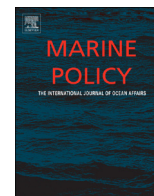




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Climate science strategy of the US National Marine Fisheries Service



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ABSTRACT

Changes to our climate and oceans are already affecting living marine resources (LMRs) and the people, businesses, and economies that depend on them. As a result, the U.S. National Marine Fisheries Service (NMFS) has developed a Climate Science Strategy (CSS) to increase the production and use of the climate-related information necessary to fulfill its LMR stewardship mission for fisheries management and protected species conservation. The CSS establishes seven objectives: (1) determine appropriate, climate-

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informed reference points; (2) identify robust strategies for managing LMRs under changing climate conditions; (3) design decision processes that are robust to climate-change scenarios; (4) predict future states of ecosystems, LMRs, and LMR-dependent human communities; (5) determine the mechanisms of climate-change related effects on ecosystems, LMRs, and LMR-dependent human communities; (6) track trends in ecosystems, LMRs, and LMR-dependent human communities and provide early warning of change; and (7) build and maintain the science infrastructure required to fulfill NMFS mandates under changing climate conditions. These objectives provide a nationally consistent approach to addressing climate-LMR science needs that supports informed decision-making and effective implementation of the NMFS legislative mandates in each region. Near term actions that will address all objectives include: (1) conducting climate vulnerability analyses in each region for all LMRs; (2) establishing and strengthening ecosystem indicators and status reports in all regions; and (3) developing a capacity to conduct management strategy evaluations of climate-related impacts on management targets, priorities, and goals. Implementation of the Strategy over the next few years and beyond is critical for effective fulfillment of the NMFS mission and mandates in a changing climate.

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1. Introduction

The climate and oceans are changing, and these changes are already affecting the nation's marine, estuarine, and diadromous living resources. Stewardship of these resources, hereafter termed *living marine resources* or LMRs, is the responsibility of the National Marine Fisheries Service (NMFS) and includes the management, conservation, and protection of LMRs while providing benefit to the nation through their sustainable use (e.g., food, materials, protection, etc.). Changes in the climate system (including ocean acidification and other alterations of aquatic systems related to increases in atmospheric CO₂ and hereafter referred to as *climate change*) affect the services LMRs provide and the many people, businesses, and communities that depend on them [1–3]. These varied impacts will also affect the NMFS LMR conservation and management efforts and LMR-dependent sectors at local, state, regional, national, and international levels.

Understanding, preparing for, and responding to climate impacts on LMRs can help decision makers reduce impacts, increase resilience, and advance adaptive⁴ capacity of LMRs and LMR-dependent human communities [1,3,4]. Meeting this need requires increasing the production and use of science-based, climate-related information in nearly all aspects of LMR stewardship. Doing so is critical to fulfilling the NMFS stewardship mission to sustainably conserve and manage LMRs and their ecosystems for the benefit of the nation. To this end, NMFS has developed a Climate Science Strategy (hereafter referred to as the *Strategy*) to identify key steps to inform and fulfill the NMFS mission in a changing climate [5] and address the calls in the recent NOAA Strategic Plan and the 2013 Presidential Climate Action Plan for readiness to climate change [6,7]. Here we provide a short description of the Strategy, the rationale for it, and some first steps for its implementation.

1.1. Impacts of a changing climate on marine and coastal ecosystems

The impacts of both climate variability and change (Fig. 1) on

the physical, chemical, biological, and social components of marine, coastal, and freshwater ecosystems are well documented and expected to increase (Fig. 2) [1,2,4,8,9]. Climate-related changes in physical and chemical conditions can have a variety of impacts on LMRs, ecosystems, and LMR-dependent human communities across a range of spatial and temporal scales [1,10]. Assuming the effects of climate change will be uniform and consistent across species and ecosystems is inconsistent with our scientific understanding and, thus, imprudent. Studies suggest that changes in regional environmental conditions may enhance conditions for some species in that region while degrading conditions for other species, the latter being particularly important for species and stocks protected by the Endangered Species Act or Marine Mammal Protection Act or managed by the Magnuson-Stevens Fishery Conservation and Management Act [e.g., 11,12,13]. Furthermore, some wide-ranging species may experience positive effects of climate change in one habitat during one life stage and negative effects in another distantly located habitat during another life stage. Shifting distributions may result in gaps in management regulations; for example, most stock area definitions developed under Fishery Management Plans assume stock boundaries do not shift, yet it is clear that one of the major impacts of changing ocean conditions on LMRs is the shifting of stock boundaries [14].

Because climate change impacts will affect LMR species in different ways, there is an urgent need for careful evaluation of climate impacts in the design, implementation, and evaluation of LMR management. Changes in species abundance, productivity, distribution, and diversity due to a changing environment may require changes to the fundamental thresholds and metrics used in LMR management (e.g., biological reference points [15,16]). Information on what is changing and why it is changing can be used to improve early warnings, near-term forecasts, and longer-term projections of future conditions. This improved information can inform science priorities, vulnerability assessments, management strategy evaluations, and, ultimately, management decisions.

The combined physical, chemical, and biological effects of climate change on LMRs will alter the products and services people derive from marine ecosystems, including food, jobs, recreation, medicinal products, aesthetics, tourism, regional culture and sense of place, and even health benefits [17]. For example, the species available for harvest in a given region could change, requiring fishermen to develop new strategies for harvesting (e.g., switching their target species and gear types) and bycatch reduction [18]. Shifts in the distribution and/or abundance of species may also affect the location of fishing industries, working waterfronts, supply chains, and the social and economic dynamics of LMR-dependent coastal communities, cultures, and industries [9,19,20]. Changes in the availability of commercial fish species and fishing

⁴ The words “adapt,” “adaptive,” and “adaptation” are commonly used in the climate change literature to refer both to wild species/populations and to human institutions. When these terms are used in this document to refer to LMRs, they refer to the biological process of adaptation, which involves genetic change over time in a direction that improves fitness. Previous evolutionary changes largely determine a species' current adaptive capacity, but new adaptations might be required to maintain fitness in the face of climate change. When these terms are used to refer to changes by humans, they relate to the concept of adaptive management, which describes flexible management and decision-making procedures that are designed to be able to incorporate new information and make changes that will maximize the chances of achieving stated goals or objectives.

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