death (survivability). Other physiological mechanisms may also be fixed within narrow age limits. The longer the reproductive longevity, the greater the total lifetime reproductive output and, thus, the less sensitive the population is.

Climate change is likely to alter many of these proxies (Azanza-Ricardo et al. 2017, Butler 2019). However, we make no attempt to estimate the magnitude of that change, and assess these proxies as they are currently understood rather than how they may change.

Relationship to abundance: A population with greater lifetime reproductive potential is less likely to experience declines in abundance due to climate-driven changes.

Relationship to distribution: N/A. Range expansion, contraction, or shift may occur based on population sizes, which are mediated by reproductive potential. Therefore, the relationship between this attribute and distribution is secondary. Changes in distribution are considered with the population abundance attribute rather than here.

Relationship to phenology: N/A. Shifts in the timing of life history events may occur based on population sizes, which are mediated by reproductive potential. Therefore, the relationship between this attribute and phenology is secondary. Changes in phenology are considered with the population abundance attribute rather than here.

Lifetime Reproductive Potential Scoring:
We provide bookends for a spectrum of reproductive output. Experts should consider the proxies for recruitment presented above when estimating reproductive output relative to other sea turtle populations.

Bin	Criteria
Bin 1 (low sensitivity)	High reproductive output and survival to maturity
Bin 2 (moderate sensitivity)	Closer to high reproductive output and survival to maturity
Bin 3 (high sensitivity)	Closer to low reproductive output and survival to maturity
Bin 4 (very high sensitivity)	Low reproductive output and survival to maturity

B.7 Length of Nesting Season

Goal: To estimate the peak timing and duration of female nesting to infer the ability of a population to adapt its reproductive timing to changing conditions.

Background: Reproduction is often associated with seasonal timeframes and temporal constraints; however, uninterrupted year-round nesting has been recorded at some locations (Hamann et al. 2003). Those populations that have reproductive events that are highly correlated with a specific timeframe are expected to be more sensitive to changes in environmental conditions while those populations with reproductive events that are loosely correlated to time frames are expected to be exhibit more adaptability and be less sensitive (Morrison et al. 2015). Here we define the nesting season as the period during which females deposit eggs. We exclude incubation and emergence from this timeframe.

A population that can shift reproductive activities to track environmental variables in time and space will be better able to adapt. The timing of the activity among individuals influences the magnitude of this attribute. For example, an activity that occurs among all individuals within days of each other (e.g., arribadas) would cause the population to be more sensitive than if the activity occurs across weeks or months.

Sea turtle populations typically nest seasonally, although the timing and duration of nesting activities could change in response to environmental disturbances such as climate change that can directly affect ocean temperature, biogeochemical composition, and sea level (Dalleau et al. 2012). Changes in environmental conditions in nesting areas during those months may alter the success rates of nests and hatchlings. If conditions at historical nesting beaches become too warm during nesting months, populations may shift nesting beaches poleward to cooler conditions. Likewise, populations may also shift the seasonal timing of nesting. Nesting primarily during warmer months affords populations the opportunity to shift nesting months to cooler times of the year if conditions become too warm - assuming populations can respond as quickly as climate is changing. Nesting primarily during cooler months does not afford the same opportunity to shift the timing of nesting to cooler times of the year, if conditions become too warm, thereby making those populations more sensitive. Sea surface temperature has been correlated with the length of the nesting season for some populations (Pike et al. 2006, Mazaris et al. 2008), but not for others (Pike 2009).

Populations typically exhibit peak nesting periods, with differences in peak intensity and duration observed between species, populations, and regions (Bjorndal et al. 1985, Miller 1996, Chaloupka 2001, Hamann et al. 2003, Eckert et al. 2012). This temporal density of nesting activity contributes to the sensitivity of a population to climate change. Populations with shorter peak nesting seasons are more sensitive to destructive stochastic events (e.g., heat waves, storms, etc.), while populations with a longer peak nesting season may be more resilient to those events (Pike and Stiner 2007).

Relationship to abundance: A population that has a longer nesting season is less likely to experience climate-driven declines in abundance because it can more easily shift timing of nesting to match favorable conditions, thereby maintaining nesting success.

Relationship to distribution: N/A. While populations may shift the location of nesting, the length of the nesting season does not determine the location of nesting.

Relationship to phenology: A population that has a longer nesting season is less likely to experience climate-driven shifts in phenology because its historical nesting seasons are more likely to coincide with favorable conditions. A population that has a shorter nesting season is more likely to experience shifts in phenology because it would have to shift timing into periods outside of historical nesting seasons to match favorable conditions.

Instructions for expert elicitation: Consider temporal density of nesting activity when placing points. Place points to match the highest peak nesting season, when approximately 80% of sea turtles are nesting. However, if there is sporadic nesting through the year, for example, also place a point in bin 1.

Length of Nesting Season Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Population nests 10-12 months per year
Bin 2 (moderate sensitivity)	Population nests 7-9 months per year
Bin 3 (high sensitivity)	Population nests 4-6 months per year
Bin 4 (very high sensitivity)	Population nests 1-3 months per year

B.8 Adult Physiological Sensitivity to Temperature

Goal: To estimate the influence of temperature on physiological processes of nesting females.

