



# **Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act:**

## **EPA's Response to Public Comments**

### **Volume 7: Impacts and Risks to Public Health and Welfare: Water Resources, Coastal Areas, and Ecosystems and Wildlife**

# **Impacts and Risks to Public Health and Welfare: Water Resources, Coastal Areas, and Ecosystems and Wildlife**

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Office of Atmospheric Programs  
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## FOREWORD

This document provides responses to public comments on the U.S. Environmental Protection Agency's (EPA's) Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, published at 74 FR 18886 (April 24, 2009). EPA received comments on these Proposed Findings via mail, e-mail, and facsimile, and at two public hearings held in Arlington, Virginia, and Seattle, Washington, in May 2009. Copies of all comment letters submitted and transcripts of the public hearings are available at the EPA Docket Center Public Reading Room, or electronically through <http://www.regulations.gov> by searching Docket ID *EPA-HQ-OAR-2009-0171*.

This document accompanies the Administrator's final Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act (Findings) and the Technical Support Document (TSD), which contains the underlying science and greenhouse gas emissions data.

EPA prepared this document in multiple volumes, with each volume focusing on a different broad category of comments on the Proposed Findings. This volume of the document provides responses to public comments regarding water resources, coastal areas, and ecosystems and wildlife.

In light of the very large number of comments received and the significant overlap between many comments, this document does not respond to each comment individually. Rather, EPA summarized and provided a single response to each significant argument, assertion, and question contained within the totality of comments. Within each comment summary, EPA provides in parentheses one or more lists of Docket ID numbers for commenters who raised particular issues; however, these lists are not meant to be exhaustive and EPA does not individually identify each and every commenter who made a certain point in all instances, particularly in cases where multiple commenters expressed essentially identical arguments.

Several commenters provided additional scientific literature to support their arguments. EPA's general approach for taking such literature into consideration is described in Volume 1, Section 1.1, of this Response to Comments document. As with the comments, there was overlap in the literature received. EPA identified the relevant literature related to the significant comments, and responded to the significant issues raised in the literature. EPA does not individually identify each and every piece of literature (submitted or incorporated by reference) that made a certain point in all instances.

Throughout this document, we provide a list of references at the end of each volume for additional literature cited by EPA in our responses; however, we do not repeat the full citations of literature cited in the TSD.

EPA's responses to comments are generally provided immediately following each comment summary. In some cases, EPA has discussed responses to specific comments or groups of similar comments in the Findings. In such cases, EPA references the Findings rather than repeating those responses in this document.

Comments were assigned to specific volumes of this Response to Comments document based on an assessment of the principal subject of the comment; however, some comments inevitably overlap multiple subject areas. For this reason, EPA encourages the public to read the other volumes of this document relevant to their interests.

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## Acronyms and Abbreviations

CCSP	U.S. Climate Change Science Program
CaCO <sub>3</sub>	calcium carbonate
CO <sub>2</sub>	carbon dioxide
EPA	U.S. Environmental Protection Agency
GHG	greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
NOAA	National Oceanic and Atmospheric Administration
PCB	polychlorinated biphenyl
TSD	Technical Support Document
USFWS	U.S. Fish and Wildlife Service
USGCRP	U.S. Global Change Research Program

## **7.0 Impacts and Risks to Public Health and Welfare: Water Resources and Coastal Areas**

### **7.1 Water Resources**

#### **Comment (7-1):**

A commenter (7020) argues that Section 11 of the Technical Support Document (TSD) does not properly evaluate and quantify the benefits that climate change will have on water resources, and that EPA ignored many of the benefits.

#### **Response (7-1):**

We disagree that the TSD does not properly evaluate information regarding the benefits of climate change on water resources. We note that the commenter did not provide specific examples of benefits that were ignored or reasoning to accompany their comment. Section 11 of the TSD includes the following statements regarding potential benefits to the water resource sector due to climate change impacts:

Navigation benefits from climate change exist as well. For example, the navigation season for the North Sea Route is projected to increase from the current 20 to 30 days per year to 90 to 100 days by 2080 (ACIA, 2004, and references therein).

Warmer waters also transfer volatile and semi-volatile compounds (ammonia, mercury, PCBs [polychlorinated biphenyls], dioxins, pesticides) from surface water bodies to the atmosphere more rapidly (Kundzewicz et al., 2007). Although this transfer will improve water quality, this may have implications for air quality.

Please see Volume 1 of this Response to Comments document for responses to scientific comments received on the treatment of adverse and beneficial effects. Further, it appears that the commenter believes our evaluation is not proper because we did not quantify the benefits. See Section IV.B. of the Findings for our discussion of quantifying impacts.

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#### **Comment (7-2):**

Several commenters (e.g., 3136.1, 3596.2) state that specific aspects of the climate impacts evidence summarized in the TSD with respect to water resources do not support the Administrator's endangerment finding.

#### **Response (7-2):**

The specific issues that underlie these comments are addressed in the responses throughout this volume, and other volumes of the Response to Comments document. With regard to the commenters' conclusion that the current science does not support an endangerment finding with respect to water resources, we disagree based on the scientific evidence before the Administrator. See the Findings, Section IV.B, "The Air Pollution is Reasonably Anticipated to Endanger Both Public Health and Welfare," for details on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the water resource sector in particular.

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#### **Comment (7-3):**

A commenter (2750) questions why EPA considered it harmful that global mean precipitation is expected to increase.

#### **Response (7-3):**

The TSD summarizes the conclusions of assessment reports which find that changes in global mean precipitation will likely adversely impact water resources in the United States. Although it might seem that an increase in precipitation would be beneficial, a number of factors must be considered, including the timing and intensity of precipitation. The Intergovernmental Panel on Climate Change (IPCC) concluded with very high confidence that global “[i]ncreases in precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas” and that these changes will affect “the function and operation of existing water infrastructure as well as water management practices” (Kundzewicz et al., 2007). Furthermore, the IPCC concluded that, for all world regions, “the negative impacts of climate change on freshwater systems outweigh its benefits (high confidence). Areas in which runoff is projected to decline are likely to face a reduction in the value of the services provided by water resources (very high confidence). The beneficial impacts of increased annual runoff in other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality, and flood risks (high confidence)” (Kundzewicz et al., 2007).

We note that the commenters did not provide additional scientific literature to support their arguments and did not include any reasoning with their conclusion. We have determined that the literature presented in the TSD is an accurate and reasonable summary of current scientific understanding.

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**Comment (7-4):**

A commenter (2895) supports the Proposed Finding due to their local vulnerabilities associated with declining glacial storage and the resulting impacts on electricity, flood control, and fisheries.

**Response (7-4):**

EPA finds that the commenter’s discussion is generally consistent with the TSD’s summary of the assessment literature. Section 11 of the TSD describes several climate change impacts on snowpack-dependent watersheds, including risks to electrical supply, flood control, and fisheries.

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**Comment (7-5):**

A commenter (3136.1) states that the TSD does not mention that there have been no observed increases in trends of flood-related damages while global temperatures have increased over the past century. The commenter cites Downton et al. (2005), and argues that this paper indicates that there is no detectable increase in flood losses in the face of rising temperatures when population growth and wealth are accounted for. The commenter argues that given this evidence, climate change effects on flood-related damages should not be used as a basis for determining endangerment.

**Response (7-5):**

We find that the commenter has misinterpreted the findings of the Downton et al. (2005) paper. This study “presents results of a reanalysis of NWS flood damage estimates from 1926 to 2000. It describes National Weather Service methods of collecting flood damage estimates, explains some of the limitations and problems in the data, and recommends appropriate methods of interpretation and use.” After careful review, we do not find evidence within this study which suggests that increases in intense precipitation have resulted in no increases in flooding, as suggested by the commenter. In fact, this paper does not directly analyze the relation between precipitation intensity and flood frequency and/or intensity. Rather, Downton et al. (2005) analyzes trends in flood damage data and identifies sources of error in the damage estimates. At a national level, the study finds that “Total damage and per capita damage have increased significantly since 1934 (statistically significant at a 95% confidence level). On the other hand, damage per unit wealth has declined slightly (although the trend is significant only at an 85% confidence level).” However, no correlation or connection is analyzed with changing precipitation intensity or amount.

Regarding weather-related damages such as flooding, we note the conclusions of the U.S. Climate Change Science Program (CCSP) (2008i) which state that “Numerous studies indicate that both the climate and the socioeconomic vulnerability to weather and climate extremes are changing (Brooks and Doswell, 2001; Pielke *et al.*, 2008; Downton *et al.*, 2005), although these factors’ relative contributions to observed increases in disaster costs are subject to debate. For example, it is not easy to quantify the extent to which increases in coastal building damage is due to increasing wealth and population growth in vulnerable locations versus an increase in storm intensity. Some authors (*e.g.*, Pielke *et al.*, 2008) divide damage costs by a wealth factor in order to ‘normalize’ the damage costs. However, other factors such as changes in building codes, emergency response, warning systems, *etc.* also need to be taken into account. At this time, there is no universally accepted approach to normalizing damage costs (Guha-Sapir *et al.*, 2004). Though the causes of the current damage increases are difficult to quantitatively assess, it is clear that any change in extremes will have a significant impact.” These CCSP conclusions are consistent with Downton *et al.* (2005) which states that “Although flood damage fluctuates greatly from year to year, estimates indicate an increasing trend over the past century (Pielke and Downton 2000). To understand increasing damage and assess implications for policy, decision makers need to recognize the influences of climate, population growth, land use, and policy on trends in damage. An increase in flood damage due to changing climate would probably require different policy actions than would damage increases due to implementation of flood policies.”

We also note that monetized flood-related damages, as studied by Downton *et al.* (2005), are only one type of flood-related effect on health and welfare. Other important damages discussed in the TSD include increased morbidity and mortality, adverse impacts to wildlife and habitat loss, impaired water quality, and other effects that are generally not included in flood damage estimates.

To provide additional context regarding the future impacts of climate change on flooding, several studies reviewed and cited by Kundzewicz *et al.* (2007) indicate that increases intense precipitation will result in adverse impacts:

Choi and Fisher (2003) estimated the expected change in flood damages for selected U.S. regions under two climate-change scenarios in which mean annual precipitation increased by 13.5% and 21.5%, respectively, with the standard deviation of annual precipitation either remaining unchanged or increasing proportionally. They used a structural econometric (regression) model based on time series of flood damage and population, wealth indicator, and annual precipitation as predictors. They found that the mean and standard deviation of flood damage are projected to increase by more than 140% if the mean and standard deviation of annual precipitation increase by 13.5%. The estimates suggest that flood losses are related to exposure because the explanatory power of population and wealth is 82%, while adding precipitation increases the explanatory power to 89%.

Another study examined the potential flood damage impacts of changes in extreme precipitation events using the Canadian Climate Centre model and the IS92a emissions scenario for the metropolitan Boston area in the northeastern United States (Kirshen *et al.*, 2005). They found that, without adaptation investments, both the number of properties damaged by floods and the overall cost of flood damage would double by 2100 relative to what might be expected with no climate change, and that flood-related transportation delays would become an increasingly significant nuisance over the course of the century.

After review of the studies submitted during the public comment process, we find that literature presented in the TSD is an accurate and reasonable summary of current scientific understanding. See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and

Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-6):**

A commenter (3136.1) argues that the TSD should be modified to recognize that the observed increases in U.S. rainfall (on average) will likely result in a net benefit in helping to meet the United States’ growing water demand. This commenter references several studies, which in the commenter’s view show that increases in precipitation (generally) have not had adverse effects: 1) although annual precipitation increases have been accompanied by increases in heavy rainfall events, the additional precipitation has positive effects (Michaels et al., 2004), and 2) the rainfall increases have not led to increases in flood events (Lins and Slack, 1999; Small et al., 2006; Downton et al., 2005).

**Response (7-6):**

The assessment literature provides robust evidence with high confidence that the negative impacts of climate change on freshwater systems outweigh its benefits. In some areas, annual runoff is projected to decline, leading to a reduction in the value to water resources provided by water resources, and the beneficial impacts of increased annual runoff in other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality, and flood risks (Kundzewicz et al., 2007). While annual precipitation averaged across the United States is projected to increase with climate change, precipitation changes—including the form, timing, and amount—will vary from region to region. Changes in annual average precipitation cannot be used in isolation to determine water resource vulnerability because observed trends and projected changes in precipitation have strong regional and seasonal variation (Karl et al., 2009), changing the form, timing, and amount of precipitation at any one location. For example, increasing intensity of rainfall projected for the United States, especially in the Southeast, Midwest, and Northwest, will result in greater risk of flooding (Karl et al., 2009). Heavier downpours will exacerbate existing combined sewer overflow problems in many cities. Since sewer infrastructure is very expensive to install and maintain, climate change will present a new set of challenges for designing upgrades to the nation’s water delivery and sewage removal infrastructure (Karl et al., 2009).

Regarding the findings of Michaels et al. (2004), Lins and Slack (1999), and Small et al. (2006) on the relationship between heavy rainfall events and average precipitation, we refer the commenters to Volume 4: Section 5 for our responses to the findings of these studies and to similar comments on precipitation changes and flooding. Regarding the referenced study showing that rainfall increases have not led to greater flooding (Downton et al., 2005), please refer to the previous response to comment (#7-5). None of the studies referenced by the commenter provide evidence that increases in average annual runoff in the United States will result in net benefits in helping to meet growing water demands. We have determined that the literature presented in the TSD is an accurate and reasonable summary of current scientific understanding.

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**Comment (7-7):**

A commenter (3136.1) suggests that appropriate measures should be investigated for taking the best advantage of the changes in the patterns of increased precipitation delivery.

**Response (7-7):**

See the finding, Section III.C, “Adaptation and Mitigation,” for our response to comments on the treatment of adaptation and mitigation in the finding.

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**Comment (7-8):**

A commenter (3537.1) disagrees with the TSD that climate change will result in longer periods of low stream flow and that these impacts have not been observed. The commenter references several studies (Lins and Slack, 1999; Small et al., 2006; Michaels, et al. 2004) and argues that these papers support the comment.

**Response (7-8):**

The assessment literature as summarized in the TSD provides compelling evidence that climate change has already affected and will continue to affect the water cycle, with implications for water resources available for human use, including longer and more intense drought. We note that while annual precipitation averaged across the United States is projected to increase with climate change, precipitation changes—including the form, timing, and amount—will vary from region to region. Observations show that over the past several decades, extended dry periods have become more frequent in parts of the United States, especially the Southwest and the eastern United States. Longer periods between rainfalls, combined with higher air temperatures, dry out soils and vegetation, causing drought (Karl et al., 2009). Karl et al. (2009) also conclude that droughts and low flow periods are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between).

Regarding the findings of Michaels et al. (2004), Lins and Slack (1999), and Small et al. (2006) on the relationship between heavy rainfall events and average precipitation, we refer the commenters to Volumes 4 and 2 for our responses to the findings of these studies and to similar comments on precipitation changes.

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**Comment (7-9):**

In the following text from the TSD (from Section 11, “Water Resources”), a commenter (2972.1) argues that EPA does not appropriately differentiate between expectations and magnitudes of risk related to our climate versus those related to climate change.

Drought events are already a frequent occurrence, especially in the western U.S. Vulnerability to extended drought is, according to IPCC (Field et al., 2007), increasing across North America as population growth and economic development increase demands from agricultural, municipal, and industrial uses, resulting in frequent over-allocation of water resources. Though droughts occur more frequently and intensely in the western part of the U.S., the east is not immune from droughts and attendant reductions in water supply, changes in water quality and ecosystem function, and challenges in allocation (Field et al., 2007).

**Response (7-9):**

In response to this comment, we have clarified this text in Section 11 of the TSD. The revised text now reads:

It is likely that anthropogenic warming has increased the impacts of drought over North America in recent decades, but the magnitude of the effect is uncertain (CCSP, 2008g). The socioeconomic impacts of droughts arise from the interaction between climate, natural conditions, and human factors such as changes in land use. In dry areas, excessive water withdrawals from surface and ground water sources can exacerbate the impacts of

drought (Kundzewicz et al., 2007). Although drought has been more frequent and intense in the western part of the United States, the East is also vulnerable to droughts and attendant reductions in water supply, changes in water quality and ecosystem function, and challenges in allocation (Field et al., 2007).

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**Comment (7-10):**

A commenter (7020) argues that Section 11(c) of the TSD on “Extreme Events” presents information previously discussed in other parts of the water resource section.

**Response (7-10):**

We have reviewed this comment regarding the organization of this document, we do not find the information presented in Section 11(c) to be redundant. This section of the TSD provides important information regarding the impacts associated with extreme flooding and drought, including impacts to infrastructure, development, and other components of the water resource system.

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**Comment (7-11):**

A commenter argues that there is “little evidence to suggest that projections of increasing extreme weather events (specifically drought and floods) are in line with the observations during the recent period of rising temperatures in the U.S.” The commenter cites Small et al. (2006) and argues that the paper finds no trends in annual highest stream flow despite increases in precipitation across the eastern United States.

**Response (7-11):**

In contrast to the commenter’s assertion, the assessment literature provides substantial evidence linking rising temperatures to projected increases in droughts and floods. For example, the IPCC (Kundzewicz et al., 2007), as summarized in Section 11 of the TSD, concluded that higher temperatures increase the water-holding capacity of the atmosphere and evaporation into the atmosphere, which contributes to increased climate variability, more intense precipitation events, and more droughts. The U.S. Global Change Research Program (USGCRP) found that, in the past century and averaged over the United States, total precipitation has increased by about 7%, while the heaviest 1% of rain events increased by nearly 20% (Karl et al., 2009). Flooding is a common response when heavy precipitation persists for weeks to months in large river basins, and such extended periods of heavy precipitation have been increasing over the past century, most notably in the past two to three decades in the United States (Karl et al., 2009). In addition and consistent with model projections, extended dry periods have become more frequent in parts of the United States, especially the southwest and eastern regions (Karl et al., 2009).

Regarding the findings of the Small et al. (2006), we refer the commenters to Volume 4: Section 5 for our response to the findings of this study and to similar comments on precipitation changes and stream flow.

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**Comment (7-12):**

Several commenters (3136.1, 3394.1, 3411.1, 3596.2, and 5844) disagree with the TSD’s conclusion that North America’s water resources are over-allocated and that society has been hindered by a shortage of water. Two commenters (3136.1 and 3411.1) argue that adaptation and water efficiency measures will be more than sufficient in dealing with any water shortage problems brought on by climate change. Similarly, a commenter (3283.1) indicates that EPA does not discuss any adaptation measures that will increase water supplies in the West.

**Response (7-12):**

The commenters did not provide any scientific literature to support their assertion that North America's water resources are not over-allocated. The assessment literature provides substantial supporting evidence that climate change–related changes in the timing and amount of precipitation will result in water shortages in many regions of the United States, particularly in areas with currently over-allocated water supplies. For example, Karl et al. (2009) finds that in many places, the nation's water systems are already taxed due to aging infrastructure, population increases, and competition among water needs for farming, municipalities, hydropower, recreation, and ecosystems. The U.S. Bureau of Reclamation has identified many areas in the West, including the Colorado and Columbia River systems, which are already at risk for serious conflict over water even in the absence of climate change (Karl et al., 2009). Although the commenters appear to disagree that some U.S. water resources are over-allocated, EPA has concluded that there are numerous examples of this situation. Where water resources are over-allocated, now or in the future, both the IPCC (Field et al., 2007) and USGCRP (Karl et al., 2009) conclude that climate change will exacerbate many stressors and increase competition among agricultural, municipal, industrial, and ecological uses in North America and the United States. The USGCRP also reported the following projected water supply impacts for various regions of the United States:

Reduced snowpack, earlier spring snowmelt, and increased likelihood of seasonal summer droughts in the Northeast, Northwest, and Alaska.

More severe, sustained droughts and water scarcity in the Southeast, Great Plains, and Southwest.

See the finding, Section III.C, “Adaptation and Mitigation,” for our response to comments on the treatment of adaptation and mitigation in the finding.

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**Comment (7-13):**

A commenter (3136.1) argues that there is no trend in the scatter plot presented in panel (a) of Figure 14.1 in the TSD, a graphic originally developed by IPCC (Field et al., 2007). Panel (a) displays the trend in April 1 snow water equivalent across western North America from 1925 to 2002, with a linear fit from 1950 to 2002. The commenter references a study (Cayan, 1996) on snow water equivalent histories in the western United States during the 20<sup>th</sup> century. The commenter states that the Cayan paper supports their conclusion of no observable trend.

**Response (7-13):**

The statistical methods (linear regression with application of best fit line) used by IPCC to develop panel (a) of Figure 14.1 in the TSD are straightforward and widely used in the scientific community. Furthermore, we note that while the Cayan paper may have found a different trend, it was published in 1996 and as such cannot be interpreted as a direct critique of the paper the IPCC figure drew upon (Mote, 2003). EPA reviewed the Cayan paper and found that there are important differences in the scope and methodology that make direct comparison difficult. First, the two papers cover different time periods; the paper referenced by the commenter was published in 1996 and deals with snow water equivalent histories during the 20<sup>th</sup> century (1930–1989), whereas the paper used for the IPCC figure covers the 1950–2002 period. Second, the two papers differ in geographic scope. EPA notes the study used by IPCC (Mote, 2003) focuses on the Pacific Northwest region defined as Idaho, Oregon, Washington, and portions of British Columbia and Montana, whereas the Cayan paper focused on 11 western states (Washington, Oregon, California, Arizona, Nevada, Utah, Idaho, Montana, Wyoming, Colorado, and New Mexico). Thus, EPA finds that the study referenced by the commenter does not negate the snow water equivalent trends provided by IPCC, or the observed role of temperature in reducing snowpack since the mid-20<sup>th</sup> century specifically discussed in Mote (2003).

Furthermore, we find a number of studies (Stewart et al., 2005; Barnett et al., 2005; Pierce et al., 2008) that confirm the declining snow water equivalent trends presented in Mote (2003).

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**Comment (7-14):**

In discussing the impacts of climate change on specific water-related recreational activities (e.g., skiing), a commenter (3136.1) argues that the TSD does not consider all of the activities that are not anticipated to be affected by climate change.

**Response (7-14):**

While some recreational activities may be minimally impacted by climate change or not at all, a discussion of all these activities falls outside the scope of the TSD. The purpose of the TSD is to provide an overview of the scientific and technical information with regard to impacts concerning GHG emissions. Therefore, the document focuses primarily on those aspects of public health and welfare that are likely to be significantly affected by changes in climate associated with elevated GHG concentrations. That particular aspects of human welfare (e.g., access to a particular recreational activity) may only be minimally affected by climate change is not relevant to the findings in light of the numerous aspects of health and welfare that face significant impacts, whether positive or negative.

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**Comment (7-15):**

A commenter (5844) argues that the American West, especially Idaho, is particularly vulnerable to the impacts of climate change on water resources due to earlier spring runoff, lighter snowpack, increased evaporation due to rising temperatures, reduced water flow resulting in impacts to trout populations, and decreased recharge of ground water aquifers.

**Response (7-15):**

We find the discussion submitted by the commenters to be generally consistent with the body of scientific literature summarized in the TSD. Sections 11 and 15 describe in detail the vulnerability of water resources in the West to rising temperatures and changes in the form, timing, and intensity of precipitation.

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**Comment (7-16):**

Referring to the TSD's statements about observed changes in streamflow during the 20<sup>th</sup> century, a commenter (3283.1) argues that "EPA did not cite any causality information showing whether these changes are due to decreased precipitation, warmer temperatures or greater diversion as population has grown." Similarly, two commenters (3347.1 and 3747.1) argue that does not sufficiently describe how observed impacts to water resources are attributed to climate change.

**Response (7-16):**

As described in Section 11(a) of the TSD, the IPCC (Field et al., 2007) reviewed a number of studies showing trends in U.S. precipitation patterns, surface water supply, and snowpack, and how climate change may be contributing to some of these trends. A causal relationship between climate change and 20<sup>th</sup> century streamflow trends is described in this discussion, but we have added the following statement to Section 11 of the TSD to provide additional clarification:

According to the USGCRP, climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses (Karl et al., 2009).

Please see Volume 3 of the Response to Comments document for our responses to comments regarding the attribution of water resource impacts to increases in GHG concentrations. In addition, see Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors.

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**Comment (7-17):**

Several commenters (3347.1, 3449.1, and 3747.1) argue that the TSD’s discussion related to water resources is based on selective information and contains significant uncertainties, and therefore does not support the endangerment finding.

**Response (7-17):**

We disagree that the TSD’s discussion of water resources is based on selective information. In developing the TSD, we considered and included descriptions of the full range of potential beneficial and adverse impacts presented in the assessment literature. As is appropriate when discussing projections into the future, we communicate the level of certainty regarding future climate impacts to water resources. See Section III.A., “The Science on Which the Decisions Are Based,” for our response to comments on the use of the assessment literature. We respond to the specific concerns raised by the commenters in this and other volumes of the Response to Comments document. Also, please see Volume 1, Section 2, of this document for our general response to comments on the treatment of uncertainty. For these reasons, we find that the discussion of water resources in the TSD is reasonable and appropriate.

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-18):**

A commenter (3394.1) states that the TSD describes the potential negative impacts on water quality and supply from population increases, and argues that because these influences are independent of climate change, they cannot be considered in assessing endangerment.

**Response (7-18):**

See Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors. We agree that potential negative impacts on water quality and supply from population increases can occur independently of climate change, but we disagree that the TSD handles these issues inappropriately with respect to assessing endangerment. To the extent that the TSD addresses population growth, it does so in the context of interactions with climate change, noting that climate change has the potential to exacerbate the effects of population growth in some water-stressed regions. In addition, the TSD makes clear that there is already significant competition for water resources in some locations, and that even with current population levels, climate change is likely to exacerbate existing management challenges in these areas. Furthermore, as described previously in this section, the Administrator’s consideration of the scientific evidence regarding the present risks to public health and welfare includes consideration of how climate change effects will interact with existing stressors. See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-19):**

A commenter (3394.1) states that the TSD fails to address how climate change impacts on water resources would be moderated through implementation of existing laws, such as the Safe Drinking Water Act and the Clean Water Act. Similarly, a commenter (3283.1) discusses how EPA must enforce the Clean Water Act and help advance the technological changes necessary to mitigate any possible changes in water quality.

**Response (7-19):**

The TSD provides a synthesis of the peer-reviewed assessment literature with regard to impacts on water resources. The TSD does not consider how the implementation of existing laws would reduce the impacts from climate change. See Section IV.B.1.f.iii of the findings for EPA's response to a similar comment regarding how implementation of existing regulations would reduce vulnerability to climate change impacts.

EPA considers adaptation, including the implementation of the Clean Water Act and Safe Drinking Water Act, to be potential responses to endangerment, and as such has determined that they are outside the scope of the endangerment analysis. EPA did not undertake a separate analysis to evaluate potential societal and policy responses (e.g., implementation of the Clean Water Act or Safe Drinking Water Act) to any threat (i.e., the endangerment) that may exist due to human emissions of GHGs.

Furthermore, with respect to current water management practices, we note that the IPCC concluded with very high confidence that current water management practices are very likely to be inadequate in reducing the negative impacts of climate change on water supply reliability, flood risk, and aquatic systems (Kundzewicz et al., 2007).

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**Comment (7-20):**

A commenter (3394.1) argues that since the TSD acknowledges that studies on the vulnerability of ground water supplies to climate change are limited, EPA should not use conclusions from IPCC regarding observed and projected impacts to ground water systems.

**Response (7-20):**

We disagree that relatively limited data on a given topic should preclude us from referencing the conclusions of a peer-reviewed assessment report. First, the fact that limited data can make analyzing certain effects of climate change on ground water difficult does not mean that it is inappropriate to draw any conclusions from the available data. Second, some impacts to ground water systems, such as increased saltwater intrusion into coastal freshwater acquirers, are well understood and the science indicates that these impacts could have substantial consequences for coastal areas. Finally, we note that the TSD has been developed to summarize the science and that our acknowledgements regarding the nature of the underlying literature, such as the issue this particular commenter has noted, are intended to provide information to the Administrator to inform how she weighs various impacts in making her endangerment determination. We have determined that it is reasonable for the endangerment analysis to be informed by a comprehensive discussion of impacts, accompanied by clear acknowledgements of uncertainties, confidence statements, and caveats (such as this one) about the extent of the data.

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**Comment (7-21):**

Commenter (10076) states that with the melting of Bolivia's Chacaltaya glacier, an 18,000-year-old source of the area's water is gone, along with its skiing industry. Commenter notes that water supplies are threatened as glaciers all over the world disappear, and water is already a major source of conflict.

**Response (7-21):**

EPA agrees that climate change poses significant risks to human health through impacts to water supply and quality. We find that the commenter's arguments are generally consistent with the conclusions and findings presented in the TSD. Additional information regarding climate change effects on water availability and international conflict can be found in TSD Sections 11 and 15, respectively, and in Volume 8: Sections 8.2 and 8.3 of this Response to Comments document.

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**Comment (7-22):**

Three commenters (3347.1, 3394.1, and 3747.1) argue that in discussing climate change impacts to water resources in Section 11 of the TSD, EPA fails to distinguish between global and U.S. effects.

**Response (7-22):**

We disagree that Section 11 of the TSD fails to distinguish between global and U.S. effects. Consistent with the rest of the document, Section 11 describes impacts specific to the United States. The commenter did not provide specific instances where this was the case, and we find that the TSD clearly describes the geographic scope (global vs. North America vs. United States) for the water resource impact information. Further, we note that the TSD includes a section that specifically addresses global climate change impacts in the United States at national and region scales (see Section 15 of the TSD). Please see Section III.D. of the Findings for our response to general comments on the treatment of international impacts in the context of the endangerment finding.

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**Comment (7-23):**

A commenter (3501.1) states that drought and the loss of critical glacial and fresh water resources will be a major factor in the survival of human populations in several parts of the world, as fresh water supplies are essential for human health, agriculture, and food security, in addition to the health of domestic animals and plants. In Utah, decreases in the Rocky Mountain snowpack and earlier melting of snowpack are affecting the flow of the Colorado River and are reducing the water available for agriculture and electric power generation.

**Response (7-23):**

We agree that climate change poses significant risks to human health and the environment through impacts to water supply and quality. We find that the discussion provided by the commenter is generally consistent with the conclusions and findings presented in Sections 11 and 15 of the TSD.

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**Comment (7-24):**

A commenter (3411.1) states that the current changes in snowpack and water supplies being experienced in the West are a regional phenomenon that is not being observed throughout the United States, and that these changes are likely caused by variations in natural climate cycles, rather than the current rise in ambient carbon dioxide (CO<sub>2</sub>).

**Response (7-24):**

We agree that the changes in snowpack and water supplies being experienced in the West are impacts specific to that region and distinct from those taking place in other parts of the country; however, we disagree that changes in snowpack and water supplies are not being experienced elsewhere in the U.S. Since many areas in the mountainous West are strongly dependent on snowpack for water supplies and other uses, trends in precipitation and snowpack levels are critically important. As discussed in Sections 4, 6, and 11 of the TSD, changes in precipitation have not been uniform and are projected to remain regionally variable. Increased evaporation linked to warming temperatures is projected to lead to increased precipitation in some areas and less precipitation in others. In general, wet areas are projected to get wetter and dry areas drier.

While we acknowledge that variations in natural cycles may be playing a role in changes in the water cycle in various regions (see Section 3.1 of this Response to Comments document for our response to comments on natural variability and attribution to climate change), the claim that observed changes are unrelated to increasing CO<sub>2</sub> concentrations is not supported by the assessment literature. We note that the commenter did not provide any scientific literature to support their assertions, and that the assessment literature indicates that the observed changes are consistent with climate model projections (Karl et al., 2009). We have added the following statement to Section 11 of the TSD to provide additional clarification: “According to the USGCRP, climate change has already altered, and will continue to alter, the water cycle, affecting where, when, and how much water is available for all uses (Karl et al., 2009).”

As noted by the USGCRP, climate models consistently project substantial declines in runoff in the interior West, especially the Southwest. Consistent with this projection, much of the Southwest and West has experienced observed reductions in precipitation and increases in drought (Karl et al., 2009). EPA notes that additional information about observed and projected U.S. regional climate impacts, including changes in snowpack and water supplies, are included in Section 15 of the TSD.

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**Comment (7-25):**

Two commenters (3449.1 and 3747.1) describe how the proposed TSD did not contain a conclusion from CCSP 4.3 that had been included in the TSD associated with the ANPR—the conclusion indicated that water quality changes so far in the United States are likely attributable to causes other than climate change. The commenters argue that EPA inappropriately screened this conclusion and presents an inaccurate basis for an endangerment finding.

**Response (7-25):**

We reviewed the TSD in light of this comment and we agree that the conclusion from CCSP 4.3 should include the complete statement which originated from the water resource chapter of CCSP 4.3. This language was inadvertently admitted, not dropped or “inappropriately screened,” and we have replaced it in the final TSD. For clarification and further context, Section 11(b) of the TSD now reads:

The IPCC concluded with high confidence that higher water temperatures, increased precipitation intensity, and longer periods of low flows exacerbate many forms of water pollution and can impact ecosystems, human health, and water system reliability and operating costs (Kundzewicz et al., 2007). A CCSP (2008e) report also acknowledges that water quality is sensitive to both increased water temperatures and changes in precipitation; *however, most water quality changes observed so far in the U.S. are likely attributable to causes other than climate change.*

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-26):**

A commenter (3475.5) submitted a 31-page report authored by Sarah Kapnick and Alex Hall entitled *Observed Climate-Snowpack Relationships in California and Their Implications for the Future*.

**Response (7-26):**

Section 11 of the TSD includes detailed discussion of how the climate change impacts on snowpack will create significant risks for all snowpack-dependent human and natural systems. Kapnick and Hall (2009) conduct an analysis of California snowpack by using snow station observations and reanalysis of surface temperature data. Their findings show that “Since 1930, there has been a trend toward earlier snow mass peak timing by 0.4 days per decade. The trend towards earlier timing also occurs at most individual stations. The majority of stations have experienced simultaneous reductions in April 1 snow water equivalent...Regional mean March temperatures have increased at a rate of 0.4°C or 1.8°F per decade since 1948, and the robustness of the March temperature influence on peak timing suggests the trend towards earlier peak timing is attributable to the March temperature trend. Given scenarios of warming in California, we can expect to see acceleration in the peak timing trend; this will reduce the warm season storage capacity of the California snowpack.”

We find that these findings are consistent with the conclusions of the broader assessment literature (Karl et al., 2009; Field et al., 2007; Kundzewicz et al., 2007) as summarized in the TSD.

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**Comment (7-27):**

Several commenters state their support for the findings and express concern over future impacts of climate change on water resources. Many commenters (0731, 3015, 3383.1, 3419, 3696.1, 4249, 10809, 10838, 11357, 11433) cite harm to sustainable water resources and/or water shortages as an additional effect of climate change. A commenter (1188.1) states that snowpack in the North Cascade Mountains has declined on average by as much as 50%. A commenter (1926) voices concern that global warming would impact the glaciers that feed the hydroelectric facility, and subsequently the operations that power the region. Many commenters (e.g., 3089, 3805, 4497, 6679, 8516, 8874, 10715) express concern for freshwater resources, stating that the retreating glaciers, precipitation pattern changes, saltwater intrusion, and the receding of the Great Lakes and Reservoirs all threaten the fresh water supplies we have to sustain us. Another commenter (4736) specifically identifies pollution impacting the Columbia River.

**Response (7-27):**

EPA has reviewed these comments and we agree that climate change poses substantial risks to water resources, including declining snowpack with impacts to snow-fed river systems, water shortages, impacts to hydropower generation, saltwater intrusion, and water quality. We find that the discussions of the commenters are generally consistent with the findings of the assessment literature, as summarized in Sections 11, 12, 13, and 15 of the TSD.

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**Comment (7-28):**

A commenter (3477) states that water resources in the West are being impacted more by Endangered Species Act restrictions than by CO<sub>2</sub> and other GHGs. The commenter suggests that the endangerment finding will negatively impact water quality for human and animal use.

**Response (7-28):**

With respect to the comment on the impact of the Endangered Species Act on water resources in the West, we note that there is no evidence of this in the assessment reports, and that the commenter did not provide any additional scientific literature to support this assertion. Thus, we find that there is insufficient support for this comment. In addition, the commenter does not explain how their conclusion would lead to any change in the conclusions in the assessment reports about the impacts of climate change.

Regarding the commenter's concern that the endangerment finding itself will adversely impact water quality, please see Section III.F. of the Findings for our response to comments regarding the implications of the endangerment finding.

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**Comment (7-29):**

A commenter (3248) submitted a 41-page research paper published in the May 2009 by *Lancet* and the University College London Institute for Global Health Commission on "Managing the Health Effects of Climate Change." This report discusses the potential impacts that climate change will have on water supply and water quality, and the subsequent impacts on human health.

**Response (7-29):**

We agree that climate change poses significant risks to human health through impacts to water supply and quality. The *Lancet* report describes a number of water resource-related impacts, including changing rainfall patterns affecting access to reliable water supplies, decreased water quality due to reduced and flashier flows, and more frequent and intense droughts and flooding events. We find that the key conclusions of these studies are generally consistent with the conclusions and findings presented in the assessment literature and summarized in the TSD. We also note that the *Lancet* report heavily referenced IPCC's Fourth Assessment Report.

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**Comment (7-30):**

A commenter (3596.2) discusses how the North American chapter of the Working Group II contribution to IPCC's Fourth Assessment Report (Field et al., 2007) does not reference recent work on how the Great Lakes have responded to ongoing climate changes. The commenter references a study by McBean and Motiee (2008), which examined historical precipitation and hydrology trends of the Great Lakes system. According to the commenter, the study's findings indicate that the observed hydroclimate of the Great Lakes over the past 70 years has not followed the pattern predicted by climate models, which project lake declines to occur with climate change. The commenter also describes results of another study (Wiles et al., 2009), which, according to the commenter, suggests that Great Lakes water levels were at their highest during the late 20<sup>th</sup> century. The commenter concludes that "[c]oncerns the water levels in the Great Lakes will greatly decline with a changing climate do not reflect ongoing trends."

**Response (7-30):**

This comment is part of larger set of comments generally intended to indicate "where Proposed Endangerment and the Technical Document fail to account for scientific studies and data that may contradict the conclusion of Proposed Endangerment." As such, this response focuses on the conclusions of the referenced studies in relation to the conclusions of the assessment literature as summarized in the TSD. The commenter is correct that Field et al. (2007) do not reference McBean and Motiee (2008) or

Wiles et al. (2009); however, we have reviewed these studies and concluded that they do not in fact contradict the conclusions of Field et al. (2007) that are summarized in the TSD, as the commenter implied.

The commenter states that the findings of McBean and Motiee (2008) “indicate that the observed hydroclimate of the Great Lakes over the past 70 years has not followed the pattern predicted by climate models which project lake declines to occur with an increasing greenhouse effect.” However, this statement is inconsistent with the study, the abstract of which states: “Given the general agreement as derived from very different procedures, predictions extrapolated from historical trends and from GCMs, there is evidence that hydrologic changes particularly for the precipitation in the Great Lakes Basin may be demonstrating influences arising from global warming and climate change.” Further, McBean and Motiee do not mention Great Lake water levels (which are not the focus of the study) at all, except to note that “any changes arising from climate change or water diversions may create long-term repercussions on water levels and water budgets.” Therefore, we conclude that the commenter misrepresented the study’s main conclusions.