Background: Changes in temperature are one of the most readily observed conditions in a changing climate. Temperature has a well-documented impact on the physiology and performance of ectothermic species (e.g., Davenport et al. 1997, Hayden and Harrison 2007, Madrak et al. 2016). Reaching temperature extremes at either end of the spectrum can result in mortality. For ectothermic species, size plays a major role in temperature sensitivity and the physiological response to changes in temperature (Stevenson 1985). As temperatures change spatially and temporally, individuals may shift their distribution or phenology to avoid extreme temperatures (Dudley et al. 2016).

Some sea turtle species display characteristics of endothermy, raising body temperatures above ambient temperatures with metabolic heat (Standora et al. 1982, Sato et al. 1995, Eckert 2002, James and Mrosovsky 2004, Bostrom and Jones 2007). Larger species are less susceptible to rapid changes in temperature, and therefore have more difficulty shedding heat, particularly when on land during daylight hours (Spotila and Standora 1985). When combined with the effects of raised ambient temperatures, larger species may suffer from an inability to reduce their body temperature, particularly during nesting (Burns et al. 2015).

This attribute considers only adults; eggs and nests are addressed in nest/egg sensitivity to temperature. Hatchlings and juveniles are not considered because populations would not differentiate based on size during those life stages.

We assess species or populations using *curved carapace length*. Straight carapace length may be the only metric available for some populations. Relationships between curved carapace length and straight carapace length have been established for some species (Bjorndal and Bolten 1989).

Relationship to abundance: A population with greater sensitivity to temperature is more likely to experience climate-driven shifts in abundance.

Relationship to distribution: A population with greater sensitivity to temperature is more likely to experience climate-driven shifts in distribution.

Relationship to phenology: A population with greater sensitivity to temperature is more likely to experience climate-driven shifts in phenology.

Adult Physiological Sensitivity to Temperature Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Average nesting female curved carapace length is less than 80 cm
Bin 2 (moderate sensitivity)	Average nesting female curved carapace length is greater than or equal to 80 cm but less than 100 cm
Bin 3 (high sensitivity)	Average nesting female curved carapace length is greater than or equal to 100 cm but less than 150 cm
Bin 4 (very high sensitivity)	Average nesting female curved carapace length is greater than or equal to 150 cm

B.9 Nest/Egg Sensitivity to Temperature

Goal: To estimate the effect of temperature on the nests and eggs of a population based on critical temperature thresholds.

Background: Temperature has a well-documented impact on the sex-ratio and viability of sea turtle eggs (Mrosovsky 1994, Ackerman 1997, Hawkes et al. 2009). Having many nests deviate from the pivotal temperature, the temperature at which the female:male hatchling sex ratio is 1:1 (Mrosovsky and Pieau 1991), in the same direction can have lasting impacts on the population structure, and surpassing the lethal temperature threshold can result in the mortality of an entire nest (Saba et al. 2012, Santidrián Tomillo et al. 2014, Jensen et al. 2018).

The transitional range of temperature (TRT) is a range of incubation temperatures that produces hatchlings of both sexes (Mrosovsky and Pieau 1991). Nests at temperatures below the TRT result in 100% male hatchlings while temperatures above the TRT result in 100% female hatchlings. Populations that have a greater proportion of nests near the upper temperature threshold will show greater sensitivity than populations near the pivotal temperature (Santidrián Tomillo et al. 2014). Of all the abiotic factors that influence hatching success, particularly in some species (i.e., leatherbacks), temperature may singularly be the most important variable affecting egg development and hatchling output (Santidrián Tomillo et al. 2012). The effect of high temperature accelerates developmental rates, reduces hatching success and emergence rates, and may potentially affect hatchling fitness (Poloczanska et al. 2009, Santidrián Tomillo and Swiggs 2015). Some populations are already trending toward feminization of the population due to temperatures (Jensen et al. 2018).

The impact of air temperature on the incubation temperature of nests may be modified by a number of other factors (e.g., precipitation, sand color, groundwater influences) (Tapilatu and Tiwari 2007, Santidrián Tomillo et al. 2014) and for this assessment we consider the net effect of all of those factors on the temperature of a nest.

The viability of eggs and hatchlings within the nest can be compromised by extreme temperatures, with high sand temperatures adding additional stress affecting both hatchling behavior as well as overall nest success (Hewavisenthi and Parmenter 2001, Burgess et al. 2006, Kobayashi et al. 2017). When temperatures are particularly high in nests, embryonic and hatchling deaths may result either directly through an increase into the upper lethal temperature range or potentially as a result of behavioral inhibition to the point of non-emergence by hatchlings (Milton and Lutz 2003). Species that have lower lethal temperatures would be expected to have greater sensitivity to climate changes, as increasing temperatures would more rapidly impact nests of those species compared to species with higher lethal temperatures (Howard et al. 2014). Currently, knowledge of species-specific lethal temperatures is not advanced enough to use as a metric for scoring, but future iterations of this assessment are encouraged to include lethal temperature as a metric as data improves.

We explored using a metric that measures proximity to upper bounds of the TRT or proximity to upper lethal thresholds. However, available information relating to sand temperatures was lacking for many nesting sites and required the use of proxies. Deriving those nest temperature proxies required a series of steps that resulted in error propagation and poor confidence.