It is possible that the commenter based the comment on an assumption that increased precipitation and streamflow would necessarily mean lake levels will not decline. However, average Great Lakes levels depend not just on precipitation and corresponding runoff but on the balance between precipitation on the one hand and evaporation and outflow on the other. As Karl et al. (2009) note: “Higher temperatures will mean more evaporation and hence a likely reduction in the Great Lake water levels. Reduced lake ice increases evaporation in the winter, contributing to the decline.” Karl et al. (2009) report that the maximum seasonal coverage of Great Lakes ice decreased at a rate of 8.4% per decade from 1973 through 2008, amounting to a roughly 30% decrease in ice coverage.

The Wiles et al. (2009) study suggests that Pacific Decadal Variability is an important determinant of Lake Erie water levels, and that the highest lake levels in the reconstruction are found over the past few decades. But, whether or not this finding is correct, high Lake Erie water levels relative to the last 256 years do not necessarily suggest that climate change has not, or will not, lead to declining Great Lake levels. The authors of the study never make that claim, and the commenter did not provide any discussion or evidence as to why that would necessarily be the case. Wiles et al. (2009) do note that Lake Erie water level fluctuations are determined primarily by climate and its effect on the lake’s water balance in the drainage basin. They also note that future model projections generally call for warmer winters, air and water temperature increases, decreases in duration of ice cover, and more frequent precipitation events.

It is not entirely clear what the commenter intends the phrase “greatly decline” to mean. We note that neither the TSD nor the findings use this terminology in relation to potential changes in Great Lakes water levels. Rather, the TSD reports the IPCC (Field et al., 2007) conclusion that many, but not all, assessments project lower net basin supplies and lake levels for the Great Lakes–St. Lawrence Basin (Section 11[a]), as well as the following statement from Karl et al. (2009): “Water levels in the Great Lakes are projected to fall up to 12 inches (30cm) by the end of the century under a lower emissions scenario and between 12 and 24 inches (30 to 60 cm) under a higher emissions scenario” (Section 15[c]).

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**Comment (7-31):**

A commenter (3136.1) argues that the TSD does not provide a thorough discussion of natural variability surrounding changing water levels in the Great Lakes and the resulting effects on society and the environment. The commenter additionally argues that “you’ve already set it up that it [is] going to be bad—higher water levels are bad, lower water levels are bad...what if future variations in Lake levels are of similar timing and magnitude of past variations?”

**Response (7-31):**

While we agree that natural variability can affect water levels in the Great Lakes, we disagree that an in-depth discussion of this topic would be appropriate for the TSD. The TSD focuses primarily on the observed and projected vulnerabilities, risks, and impacts due to the elevated levels of GHGs in the atmosphere and associated climate change. Its purpose is to provide scientific and technical information for an endangerment analysis; it does not focus on observed and projected changes that are clearly not related to human-induced climate change.

However, we agree with the commenter that it is important to distinguish those changes and variations that are likely related to climate change from those which are not. Therefore, we have reviewed the TSD in light of this comment, and we have determined that it accurately represents key conclusions from the literature on the potential effects of human-induced climate change on Great Lakes hydroclimate and associated impacts to health and welfare.

The TSD summarizes key conclusions from the assessment literature on this topic, describing a series of potential impacts associated with higher lake levels (e.g., flooding) and lower lake levels (e.g., transportation difficulties) brought on by climate change (see Sections 11 and 12 of the TSD). In response to this comment, the following sentence (in italics, below) has been added to Section 12(a) of the TSD. This sentence clarifies that hydrological changes resulting from climate change are major drivers of lake level changes, and may exacerbate future climate impacts in the Great Lakes.

In the Great Lakes where sea level rise is not a concern, both extremely high and low water levels resulting from changes to the hydrological cycle have been damaging and disruptive to shoreline communities (Nicholls et al., 2007). *Future changes to the hydrological cycle brought on by climate change may exacerbate these effects (Field et al., 2007; Nicholls et al., 2007).* High lake water levels increase storm surge flooding, accelerate shoreline erosion, and damage industrial and commercial infrastructure located on the shore.

Please refer to Volume 3 for EPA's response to comments on natural variability in relation to the attribution of observed climate change.

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**Comment (7-32):**

A commenter (3747.1) argues that the TSD does not adhere to information quality guidelines under the Information Quality Act because EPA failed to consider studies, which according to the commenters suggest that heavier rain events do not result in increased flood damages (e.g., Small et al., 2006; Lins and Slack, 1999). The commenter requests that EPA provide information on how scientific studies were selected to serve as the basis for the TSD and how EPA dealt with studies that have come out since the release of the assessment reports.

**Response (7-32):**

Please see Volume 1: Section 5 of this Response to Comments document for EPA's general response to the information quality concerns submitted during the public comment process. The science upon which the Administrator relied, including a discussion of how the literature was identified, is discussed in Section III of the Findings, and our response to comments on this can be found in Volume 1: Section 1 of the Response to Comments document. This section also describes our treatment of new and additional studies that are not incorporated into the assessment literature. EPA's approach is fully consistent with EPA's IQA guidelines in accordance with sound, transparent and objective scientific practices.

With regard to the commenter's reference to studies on the effects of increased precipitation intensity on flood damages, please see previous responses to comments in this section (numbers 7-5 and 7-6) which reply to references or include references to several key studies specifically pertaining to this topic. We have carefully reviewed and responded to the studies submitted by the commenter (e.g., Small et al., 2006; Lins and Slack, 1999), along with other studies on this topic.

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**Comment (7-33):**

A commenter (6809) states that the world's drinking water supply is highly vulnerable to the effects of climate change due to elevated melting of glaciers and snowpack, increased evaporation of lakes and reservoirs, and increased demand from growing populations.

**Response (7-33):**

EPA agrees with the commenter that climate change poses significant risks to human populations through impacts to water supply. We find that the commenter's arguments are consistent with the conclusions and findings presented in the assessment literature and summarized in the TSD. Additional information regarding climate change effects on water supply can be found in Sections 11 and 15 of the TSD.

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## 7.2 Coastal Areas

**Comment (7-34):**

Several commenters (3136.1, 3347.1, 3394.1 and 3747.1) argue that the TSD does not present sufficient evidence to conclude that anthropogenic climate change (excluding other human-caused impacts, such as increasing population) is impacting coastal systems and that EPA's analysis of coastal impacts associated with climate change cannot, therefore, support a positive endangerment finding.

**Response (7-34):**

Please see Volume 1: Section 2 for our general response regarding how climate change effects interact with existing stressors.

EPA reviewed these comments; we note that these general statements were followed by several specific comments which we address in subsequent responses. With respect to the general claim, we disagree that the TSD does not present sufficient evidence of the link between climate change and impacts on coastal systems. We reviewed the TSD in light of these comments, and conclude that it summarizes robust evidence from the assessment literature regarding the observed and projected impacts of anthropogenic climate change to coastal areas. The established body of scientific assessment literature, as summarized in the TSD, finds that the likely effects of sea level rise associated with elevated GHG concentrations include, but are not limited to: 1) the loss of waterfront property and increased vulnerability to inundation hazards (Nicholls et al., 2007); 2) the loss of coastal wetlands (Field et al., 2007, and references therein); 3) saltwater intrusion into coastal sources of ground water in the United States and other world regions due to sea level rise combined with high rates of water withdrawal (Kundzewicz et al., 2007); and 4) more severe coastal flooding and erosion hazards (Nicholls et al., 2007).

Section 12 of the TSD also summarizes the following conclusions from IPCC (Field et al., 2007) regarding how climate change is interacting with existing stressors to enhance current vulnerability and may lead to additional vulnerabilities in the future:

### *Observations*

In San Francisco, 140 years of tide-gauge data suggest an increase in severe weather storms since 1950, along with accelerated rates of coastal erosion.

Some coastal Alaskan villages are threatened due to increased erosion brought on by the disappearance of sea ice along the coastline.

Recent winters with less ice in the Great Lakes and Gulf of St. Lawrence have increased coastal exposure to damage from winter storms.

### *Projections*

Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution (very high confidence). Sea level is rising along much of the coast, and the rate of change will increase in the future, exacerbating the impacts of progressive inundation, storm surge flooding, and shoreline erosion.

Storm impacts are likely to be more severe, especially along the Gulf and Atlantic coasts. Salt marshes, other coastal habitats, and dependent species are threatened by sea level rise, fixed structures blocking landward migration, and changes in vegetation. Population growth and rising value of infrastructure in coastal areas increases vulnerability to climate variability and future climate change.

In addition, we have revised the TSD to include the findings of the recently released USGCRP report (Karl et al., 2009), addressing information on projected regional coastal impacts resulting from climate change in Section 15 of the TSD.

To the extent that the commenters are claiming that human-caused impacts such as population growth are the driver of these impacts, we note that these drivers were accounted for in the assessment literature and that the conclusions were made assuming trends in those drivers. As support for their claim, the commenters reference Pielke et al. (2008). Please see our response to this study below in comment response (7-38).

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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### **Comment (7-35):**

Several commenters (e.g., 3136.1, 3596.2) state that specific aspects of the climate impacts evidence summarized in the TSD with respect to coastal areas do not support the Administrator’s endangerment finding.

### **Response (7-35):**

The specific issues that underlie these comments are addressed in the responses throughout this volume, and other volumes of the Response to Comments document. With regard to the commenters' conclusion that the current science does not support an endangerment finding with respect to coastal areas, we disagree based on the scientific evidence before the Administrator. See the Findings, Section IV.B, “The Air Pollution is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for details on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the coastal sector in particular.

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**Comment (7-36):**

Two commenters (3394.1 and 3747.1) state that EPA did not properly acknowledge uncertainties surrounding the impacts that sea level rise will have on coastal areas (e.g., saltwater intrusion, salt marsh loss).

**Response (7-36):**

Upon review of the discussion of these issues in the TSD, we have determined that uncertainties surrounding sea level rise (and other impacts) are appropriately discussed throughout the TSD. For example, with regard to saltwater intrusion, Section 12 of the TSD states the following: “Climate change is *likely* to have a strong impact on saltwater intrusion into coastal sources of ground water in the U.S. and other world regions” (italics added for emphasis). With respect to salt marsh loss, we employ the same qualifier, based on the characterization of uncertainty in the underlying assessment report. In this case, Section 12 of the TSD states: “Salt-marsh biodiversity is *likely* to decrease in north-eastern marshes through expansion of non-native species such as *Spartina alterniflora*, at the expense of high-marsh species (Field et al., 2007).” We further note that we provide a thorough discussion of how uncertainty is addressed in the TSD in Section 1(d), including Box 1.2, “Communication of Uncertainty in the IPCC Fourth Assessment Report and CCSP/USGCRP),” which describes the lexicon used by the IPCC and USGCRP/CCSP to communicate uncertainty. Following that lexicon, the term “likely,” as used in the two sentences quoted above, conveys a 66% to 90% probability of occurrence.

We note that the commenters did not provide any evidence or literature indicating that the uncertainties were improperly characterized or that the TSD failed to account for a specific (or set of specific) uncertainties. Please see Volume 1: Section 2 of the Response to Comments document for our responses on general comments on the issue of uncertainty.

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**Comment (7-37):**

Several commenters (3449.1, 3747.1, and 7020) argue that the proposal and TSD do not differentiate between climate-driven coastal changes and those changes impacted by non-climate drivers such as human development and subsidence.

**Response (7-37):**

See Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors. EPA reviewed the TSD in light of this comment, and we find that the TSD 1) summarizes information in the assessment literature that differentiates climate and non-climate drivers and 2) clearly communicates that both climate and non-climate drivers impacts coastal impacts. Section 12 of the TSD presents a number of conclusions from the assessment literature that deal specifically with non-climate drivers and the potential for climate change to exacerbate their effects in coastal areas (Nicholls et al., 2007; Field et al., 2007; CCSP, 2009b). For example, the TSD explains that many coastal systems are already stressed due to increased development, and that even with current population levels, climate change is likely to exacerbate existing management challenges in these areas. Section 12 of the TSD includes a subsection on “Interactions With Coastal Development,” which describes existing non-climate drivers of change in coastal areas. This subsection notes that although climate change is impacting coastal systems, non-climate human impacts have been more damaging over the past century. The major non-climate impacts for the United States and other world regions include drainage of coastal wetlands, resource extraction, deforestation, introductions of invasive species, shoreline protection, and the discharge of sewage, fertilizers, and contaminants into coastal waters (Nicholls et al., 2007). The cumulative effect of these non-climate, anthropogenic impacts increases the vulnerability of coastal systems to climate-related stressors.

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**Comment (7-38):**

Several commenters (1616.1, 3136.1, 4528, 4632R18, 4666, 4670, 4766, and 7020) argue that increasing raw damage totals associated with tropical storm damage in coastal communities are not the result of climate change, but rather are caused by changes in coastal population, wealth of the population, inflation, and poor sediment management practices. A couple of these commenters reference Pielke et al. (2008) as supporting evidence. One commenter (4632R18) describes how recent studies (e.g., Zhang et al., 2000; Woodworth and Blackman, 2002) indicate that storm surges around the world have not increased in frequency or magnitude while temperatures have increased.

**Response (7-38):**

EPA agrees that the interaction of a series of drivers adversely impacts coastal areas and can contribute to tropical storm damage totals. These drivers include changes in coastal population, wealth of the population, inflation, and sediment management practices. We disagree, however, with the implied claim that anthropogenic climate change has not affected or will not affect storm surge frequency, storm surge intensity, and storm damage totals. The assessment literature, as summarized in the TSD, draws a number of key conclusions about projected climate change effects on storm damage totals. These include:

Superimposed on accelerated sea level rise, the present storm and wave climatology and storm surge frequency distributions suggest more severe coastal flooding and erosion hazards (Nicholls et al., 2007).

Higher sea level provides an elevated base for storm surges to build upon and diminishes the rate at which low-lying areas drain, thereby increasing the risk of flooding from rainstorms (CCSP, 2009b).

Apart from non-climatic events such as tsunamis, extreme sea levels occur mainly in the form of storm surges generated by tropical or extra-tropical cyclones. There is evidence for an increase in extreme high sea level since 1975 based upon an analysis of 99<sup>th</sup> percentiles of hourly sea level at 141 stations over the globe (Bindoff et al., 2007).

With regard to insured losses from extreme weather events (e.g., coastal flooding), the USGCRP concluded that economic and demographic factors do not fully explain the upward trend in costs or numbers of observed increases in losses. For example, from 1980 to 2004, the U.S. population increased by a factor of 1.3, while losses increased by a factor of 15 to 20 in inflation-corrected dollars. Numerous studies indicate that both the climate and the socioeconomic vulnerability to weather and climate extremes are changing (Brooks and Doswell, 2001; Pielke et al., 2008; Downton et al., 2005), although these factors' relative contributions to observed increases in disaster costs are subject to debate (Karl et al., 2009). Analyses asserting minimal or no role of climate change in increasing the risk of losses are limited in that they often 1) tend to focus on a highly limited set of hazards and locations; 2) fail to account for the vagaries of natural cycles and inflation adjustments; and 3) fail to normalize for countervailing factors such as improved pre- and post-event loss prevention (e.g., dikes, building codes, and early warning systems) (Karl et al., 2009). The USGCRP concludes that future increases in losses will be attributable to climate change with high confidence as climate change increases the frequency and intensity of many types of extreme weather (Karl et al., 2009). Please see Section 1 of this volume for our specific response regarding the Downton et al. (2005) paper and other studies

Pielke et al. (2008) conclude that the absolute damage from mainland U.S. hurricane damage, from 1900 to 2005, is shown not to have increased when the data are normalized to account for changes in inflation and wealth at the national level and changes in population and housing units at the coastal county level. However, we note that the potential for increasing tropical cyclone activity is just one aspect of coastal vulnerability. The core issue is whether or not the sum of climate change effects poses risks for coastal

damages, and the question of whether hurricane damage has increased from 1900 to 2005 offers limited insight on only one type of risk. Pielke et al. (2008) do not address sea level rise and how storm surge damages can increase with elevated sea levels, which are major projected coastal climate impacts.

Regarding the comment that storm surges have not increased in magnitude or frequency, we note that the TSD does not argue that storm surges have increased in magnitude or frequency. We find that the articles submitted by the commenter (Zhang et al., 2000; Woodworth and Blackman, 2002) are generally consistent with the information presented in the assessment literature, which shows large inter-annual and inter-decadal variation in historical storm surge data, but stability over the last 100 years (Nicholls et al., 2007).

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**Comment (7-39):**

A commenter (3394.1) argues that since EPA used overstated sea level rise projections in the TSD, then the related impacts to coastal areas (e.g., shoreline erosion and salt water intrusion) are also overstated.

**Response (7-39):**

Please see Volume 4: Section 6 for our response as to why the sea level rise projections summarized in the TSD are representative of the best available science and not overstated. Since we maintain that our sea level rise projections are accurate, we disagree with this comment that the related impacts are also overstated.

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**Comment (7-40):**

Several commenters voice support for the findings and describe various climate impacts on coastal areas. A commenter (3400.1) from Washington state mentions that he is seeing rising sea levels that will impact thousands of miles of coastal land. One commenter (9643) from Louisiana shares that rising sea levels associated with global warming threaten her family and friends still living in the area. One commenter (3421) mentions the threat of rising sea levels to infrastructure. The commenter emphasizes that infrastructure cannot be evacuated or replaced, including water and sewage treatment plants, roads and bridges necessary to get people to work and deliver food and medical supplies, and homes and buildings that house people, commerce, and the necessary trappings of a functional society.

**Response (7-40):**

EPA has reviewed these comments, and we agree that climate change poses substantial risks to coastal areas and communities, including land loss due to inundation and erosion and impacts to infrastructure and development. We find that the discussions submitted by the commenters are generally consistent with the findings of the assessment literature, as summarized in Sections 12, 13, and 15 of the TSD.

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**Comment (7-41):**

A commenter (3136.1) refers to a study by the Maryland Geological Survey (MDP, 2004) on the impacts of storm surge on the State's coastal areas, which was referenced in NRC (2006a) and summarized in the TSD. The commenter argues that this study should not be used as a basis for endangerment because the study did not compare the economic impacts of tropical storm Isabel to what the impacts would have been 30 years earlier, and because it did not properly control for the influence of population growth on cost estimates.

**Response (7-41):**

The study referenced by the commenter is cited in the TSD to illustrate the extent of damage that storm surge can cause and to provide meaningful context with regard to the potential costs associated with an elevated base for storm surge to build upon. The TSD is not asserting that tropical storm Isabel was directly due to climate change, and we find no merit in the argument that the study has to compare economic impacts to what they would have been 30 years ago in order to provide relevant information about the impacts of sea level rise and storm surge. The mention of hurricane Isabel simply provided an example of storm surge damage, which was followed by a summary of the scientific literature describing how climate change affects storm surge. However, we have removed this information and reference from the TSD after further review of the study's methods.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-42):**

Two commenters (3347.1 and 3747.1) argue that since the climate science community is unable to project whether hurricanes will become more frequent, EPA cannot use the vulnerability of coastal areas to storm surge as a basis for finding endangerment.

**Response (7-42):**

As noted in the assessment literature and summarized in the TSD, there are several climate impacts that increase the vulnerability of coastal areas. Irrespective of whether hurricanes become more frequent, the body of scientific assessment literature concludes that sea level rise and storm surge are relevant risks posed by climate change to coastal areas. As Section 12 of the TSD notes, higher sea level provides an elevated base for storm surges to build upon and also diminishes the rate at which low-lying areas drain, thereby increasing the risk of flooding from rainstorms (CCSP, 2009b). We also note that the discussion of extreme events in Section 12 does not make any statements about increasing hurricane frequency, but rather describes these other impacts.

We refer the reader to Section 4.5 of this Response to Comments Document for our response to comments on the validity of future projections of extreme weather events, including hurricanes. See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-43):**

A commenter (3722) argues that the TSD contains conclusions regarding the impacts that sea level rise will have on U.S. coastlines that have attached probabilities which are not certain enough for an endangerment determination. The commenter provides the following example from the TSD: "If sea-level rise occurs over the next century at a rate consistent with the higher range of the 2007 IPCC scenarios (i.e., 50-60 cm rise in sea level by 2100), it is about as likely as not that some barrier island coasts in the mid-Atlantic region will cross a geomorphic threshold and experience significant changes. Such changes include more rapid landward migration or barrier island segmentation (Gutierrez et al., 2009)."

**Response (7-43):**

In light of this comment, EPA reviewed the statement highlighted by the commenter and finds that it provides important and appropriate information to inform the Administrator's endangerment analysis. We

note that the statement referenced by the commenter uses IPCC terminology (described in Box 1.2 of the TSD) to convey a probability of 33% to 66%. Consistent with our approach toward conveying uncertainties, we find that this conclusion provides useful context regarding the vulnerability of barrier island systems to future sea level rise. The discussion in the TSD also provides information on the significant implications of landward migration or barrier island segmentation, which is also a relevant consideration for the Administrator's decision. Section II.A. of the Findings discusses the Agency's authority to consider risks of varying probability when making a determination of endangerment.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-44):**

One commenter (7020) argues that the TSD does not describe how increased storm surge will result in adverse impacts.

**Response (7-44):**

We disagree that the TSD does not describe how increased storm surge will result in adverse impacts to coastal areas. Section 12 of the TSD explains that accelerated sea level rise in the future, along with the present storm and wave climatology and storm surge frequency distributions, suggests more severe coastal flooding and erosion hazards (Nicholls et al., 2007). Higher sea level provides an elevated base for storm surges to build upon and diminishes the rate at which low-lying areas drain, thereby increasing the risk of flooding from rainstorms (CCSP, 2009b). This will result in increased coastal inundation (land loss), erosion, infrastructure damage, and habitat loss.

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**Comment (7-45):**

One commenter (3136.1) asks what reference EPA used for the assertion that climate changes have been damaging coastal systems.

**Response (7-45):**

Section 12 of the TSD focuses on sea level rise and coastal areas and provides robust evidence that human-caused climate change has been impacting and will continue to impact coastal systems. Key assessment literature sources for this section include: Field et al., 2007; IPCC, 2007b; Mimura et al., 2007; Nicholls et al., 2007; Anisimov et al., 2007; ACIA, 2004; NRC, 2006a; Cahoon et al., 2009; Kundzewicz et al., 2007; Wilbanks et al., 2007; CCSP, 2008i; and CCSP, 2009b. Full citations for the references cited in the TSD may be found in the reference section of the TSD, and citations for new literature provided through public comments can be found at the end of this Response to Comments volume.

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**Comment (7-46):**

A commenter (1309.1) states that the TSD contains conflicting arguments regarding the causes of saltwater intrusion into coastal waterbodies and underground sources. The commenter argues that the TSD suggests that both decreases and increases in precipitation will lead to saltwater intrusion.

**Response (7-46):**

Consistent with the assessment literature (Nicholls et al., 2007; Kundzewicz et al., 2007), Section 12 of the TSD states that the three main causes of saltwater intrusion in coastal areas are sea level rise,

extraction of underground water supplies, and decreased precipitation in the watershed leading to migration of the salinity gradient upstream and decreased recharge of coastal aquifers. In light of this comment, we reviewed the discussion in the TSD and did not find any suggestion that increases in precipitation will lead to saltwater intrusion or conflicting arguments regarding the causes of saltwater intrusion.

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**Comment (7-47):**

A commenter (3136.1) argues that if society in the United States has adapted to rising sea levels so far (the commenter provides some observed rates of rise in several places around the country), then future increases in sea level will not lead to endangerment. The commenter states that the TSD is therefore insufficient basis for an endangerment finding.

**Response (7-47):**

In combination with other information about impacts presented in the TSD, the sea level rise projections described in Section 12 and elsewhere strongly support the conclusion that sea level rise poses risks to health and welfare. For example, the TSD summarizes the assessment literature and notes that coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution (very high confidence). Sea level is rising along much of the coast, and the rate of change will increase in the future, exacerbating the impacts of progressive inundation, storm surge flooding, and shoreline erosion (Field et al., 2007).

For EPA's responses to comments specific to EPA's consideration of adaptation and emissions mitigation, please refer to Volume 1, Section 1.3: "Role of Adaptation and Emissions Mitigation Considerations."

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**Comment (7-48):**

A commenter (3596.2) submitted several papers (e.g., Heberger et al., 2009; Solomon et al., 2009) regarding the causes of sea level rise and the likely impacts of these changes on the California coastline.

**Response (7-48):**

We have reviewed the submitted papers and find that they are consistent with the information presented in Sections 12 and 15 of the TSD. We agree with the commenter's assertion that anthropogenic warming is resulting in sea level rise and that the California coastline will be impacted.

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**Comment (7-49):**

In discussing the effects of decreased precipitation on saltwater intrusion rates in coastal areas, a commenter (3136.1) argues that EPA should provide a detailed discussion of whether precipitation is supposed to increase or decrease in coastal areas.

**Response (7-49):**

In light of this comment, we examined the discussion of precipitation in the TSD, and have determined that it already contains information on projected precipitation changes for U.S. coastal areas and clearly indicates the potential coastal impacts that would accompany changes in temperature, precipitation, or sea level rise. Section 6(c) describes projected changes in precipitation for the United States, including coastal areas, while Section 12(a) discusses the observed and projected impacts of climate change (for numerous climate change variables) on coastal areas. For example, Section 12(a) states that "Reduced groundwater recharge associated with decreases in precipitation and increased evapotranspiration will exacerbate sea

level rise effects on salinization rates (Kundzewicz et al., 2007).” We disagree that it is necessary to repeat information about projected precipitation changes in the discussion of saltwater intrusion and conclude that the current discussion is reasonable and provides useful scientific information for the endangerment analysis.

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**Comment (7-50):**

A commenter (3133.1) argues that coastal inundation and erosion cannot be fully attributed to sea level rise because many other anthropogenic activities are exacerbating vulnerability to land loss (e.g., preventing sediment recharge to coastal wetlands through the use of levees and other flood control measures). The commenter argues that since rising sea levels are not the only cause and cannot be measurably isolated from other contributors to land loss, then this argument cannot be used in the TSD to support endangerment.

**Response (7-50):**

EPA agrees that non-climate factors (e.g., increasing coastal development, flood control measures) are contributing to coastal impacts. However, the assessment literature as summarized in Section 12 of the TSD provides robust evidence that climate change, by itself, has been observed to and is projected to adversely impact coastal areas as a result of sea level rise and intensified storm surges, which in turn increase damages and land loss from coastal inundation and erosion (Nicholls et al., 2007; Field et al., 2007). We note that the commenter did not provide any evidence to the contrary, and find that this information is reasonable and provides useful scientific information for the endangerment determination.

We do not agree that endangerment has to be limited to impacts that are solely caused by climate change, or impacts where the effect of climate change can be measurably isolated. See Section II. of the Findings for a detailed discussion of EPA’s interpretation of the endangerment criteria in section 202(a) of the Clean Air Act.

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**Comment (7-51):**

A commenter (3686.1) identifies a series of concerns regarding the vulnerability of coastal Louisiana to the impacts of climate change, including that: 1) the current rate of land loss is very high, 2) sea level rise will lead to more land loss, and 3) the declining health of coastal marshes will result in more storm damage, as the wetlands serve as important buffers during surge and flooding events.

**Response (7-51):**

We agree with the commenter that sea level rise poses significant threats for low-lying coastal areas such as southern Louisiana. Section 12 of the TSD describes vulnerabilities specific to this area of the United States, and we find that the commenter’s arguments are generally consistent with the conclusions of the assessment literature and the TSD.

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**Comment (7-52):**

A commenter (3136.1) argues that saltwater intrusion in Louisiana is caused by water control activities (e.g., canal dredging), rather than climate change.

**Response (7-52):**

See Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors. We note that TSD does not state that saltwater intrusion has been occurring in Louisiana. Rather it summarizes the assessment literature’s conclusions

regarding how projected rates of sea level rise will likely have a strong impact on saltwater intrusion. EPA acknowledges that water control activities can contribute to saltwater intrusion in coastal areas, and are likely responsible for some level of current intrusion in Louisiana. However, we find that there is strong scientific evidence suggesting that saltwater intrusion will increase in the future due to sea level rise.

The assessment literature provides multiple lines of evidence that sea level rise resulting from climate change will advance salinity gradients further upstream in estuaries and coastal river systems, including those in Louisiana (Nicholls et al., 2007; Field et al., 2007). Section 12(a) of the TSD states that climate change is likely to have a strong impact on saltwater intrusion into coastal sources of ground water in the United States. The IPCC concluded that sea level rise and high rates of water withdrawal promote the intrusion of saline water into the ground water supplies, which adversely affects water quality (Kundzewicz et al., 2007). We have added the following IPCC statement on this issue in Section 11(b) of the TSD on water quality: “In coastal areas, the direct influence of sea level rise on freshwater resources comes principally from seawater intrusion into surface waters and coastal aquifers and further encroachment of saltwater into estuaries and coastal river systems. These changes can have significant impacts on coastal populations relying on surface water or coastal aquifers for drinking water (Nicholls et al., 2007).”

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**Comment (7-53):**

A commenter (5844) argues that climate change threatens coastal communities and wildlife in Oregon.

**Response (7-53):**

We find the discussion submitted by the commenters to be consistent with the body of scientific literature summarized in the TSD. Sections 12 and 15 describe in detail the vulnerability of U.S. island and coastal areas to sea level rise, coastal storms, extreme events like tropical storms and hurricanes, and other climate change effects.

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**Comment (7-54):**

Two commenters (3136.1 and 3596.2) state that Alaskan shorelines have been eroding for decades, often forcing the relocation of settlements. Commenter 3136.1 disagrees with the TSD statement that sea level rise and the decreasing extent of ice cover along Alaskan shorelines during the winter will further accelerate the high rates of erosion. The commenter cites MacCarthy (1953), which, according to the commenter, shows that Alaskan coastal villages have been eroding for decades. The commenter also describes how this problem “has less to do with anthropogenic climate change than it does to poor planning in the light of well-established environmental threats—threats that have existed for at least the better part of the 20<sup>th</sup> century.”

**Response (7-54):**

See Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors. EPA acknowledges that coastal erosion is caused by a variety of factors and that some coastal erosion in Alaska can be attributed to non-climate human influence. We also note that the TSD does not state that coastal erosion in Alaska has not occurred over the past several decades. Rather, the TSD summarizes the findings of the assessment literature in describing that reductions of sea ice due to warming temperatures, along with sea level rise, will increase the rate of existing coastal erosion in Alaska.

We do not find scientific support for the commenter's claim that decreasing ice cover during winter will not further accelerate the high rates of erosion. We also note that the commenter did not provide studies suggesting that decreasing ice cover will not further accelerate erosion. We find that the commenter's argument that poor planning and existing environmental threats are the primary drivers of coastal settlement vulnerability is not consistent with the conclusions of the body of scientific assessment literature on climate impacts and vulnerability. Further we argue that even if there is poor planning, this does not mean that these native communities are not at risk from climate change. Therefore, we find that the inclusion of this impact in the TSD is appropriate.

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**Comment (7-55):**

A few commenters challenge the TSD's discussion of climate impacts to salt marsh ecosystems. A commenter (3136.1) argues that since U.S. salt marshes may be able to vertically accrete and keep up with sea level rise, climate change is not the primary problem and therefore this impact cannot be used as a basis for endangerment. Instead, the commenter suggests that other, non-climate change stressors impacting salt marshes are the most important stressors to be addressed. In addition, other commenters (3136.1 and 3596.1) state that the risk of non-native species invasion into Northeastern marshes is not credible evidence for an endangerment finding because *Spartina alterniflora* (an exemplary species mentioned in the TSD in this context) has already spread to salt marshes throughout New England.

**Response (7-55):**

Please see Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors. Section 12 of the TSD explains that many U.S. salt marshes in less-developed areas can potentially keep pace with sea level rise through vertical accretion. However, some salt marshes will not be able to vertically accrete fast enough to keep up with higher rates of sea level rise. CCSP (Cahoon et al., 2009) concluded that for the Mid-Atlantic, those wetlands keeping pace with 20<sup>th</sup> century rates of sea level rise would survive a 2-millimeter-per-year acceleration of sea level rise only under optimal hydrologic and sediment supply conditions, and would not survive a 7-millimeter-per-year acceleration of sea level rise (Note that this conclusion has been added to Section 12 of the TSD). Given this evidence, we find that substantial risks to salt marshes exist as a result of sea level rise and climate change. While we acknowledge that stressors exist (e.g., sediment starvation in southern Louisiana wetlands), we find that these stressors are not the only factors, that sea level rise will play an important role in determining saltmarsh loss, and that local/regional conditions are important in determining specific vulnerabilities (i.e., subsidence is an important factor in saltmarsh loss in some areas along the U.S. coastline and not in others).

We also note that other projected climate impacts will negatively affect salt marshes, such as increasing air and water temperatures and saltwater intrusion (Nicholls et al., 2007). For example, warming temperatures in northeastern marshes are expected to facilitate the expansion of non-native species such as *Spartina alterniflora* and contribute to a decline in salt marsh biodiversity. The assessment literature's conclusions that climate change poses significant risks to coastal areas and ecosystems such as salt marshes provides appropriate basis for the endangerment determination.

We agree with the commenters that *Spartina alterniflora* has already invaded many salt marshes throughout the Mid-Atlantic and Northeast regions of the country. However, there are local areas where this species is currently not found, or where it is not the dominant species of grass (CCSP, 2009b). More importantly, the TSD's discussion of non-native species invasions does not focus exclusively on *Spartina alterniflora*; it also highlights projected climate change impacts on high-marsh species (e.g., salt meadow cord grass, black grass). Future inundation due to sea level rise is projected to decrease the extent of high-marsh species that are not tolerant of wetter, more saline soils. Inland migration of high-marsh species may be possible in areas where biochemical and geophysical conditions are suitable; however, coastal

development impedes migration along much of the Mid-Atlantic and Northeast coastline (CCSP, 2009b). We find that the TSD draws appropriate conclusions from the existing body of scientific literature regarding the vulnerability of high-marsh species and overall salt marsh biodiversity.

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-56):**

In discussing the vulnerability of small islands to sea level rise, the TSD mentions several specific locales, including Hawaii, the Pacific Islands, the Caribbean, and islands in the Chesapeake Bay. A commenter (3136.1) argues that comparing islands in Hawaii to islands in the Chesapeake is an inappropriate basis for an endangerment finding because the two locales are different in many ways.

**Response (7-56):**

EPA agrees that islands in Hawaii and in the Chesapeake Bay differ in many ways, but we also recognize that islands confront common issues in the context of climate change. The TSD summarizes the conclusions of the assessment literature that small islands are at risk of loss of both developed and undeveloped land, as well as valuable coastal infrastructure, and also threatened by inundation, storm surge, erosion, and other coastal hazards resulting from climate change (Mimura et al., 2007). We have also determined, upon review of the TSD in light of this comment, that the discussion in Section 12(a) does not “compare” the islands. Rather, it summarizes the risks and vulnerabilities confronted by islands and provides some examples, from the scientific literature, regarding particular vulnerabilities in different locations. To provide more region-specific information on these vulnerabilities, we have added additional information about projected regional climate impacts to U.S. and U.S.-affiliated islands in Section 15 of the TSD.

We note that the commenter did not provide any evidence to support the view that islands will not be adversely impacted by climate change, and discussion of this issue in the TSD is reasonable and provides useful scientific information for the endangerment determination. See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-57):**

Two commenters express their concern for the climate change vulnerabilities of specific regions of the United States. One commenter (2895) describes specific climate change vulnerabilities of Whidbey Island and the surrounding Puget Sound area, including sensitivity to sea level rise, coastal storms, and storm surge. The commenter also discusses the significant damages resulting from hurricanes Katrina and Ike. Another commenter (3526.1) discusses the potential impacts to Gulf Coast and Southern states’ coastlines associated with sea level rise and storm surge, including the factors like subsidence which exacerbate the vulnerability of Gulf coastlines.

**Response (7-57):**

EPA has reviewed the commenters’ concerns about the vulnerabilities of Whidbey Island, the Puget Sound area, and the Gulf coast to sea level rise, coastal storms, and storm surge. EPA acknowledges the commenter’s description of how she was personally affected by the 2008 hurricane season as well as her observation that hurricanes may become more violent and storm surge stronger. We find the information

submitted by the commenters to be consistent with the body of scientific literature summarized in the TSD. Section 12 describes in detail the vulnerability of U.S. island and coastal areas (including the Gulf Coast and Southern coastal areas) to sea level rise, coastal storms, extreme events like tropical storms and hurricanes, and other climate change effects.

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**Comment (7-58):**

A commenter (3136.1) argues that since New Orleans is already below sea level and therefore vulnerable to flooding regardless of future climate change, this information should not be used as a basis for an endangerment finding.

**Response (7-58):**

EPA has determined that information regarding whether New Orleans is more vulnerable to flooding with future climate changes is relevant in the context of the Administrator's endangerment analysis. The TSD is clearly focusing on the issue of whether New Orleans is vulnerable due to changes caused by climate change, not on its vulnerability in the absence of climate change. To inform this issue, the TSD summarizes the findings of the IPCC and the USGCRP, concluding that it is likely that New Orleans will be located further below sea level than it is now due to climate change and will therefore be more vulnerable to flooding from storm surge than it would have been without climate change.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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### **7.3 Ecosystems and Wildlife**

**Comment (7-59):**

A commenter (3394.1) asserts that EPA does not include sufficient background information in the TSD on ocean acidification to justify its conclusions on the topic and argues that the uncertainties surrounding ocean acidification are not properly acknowledged. The commenter also argues that "EPA does not even attempt to assign probabilities to various potential outcomes."

**Response (7-59):**

We disagree with the commenter that the TSD does not provide sufficient information to support the conclusions from the assessment literature. We note that Section 4 of the TSD presents global observations of ocean chemistry changes, Section 6 presents projections for future changes, and Section 14 describes projected impacts to marine calcifiers and broader ecosystems.

We also disagree that the TSD does not properly acknowledge uncertainties surrounding ocean acidification and its effects on marine biota. For example, Section 14 of the TSD notes that "The overall reaction of marine biological carbon cycling and ecosystems to a warm and high-CO<sub>2</sub> world is not yet well understood. In addition, the response of marine biota to ocean acidification is not yet clear, both for the physiology of individual organisms and for ecosystem functioning as a whole (Denman et al., 2007)." The TSD also conveys the assessment literature's determination of likelihood in the following conclusions from Section 14 (see Box 1.2 of the TSD for definitions on IPCC's lexicon for conveying likelihood):

The impacts of elevated CO<sub>2</sub> concentrations on oceanic chemistry will *likely* be greater at higher latitudes (Fischlin et al., 2007).

These impacts [ocean acidification in polar and sub-polar surface waters] will *likely* threaten ecosystem dynamics in these areas where marine calcifiers play dominant roles in the food web and in carbon cycling (Fischlin et al., 2007).

[Note: *italics* added for emphasis].

We acknowledge that we did not assign probabilities to the projections. See Volume 1: Section 2 of this Response to Comments document for responses regarding our treatment of uncertainty and probability in the TSD.

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**Comment (7-60):**

Several commenters (e.g., 3136.1, 3596.2) state that specific aspects of the climate impacts evidence summarized in the TSD with respect to ecosystems and wildlife do not support the Administrator's endangerment finding.

**Response (7-60):**

The specific issues that underlie these comments are addressed in the responses throughout this volume, and other volumes of the Response to Comments document. With regard to the commenters' conclusion that the current science does not support an endangerment finding with respect to ecosystems and wildlife, we disagree based on the scientific evidence before the Administrator. See the Findings, Section IV.B, "The Air Pollution is Reasonably Anticipated to Endanger Both Public Health and Welfare," for details on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to the ecosystem sector in particular.