Relationship to abundance: A population with a greater TRT is less likely to experience climate-driven declines in abundance.

Relationship to distribution: A population with a greater TRT is less likely to experience climate-driven shifts in distribution.

Relationship to phenology: N/A.

Nest/Egg Sensitivity to Temperature Scoring:

Bin	Criteria (TRT – difference between upper and lower bound)
Bin 1 (low sensitivity):	TRT > 5°C
Bin 2 (moderate sensitivity):	3.5°C ≤ TRT < 5°C
Bin 3 (high sensitivity):	2°C ≤ TRT < 3.5°C
Bin 4 (very high sensitivity):	TRT <2°C

B.10 Migration

Goal: To estimate migratory patterns and distribution of a population.

Background:

The impact of migration on a population's sensitivity and vulnerability to climate change is likely the most difficult to characterize of the attributes we assessed.

Migration is characterized by regular, repeated, long-distance movement (Dingle 1996, Stern 2009) such as between breeding and foraging grounds. Migratory species are often seeking specific conditions or abandoning areas that become unsuitable for parts of the year. Species may engage in annual or seasonal migrations. Dingle and Drake (2007) define annual migrations as round-trip movements synchronized with a yearly pattern and seasonal migrations as the individual stages of those annual patterns. Here, we consider seasonal migrations more closely to those defined by Dingle and Drake (2007) as "commuting," movements between discrete areas on a more frequent basis than annual migrations. Other frameworks have considered migration as a factor contributing to climate sensitivity and/or adaptive capacity for various reasons. As creatures that spend their entire lives in marine or estuarine habitats (except for nesting or basking), sea turtles' physiological and behavioral adaptations have evolved largely in response to selection in the aquatic environment and are resource driven. Data accumulated from years of mark-recapture and satellite telemetry studies, as well as sightings and strandings records, demonstrate that adult sea turtles travel hundreds to thousands of miles between established feeding and breeding areas, at regular or seasonal intervals. While some sea turtle species have relatively restricted ranges, foraging as mature animals in neritic zones, others may undergo several years of trans-oceanic migrations between nesting seasons, and therefore may have a longer remigration interval (i.e., the period (in years) between nesting events) (Plotkin 2003). Longer reproductive migrations should be differentiated from the shorter-term foraging migrations that may occur on a seasonal to annual frequency.

Migratory species are often considered to be more vulnerable to climate change due to a specific temporal or seasonal reliance on a certain habitat (Laidre et al. 2008, ZSL 2010). The reliance on specific habitat is considered elsewhere in this assessment (see Habitat Specificity) but the temporal aspect and potential for mismatches between the migrant and habitat conditions remain important (Laidre et al. 2008, Chin et al. 2010, Gardali et al. 2012, Pecl et al. 2014). Environmental cues play a greater role in the life history of migratory species than non-migratory species (Bauer et al. 2011, Shuter et al. 2011), therefore making migratory species more sensitive to climate-driven shifts in phenology. However, climate-driven shifts in the phenology of predators and/or prey may have cascading effects on both migratory and non-migratory species (Shuter et al. 2011).

Some frameworks only assessed part of a population's range and used the migration attribute to account for potential impacts in other regions (e.g., Chin et al. 2010, Bagne and Friggens 2011). Migratory species may experience varying levels of climate change across their ranges, thereby compounding their exposure to climate change. Here we consider the climate exposure throughout the entire annual range of the population and therefore do not need to use a proxy for areas outside of the scope of the assessment. Those potential changes outside the scope of other assessments are explicitly considered in the exposure score of this assessment.

Several frameworks use migration as a proxy for dispersal ability (e.g., Gardali et al. 2012, ZSL 2010, Hagger et al. 2013). While we also consider the home range of individuals of a population

(see Home Range), the fact that a population undergoes a long distance migration and the diversity of the pathways the population uses within and between years confer a degree of adaptive capacity.

Populations that utilize a variety of migratory routes may be less susceptible to the impacts of climate change and likely have evolved migratory flexibility within their large dynamic marine ecosystem to adapt to unpredictable environmental changes (Plotkin 2010). Climate change can alter currents and other oceanographic features that could, in turn, affect the route that sea turtles would take on their migrations. Although adult sea turtles are active swimmers, some species can utilize or traverse currents to facilitate reaching their final destination (Shillinger et al. 2008) while others may be nomadic, displaying little to no fidelity to specific foraging habitats (Plotkin 2010). Neonate and juvenile sea turtle movement may be aided by currents, though that effect is more one of dispersion than migration (Witherington 2002, Kobayashi et al. 2008).

Climate-driven impacts to a migratory pathway could have devastating effects on a population that relies solely on that pathway while a population that utilizes a variety of pathways would see a reduced impact on the overall population.

Finally, migratory species may be able to escape unfavorable conditions and find new habitat more easily than non-migratory species. While most sea turtles are highly mobile and capable of traveling long distances, migratory populations tend to engage in behavior that would encourage the discovery of new areas.

All aspects of a population's life history should be considered when scoring this attribute.

Relationship to abundance: N/A. A consistent directional effect could not be established. The effect of migratory behavior may add adaptive capacity and sensitivity. We were unable to determine whether the added adaptive capacity or the added sensitivity has a greater influence.