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**Comment (7-61):**

A number of commenters (0700.1, 1961, 2759, 2818, 2828.1, 2972.1, 3411.1, 3440.1, 3446.1, 3394.1, 3722, 3477, 7031, and 11453.1) disagree with the TSD's conclusion that ocean acidification is occurring, including the TSD statement that "Ocean CO<sub>2</sub> uptake has lowered the average ocean pH level by approximately 0.1 since 1750." Two commenters (3477 and 7031) describe that there is no compelling evidence in the scientific literature that current ocean water chemistry is different from historical water chemistry. Similarly, a commenter (3722) argues that the 0.1 pH unit decline cannot be validated in the historical record and references several studies (Wei et al., 2009; Pelejero et al., 2005; and Liu et al., 2009) in describing that pH has not decreased.

**Response (7-61):**

We reviewed the discussion in the TSD, and the underlying assessment literature, in light of these comments, and we find that the TSD provides a balanced summary of the robust lines of evidence from the assessment literature demonstrating that increased absorption of CO<sub>2</sub> in the oceans has resulted in a 30% increase in average acidity compared with the pre-industrial baseline (decrease of ~0.1 in pH units). This statement is taken from Bindhoff et al. 2007, and it is based on a methodology described in Raven et al. (2005) that integrates current observations of ocean pH, analyses of CO<sub>2</sub> concentration in ice cores, our understanding of the rate of CO<sub>2</sub> absorption and retention in the surface oceans (air-sea gradient in partial pressure of CO<sub>2</sub> between atmosphere and ocean), and knowledge of the CaCO<sub>3</sub> buffer (a geochemical feature in the oceans which allows seawater to accommodate the addition of an acid or base without appreciable pH change). The measured 0.1 pH unit decrease using this methodology is consistent with global time series station measurements which indicate that pH has decreased 0.02 units per decade

(Bindoff et al., 2007). We disagree with the comments that there is no compelling evidence that current water chemistry is different from historical water chemistry or that the observed 0.1 unit decline cannot be validated in the historical record. The assessment literature, as summarized in Sections 4, 6, and 14 of the TSD, provides robust evidence that (Denman et al., 2007; Fischlin et al., 2007; Nicholls et al., 2007; Janetos et al., 2007; and CCSP, 2009d) global average marine pH has decreased consistent with CO<sub>2</sub> absorption by the oceans. Regarding the studies submitted (Wei et al., 2009; Pelejero et al., 2005; and Liu et al., 2009), we find that these papers do not support the commenter's argument that global average pH has not declined. These studies present evidence of pH changes at local scales: Arlington Reef, Australia (Wei et al., 2009); Flinders Reef, Coral Sea (Pelejero et al., 2005); and South China Sea (Liu et al., 2009). These papers do not analyze or assess changes to global average pH, and these local results cannot be used to represent larger trends. Further, we note that the commenter misrepresents the findings of the studies. For example, the commenter argues that the findings of Wei et al. (2009) indicate that "no long term trend" of declining pH at Arlington Reef exists; however, the study's authors found that the "increasing trend towards ocean acidification over the past 60 years in this region is the result of enhanced dissolution of CO<sub>2</sub> in surface waters from the rapidly increasing levels of atmospheric CO<sub>2</sub>, mainly from fossil fuel burning. This suggests that the increased levels of anthropogenic CO<sub>2</sub> in atmosphere has already caused a significant trend towards acidification in the oceans during the past decades. Observations of surprisingly large decreases in pH across important carbonate producing regions, such as the Great Barrier Reef of Australia, raise serious concerns about the impact of Greenhouse gas emissions on coral calcification."

We conclude that the information summarized and presented in the TSD regarding the causes of ocean acidification, observations of change, projections for the future, and impacts to marine life appropriately summarizes the findings of the assessment literature is reasonable, accurate, and sound, and reflects the best available scientific information.

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**Comment (7-62):**

Two commenters (0700.1, 3411.1, and 3722) argue that ocean acidity has been higher than current levels in the past and that marine life survived through these periods, showing that ocean acidification risks are not an appropriate basis for endangerment.

**Response (7-62):**

The scientific literature is clear that ocean acidification over the past century has led to substantial changes in ocean water chemistry, including a 30% increase in acidity (Denman et al., 2007). While ocean pH levels may have been lower in the distant past (lower pH = higher acidity), Denman et al. (2007) concludes that the implications of the projected continuing decline in ocean pH may lead within a few centuries to ocean acidification levels that have not occurred for a few hundred million years. Moreover, the rate of ocean acidification change is much faster than in the past, which reduces the ability of ocean systems to cope (Denman et al., 2007). Robust evidence exists across the assessment literature, as summarized in Sections 4, 6, and 14 of the TSD, that increased oceanic absorption of CO<sub>2</sub> will overwhelm the carbonate buffer system in the next several decades (Fischlin et al., 2007), resulting in adverse impacts on marine calcifiers and ecosystems (Denman et al., 2007; Fischlin et al., 2007; Nicholls et al., 2007).

Furthermore, we note the findings of Hoegh-Guldberg et al. (2007) which described that "although Scleractinian (modern) corals arose in the mid-Triassic and lived under much higher (CO<sub>2</sub>)<sub>atm</sub> [atmospheric CO<sub>2</sub>], there is no evidence that they lived in waters with low-carbonate mineral saturation. Knoll *et al.* succinctly state that 'it is the rapid, unbuffered increase in (CO<sub>2</sub>)<sub>atm</sub> and not its absolute values that causes important associated changes such as reduced (CO<sub>3</sub><sup>2-</sup>), pH, and carbonate saturation of sea

water'. The rate of (CO<sub>2</sub>)<sub>atm</sub> change is critical given that modern genotypes and phenotypes of corals do not appear to have the capacity to adapt fast enough to sudden environmental change.”

We note that the commenter did not provide additional literature to support their statements; the comment that marine life will be able to survive through the impacts of ocean acidification is inconsistent with the assessment literature, which finds that by 2070, surface waters where many coral reefs and marine calcifiers live could reach critical aragonite saturation states, resulting in reduced coral cover and greater erosion of reef frameworks (Fischlin et al., 2007). The following statement has been added to Section 14 of the TSD to complement the existing discussion on this topic: “the migration of corals to higher latitudes with more optimal sea surface temperatures is unlikely, due to latitudinally decreasing aragonite concentrations, projected acidification from increasing CO<sub>2</sub> in the atmosphere, and the lack of available substrate (Fischlin et al., 2007).” Finally, see the Finding, Section III.C, “Adaptation and Mitigation,” for our response to comments on the treatment of adaptation in the finding.

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-63):**

Four commenters (2818, 3722, 3751.1, and 4632) provided the following reference: Idso, Craig D. (2009) CO<sub>2</sub>, Global Warming, and Coral Reefs: Prospects for the Future. Center for the Study of Carbon Dioxide and Global Change & Science and Public Policy Institute. (Washington, DC 2009) 84pp. This study reviews the scientific literature on the effects of increased atmospheric CO<sub>2</sub> and warming temperatures on coral reefs and concludes that coral reefs are not vulnerable as the general scientific literature suggests. Three of these commenters (2818, 3722, and 3751.1) cite this report in arguing that the 20<sup>th</sup> century witnessed the second highest period of above-average calcification in the last 237 years and that this serves as evidence that ocean acidification is not a threat.

**Response (7-63):**

EPA has reviewed this report carefully. We note that the analyses by the author of increased CO<sub>2</sub> effects on ocean acidity and the subsequent effects on marine life are not consistent with previous assessments completed by IPCC (e.g., Fischlin et al., 2007, as cited in the TSD) and CCSP (Janetos et al., 2007; CCSP, 2009d). This paper lacks the rigorous procedures and transparency required to serve as a foundation for the endangerment analysis. The report provides no evidence that a peer review from experts in the field was conducted and the report was published by the same organization of which the author is chairman.

After reviewing this report, we find that the author frequently misinterprets and misrepresents the findings of the studies cited in his own report, or uses specific findings from studies to suggest that they represent the state of the science on an issue, without considering or weighing the conclusions of the broader literature. For example, Idso cites Lough and Barnes (1997) as evidence that calcification rates have increased, or will increase because of climate change and ocean acidification. Idso writes: “In light of these real-world observations, and in stark contrast to the doom-and-gloom prognostications of the world's climate alarmists, Lough and Barnes concluded that coral calcification rates ‘may have already significantly increased along the GBR [Great Barrier Reef] in response to global climate change.’ ” After careful review of the Lough and Barnes (1997) paper, we find that such a conclusion was never made, and that those words (or anything close to it) do not appear in the study. In fact, Lough and Barnes find that “[t]he majority of the 35 very large colonies of *Porites* analyzed show a decline in calcification in recent decades.” Further, we note that Idso inappropriately uses the findings of Lough and Barnes to suggest that

calcification will increase under climate change and ocean acidification, when that particular study did not analyze the effects of increased CO<sub>2</sub>.

Idso also cites Pelejero et al. (2005) in arguing that marine pH levels and aragonite saturation state levels have not decreased. This is a misrepresentation of the findings from this study, when Pelejero et al. state upfront that “[t]he oceans are becoming more acidic due to absorption of anthropogenic carbon dioxide from the atmosphere.” Pelejero et al. analyzed the natural variability of reef water pH at Flinders Reef in the Coral Sea, a location known to have high variability in pH. They concluded that: “Our findings suggest that the effects of progressive acidification of the oceans are likely to differ between coral reefs because reef-water *PCO*<sub>2</sub> [partial pressure of CO<sub>2</sub>] and consequent changes in seawater pH will rarely be in equilibrium with the atmosphere. Although the relatively large variations in seawater pH at Flinders Reef suggest that coral reefs may be resilient to the shorter term effects of ocean acidification, in the coming decades many reefs are likely to experience reduced pH that is unprecedented relative to ‘natural’ levels.” We do not find that this study supports the arguments made in the Idso report.

Regarding the comment that the 20<sup>th</sup> century experienced above average calcification, the assessment literature has concluded that cores from long-lived massive corals indicate minor historical variations in calcification. This is because of the fact that the ocean’s carbonate buffer system<sup>1</sup> in the past million years has regulated marine pH (keeping it rather constant) resulting in a sufficient supply of carbonate minerals, such as aragonite, for marine calcifiers (Denman et al., 2007). Ocean acidification over the past century has led to substantial changes in pH (a 30% increase in acidity); however, these changes have not led to observable decreases in calcification rates of marine calcifiers (Denman et al., 2007). However, robust evidence exists across the assessment literature that increased oceanic absorption of CO<sub>2</sub> will overwhelm the carbonate buffer system in the next several decades (Fischlin et al., 2007).

Multiple lines of evidence from the assessment literature, as summarized in Sections 6 and 14 of the TSD, support the conclusion that ocean acidification resulting from elevated CO<sub>2</sub> concentrations in the atmosphere will adversely affect marine calcifiers. IPCC concluded that over the next century oceanic pH projections will decrease at a greater rate and to a lower level than experienced over the past 20 million years. Average pH for the ocean surface is projected to decrease by up to 0.3–0.4 units by 2100 (Fischlin et al., 2007). By 2070, many reefs could reach critical aragonite saturation states, resulting in reduced coral cover and greater erosion of reef frameworks (Fischlin et al., 2007). These impacts could result in potentially severe ecological changes to tropical and coldwater marine ecosystems where carbonate-based phytoplankton and corals are the foundation for the trophic system (Schneider et al., 2007). In addition, the impacts of elevated CO<sub>2</sub> concentrations on oceanic chemistry will likely be greater at higher latitudes (Fischlin et al., 2007). Polar and sub-polar surface waters and the Southern Ocean are projected to be aragonite (a form of calcium carbonate [CaCO<sub>3</sub>]) under-saturated by 2100, and Arctic waters will be similarly threatened (Denman et al., 2007).

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**Comment (7-64):**

Several commenters (2828.1, 2972.1, 3411.1, 3440.1, 3477, 3722, and 3751.1) assert that the global oceanic carbon/calcification cycle in the oceans and ocean acidification will benefit marine calcifiers by enhancing calcification rates. Two commenters (3411.1 and 4632) submitted a study (Iglesias-Rodriguez et al., 2008) reporting that calcification and productivity rates of coccolithofores (*Emiliania huxleyi*) in laboratory settings increased at high CO<sub>2</sub> partial pressures; according to the commenter, this contradicts other literature sources on ocean acidification, suggesting that marine biota will be adversely impacted through decreased calcification rates. A commenter (2972.1) references a series of studies (e.g., Feng et

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<sup>1</sup> The marine carbonate buffer system allows the ocean to take up CO<sub>2</sub> far in excess of its potential uptake capacity based on solubility alone, and in doing so controls the pH of the ocean.

al., 2008; Riebesell, 2004; Iglesias-Rodriguez et al., 2008) and argues that they show how CO<sub>2</sub> does not present a danger to marine calcifiers and the environment.

**Response (7-64):**

EPA has carefully reviewed the assessment literature and determined that multiple lines of evidence (e.g., calcification modeling studies, *in-situ* experiments, laboratory simulations) support the conclusion summarized in the TSD that ocean acidification will adversely affect marine calcifiers (Denman et al., 2007; Fischlin et al., 2007; Nicholls et al., 2007; Janetos et al., 2007; and CCSP, 2009d). Conclusions from the assessment literature include the following, all of which are mentioned in Section 14 of the TSD:

Cold-water corals are likely to show large reductions in geographic range this century (Denman et al., 2007).

The dissolution of CaCO<sub>3</sub> at the ocean floor will be enhanced, making it difficult for benthic calcifiers to develop protective structures (Denman et al., 2007).

Average pH for the ocean surface is projected to decrease by up to 0.3–0.4 units by 2100 (Fischlin et al., 2007). These impacts could result in potentially severe ecological changes to tropical and coldwater marine ecosystems where carbonate-based phytoplankton and corals are the foundation for the trophic system (Schneider et al., 2007).

Regarding the Iglesias-Rodriguez study, EPA has reviewed this submission carefully. This article states that the degree of marine calcifier sensitivity to increasing CO<sub>2</sub> levels varies among species, and that a small set of taxa *may* show enhanced calcification over the 21<sup>st</sup> century. However, other heavily-cited assessment-like reports (Raven et al., 2005; Kleypas et al., 2006) and individual studies (Langdon and Atkinson, 2005; Schneider and Erez, 2006; Ohde and van Woessik, 1999; Fabry et al., 2008; Silverman et al., 2007; Reynaud et al., 1999; Doney et al., 2009; Zondervan et al., 2007; Yates and Halley, 2006) have shown reduced calcification rates in a wide variety of calcareous organisms in response to increasing CO<sub>2</sub> levels. It is possible that various species may respond differently to increased ocean acidification, and that some taxa may have increased calcification and productivity rates. However, the findings of the Iglesias-Rodriguez et al. study should be viewed within the context of the vast body of scientific assessment literature (Denman et al., 2007; Fischlin et al., 2007; Nicholls et al., 2007; Janetos et al., 2007; and CCSP, 2009d). When viewed in this way, this study clearly does not support the conclusion that the widely accepted understanding of marine calcifier response to these changes is flawed. EPA further notes that a recent meta-analysis of the 26 most recent acidification impact studies on marine calcifiers, including the Iglesias-Rodriguez et al. paper, concluded that calcification rates decreased in response to decreasing aragonite saturation state in almost all studies (Doney et al., 2009). Doney et al. (2009) also concluded the following regarding the Iglesias-Rodriguez et al. study: “significantly reduced growth rates at elevated pCO<sub>2</sub> suggest that this *E. huxleyi* strain would be more at risk of outcompetition by other phytoplankton species under future high-CO<sub>2</sub> conditions.” In addition, Riebesell et al. (2009) provided a critique of the Iglesias-Rodriguez et al. study stating that the “shortcomings in the experimental protocol compromise the interpretation of these data and raise doubts about the conclusions drawn from them.” Riebesell et al. go on to explain that the methods employed by Iglesias-Rodriguez et al. had four main issues: 1) abnormally high concentrations of cells in precultures, 2) unusual nutrient limitation of the precultures exposed to the high CO<sub>2</sub>, therefore inconsistent with the other samples, 3) a short duration of experimental growth (only 1.5 to 3 days), and 4) the cells grown at high CO<sub>2</sub> had a carbon quota (cellular biomass) two to three times greater than the low-CO<sub>2</sub> samples. Riebesell et al. conclude that, “We contend that, to date, there is no unequivocal laboratory or field study showing that increasing CO<sub>2</sub> causes an increase in coccolithophore calcification.” Given the narrow focus of the Iglesias-Rodriguez paper on one taxa of coccolithophores, the findings of Riebesell et al. (2009), and the conclusions of both the assessment literature and the recent Doney et al. (2009) study, we conclude that the discussion of this issue in the TSD is reasonable.

Regarding the studies submitted by one of the commenters (2972.1), we find that the commenter frequently misinterprets and misrepresents the findings of the studies referenced. For example, the commenter states that the primary conclusion of the Riebesell (2004) paper is that “a moderate increase in CO<sub>2</sub> facilitates photosynthetic carbon fixation of some phytoplankton groups.” After careful review of this study, we find that the commenter has selected a narrow finding and misrepresents the overarching conclusions. The following text from Riebesell (2004) provides this conclusion in the broader context of how ocean acidification will result in adverse impacts to coccolithofore species:

Rising atmospheric CO<sub>2</sub> and deliberate CO<sub>2</sub> sequestration in the ocean change seawater carbonate chemistry in a similar way, lowering seawater pH, carbonate ion concentration and carbonate saturation state and increasing dissolved CO<sub>2</sub> concentration. These changes affect marine plankton in various ways. On the organismal level, a moderate increase in CO<sub>2</sub> facilitates photosynthetic carbon fixation of some phytoplankton groups. It also enhances the release of dissolved carbohydrates, most notably during the decline of nutrient-limited phytoplankton blooms. A decrease in the carbonate saturation state represses biogenic calcification of the predominant marine calcifying organisms, foraminifera and coccolithophorids. On the ecosystem level these responses influence phytoplankton species composition and succession, favouring algal species which predominantly rely on CO<sub>2</sub> utilization. Increased phytoplankton exudation promotes particle aggregation and marine snow formation, enhancing the vertical flux of biogenic material. A decrease in calcification may affect the competitive advantage of calcifying organisms, with possible impacts on their distribution and abundance.

It is clear that the Riebesell (2004) paper does not support the commenter’s (2972.1) argument. Instead, this study concludes that “[c]onsiderable evidence is now accumulating and indicating that CO<sub>2</sub>-related changes in seawater carbonate chemistry can directly affect the marine biosphere” and that “continued acidification of surface seawater due to rising atmospheric CO<sub>2</sub> will further deteriorate the chemical conditions for biogenic calcification.”

Another example of how the commenter (2972.1) misinterprets the literature is their statement that Feng et al. (2008) shows that “claims of impending marine species extinctions due to ocean acidification are refuted by real-world evidence.” After careful review of Feng et al. (2008), we find that this study does not support commenter’s argument. Instead, Feng et al. conclude that “[s]imultaneous increases in temperature, irradiance and pCO<sub>2</sub> in the upper ocean over the coming years will probably have a great cumulative impact on marine coccolithophores such as *E. huxleyi*, fundamentally influencing the future oceanic rain ratio and the marine and global carbon cycles.”

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**Comment (7-65):**

A commenter (3411.1) submitted several reasons why the Administrator should not rely on the ocean acidification findings of IPCC:

All observed and projected changes in pH are model-based and therefore inappropriate because actual measurements do not exist.

The natural variability in marine pH at specific sites is greater than the observed pH changes to date (0.1 units). The commenter references the findings of Pelejero et al. (2005) and argues that the study shows that adverse effects on marine calcifiers are not occurring.

Ocean acidification models do not include an important source of oceanic carbonate from fish stocks. The commenter references the findings of Wilson et al. (2009).

**Response (7-65):**

Regarding the comment that actual measurements of pH decline do not exist, we disagree with the commenter. As described in Raven et al. (2005), “It is possible to measure the amount of carbon added to seawater over the past two centuries as a result of human activities. This information has been developed using a substantial database taken through the global oceans observing programs of the World Ocean Circulation Experiment and the Joint Global Ocean Flux Study in the 1990s. In these programs data were collected from around 10000 monitoring stations. This data set provides the most accurate and comprehensive overview of the past and current distribution of DIC in the oceans.” Using this data, scientists are then able to calculate the resultant changes in pH (Raven et al., 2005). Ocean acidification modeling studies confirm and validate the actual measurements (Raven et al., 2005; Denman et al., 2007). We further note that the commenter does not provide any evidence or peer-reviewed literature indicating that the model-based estimates of pH change are incorrect.

We agree with the commenter that the natural variability of marine pH at specific sites can vary by amounts greater than 0.1 units. However, the findings of Pelejero et al. (2005) do not support the commenter’s argument that pH changes associated with rising atmospheric CO<sub>2</sub> concentrations will be within the natural range of variability and that these changes will not have adverse effects on marine calcifiers. Instead, Pelejero et al., (2005) found that, “Although the relatively large variations in seawater pH at Flinders Reef suggest that coral reefs may be resilient to the shorter term effects of ocean acidification, in the coming decades many reefs are likely to experience reduced pH that is unprecedented relative to ‘natural’ levels.” We further note that the vulnerability of marine calcifiers to ocean acidification cannot be determined simply by looking at changes in pH. Factors affecting calcification rates include pH, temperature, irradiance, salinity and the availability of key minerals and nutrients. As a result, a particular location’s conditions (e.g., Flinders Reef as described in the Pelejero et al. study) cannot be used to represent the vulnerability of marine calcifiers globally, where physical conditions (i.e., temperature, pH, nutrient availability) vary. Therefore, we find that the assessment literature (Denman et al., 2007; Fischlin et al., 2007; Nicholls et al., 2007; Janetos et al., 2007; and CCSP, 2009d; Raven et al., 2005; Kleypas et al., 2006) which looks across the spectrum of available studies to draw conclusions, represents the best available information regarding the vulnerability of marine calcifiers.

Regarding the findings of Wilson et al. (2009), we acknowledge that this study suggests that fish play a large role in the marine inorganic carbon cycle. However, this study by itself does not provide evidence that ocean acidification models do not incorporate biological components of the carbon cycle, such as the role of carbonates produced from fish. We note that the commenter did not provide additional evidence to support this argument.

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**Comment (7-66):**

A commenter (2895) states that increasing concentrations of atmospheric CO<sub>2</sub> are causing ocean acidification and resulting in a variety of ecosystem impacts in the Pacific Northwest, including effects to skeleton-building zooplankton (e.g., krill) that are important food sources to salmon and orca whales. Similarly, a commenter (3386) argues that ocean acidification will pose significant risks to the fishing industry, as many fish stocks rely on small marine calcifiers for food (e.g., small marine snails), or in some cases acidification will directly effect the stocks (e.g., crabs, clams, and other fauna that require use calcium carbonate in the formation of their shells and skeletons).

**Response (7-66):**

EPA agrees with the commenters that ocean acidification poses large potential risks to marine ecosystems, species, and the commercial industries that rely on them. We find that the information submitted is consistent with the findings of the assessment literature and the TSD’s discussion of

observed changes in ocean acidity, projections for the future, and the potential impacts that these changes will have on marine life. Additional information about ocean acidification and projected U.S. regional climate impacts has been added to Section 15 of the TSD.

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**Comment (7-67):**

A commenter (3722) submitted the following reference in support of their comments: C.D. Idso, Comments to EPA, Re: April 15, 2009 Notice of Data Availability on Ocean Acidification and Marine pH Water Quality Criteria, EPA -HQ-O W-2009-0224, June 9, 2009 (Idso, 2009a). This document has four key findings: 1) that observed declines in marine pH cannot be validated in the historical record, 2) that corals will overcome physical and chemical changes in their environment, 3) that coral calcification has increased over the past century, and 4) that pH declines will not adversely affect marine calcifiers and that some species may benefit.

**Response (7-67):**

See previous responses to comments in this Section of Volume 7 regarding our response to the four key findings submitted by the commenter.

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**Comment (7-68):**

Two commenters (3344.1 and 3753) describe how the discussion of ocean acidification in the TSD is not complete and that the EPA must consider additional information, particularly about the susceptibility of Arctic waters, as it moves forward in making a final determination. The commenters discuss how carbon dioxide emissions endanger the public health and welfare through ocean acidification that will have substantial effects on marine ecosystems and those that depend on them. Accompanying comment (3344.1), a list of relevant ocean acidification references were discussed (e.g., Feely et al., 2004; Doney et al., 2009; Fabry et al., 2008; Guinotte et al., 2006).

**Response (7-68):**

EPA has reviewed these comments and the studies provided. We agree with the commenters that ocean acidification presents significant potential risks for marine calcifiers, including those in polar waters. The assessment literature has made it clear that calcifiers in polar regions (e.g., the Southern Ocean) are particularly vulnerable due to the likelihood that aragonite will decline or become undersaturated within this century. The decline of calcifiers in these polar regions, where these organisms play important roles in the trophic system, could have larger effects on the overall ecosystem (Fischlin et al., 2007). Section 14 of the TSD conveys these findings from the assessment literature and contains several specific statements regarding the vulnerability of cold-water calcifiers to increases in ocean acidity (see below):

Cold-water corals are likely to show large reductions in geographic range this century (Denman et al., 2007).

The impacts of elevated CO<sub>2</sub> concentrations on oceanic chemistry will likely be greater at higher latitudes (Fischlin et al., 2007). Polar and sub-polar surface waters and the Southern Ocean are projected to be aragonite (a form of CaCO<sub>3</sub>) under-saturated by 2100, and Arctic waters will be similarly threatened (Denman et al., 2007). These impacts will likely threaten ecosystem dynamics in these areas where marine calcifiers play dominant roles in the food web and in carbon cycling (Fischlin et al., 2007).

EPA has reviewed the submitted studies carefully. We note that these studies (e.g., Feely et al., 2004; Doney et al., 2009; Fabry et al., 2008; Guinotte et al., 2006) are consistent with the assessment literature

(Denman et al., 2007; Fischlin et al., 2007; Nicholls et al., 2007) and CCSP (Janetos et al., 2007; and CCSP, 2009d), and that the papers reinforce the conclusions of the TSD.

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**Comment (7-69):**

Many commenters (e.g., 1318.1, 4249, 6936, 10809) stated their support for the findings, noting ocean acidification as one of the environmental effects of climate change. One commenter (3353) suggests there is an increased rate of extinction due to climate change, while others (e.g., 4739, 10124) indicated that extreme climate change can precede mass extinctions. One commenter (10298) states concern for the impacts of acidification on local marine populations, including coral, starfish, krill, grey whales, and salmon. One commenter (3601.1) voices his support for the findings and states that there is evidence of serious harm that has already occurred, citing a National Oceanic and Atmospheric Administration (NOAA) study showing the death of 67% of larval blue king crab when exposed to levels of acidification.

**Response (7-69):**

EPA has reviewed these comments and we agree that ocean acidification and climate change pose substantial risks to marine and coastal ecosystems and wildlife. Impacts to these ecosystems include reduced calcification of marine calcifiers and increased risk of species loss. We find that the discussions of the commenters are generally consistent with the findings of the assessment literature, as summarized in Sections 14 and 15 of the TSD. Regarding the comment on the risk of mass extinctions, please see our discussion of this issue in the TSD and in responses to comments in this section. We note that the commenter did not define what a mass extinction event would consist of and did not provide scientific evidence or literature to support their argument. However, IPCC has concluded that about 20% to 30% of species (global uncertainty range from 10% to 40%, but varying among regional biota from as low as 1% to as high as 80%) will be at increasingly high risk of extinction, possibly by 2100, as global mean temperatures exceed 2 to 3°C above pre-industrial levels (Fischlin et al., 2007).

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**Comment (7-70):**

Several commenters (0700.1, 3136.1, 3596.2, 3722, and 5846) state that plants and animals have historically responded to changes in climate by shifting habitat ranges and adapting to changing conditions. The commenters argue that this shows how plants and animals are not threatened, but capable of resisting the effects of climate change. In discussing the vulnerability of coral reefs to climate change, commenters argue that the TSD ignores the possibility that corals will adapt by migrating northward to areas with more suitable conditions (e.g., cooler sea surface temperatures). Two commenters (2972.1 and 3136.1) reference a study (Precht and Aronson, 2004) describing migratory response of corals to changing conditions during the Holocene periods.

**Response (7-70):**

EPA acknowledges that plants and animals have historically responded to some changes in their surroundings, but disagrees with the comment that all ecosystems and species will be able to resist the effects of climate change through adaptation. The assessment literature, as summarized in the TSD, finds that many organisms cannot shift their ranges fast enough to keep up with the current pace of climate change (Fischlin et al., 2007). In addition, species that require higher-elevation habitat (e.g., alpine pikas), or habitat that may not exist at higher latitudes (e.g., coral reefs), often have nowhere to migrate (Fischlin et al., 2007). In addition, many changes in phenology (the timing of lifecycle events) are occurring faster than the abilities of ecosystems and species to resist adverse impacts (Fischlin et al., 2007). In its Fourth Assessment Report, IPCC explains that “ecosystems are expected to tolerate some level of future climate change and, in some form or another, will continue to persist, as they have done repeatedly with palaeoclimatic changes. A primary key issue, however, is whether ecosystem resilience (understood as the

disturbance an ecosystem can tolerate before it shifts into a different state) inferred from these responses will be sufficient to tolerate future anthropogenic climate change” (Fishlin et al., 2007) This statement from the IPCC has been added to the TSD to provide further clarification of this issue.

Regarding coral adaptation through migration, EPA notes that the IPCC finds that coral migration to higher latitudes with more optimal sea surface temperatures is unlikely, due both to latitudinally decreasing aragonite concentrations and projected atmospheric CO<sub>2</sub> increases. Coral migration is also limited by lack of available substrate (Fischlin et al., 2007). The coral migratory responses observed during the Holocene periods, as described in the Precht and Aronson (2004) study, occurred over much longer time periods (i.e., thousands of years) than will be available to coral species confronting current rates of climate change and ocean acidification (Fischlin et al., 2007). To provide additional clarity, the following conclusions from Fischlin et al. (2007) have been added to the coral reef impacts discussion in Section 14 of the TSD.

Coral migration to higher latitudes with more optimal sea surface temperatures is unlikely, due both to latitudinally decreasing aragonite concentrations and projected atmospheric CO<sub>2</sub> increases. Coral migration is also limited by lack of available substrate (Fischlin et al., 2007).

See the finding, Section III.C, “Adaptation and Mitigation,” for our response to comments on the treatment of adaptation in the finding.

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**Comment (7-71):**

A commenter (9733) indicates the Great Barrier Reef is not dying, because the reefs have fully recovered after major bleaching events, and that corals will not be susceptible to future impacts from elevated GHG concentrations.

**Response (7-71):**

First, we note that the fact that the Great Barrier Reef has recovered should not be interpreted to mean that it is not susceptible to future levels of ocean acidification and bleaching, nor that the Great Barrier Reef is an appropriate indicator or representation of U.S. coral reef health.

Second, we note that the arguments submitted by these commenters are not consistent with the findings of the assessment literature. For example, the IPCC, as summarized in the TSD, concludes that climate change (very high confidence) and ocean acidification due to the direct effects of elevated CO<sub>2</sub> concentrations (medium confidence) will impair a wide range of planktonic and other marine organisms that use aragonite to make their shells or skeletons (Fischlin et al., 2007). Average pH for the ocean surface is projected to decrease by up to 0.3–0.4 units by 2100 (Fischlin et al., 2007). These impacts could result in potentially severe ecological changes to tropical and coldwater marine ecosystems where carbonate-based phytoplankton and corals are the foundation for the trophic system (Schneider et al., 2007). In addition, IPCC concluded that annual or bi-annual exceedance of bleaching thresholds is projected at the majority of reefs worldwide by 2030 to 2050. After bleaching, algae quickly colonize dead corals, possibly inhibiting later coral recruitment. Modeling predicts a phase switch to algal dominance on the Great Barrier Reef and Caribbean reefs in 2030 to 2050 (Fischlin et al., 2007). Furthermore, there is widespread agreement among the assessment reports that the risks posed to coral reefs will increase over the next decade (Fischlin et al., 2007; Denman et al., 2007; Janetos et al., 2008).

Finally, we note that the commenter did not provide evidence or literature to support their argument that coral reefs will not be susceptible to future impacts. EPA finds that the assessment literature provides

robust evidence that coral reefs are being adversely impacted by warmer sea surface temperatures and ocean acidification.

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**Comment (7-72):**

A commenter (10076) states that key coral reefs could disappear with increasing GHG levels in the atmosphere. The commenter states that at the recent World Oceans Conference, focus was placed on the Coral Triangle off Indonesia—the world’s richest coral reef, likened to the Amazon rainforest in biodiversity—being destroyed and taking with it the fish on which natives rely.

**Response (7-72):**

We agree that increasing GHG concentrations will adversely impact coral reefs through increased water temperatures, ocean acidification, and greater frequency and intensity of high-temperature bleaching events. Sections 4, 6, and 14 of the TSD include a number of conclusions relevant to the risks that elevated GHG concentrations pose for coral reefs and the services that those reefs provide.

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**Comment (7-73):**

Many commenters (e.g., 1156.1, 1672, 3570.1, 3574.1, 4184, 4249, 6733, 6735) stated their support for the findings, noting the endangerment of plants and animals world-wide as one of the environmental effects of climate change. One commenter (3961) notes that various plant and animal species studied have shown changes in timing of migration or reproduction, shifts in habitat or migratory routes, or other changes associated with global warming that threaten their populations. Several commenters (9587, 10298, 11271) spoke to the degradation of natural ecosystems, including forests, rivers, rainforests, and oceans. A commenter (3400.1) from Washington state mentions that he is seeing salmon habitat degradation due to warming streams.

**Response (7-73):**

EPA has reviewed these comments and we agree that climate change poses substantial risks to ecosystems and wildlife, including impacts associated with changes in life-cycle characteristics, range shifts, habitat degradation or loss, and fisheries. We find that the discussions of the commenters are generally consistent with the findings of the assessment literature, as summarized in Sections 9, 10, 14 and 15 of the TSD.

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**Comment (7-74):**

Two commenters (0700.1 and 5846) argue that mass extinctions of plant and animal species will not occur because any future warming will be well within the natural climate variability over the past 10,000 years. One commenter (0700.1) states that the main processes responsible for historical extinctions have been asteroids impacting Earth, human hunting, the advent of human agriculture, and the increased occurrence of exotic species invasions due to human activity.

**Response (7-74):**

EPA has reviewed the commenters’ statements regarding climate change effects on extinction rates and we find that these arguments are not consistent with the findings of the assessment literature. We note that the commenters did not cite any scientific literature to support their assertions, and further note that the fact that, in the past, mass extinctions have resulted from events other than climate change in no way leads to the conclusion that current and projected climate change would not cause extinctions. For example, IPCC concludes, as summarized in the TSD, that with global average temperature changes of 2°C above pre-industrial levels, many terrestrial, freshwater and marine species (particularly endemics

across the globe) are at a far greater risk of extinction than in the recent geological past. On a global scale, about 20% to 30% of species (global uncertainty range from 10% to 40%, but varying among regional biota from as low as 1% to as high as 80%) will be at increasingly high risk of extinction, possibly by 2100, as global mean temperatures exceed 2 to 3°C above pre-industrial levels (Fischlin et al., 2007). While there have been a number of causes of extinctions in the past, including those described by commenter 3707.1, the assessment literature provides robust evidence that climate change is currently impacting many plant and animals species in adverse ways, and that these impacts will continue to intensify with future warming (Fischlin et al., 2007).

The scientific literature which is summarized in the TSD addresses these issues in a reasonable and appropriate manner. Regarding the comment that future warming levels will remain within the natural climate variability over the past 10,000 years, please see responses in Volume 2: Section 2 and Volume 4: Section 3, of this Response to Comments Document.

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**Comment (7-75):**

A commenter (3440.1) states that the temperature changes that species tolerate on daily (day vs. night) and annual (summer vs. winter) timeframes are much greater than what is being projected for annual average temperature changes resulting from climate change. The commenter argues that species will be able to tolerate these impacts.

**Response (7-75):**

While many ecosystems are expected to tolerate some level of future climate change, the comment that all species will be able to tolerate these impacts is inconsistent with the conclusions of the assessment literature. We further note that the commenter did not provide new literature to support their assertions.

As summarized in Sections 6(b) and 6(c) of the TSD, projected changes in average temperature will affect ecosystems and species by changing the range of temperatures to which they have become accustomed. We acknowledge that many species can tolerate temperature ranges due to annual changes in the seasons (e.g., below freezing in the winter and above 90°F in the summer) and on daily timescales (day vs. night). We also note that these temperature ranges are greater than projected average temperature changes over the next century (e.g., 3.2°F to 7.2°F). However, it is important to note that climate change will expose ecosystems and species to seasonal temperatures that are uncharacteristic for a particular region (see Section 6[c] of the TSD for a more detailed discussion of this topic). In this sense, summer temperatures will be hotter than normal, causing heat stress (Fischlin et al., 2007). Winter temperatures will not be as cold; however, this can have adverse effects on ecosystems as well, such as the proliferation of pine bark beetles that will not be killed off by cold temperatures. On this topic, IPCC found that warmer summer temperatures are projected to extend the annual window of high fire ignition risk by 10%–30% in North American forests, and the risks of tree loss from Southern pine beetles will likely depend on the seasonality of warming, with winter and spring warming leading to the greatest damage (Easterling et al., 2007).

Furthermore, many temperature changes are occurring faster than the abilities of ecosystems and species to resist adverse impacts (Fischlin et al., 2007). The assessment literature, as summarized in the TSD, states that many organisms cannot shift their ranges fast enough to keep up with the current pace of climate change (Fischlin et al., 2007). To further describe this vulnerability, the following statement has been added to the TSD: “Migration rates of tree species from paleoecological records are on average 200–300 m/yr, which is significantly slower than what would be required to respond to anticipated climate change, which has been estimated to be greater than 1 km/yr (Fischlin et al., 2007).”

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**Comment (7-76):**

A commenter (3136.1) contends that, in discussing shifts in species' ranges in response to changing conditions, the TSD only references instances of species disappearing from areas, instead of also mentioning appearances of new species in areas they previously did not inhabit. The commenter states that the TSD should be modified to reflect the ongoing positive, adaptive responses to climate change throughout the biosphere. The commenter cites Precht and Aronson (2004), which according to the commenter shows the migratory potential of coral species in response to changing conditions.

**Response (7-76):**

When Chapter 14 of the TSD identifies a number of observed species shifts from one habitat to another, it should be clear that the plant or animal is disappearing from one area and appearing in another. Regarding the commenter's request that the TSD be modified to reflect these ongoing positive adaptive responses, based on our review of this comment, we did not find new information that warranted modification of the TSD or our conclusions regarding the impacts of climate change on species' ranges. Regarding the submission of Precht and Aronson (2004), please see previous response to comments (#7-70). We note that the commenter did not provide scientific support for their assertions that such migrations are positive, and we note the assessment literature does not support the conclusion that shifts in species ranges are positive. For example, the IPCC clearly states that the rates of changing conditions and the resulting habitat shifts of plants and animals generally have adverse effects on species, including decreased productivity and fitness (Karl et al., 2009; Fischlin et al., 2007). Furthermore, the appearance of a new species to a region often has negative consequences on broader ecosystem dynamics by disrupting predator-prey relationships and other trophic dynamics (Fischlin et al., 2007). For example, warming temperatures will likely allow species in the southern Arctic areas of North America to colonize higher-latitude areas, resulting in new assemblages. Many of these, particularly fishes, will be likely to out-compete or prey upon established Arctic species, resulting in negative local effects on the broad ecosystem. These southern emigrants to the Arctic will also bring with them new parasites and diseases to which Arctic species are not adapted, thereby increasing mortality (Anisimov et al., 2007). Finally, changing conditions which force species to abandon their previous habitats can adversely impact populations where suitable replacement habitat does not exist.