Relationship to distribution: A population that does not engage in migratory behavior is more likely to require shifts in distribution relative to historical distribution than a population that engages in migratory behavior, whereas a population that engages in migratory behavior may still require shifts in distribution but these shifts will be less consequential due to the already-expansive distribution of the population.

Relationship to phenology: N/A. A consistent directional effect could not be established. A population that engages in migratory behavior is more likely to experience shifts in timing of reproduction than a population that does not engage in migratory behavior due to potential changes in distant foraging areas.

Migration Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Reproductive migration; multiple migratory foraging area destinations
Bin 2 (moderate sensitivity)	Reproductive migration; few or single foraging area destinations
Bin 3 (high sensitivity)	No reproductive migration; seasonal foraging migration
Bin 4 (very high sensitivity)	No migration; local movement only

B.11 Foraging Home Range

Goal: To estimate the spatial extent of the foraging range of individuals within a population.

Background:

The foraging home range of an individual includes the areas regularly visited to forage (Burt 1943). The extent of foraging home range differs between individuals of a population and is generally smaller than the foraging extent of the population.

Populations with individuals that forage across a broad range likely have greater resilience to climate impacts, because foraging across a broader range confers greater redundancy of available forage habitat and implies a greater diversity of foraging habitat. Other foraging areas are likely to be available if any single foraging area within the range becomes unsuitable. In a narrow foraging home range, a change that renders any single foraging area unsuitable is likely to impact a greater proportion of the foraging extent. While range distributions may be largely defined by temperature, food availability serves as an important factor in defining the foraging home range. Sea turtles that have a broad generalist diet (e.g. loggerheads) are less likely to be restricted by climate and may have a broad foraging range while those species that are more specialists (e.g., hawksbills and green turtles) may have a more restrictive home range that may be less adaptable with changing environmental conditions (Witt et al. 2010).

Populations with individuals that have a broad foraging home range may be better suited to adapt to changing conditions within their foraging home range and find new foraging areas. These individuals have shown the ability to locate resources within a broad area. Individuals with a small foraging home range have not historically shown a tendency to forage across broad areas and may not regularly encounter new foraging areas. These individuals may also exhibit high foraging site fidelity, which would also increase sensitivity and limit the ability to adapt to changing conditions within the foraging home range.

Other vulnerability assessment frameworks use discrete areal extents (Thomas et al. 2011, Pecl et al. 2014), latitudinal extents (Chin et al. 2010, Stortini et al. 2015), or longitudinal extents (Laidre et al. 2008) to describe the geographic extent of a population. We use qualitative terms to define the foraging home range of individuals to gain a sense of their potential connectivity with other suitable foraging habitat. We consider geographic extent as two separate attributes: "Geographic Extent of Nesting" and "Foraging Home Range."

Considering that sea turtles are long-lived and highly mobile, the foraging home range of the individual (including all life stages) is more important than foraging geographic extent of the population for the time frame considered in this assessment. Adaptation to changing conditions within the foraging grounds is more likely to manifest through individual behavioral changes, rather than genetic shifts in the population. Increasing availability of satellite tag data has improved our understanding of the movements of sea turtles within the foraging range (Godley et al. 2008).

Relationship to abundance: A population consisting of individuals with broad foraging home ranges is less likely to experience declines in abundance due to climate-driven changes.

Relationship to distribution: A population consisting of individuals with broad foraging home ranges is less likely to require shifts in distribution relative to historical distribution than a population of individuals with a narrow foraging distribution. A population with a broad foraging

home range may still require shifts in distribution but these shifts will be less consequential due to the already-expansive distribution of the population.

Relationship to phenology: N/A. This attribute relates only to geographic extent and does not consider shifts in timing.

Instructions for expert elicitation: If the various life stages of a population would be scored differently, score the most restrictive life stage.

Foraging Home Range Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Individuals' foraging home ranges are broad, primarily including oceanic pelagic habitat
Bin 2 (moderate sensitivity)	Individuals transit coastlines within continental shelf waters to forage
Bin 3 (high sensitivity)	Individuals typically remain in bays or archipelagos to forage but occasionally travel farther and have the capacity to find other locations
Bin 4 (very high sensitivity)	Individuals' foraging ranges are narrow, primarily confined to bays or archipelagos

B.11 Population Abundance

Goal: To estimate a population's current abundance.

Background: Smaller population sizes have an implied reduced genetic diversity (Frankham 1996), reduced behavioral diversity (Whitehead et al. 2004), experience more demographic stochasticity (Purvis et al. 2000), and are generally at greater extinction risk (Purvis et al. 2000), likely because they have lesser adaptive evolutionary capabilities than large populations (Frankham et al. 2002). Greater diversity (e.g., genetic, behavioral) confers a greater ability to adapt to changing conditions (Morrison et al. 2015). Larger populations presumably are better poised to colonize new areas or re-establish in formerly occupied extirpated areas (Laidre et al. 2008) and buffer inter-annual variability in population size with potentially smaller percentage declines in population abundance when experiencing an environmental disturbance. In addition, those sea turtle populations that exhibit strong philopatry (natal homing) may limit the establishment or exploitation of new areas with suitable habitat, as opposed to populations favoring a "dispersal" strategy, where individuals may actively search for new areas to use for nesting or foraging (Carreras et al. 2018).

Abundance estimates of sea turtle populations are most reliably indicated by monitoring the number of nests/nesting females on the nesting beaches, although abundance estimates in particular foraging areas can be made from aerial surveys and mark/re-capture studies (National Research Council 2010). For consistency between populations, we score using nesting females as the criterion for population abundance.

Breaks in the scoring criteria come from generalizations from sea turtle recovery plans (NMFS and USFWS 1991, 1992, 1993, 1998a, 1998b, 1998c, 1998d, 1998e, 1998f, 2008, 2016, NMFS et al. 2011). Many species and DPS delisting criteria utilize values of 5,000 or 10,000 nests/nesting females. We use these values to differentiate between low/moderate sensitivity and high/very high sensitivity.

Relationship to abundance: A population with high abundance is less likely to experience declines in abundance due to climate-driven changes.

Relationship to distribution: A population with high abundance is less likely to experience large relative shifts in distribution due to climate-driven changes.

Relationship to phenology: A population with high abundance is less likely to experience large relative shifts in phenology due to climate-driven changes.

Population Abundance Scoring:
Population abundance is often defined by the survey counts of females as they come to beach.

Bin	Criteria
Bin 1 (low sensitivity)	>10,000 nesting females
Bin 2 (moderate sensitivity)	5,000-10,000 nesting females
Bin 3 (high sensitivity)	1,000-5,000 nesting females
Bin 4 (very high sensitivity)	<1,000 nesting females

B.12 Population Abundance Trend

Goal: To identify the recent historical trend of a population's abundance through time.

Background: Populations with declining abundance may have a reduced ability to recover from disturbances and are more likely to be sensitive to climate change. The "Framework for Categorizing the Relative Vulnerability of Threatened and Endangered Species to Climate Change" (Galbraith and Price 2009) assesses population size reduction over a 10-year or three-generation period, derived from one of the criteria used to determine the International Union for the Conservation of Nature (IUCN) Red List status (IUCN 2012). Here, we follow the model of Thomas et al. (2011) to establish scoring bins. Thomas et al. (2011) use a criterion of 7.5% rate of decline to differentiate between 'declining' and 'rapidly declining'. We realize that such precision may not be possible for many populations because long time series are not available for many populations. While the trend is likely unknown for certain populations, we anticipate experts will score based on their scientific knowledge and experience.

Multiple metrics are available for estimating abundance trend (e.g., aerial survey estimates in known foraging hotspots (e.g., Seminoff et al. 2014, Eguchi et al. 2018), number of nests, number of nesting females (National Research Council 2010). We ask experts to use trends in nesting females (NMFS and USFWS 2016) where available and to use their expert opinion in selecting the next best available metric where necessary.

The period over which a trend is estimated can affect the direction and magnitude of a trend. Many sea turtle populations have experienced historical declines, such that when examined on a long time scale indicate an overall decline (National Research Council 1990, McClenachan et al. 2006, IUCN 2016), though the trend in the recent period may indicate an increase. For the purposes of this assessment, we ask experts to consider the recent population abundance trend (e.g., past decade). We give greater weight to the recent trend over the long-term trend (e.g., 50–100 years) to reflect the recent advances in conservation.

Relationship to abundance: A population with a rapidly declining abundance is more likely to experience declines in abundance due to climate-driven changes

Relationship to distribution: A population with a rapidly declining abundance is more likely to experience shifts in distribution due to climate-driven changes

Relationship to phenology: A population with a rapidly declining abundance is more likely to experience shifts in phenology due to climate-driven changes

Population Abundance Trend Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Increasing abundance trend over recent period
Bin 2 (moderate sensitivity)	Stable abundance trend over recent period
Bin 3 (high sensitivity)	Declining abundance trend over recent period
Bin 4 (very high sensitivity)	Rapidly declining abundance trend over recent period or deficient data to estimate trend

B.14 Cumulative Stressors

Goal: To estimate the level to which a population is currently impacted by non-climate stressors.

Background: Climate change is expected to exacerbate the impacts of other non-climate stressors that already impact sea turtles. Populations that experience stress from non-climate sources will have reduced fitness and capacity to adapt to climate change (Morrison et al. 2015). Sea turtles may encounter a wide variety of stressors, both natural and anthropogenic, and these may include environmental factors (e.g., salinity, pollution), physiological factors, physical factors (e.g., trauma, forced submersion) and biological factors (e.g., disease, toxic blooms). The adaptive function of a response to a particular stressor will depend on the intensity, duration, and whether populations can adapt (Milton and Lutz 2003). The magnitude of impact experienced by additional stressors will vary by species and region.

While any level of a stressor can result in negative impacts on a population, for the purposes of this assessment a stressor is considered anything that has population-level effects.