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**Comment (7-77):**

A commenter (3136.1) disagreed with the findings of several studies discussed by IPCC (Fischlin et al., 2007) and mentioned in the TSD regarding:

The poleward migration of species (Root et al., 2003; Parmesan and Yohe, 2003).

The timing of breeding calls in several frogs species in Upstate New York (Gibbs and Breisch, 2001).

The increased exposure of toad eggs in Oregon to UVB resulting from decreased lake levels brought on by climate change-driven drought (Kiesecker et al., 2001).

The extirpation (local extinction) of the Edith's checkerspot butterfly from the southern end of its range, and the expansion of the species' range 90 kilometers north into British Columbia (Parmesan, 1996).

The commenter argues that these studies are not appropriate for use in the endangerment findings because the methods used by the authors are problematic or inappropriate (e.g., the temperature record data used are inaccurate or the interpretation of precipitation data by the scientists was incorrect) and the conclusions are unsupported. The commenter objects to the projections of northward shifting ecosystems: e.g., Root et al. 2003 (cited by IPCC) has a 3.8 mile per decade ecosystem migration, and

with a constant rate of warming (e.g., A1B ensemble) this would continue. The commenter also argues that the Parmesan and Yohe projection that spring onset in D.C. would look like North Carolina in 100 years (a shift of 232 miles) is not “an ecological catastrophe.”

**Response (7-77):**

After reviewing the five studies cited by IPCC (Root et al., 2003; Parmesan and Yohe, 2003; Gibbs and Breisch, 2001; Kiesecker et al., 2001; Parmesan and Yohe, 1996), EPA maintains that the underlying data were properly analyzed, applied, and interpreted by the authors of the studies, and that IPCC accurately captured the major findings of the studies.

The commenter extrapolates the rate of ecosystem shifts from Root et al. and Parmesan and Yohe out 100 years by assuming that the rate of temperature change will stay constant. We disagree that this is an appropriate assumption to make, given that the range of temperature projections for warming in the 21<sup>st</sup> century are 30% to 800% higher than observed in the 20<sup>th</sup> century. Rates of changes will also differ from one location to another, with some locations having much greater temperature changes. Additionally, it is premature to assume that the changes observed in the Root and Parmesan papers have reached equilibrium.

The commenter’s argument regarding the Gibbs and Breisch (2001) study focuses on the temperature trends over the course of the 20<sup>th</sup> century. The main conclusion of this study is that frog breeding calls are commencing earlier because of warming temperatures. The commenter provides no evidence that the calls are not occurring earlier because of warming. Regarding the Kiesecker et al. (2001) study, the commenter references a different precipitation data set and argues that it shows no decreasing trend in rainfall for the October–March timeframe. The commenter provides no information regarding what region the data refers to, and the interval appears to be annual average precipitation. The Kiesecker study used monthly average precipitation for all weather stations within Oregon’s Cascade mountains for the months October through March (data from Oregon Climate Center). Given the information provided, we do not find that the commenter’s data is an appropriate representation or surrogate for the data used by Kiesecker et al. Regarding the Parmesan (1996) study, the commenter provides a graph of temperature history data (from the Climate Research Unit at the University of East Anglia) and argues that temperatures have not warmed in Northern Mexico, where the butterflies were observed to be disappearing from. We note that the commenter did not provide specific information regarding the exact location the data corresponds to (other than ‘Northern Mexico’), specifics regarding what the data represents (e.g., timeframe of data, such as daily versus monthly versus annual departure), or other information necessary in order to reproduce the graph. Therefore, we are unable to properly assess the data provided.

Upon review of the detailed comments offered on these studies, EPA concludes that the studies are robust and that their inclusion in the IPCC Fourth Assessment Report is reasonable. We note that the commenter did not provide alternative scientific literature either critiquing the methods in the five studies or articulating a different interpretation or outcome than the conclusions of the studies. The lack of peer-reviewed literature documenting the purported flaws in the studies, and the ad hoc nature of the commenter’s own critiques, do not provide reasons to conclude that the studies are flawed and should not be discussed in the TSD. EPA has determined that these studies are an appropriate source of information for describing observed impacts of climate change on animal behavior and phenology.

See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

**Comment (7-78):**

A commenter (3347.1) argues that EPA’s TSD fails to separate climate change impacts on wildlife from degradation caused by other non-climate-related anthropogenic pressures (e.g., overfishing). The commenter provides an example and states that “EPA asserts that potentially climate-driven decreases in the pH and carbonate ion concentration of the surface oceans could affect coral reefs. Yet, EPA acknowledges, “[t]he effects of various other stressors, particularly human impacts such as overfishing, pollution, and the introduction of invasive species, appear to be exacerbating the thermal stresses on reef systems and, at least on a local scale, exceeding the thresholds beyond which coral is replaced by other organisms.”

**Response (7-78):**

See Volume 1.2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors. EPA disagrees with the commenter that the TSD handles these issues inappropriately with respect to assessing endangerment. The TSD summarizes the findings of the assessment literature in describing that climate change effects on ecosystems do not occur in isolation, and the discussion in the TSD is clear that the climate change, other stressors, and the compounded effects of both will present new threats to ecosystems and wildlife, while also compounding existing stressors. Section 14 of the TSD summarizes findings from the assessment literature which discuss impacts to ecosystems and species resulting solely from climate change or from both climate change and non-climate-related stressors (and how the two interact). For additional clarity, however, we have added additional statements regarding the interaction between climate change and other anthropogenic pressures to both Sections 12 and 14 of the TSD. For example, the following text was added to Section 14(a) in the discussion of how climate change will interact with existing stressors on ecosystems and wildlife:

Climate change effects on ecosystems do not occur in isolation. Ecosystems are increasingly being subjected to other human-induced pressures, such as land-use change, extractive use of goods, increasing degradation of natural habitats, air pollution, wildfires, and competition with invasives (Field et al., 2007; Fischlin et al., 2007). In the medium term (i.e., decades), climate change will increasingly exacerbate these human-induced pressures, causing a progressive decline in biodiversity (Fischlin et al., 2007).

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**Comment (7-79):**

A commenter (3136.1) argues that projections of ecosystem impacts (i.e., asynchronous timing of breeding cycles for freshwater animals) due to pond drying are “meaningless” because precipitation is predicted to increase over the United States, except in the Southwest where there few natural ponds.

**Response (7-79):**

As the commenter correctly notes, the assessment literature, as summarized in Section 6(c) of the TSD, states that there will generally be an increase in annual average precipitation across most of North America and the United States, except in southwestern areas (Christensen et al., 2007). However, the commenter’s conclusion that pond drying would not occur in areas where precipitation increases is incorrect. As explained in the TSD, there will be regional variations in the frequency, timing, and magnitude of precipitation changes and increasing temperatures across the United States are projected to increase evaporation rates. The IPCC concluded that because the increased saturation vapor pressure can yield greater evaporation, projected increases in annual precipitation are partially offset by increases in evaporation; regions in central North America may experience net surface drying as a result (Christensen et al., 2007). The literature summarized in the TSD accounts for these multiple interacting effects, and EPA has determined that the statement in the TSD, which is taken from CCSP (2009d) regarding the drying and projected reductions of freshwater ponds in the north central United States, is accurate, appropriate, and representative of the best available science. Finally, we note that the commenter did not

provide evidence or literature to support their argument that 1) pond drying will not occur, and 2) there will not be impacts on the timing of breeding cycles in freshwater animals (e.g., amphibians).

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**Comment (7-80):**

A commenter (3347.1) argues that EPA relies on non-U.S. impacts to support the endangerment finding for wildlife; according to the commenter, this is inconsistent with the plain language of Section 202(a)(1) and is irrelevant to, and cannot support, the finding.

**Response (7-80):**

After reviewing Section 14 of the TSD in light of the comment, EPA disagrees with the commenter and finds that this section primarily discusses observed and projected ecosystem impacts in the United States and North America. The commenter may have assumed that the TSD included impacts outside the United States because information from the North America chapter (14) of Working Group II's contribution to the IPCC Fourth Assessment Report (Field et al., 2007) covers both Canada and the United States. We recognized this issue during development of the TSD, and have taken care to ensure that the material summarized in the TSD refers to the many U.S.-specific findings contained in that chapter. See Volume 1: Section 1 of the Response to Comments document for our general response to comments on this issue. The commenter did not provide specific examples of statements in the TSD that do not apply to the U.S., and our review concludes that the information provided in the TSD is applicable, appropriate, and accurate for the U.S. context.

We also note that the TSD includes a brief review of international impacts on ecosystems and wildlife where those impacts transcend national boundaries and/or raise concerns for the United States. For example, the TSD summarizes information on migratory species whose ranges span national boundaries or suitable habitat ranges that border these boundaries (e.g., the likelihood that sugar maples will shift their ranges out of New England into Southern Canada, with consequences to ecosystem dynamics and humans who rely on the trees for economic activity). See Volume 8 of the Response to Comments document for our general response to comments on the consideration of international impacts in the context of the Administrator's endangerment analysis. Also note that Section III.D. and IV.B. of the Findings provide our response to broader legal and policy comments raised regarding international impacts.

See the Findings, Section IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-81):**

Several commenters (0070.1, 3136.1, 3596.2, and 3722) disagree with the TSD conclusions that climate change will adversely affect plants and animals in the Arctic. One commenter (3136.1) argues that the fact that these species have survived through changing conditions in the past indicates that they will adapt to future changes as well. The commenter presents results of studies suggesting that there has been less Arctic sea ice (Kaufman et al., 2004), that summertime temperatures south of the Laurentide ice sheet during the Holocene may have been warmer than previously expected (Webb III et al., 1998), and that the treeline over Russia was closer to the North pole (MacDonald et al., 2000). Several commenters (3136.1, 3596.2, and 3722) argue that ice-dependent species, such as polar bears, are not vulnerable to changes in sea ice because they survived through these historical periods.

**Response (7-81):**

EPA has reviewed the comments and literature provided, and determined that they do not provide sufficient evidence to conclude that climate change will not adversely impact the Arctic. As noted previously, the fact that certain plants or animals have survived changing conditions in the past, in and of itself, does not prove that the same species will not be adversely affected by climate change. Many factors will determine how climate change affects species, including the rate of change and broader impacts on the ecosystem in which the species lives.

EPA has reviewed the studies provided (MacDonald et al., 2000; Webb III et al., 1998; and Kaufman et al., 2004) and we conclude that the papers provide evidence that there has been less sea ice, that temperatures south of the Laurentide ice sheet may have been warmer during the Holocene than previously thought, and that the treeline north of Russia was closer to the North Pole at certain times in the past. However, the relevance of those facts to the assessment of the current and future impacts of climate change on ice-dependent species such as polar bears is not clear. We note that these studies do not consider or address effects of these changes on populations of any ice-dependent species, or any other ecological impacts resulting from these changes. In other words, these studies do not identify or assess how these conditions (less sea ice, a more poleward treeline) would mean that polar bears will not be adversely affected. As a result, we find that these studies do not provide credible evidence that the assessment literature's conclusions regarding the vulnerability of ice-dependent species is flawed.

Section 14 of the TSD summarizes the assessment literature's findings related to impacts on ecosystems and wildlife. For example, the IPCC states that Arctic animals are likely to be most vulnerable to warming-induced drying (invertebrates); changes in snow cover and freeze-thaw cycles that affect access to food and protection from predators; changes that affect the timing of behavior (e.g., migration and reproduction); and influx of new competitors, predators, parasites, and diseases (Anisimov et al., 2007), and also states that global warming is projected to be most pronounced at high latitudes. Ongoing rapid climatic changes will force tundra polewards at unprecedented rates, causing lagged responses in its slow-growing plant communities (Fischlin et al., 2007 and references therein). While many Arctic plants and animals may be able to tolerate some level of future climate change and some species at lower latitudes may be able to benefit by expanding their ranges into warmer areas at higher latitudes, the assessment literature provides robust evidence that the impacts of climate change in the Arctic will be negative for most species (Fischlin et al., 2007).

The comment that ice-dependent species, including polar bears, are not vulnerable to these impacts is inconsistent with the conclusions of the assessment literature (Fischlin et al., 2007; Field et al., 2007). Polar bears are specialized predators that hunt ice-breeding seals and are therefore dependent on sea ice to acquire food and survive. Regardless of whether or not Arctic conditions in historical times were different, the assessment literature provides solid evidence that sea ice extent is decreasing at rates faster than what has been observed in the recent past (few thousands of years) and that ice-dependent species are highly vulnerable to these changes. Polyak et al. (2009) indicates that the Arctic Ocean may become seasonally ice-free as early as 2040. For these reasons, in 2008, the U.S. Fish and Wildlife Service (USFWS) listed the polar bear as a threatened species under the Endangered Species Act. This decision was based on scientific evidence showing that sea ice loss threatens, and will likely continue to threaten, polar bear habitat (FWS, 2008).

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**Comment (7-82):**

A commenter (3722) argues that the TSD's conclusion that polar bears face a high risk of extinction is baseless and directly contradicts the International Union for Conservation of Nature's (IUCN's) decision to change the polar bear's Red List status from Least Concern to Vulnerable. The commenter submitted a reference (IUCN/SSC Polar Bear Specialist Group, 2005) in support of their comments. This document was also referenced by IPCC (2007e) and the findings were summarized in the TSD. The commenter

describes a section of the report which states that “[i]n many cases, harvesting is the major cause of mortality for bears,” either killed in pursuit of sport, subsistence hunting, accident, or in defense of life or property. The commenter argues that harvesting is a much greater threat to polar bears than climate change. The commenter also references comments submitted by the state of Alaska to USFWS on the proposed listing of the polar bear under the Endangered Species Act, which argue that USFWS did not use the best available scientific and commercial information in making the proposed listing.

**Response (7-82):**

EPA reexamined the IUCN report in light of this comment and maintains that the TSD’s summary of the assessment literature correctly summarizes and references the findings of the Polar Bear Specialist Group. The IUCN report clearly indicates that climate change is projected to have a larger impact on polar bears than over-harvest or other population stress factors. We find that the commenter misinterpreted the findings of the Polar Bear Specialist Group. In fact, this group concluded the following in the “Species Assessment” section of the IUCN report (<http://www.iucnredlist.org/details/22823/0>):

Polar bears rely almost entirely on the marine sea ice environment for their survival so that large scale changes in their habitat will impact the population (Derocher et al. 2004). Global climate change poses a substantial threat to the habitat of polar bears. Recent modeling of the trends for sea ice extent, thickness and timing of coverage predicts dramatic reductions in sea ice coverage over the next 50–100 years (Hassol 2004). Sea ice has declined considerably over the past half century. Additional declines of roughly 10–50% of annual sea ice are predicted by 2100. The summer sea ice is projected to decrease by 50–100% during the same period. In addition the quality of the remaining ice will decline. This change may also have a negative effect on the population size (Derocher et al. 2004). The effects of sea ice change are likely to show large differences and variability by geographic location and periods of time, although the long term trends clearly reveal substantial global reductions of the extent of ice coverage in the Arctic and the annual time frames when ice is present.

While all bear species have shown adaptability in coping with their surroundings and environment, polar bears are highly specialized for life in the Arctic marine environment. Polar bears exhibit low reproductive rates with long generational spans. These factors make facultative adaptation by polar bears to significantly reduced ice coverage scenarios unlikely. Polar bears did adapt to warmer climate periods of the past. Due to their long generation time and the current greater speed of global warming, it seems unlikely that polar bear will be able to adapt to the current warming trend in the Arctic. If climatic trends continue polar bears may become extirpated from most of their range within 100 years.

There is little doubt that polar bears will have a lesser distribution area and habitat quality in the future. However, no direct relation exists between these measures and the abundance of polar bears. While some have speculated that polar bears might become extinct within 100 years from now, which would indicate a population decrease of > 50% in 45 years based on a precautionary approach due to data uncertainty. A more realistic evaluation of the risk involved in the assessment makes it fair to suspect population reduction of >30%.

Other population stress factors that may also operate to impact recruitment or survival include toxic contaminants, shipping, recreational viewing, oil and gas exploration and development. In addition to this comes a potential risk of over-harvest due to increased quotas, excessive quotas or no quotas in Canada and Greenland and poaching in Russia.

With regard to the comments submitted to USFWS by the state of Alaska (and submitted to the Endangerment Finding Docket) on the proposed Endangered Species Act listing, we have reviewed the issues raised and found that many of the arguments posed by the state of Alaska, including the scientific information used, pertain to the proposed listing and are thus not germane to the endangerment determination. In making the polar bear listing decision, the USFWS had to consider a different set of questions compared with the endangerment determination. For example, USFWS had to consider threats from a large series of human-caused and environmental stressors. In addition, the USFWS specifically focused the public comment period on seeking comments and information on 1) the life-cycle characteristics of polar bears (e.g., habitat selection, range, food), 2) effects of sea ice change on distribution and abundance, 3) effects from other stressors (e.g., hunting, oil/gas development), and 4) regulatory mechanisms and management programs for polar bear conservation.

We also note that prior to publishing the final rule for the polar bear listing decision, USFWS reviewed and considered all comments received during the public comment process, including those submitted by the State of Alaska. USFWS summarized and responded to each comment received, which can be viewed at: <http://alaska.fws.gov/fisheries/mmm/polarbear/pdf/finalresponsefromDC.pdf>. We note that USFWS proceeded with finalizing the “threatened” listing for the polar bear, despite the comments from the state of Alaska. We refer the commenter to USFWS’s responses to all comments received; however, we provide one example of their response to a comment from the state of Alaska:

Comment: More research and a comprehensive approach is required to address the uncertainties associated with the ability of climate models to accurately reflect natural climate—sea ice—polar bear relationships and polar bear responses (adaptation) to climate change.

Response: While additional research on these topics is certainly desirable, we believe that a tremendous body of sound scientific data is available, and that information formed the basis for the USGS reports as well as the Service’s decision in the final rule. Furthermore, we note the caveat expressed by many climate modelers and summarized by DeWeaver (2007), “even if climate models perfectly represent all climate system physics and dynamics, inherent climate variability would still limit the ability to accurately issue detailed forecasts (predictions) of climate changes, particularly at regional and local geographical scales and time scales greater than a decade.” Thus, it is simply not possible to engineer all uncertainty out of climate models, and climate scientists expend considerable energy in trying to understand and interpret that uncertainty.

For these reasons, we have concluded that the scientific literature summarized in the TSD (e.g., IPCC, CCSP, USGCRP, and the Arctic Climate Impacts Assessment), as well as the IUCN Red List reports, represent the best available information regarding polar bear vulnerability to climate change and related stressors. We have also concluded that the 2008 action of the USFWS to list the polar bear under the Endangered Species Act provides further support for the summary contained in the TSD. The material provided by the commenter does not provide a basis on which to modify the conclusions reached in the assessment reports.

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**Comment (7-83):**

Several commenters (e.g., 0731, 1672, 3353, 3583, 3609.2, 3696.1, 4184, 4249, 6883, 8665, 10871, 11201) voice their support for the findings, noting that global warming threatens ecosystems and wildlife species. Commenters (e.g., 2701, 3459 10122, 10298,10823) identify both plant and animal species as at

risk, and some note a decrease in plant and animal populations locally that they attributed to warming. Multiple commenters (1545, 3459, 3836) identified the polar bear as a species at risk; others (3459, 6733) note that pandas and amphibians have been added to the endangered species list.