Examples of non-climatic additional stressors include:

- Bycatch or competition with fisheries (e.g., Wallace et al. 2010)
- Direct killing/poaching (e.g., Koch et al. 2006)
- Vessel strike (e.g., Chaloupka et al. 2008, Casale et al. 2010)
- Habitat degradation not due to climate change (e.g., coastal development, beach armoring and alteration) (e.g., Fish et al. 2008)
- Disease, parasites, and harmful algal bloom exposure (e.g., Chaloupka et al. 2008)
- Predation by and competition with feral and invasive organisms (e.g., Caut et al. 2008)
- Pollutants/toxins (e.g., Keller 2013)
- Marine debris (e.g., Carr 1987, Bjorndal et al. 1994)
- Natural population interactions such as competition and predation (e.g., Chaloupka et al. 2008)

Non-climate stressors will react to climate change in different ways. Novel interactions may emerge, for example, from responses in fishing (e.g., effort, gear, target species, target areas) as fish distributions shift, coastal development and usage as coastal conditions change, and from vessel strikes as sea turtle distributions shift. We do not attempt to anticipate how those responses will manifest but note that responses to climate change from other sectors and actors will be dynamic and, in many cases, difficult to predict.

Studies have characterized (IUCN 2016) and quantified (Wallace et al. 2011) threats to sea turtles. Scores from Wallace et al. (2011) could not be used directly because they included climate change as a threat, which would confound scores in this assessment. Scores from Wallace et al. (2011) should serve as both a baseline and comparison for this assessment.

Relationship to abundance: A population that currently experiences many non-climate stressors is more likely to experience declines in abundance due to climate-driven changes.

Relationship to distribution: A population that currently experiences many non-climate stressors is more likely to experience shifts in distribution due to climate-driven changes.

Relationship to phenology: N/A

Cumulative Stressors Scoring:

Bin	Criteria
Bin 1 (low sensitivity)	Population currently experiences 2 or fewer additional stressors
Bin 2 (moderate sensitivity)	Population currently experiences 3 or 4 additional stressors
Bin 3 (high sensitivity)	Population currently experiences 5 or 6 additional stressors
Bin 4 (very high sensitivity)	Population currently experiences more than 6 additional stressors or has one additional stressor that accounts for more than half of annual mortality.

B.15 Attributes considered but omitted

During the development of this framework, a number of potential attributes were considered to score sensitivity and adaptive capacity. We list those that were considered but ultimately omitted from the framework such that future iterations may include these attributes if appropriate. Many of these attributes were omitted because of a lack of available information or a lack of meaningful differentiation in how the attribute would score among species and populations.

Prey availability

Predictability of prey in time and space is an important consideration. Decreased predictability would increase sensitivity, making it important to consider search strategies. The attribute is not intrinsic to the subject species and would require data on all prey species.

The availability of other prey species of roughly equivalent energetic/nutrient composition adds a layer of complexity. If a species is capable of foraging on other species but none are available, or only those of considerably deficient nutrient or energetic content, the species would be more sensitive to climate impacts. Similarly, if the traditionally targeted prey consists of fewer but larger prey items and can only be replaced by smaller prey, additional or different pressures to capture more prey items may come at a higher cost to the predator in time, energy, or risk of predation. The availability of prey and the relative availability of comparable alternative prey are important considerations but beyond the scope of this attribute and therefore not included in the scoring.

Population trend of prey

Species that forage on prey with high variability in abundance may have relatively high sensitivity to climate change. The attribute is not intrinsic to the subject species and would require data on all prey species.

Distribution trend of prey

Species that forage on prey with high variability in distribution may have relatively high sensitivity to climate change. The attribute is not intrinsic to the subject species and would require data on all prey species.

Mean trophic level

The primary productivity required to sustain a population can be estimated and may be an indicator of sensitivity. While a species that feeds on high trophic levels would likely have a different sensitivity than a species that feeds on a lower trophic level, we struggled to formalize the relationship between trophic level and sensitivity. This attribute was determined to be similar to the more easily measured and qualified metric of 'prey/diet specificity.'

Influences of changes in trophic web

Climate change could lengthen or shorten the food chain, resulting in changing amounts of energy available at the apex levels. Other assessments (see NatureServe's CCVI[6]) include interspecific interactions but the attribute was deemed too complex for this application.

Complexity in reproductive strategy

Species with highly complex reproductive strategies are more likely to have at least one aspect of the strategy impacted by climate change. A lack of variability among taxa rendered this attribute impractical.

[6] http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index

Environmental variable(s) as a phenological cue for breeding
The triggers/cues for many species are likely unknown. As more data become available, this attribute could be reconsidered.

Early life history survival requirements
This attribute was considered too correlated with other attributes, particularly habitat sensitivity and reproductive plasticity.

Proximity to limit of thermal tolerance
Separating species' physiological tolerance from prey tolerance is difficult, at least in terms of proximity to a threshold.

Spatial availability of unoccupied habitat for most critical life stage
This attribute most applies for species recovering from past declines with the potential for recovering populations to recolonize historical areas where they were previously extirpated or to colonize new areas beyond historical ranges. Most populations are not at their carrying capacity, suggesting there is unoccupied habitat. This attribute is not intrinsic to the species and would be difficult to quantify.

Genetic diversity
Generally, the more genetically diverse the species, the less sensitive the species is to ecosystem perturbations. We encourage future iterations of this assessment to consider incorporating this attribute.

Temporal mismatches of life-cycle events
This attribute has been incorporated into other attributes through the use of the phenology response category.

B.16 Appendix B References

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Appendix C Sample Scoring

We show sample exposure scores (Table C1) and sensitivity scores (Table C2) for a hypothetical population. Here we highlight the process of calculating the weighted means, the component scores, the overall vulnerability score, and the response category scores.