**Response (7-83):**

EPA has reviewed these comments and we agree that climate change poses substantial risks to ecosystems and wildlife, including impacts that will increase the risk of extinction for some plants and animals. We note, however, that many species are affected by a range of climate and non-climate stressors. See Sections 12 and 14 of the TSD for more detailed information regarding how climate change interacts with these existing stressors on ecosystems and wildlife.

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**Comment (7-84):**

Commenter 3344.2 submits a report entitled *As Goes the Arctic, So Goes the Planet*, prepared by Oceana and Ocean Conservancy. The report describes how Arctic ecosystems and species are particularly vulnerable to climate change. Specifically, the report covers how impacts to biodiversity will alter ecosystems and affect the subsistence way of life, how increases in atmospheric carbon dioxide are predicted to acidify Arctic and North Pacific oceans with subsequent impacts to marine ecosystems and the people who depend upon them, and that changes to Arctic ecosystems are likely to reverberate globally by affecting migratory species.

**Response (7-84):**

EPA has reviewed the information submitted by the commenter. The findings of this report are consistent with the information presented in the TSD on the vulnerability of Arctic ecosystems and species, and the people who depend on them, to climate change and ocean acidification.

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**Comment (7-85):**

A commenter (3347.1) argues that in the TSD, EPA describes studies showing potential ecological benefits due to climate change and that these studies cannot be used as basis for an endangerment finding. Also, the commenter argues that the following TSD statement is contradictory: “positive long-term species richness, which may lead to short term decreases because species that are intolerant of local conditions may disappear relatively quickly.” Finally, the commenters argue that given the uncertainty surrounding potential short term decreases in biodiversity, EPA cannot rely on an increase in biodiversity to support an endangerment finding for welfare.

**Response (7-85):**

In the TSD, EPA summarizes the findings of the assessment literature with respect to both beneficial and adverse impacts. Thus, in describing the overall impact of climate change on ecosystems and wildlife, EPA summarized the assessment literature’s coverage of all impacts, including those which are projected to have positive and negative consequences for biodiversity and ecosystem services.

See Volume 1: Section 4 of the Response to Comments document for responses on our approach to the discussion of both beneficial and adverse impacts. See the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

Regarding the TSD statement on species richness, we have removed this statement from Section 14 of the TSD. Finally, we find that the TSD does not project that biodiversity across ecosystems will increase. We do agree with the commenter that there is uncertainty regarding short term decreases in biodiversity;

however, the assessment literature provides robust evidence that climate change, along with other stressors, will decrease biodiversity. IPCC found that climate change impacts will vary regionally and across biomes and will lead to increasing levels of global biodiversity loss, as expressed through area reductions of wild habitats and declines in the abundance of wild species, putting those species at risk of extinction. Overall, climate change has been estimated to be a major driver of biodiversity loss in cool conifer forests, savannas, Mediterranean-climate systems, tropical forests, in the Arctic tundra, and in coral reefs (Fischlin et al., 2007). We have added these IPCC conclusions to Section 14 of the TSD to clarify the assessment literature's findings regarding climate change effects on biodiversity.

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**Comment (7-86):**

A commenter (7020) states that, in discussing observed impacts of climate change on ecosystems and the services they provide, the TSD is not clear whether these changes have positive or negative consequences, and the TSD does not quantify the impacts.

**Response (7-86):**

In response to this comment, EPA reexamined Section 14 of the TSD to ensure that it provides a clear description of whether observed impacts are having beneficial or adverse effects on species. We note that Section 14(a) of the TSD contains a series of bulleted statements from the assessment literature regarding observed climate change effects on plant and animal species. In most cases, these observations themselves do not clearly state whether the observed change (e.g., earlier nesting for migratory birds) is beneficial or adverse. However, the paragraphs immediately following these observations provide the necessary context regarding the consequences of the observed changes: "Many North American species, like the Edith's checkerspot butterfly, have shifted their ranges, typically to the north or to higher elevations (Field, et al., 2007). Migrating to higher elevations with more suitable temperatures can be an effective strategy for species if habitat connectivity exists and other biotic and abiotic conditions are appropriate. However, many organisms cannot shift their ranges fast enough to keep up with the current pace of climate change (Fischlin et al., 2007). In addition, species that require higher-elevation habitat (e.g., alpine pikas), or assemblages for which no substrate may exist at higher latitudes (e.g., coral reefs), often have nowhere to migrate (Fischlin et al., 2007)."

Summarizing the assessment literature, the TSD includes quantitative estimates of impacts to the extent that they are available. However, quantification of individual climate change impacts is not necessary in order for them to be used to determine whether public welfare may be reasonably anticipated to be endangered. See the Findings, Sections II.A.2, "Summary of Response to Key Legal Comments on the Interpretation of the Section 202(a) Endangerment and Cause or Contribute Test" and IV.B, "The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare" for EPA's response to comments on the general issue of quantifying the relative impacts of climate change.

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**Comment (7-87):**

A commenter (7020) suggests that the TSD does not clearly describe how climate change will make extreme event impacts on ecosystems and wildlife more severe.

**Response (7-87):**

While ecosystems and wildlife have been exposed to extreme events throughout time, the assessment literature (e.g., Fischlin et al., 2007; Field et al., 2007) provides robust evidence (as summarized in the TSD) that "[m]any significant impacts of climate change on U.S. ecosystems and wildlife may emerge through changes in the intensity and the frequency of extreme weather events." While a comprehensive assessment of the incremental impacts to ecosystems and wildlife associated with climate change and

extreme events is beyond the scope of the TSD, the following example has been added to Section 14(c) to address the comment:

For example, the aftermath of a hurricane can cause coastal forest to die from storm surge-induced salt deposition, or wildlife may find it difficult to find food, thus lowering the chance of survival. More intense hurricanes resulting from climate change may therefore increase coastal flooding resulting in a larger extent of forest dieback or greater starvation of wildlife as the amount of damaged land increases.

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**Comment (7-88):**

A commenter (7020) argues that Section 14(d) of the TSD on “Implications for Tribes” presents information previously discussed in other parts of the ecosystems and wildlife section.

**Response (7-88):**

EPA reviewed Section 14 of the TSD in light of this comment and disagrees that the information presented in Section 14(d) is redundant. This section of the TSD summarizes the assessment literature regarding the unique vulnerabilities and implications that climate change will pose to tribes. As discussed in Sections 13(c) and 14(d) of the TSD, tribes’ health, economic well-being, and cultural traditions will likely be affected by the degradation of ecosystem goods and services associated with climate change.

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**Comment (7-89):**

Several commenters (3396, 5740, 6096, and 8319) submitted comments and concerns describing how ecosystems and wildlife are highly vulnerable to climate change and that they have very limited capacity to adapt to changing conditions. The commenters describe their support for the endangerment finding and assert that it will help protect natural systems. A commenter (3396) provides a series of examples of how climate change will lead to impacts on plant and animal species due to the disruption of phenology (timing of lifecycle events), migration, reproduction, dormancy, and geographic range.

**Response (7-89):**

EPA agrees with the commenters that climate change poses large risks to ecosystems and wildlife. The discussion provided in these comments is generally consistent with the TSD, which summarizes the findings of the assessment literature. Please see the Findings, Section IV.B, “The Air Pollution Is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for a discussion of how the Administrator weighed the scientific evidence underlying her endangerment determination.

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**Comment (7-90):**

At least one commenter (3596.3) submits a literature review which the commenter asserts provides scientific evidence that there are a number of other factors unrelated to anthropogenic global warming that are known to cause coral bleaching. These include natural climate variability, decreased seawater temperature, solar radiation, solar radiation/temperature stress synergism, reduced salinity, bacterial infections, increased sedimentation, and exposure to toxicants. The commenter asserts that the TSD does not discuss these factors, which may be just as significant as rising sea temperatures.

**Response (7-90):**

After careful review of the literature cited, we note that the commenter’s assertion that the TSD fails to discuss other factors causing coral bleaching is unsubstantiated. The summary of the assessment literature

in the TSD is clear that multiple factors influence and exacerbate stresses on coral reef systems, contributing to the incidence of coral bleaching. Section 14(a) of the TSD states:

“Additional compounding effects, such as higher seawater temperatures leading to bleaching events, or higher seawater temperatures and nutrients leading to increased risk of diseases in marine biota will make these ecosystems even more vulnerable to changes in ocean chemistry along the United States and other world regions (Fischlin, et al., 2007). Subtropical and tropical coral reefs in shallow waters have already suffered major bleaching events that are clearly driven by increases in sea surface temperatures (Janetos et al., 2008). The effects of various other stressors, particularly human impacts such as overfishing, pollution, and the introduction of invasive species, appear to be exacerbating the thermal stresses on reef systems and, at least on a local scale, exceeding the thresholds beyond which coral is replaced by other organisms (Nicholls, et al., 2007).”

For these reasons we conclude that the TSD’s summary of the science is accurate and reflects the current scientific literature. See Volume 1: Section 2 of the Response to Comments document for our general response regarding how climate change effects interact with existing stressors.

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**Comment (7-91):**

Commenter (3394.1) objects to inclusion of root anoxia die-off because it only occurs at CO<sub>2</sub> concentrations above 20% in soil.

**Response (7-91):**

While the TSD’s description is clear that anoxia is a result of unusual events, we have added a sentence to the TSD to further clarify that the CO<sub>2</sub> concentrations involved in this phenomenon are higher than those expected from atmospheric CO<sub>2</sub> concentration changes.

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**Comment (7-92):**

The commenter (3596.2) states that the TSD greatly exaggerates the effects of prospective climate change on ecosystem distribution, referring to the statement that “changes in climate will cause species to shift North...and fundamentally rearrange North American ecosystems.” According to the commenter, the primary citation on which this statement is based is Field et al. (2007), which cites Root et al. (2003). The commenter states that Root et al. (2003) find a northward ecosystem migration of 3.8 miles per decade, which would have the effect of moving the District of Columbia’s natural biological community to Baltimore by 2102. According to the commenter, another primary citation in Field et al. (2007) is Parmesan and Yohe (2003), which calculated the observed rate of change in the onset of spring. The commenter states that the authors’ calculations indicate that spring 2103 would arrive in Washington, DC (everything else being equal) about the time it arrives today in Raleigh, North Carolina, a distance of 232 miles. In other words, Washington will enjoy the growing season of Raleigh a century from now.

**Response (7-92):**

The commenter appears to believe that observed changes in species distribution—such as those identified in Root et al. (2003) and Parmesan and Yohe (2003) as cited in that the scientific assessment literature—do not support a conclusion that climate change will “fundamentally rearrange” and adversely affect ecosystems. However, the commenter does not provide evidence that the types of changes found by Root et al. (2003) and Parmesan and Yohe (2003) will have no effect on ecosystems, and we find that the commenter’s argument is not supported by the scientific assessment literature.

The assessment literature as summarized in Section 14 of the TSD presents multiple lines of evidence for adverse effects that can result from these types of phenological changes. The latest USGCRP report concluded that warming drives changes in timing and geographic ranges for various species, and that entire communities of species do not shift intact (Karl et al., 2009). The IPCC (Fischlin et al., 2007) has drawn the following conclusions regarding the ecological effects of changes in species' ranges: 1) many organisms cannot shift their ranges fast enough to keep up with the current pace of climate change; 2) many changes in phenology are occurring faster than the abilities of ecosystems and species to resist adverse impacts; 3) the life cycles of some plants, prey animals, and predators will shift out of sync and cause species to become decoupled from their resource requirements; and 4) the rates of changing conditions and the resulting habitat shifts, changes in phenology, and timing of migration generally have adverse effects on species, including decreased productivity and fitness. Therefore, we conclude that the TSD's summary of the projected effects of climate change on ecosystem distribution is accurate, balanced, and appropriately reflects the conclusions of the body of scientific literature.

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**Comment (7-93):**

A commenter (3394.1) references various statements in the TSD regarding projected adverse climate change impacts on ecosystems and wildlife, including the conclusion that climate change will result in "alter[ed] ecosystem structure, function, and services." The commenter argues that although the Administrator cites potential effects in the Proposed Endangerment Finding, she offers no explanation of how or whether these effects negatively impact public health or welfare.

**Response (7-93):**

See the Findings, Section IV.B, "The Air Pollution is Reasonably Anticipated to Endanger Both Public Health and Welfare," for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination in general, and with regard to ecosystems and wildlife in particular.

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**Comment (7-94):**

According to one commenter (3394.1), the TSD's suggestions that mass extinctions or severe ecological consequences could result from climate change based on the evidence presented in the TSD is completely unfounded and provides no basis for an endangerment finding. The commenter contends that the TSD fails to provide any objective measure of the consistency or strength of the available scientific evidence for these effects.

The commenter claims that the TSD makes the following statements which call into question the conclusions that climate change will adversely affect ecosystems and wildlife species: 1) changes observed in marine species are more difficult to attribute to climate change due to "other stresses (e.g., over fishing and pollution)"; 2) evidence for local disappearance of species (which the commenter states are not necessarily tied to extinctions or even to problems) is "limited"; and 3) different species will have different capacities for adapting to changes (which the commenter includes although he notes that EPA refuses to analyze the effects of adaptation).

**Response (7-94):**

We begin by noting that the TSD does not state that mass extinctions could result from climate change. Section 14 of the TSD describes the IPCC conclusion that about 20% to 30% of species will be at increasingly high risk of extinction, possibly by 2100, as global mean temperatures exceed 2 to 3°C above pre-industrial levels (Fischlin et al., 2007). We disagree with the commenter that the evidence presented in the TSD is inconsistent or inconclusive regarding the risks and impacts of climate change on

ecosystems and wildlife. The assessment literature as summarized in Section 14 of the TSD presents multiple lines of evidence for effects that can result from warming temperatures and changes in precipitation patterns and disturbances such as wildfire and insect outbreaks.

Our responses to the commenter's interpretation of specific statements in the TSD are as follows:

1. The TSD is clear that many species are affected by a range of climate and non-climate stressors and that climate change effects on ecosystems do not occur in isolation. We have added additional detail to Section 14 regarding how climate change interacts with these existing stressors on ecosystems and wildlife. For example, the IPCC concludes that in the medium term (i.e., decades), climate change will increasingly exacerbate human-induced pressures on species (including overfishing and pollution), causing a progressive decline in biodiversity (Fischlin et al., 2007). Therefore, we conclude that the TSD's summary of the projected effects of climate change on marine species is accurate, balanced, and appropriately reflects the conclusions of the body of scientific literature.
2. We find that the commenter takes this statement from the TSD out of context and misinterprets it. The complete sentence in Section 4 of the TSD reads "Changes in abundance of certain species, including limited evidence of a few local disappearances, and changes in community composition over the last few decades have been attributed to climate change." We disagree with the commenter that this evidence is not tied to extinctions or problems. In this context, local disappearances refer to species extirpations (local extinction) and represent one of the most severe effects of changes in species abundance and community composition. The sentence describes that there are a limited (as in, "few") number of studies documenting species extirpations. The fact that there are documented occurrences of local extirpation provides strong evidence that recent warming is strongly affecting natural biological systems—a conclusion supported by the IPCC with very high confidence (Rosenzweig et al., 2007). Therefore, we conclude that the TSD's summary of the projected effects of climate change on changes in species abundance and community composition is accurate, balanced, and appropriately reflects the conclusions of the body of scientific literature.
3. See previous responses to comments in this section regarding the capacity of wildlife to adapt to climate change impacts. See Volume 1 our responses regarding our treatment of autonomous adaptation.

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**Comment (7-95):**

A commenter (3394.1) contends that other recent evidence not cited by the TSD brings to light serious inaccuracies regarding potential impacts to species from climate change. The commenter argues that the science presented in the TSD regarding this issue is an insufficient basis for an endangerment finding.

According to the commenter, particularly important is the recent finding by Deutsch et al. (2008) that species impacts will likely be greatest in the tropics, largely outside of the United States, and that species in higher latitudes are far more resilient to climate change. The commenter also submits a journal article by Lips et al. (2008) as scientific evidence indicating that climate change is much less likely than previously thought to result in biodiversity losses. The commenter states that this analysis determined that amphibian diseases previously thought to have been exacerbated by changing climatic conditions are in fact unrelated to climate.

In addition, the commenter submits a journal article by Sax and Gaines (2008) which concluded that the introduction of invasive plant species to new ecosystems does not necessarily result in significant species loss or harm, as is often argued. The commenter also submits a journal article by Bradley et al. (2009) which concludes that climate change will in fact result in range contractions for five widespread and dominant invasive plant species.

**Response (7-95):**

We have reviewed Section 14 of the TSD in response to this comment along with the studies submitted by the commenter. Deutsch et al. (2008) found that "organisms with the greatest risk of species extinction from rapid climate change are those with a low tolerance for warming, limited acclimation ability, and reduced dispersal. Most terrestrial organisms having these characteristics are tropical and many of these organisms are occupying disappearing climate regimes." First, we note that many islands and territories in the U.S. (e.g., Hawaii, U.S. Virgin Islands, Puerto Rico) lie in the tropics. Therefore this study supports and is consistent with the information presented in the TSD that climate change poses risks to species. Second, the findings of Deutsch et al. (2008) do not suggest that species in the U.S. are not vulnerable, but rather presents evidence that tropical ectotherms (cold-blooded animals) may be more vulnerable. We also note that this study focused on terrestrial ectotherms, specifically insects, frogs, lizards, and turtles. Mammals (e.g., polar bears, walrus), other endotherms (warm-blooded animals), and other ectotherms were not considered, and all freshwater aquatic and marine species (e.g., corals). The commenter did not provide evidence regarding the vulnerability of these species not assessed in the Deutsch et al. (2008) study. As a result, we do not find that this study supports the commenter's general conclusion that all U.S. species are more resilient to climate change.

Lips et al. (2008) finds that climate change is not the primary driver of amphibian disease outbreaks in Central America. However, we note that the TSD does not suggest that climate change is the primary driver of amphibian disease in Central America, nor are these impacts covered in the TSD. Lips et al. (2008) does not contradict the findings of the assessment literature which describe that climate change is a contributing factor in the spread of amphibian disease. Also, this study does not provide evidence that amphibians in the U.S. are not vulnerable, nor that the results are appropriate for extrapolation to other species in Central America or the U.S. The commenter did not provide literature specific to the risks and impacts facing amphibians in the U.S.

Further, we find that the arguments made by the commenter in referencing specific studies are conflicting. For example, the commenter describes the findings of Deutsch et al. (2008) as suggesting that climate change will result in increased biodiversity loss worldwide (especially in the tropics), but the commenter then references Lips et al. (2008) in arguing that biodiversity loss as a result of climate change will be less than previously projected.

Bradley et al. (2009) found that "climate change could result in both range expansion and contraction for five widespread and dominant invasive plants in the western U.S." The commenter has inappropriately selected a narrow conclusion from this study and misrepresented the broader findings. For example, the authors found that of the five species studied, two are likely to expand with climate change, two are likely to both expand and contract, and only one is likely to contract. We find that Bradley et al. (2009) does not support the commenters conclusion that climate change will not pose risks to ecosystems through increased spread of invasives.

Sax and Gaines (2008) did not specifically analyze the effects of climate change on the spread of invasive plants species, but rather studied the relationship between plant invasions and extinction on islands. The authors conclude that "the ultimate consequence of these exotic species additions for native diversity is still difficult to determine with certainty." Therefore this study does not support the commenters assertion that climate change will not pose risks to ecosystems through increased spread of invasives. We also note that the TSD does not describe that the increased spread of invasives is the only or primary cause of plant extinction.

We disagree that the discussion of climate change impacts on wildlife and ecosystems in the TSD is inaccurate. Rather, we find that the conclusions of the assessment literature are robust and reflect a broad

review of the available climate science literature on ecosystem impacts. See the Findings, Section IV.B, “The Air Pollution is Reasonably Anticipated to Endanger Both Public Health and Welfare,” for our response to comments on how the Administrator weighed the scientific evidence underlying her endangerment determination.

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