Factor and Attribute Weighted Means (Section 2.4.1)

Weighted means are calculated for each climate exposure factor and each sensitivity attribute. The weighted means are calculated by multiplying the number of points in each bin by the bin number (number of points in Bin 1 times 1, number of points in Bin 2 times 2, number of points in Bin 3 times 3, number of points in Bin 4 times 4) and then dividing by the total number of points for that attribute or factor. The value of these weighted means ranges from 1.0 to 4.0.

Component Scores (section 2.4.2)

Exposure and sensitivity component scores are calculated using the attribute and factor weighted means from above and the component score logic model from Table 4 in section 2.4.2 (also below).

As shown in Table C1, weighted mean scores for sea surface temperature change in mean, air temperature change in mean, ocean pH change in mean, and dissolved oxygen change in mean are all above 3.5. The exposure component score is therefore “very high (4)."

Five sensitivity attribute weighted means (geographic extent of nesting, length of nesting season, nest/egg sensitivity to temperature, population abundance, and cumulative stressors) are greater than 3.5 (Table C2). The sensitivity component score is therefore “very high (4).”

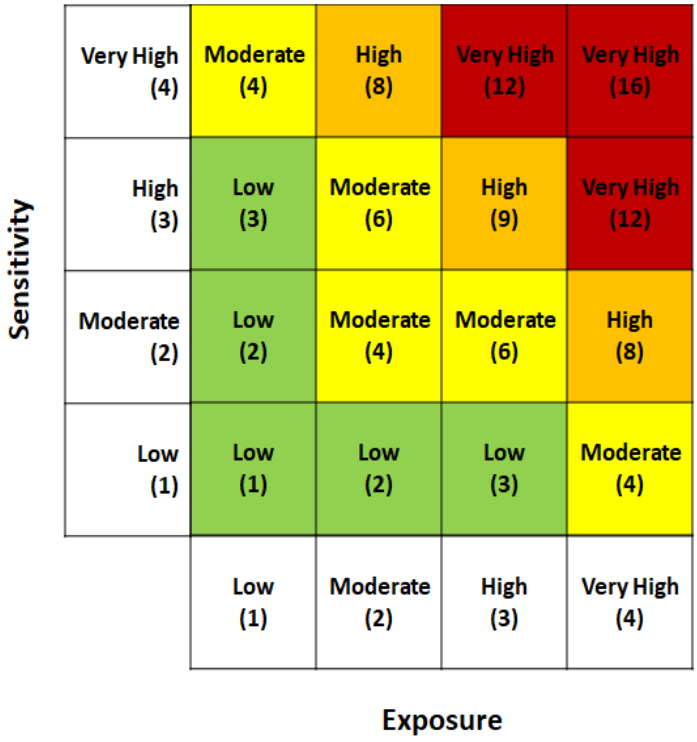
Component score logic model (see Table 4 of section 2.4.2)

Component Score	Criteria
Very High (4)	3 or more attribute or factor mean scores ≥ 3.5
High (3)	2 or more attribute or factor mean scores ≥ 3.0, but does not meet threshold for “Very High”
Moderate (2)	2 or more attribute or factor mean scores ≥ 2.5, but does not meet threshold for “High” or “Very High”
Low (1)	Less than 2 attribute or factor mean scores ≥ 2.5

Overall Vulnerability Score (Section 2.4.3)

Using the vulnerability matrix (Figure 3 in section 2.4.3) and the component scores from above, a “very high (4)” exposure component and a “high (3)” sensitivity component converge at a “very high (12)” overall vulnerability score.

Vulnerability matrix (see Figure 3 of section 2.4.3 and)



Response Category Scores (Section 2.4.4)

The distribution, abundance, and phenology response category scores are derived from the attribute weighted means calculated according to the relationships with each attribute described in Appendix B. The weighted means are used in the component score logic model (Table 4), similar to the calculation of component scores above.

The distribution response scores as “very high” because geographic extent of nesting, length of nesting season, nest/egg sensitivity to temperature, population abundance, and cumulative stressors weighted means are greater than or equal to 3.5 (Table C2). The abundance response scores as “very high” because geographic extent of nesting, length of nesting season, nest/egg sensitivity to temperature, population abundance, and cumulative stressors weighted means are greater than or equal to 3.5. The phenology response scores as “high” because prey/diet specificity, length of nesting season, and population abundance weighted means are greater than or equal to 3.0.

Table C1. Sample exposure scores

Species/Population - Common Name	Reviewer Name						
SAMPLE	SAMPLE						
Exposure Factor		USER ENTERS 5 TALLIES PER ROW Bin1 + Bin2 + Bin3 + Bin4 must equal 5				DATA QUALITY	FACTOR WEIGHTED MEAN
Sea Surface Temperature		Bin 1 (Blue)	Bin 2 (Dark Green)	Bin 3 (Light Green)	Bin 4 (Yellow)	3	**3.8**
Change in mean	Tallies			1	4		
Sea Surface Temperature		Bin 1 (Purple)	Bin 2 (Pink)	Bin 3 (Orange)	Bin 4 (Yellow)	3	**1.0**
Change in variability	Tallies	5					
Air Temperature		Bin 1 (Blue)	Bin 2 (Dark Green)	Bin 3 (Light Green)	Bin 4 (Yellow)	3	**3.6**
Change in mean	Tallies			2	3		
Air Temperature		Bin 1 (Purple)	Bin 2 (Pink)	Bin 3 (Orange)	Bin 4 (Yellow)	3	**1.0**
Change in variability	Tallies	5					
Precipitation		Bin 1 (Blue)	Bin 2 (Dark Green)	Bin 3 (Light Green)	Bin 4 (Yellow)	3	**1.0**
Change in mean	Tallies	5					
Precipitation		Bin 1 (Purple)	Bin 2 (Pink)	Bin 3 (Orange)	Bin 4 (Yellow)	3	**1.0**
Change in variability	Tallies	5					
Sea Surface Salinity		Bin 1 (Blue)	Bin 2 (Dark Green)	Bin 3 (Light Green)	Bin 4 (Yellow)	3	**1.8**
Change in mean	Tallies	1	4				
Sea Surface Salinity		Bin 1 (Purple)	Bin 2 (Pink)	Bin 3 (Orange)	Bin 4 (Yellow)	3	**1.4**
Change in variability	Tallies	3	2				
Ocean pH		Bin 1 (Blue)	Bin 2 (Dark Green)	Bin 3 (Light Green)	Bin 4 (Yellow)	3	**4.0**
Change in mean	Tallies				5		
Ocean pH		Bin 1 (Purple)	Bin 2 (Pink)	Bin 3 (Orange)	Bin 4 (Yellow)	3	**1.0**
Change in variability	Tallies	5					
Dissolved oxygen		Bin 1 (Blue)	Bin 2 (Dark Green)	Bin 3 (Light Green)	Bin 4 (Yellow)	3	**4.0**
Change in mean	Tallies				5		
Dissolved oxygen		Bin 1 (Purple)	Bin 2 (Pink)	Bin 3 (Orange)	Bin 4 (Yellow)	3	**1.0**
Change in variability	Tallies	5					
Circulation		Bin 1	Bin 2	Bin 3	Bin 4	2	**1.8**
	Tallies	1	4				
Sea level rise		Bin 1	Bin 2	Bin 3	Bin 4	2	**3.0**
	Tallies			5			

Table C2. Sample sensitivity scores

Species/Population - Common Name	Reviewer Name									
SAMPLE	SAMPLE									
Sensitivity/Adaptive Capacity Attribute		USER ENTERS 5 TALLIES PER ROW Bin1 + Bin2 + Bin3 + Bin4 must equal 5				DATA QUALITY	ATTRIBUTE WEIGHTED MEAN	DISTRIBUTION RESPONSE	ABUNDANCE RESPONSE	PHENOLOGY RESPONSE
Prey/Diet Specificity		Bin 1	Bin 2	Bin 3	Bin 4	3	**3.2**	**3.2**	**3.2**	**3.2**
	Tallies			4	1					
Habitat Specificty (in-water)		Bin 1	Bin 2	Bin 3	Bin 4	3	**1.0**	**1.0**	**1.0**	**1.0**
	Tallies	5								
Nesting Beach Type		Bin 1	Bin 2	Bin 3	Bin 4	3	**2.0**	**2.0**	**2.0**	**N/A**
	Tallies		5							
Geographic Extent of Nesting		Bin 1	Bin 2	Bin 3	Bin 4	3	**4.0**	**4.0**	**4.0**	**N/A**
	Tallies				5					
Nesting Site Fidelity		Bin 1	Bin 2	Bin 3	Bin 4	2	**3.0**	**3.0**	**3.0**	**N/A**
	Tallies			5						
Lifetime Reproductive Potential		Bin 1	Bin 2	Bin 3	Bin 4	2	**1.8**	**1.8**	**N/A**	**N/A**
	Tallies	1	4							
Length of Nesting Season		Bin 1	Bin 2	Bin 3	Bin 4	3	**4.0**	**4.0**	**N/A**	**4.0**
	Tallies				5					
Adult Physiological Sensitivity to Temperature		Bin 1	Bin 2	Bin 3	Bin 4	2	**2.0**	**2.0**	**2.0**	**2.0**
	Tallies		5							
Nest/Egg Sensitivity to Temperature		Bin 1	Bin 2	Bin 3	Bin 4	3	**4.0**	**4.0**	**4.0**	**N/A**
	Tallies				5					
Migration		Bin 1	Bin 2	Bin 3	Bin 4	3	**1.0**	**N/A**	**1.0**	**N/A**
	Tallies	5								
Foraging Home Range		Bin 1	Bin 2	Bin 3	Bin 4	3	**2.0**	**2.0**	**2.0**	**N/A**
	Tallies		5							
Population Abundance		Bin 1	Bin 2	Bin 3	Bin 4	3	**4.0**	**4.0**	**4.0**	**4.0**
	Tallies				5					
Population Abundance Trend		Bin 1	Bin 2	Bin 3	Bin 4	3	**1.8**	**1.8**	**1.8**	**1.8**
	Tallies	1	4							
Cumulative Stressors		Bin 1	Bin 2	Bin 3	Bin 4	3	**3.8**	**3.8**	**3.8**	**N/A**
	Tallies			1	4					