V. BIODIVERSITY AND HABITAT

Introduction

California is one of the most biologically diverse regions of the world and its vast array of species and habitats make it one of the 25 biodiversity "hotspots" on earth.[1] Hot spots are areas where at least 1,500 species of vascular plants (> 0.5 percent of the world's total) are endemics and where at least 70 percent of the original habitat has been lost. Of all 50 states, California has the most unique plant and animal species, as well as the greatest number of endangered species.[2] The state's extensive biodiversity stems from its varied climate and assorted landscapes which have resulted in numerous habitats where species have evolved and adapted over time. The state's ecological communities include coastal mountain ranges, coastal dunes, wetlands, rivers, lakes, streams, deserts, grasslands, chaparral, and inland forested mountains among others. The vast number of endemic species found in California, combined with the high level of threats to their persistence, makes California a 'hotspot' for biodiversity.[3]

California is one of only five regions in the world with a Mediterranean climate. Habitats in these climatic regions are considered to be more threatened by climate change than tropical forests, since over 40 percent of these lands worldwide have been converted to other uses and less than five percent are protected worldwide.[4] According to some estimates, more than 20 percent of the naturally occurring species of amphibians, reptiles, birds, and mammals in California are classified as either endangered, threatened, or "of special concern" to state and federal agencies.[5] Therefore, the preservation of California's unique biological heritage is of ever-increasing importance given the forecasted impacts associated with climate change.

The economy and the natural resources that sustain human life are dependent upon the state's biodiversity. These species and ecosystems provide numerous goods and services, including provisioning services (e.g., food and timber production, medicines, water and fuels), regulating services (e.g., water purification and carbon sequestration), supporting services (e.g., climate regulation and nutrient cycling) and cultural services (e.g., aesthetic values, and sense of place).[6] Not only do these goods and services support California's economy but they support numerous recreational activities for residents.

Future Climate Change Impacts to Biodiversity and Habitat

A. Increased Temperature

Every species has a temperature range in which it thrives and can survive. Brief exposures to extreme temperature events or repeated occurrences of temperatures outside of the range will stress plants and animals, and will exacerbate environmental pressures exerted by competitors, predators, pests and invasive species, habitat change, varying food and water supplies, diseases, and anthropogenic stressors such as contaminants and habitat fragmentation. As average temperatures rise, plant and animal species will increasingly be confronted by thermal stress This kind of thermal stress will force terrestrial plant and animal species to either adapt to these changing conditions and/or shift their geographical range to more favorable conditions. Shifts in geographical range depend upon availability and accessibility of appropriate habitat, as well as the necessary behavioral and life history characteristics that promote rapid dispersal and establishment of new populations. If species are unable to adapt *in situ* or shift their ranges, local populations may be extirpated and species may face extinction. (Figure 5.2).

Species that cannot adapt in their existing communities may, over time, shift in their ranges if appropriate habitat is available, accessible, and if their behavioral characteristics allow. If they are unable to shift their ranges, they face the threat of local extirpation, if not extinction. The amount of future warming

expected in California may likely exceed the tolerance of endemic species (i.e., those that are native to a specific location and that occur only there) given their limited distribution and microclimate.

Species that have the capacity to shift their ranges will require movement corridors that are not blocked by natural landscape features or human development. Planning to maintain natural corridors in anticipation of predicted climate changes should be factored into future local and regional habitat conservation planning efforts.

Based on current research, we can assume that species occurring together in communities will move independently from each other, not as groups. As a result, communities will reorganize and look differently from what we are familiar with today. For example, cores of fossil pollen from dozens of sites around North America show that in the last Ice Age, boreal tree pollen, which today occurs in the boreal zone in Northern Canada, was common in the Corn Belt of the United States and in areas where mixed hardwood forests exist today. Pollen cores show us that different tree species that were living together then are no longer found together.[7]

Similar stresses and barriers apply to aquatic species whose migratory/movement limitations may be even more limited. Vernal pool and freshwater lake species are likely to be more susceptible to extirpation because their habitats may disappear entirely or if they are unable to emigrate to a new aquatic environment. For example, fish and amphibian species will experience increased stream and lake temperatures that will affect their food supply and fitness. Warmer air and water conditions could also influence the introduction and spread of undesirable species or diseases.

Invasive Species

As climate change related impacts increase, the ranges occupied by certain species will change. For example, grassland and desert habitats may expand in the future due to climate change, but these ecosystems' temperature, precipitation and seasonal cycles will be altered by climate change. A changing climate would be expected to shift plant distribution, as well as animal distribution. Although desert plants and animals are adapted to live in extreme environments, even small changes in the components of an ecosystem like temperature, precipitation, seasonal variations can be amplified to cause large changes in ecosystem function[8]. In certain areas of the Sonoran and Mojave Deserts this could mean less species diversity. For example, a Conservation Policy Brief titled "Curbing Greenhouse Gas Emissions will Reduce Future California Bird Loss" published by Audubon California (Monahan, William B. and Gary Langham. "Curbing Greenhouse Gas Emissions will Reduce Future California Bird Loss." Audubon California. February 2009.) predicts that under a high emissions scenario parts of the Sonoran and Mojave Desert will lose 25-50% of their bird species while other areas will lose 50-100% of their bird species. As a result, even species that are native to certain California regions may spread into other regions, creating a new category of 'native invasives' that may alter community structure and species interactions in native habitats.

BIODIVERSITY AND HABITAT IMPACTS DUE TO WARMING

- Barriers to Species Migration and Movement
- Temperature Rise - Lakes, Streams, and Oceans
- Increase in Invasive Species Potential
- Changes in Natural Community Structure
- Threats to Rare, Threatened, or Endangered Species
- Altered Timing of Phenological Events
- Timing Disruptions Between Predators and Prey and Pollinators and Plants
- Loss of Ecosystem Goods and Services

Disturbance events or extreme weather events thought to increase due to climate change generally benefit invasive species given their tolerance to a wide range of environmental conditions. Invasive species often have greater flexibility and can survive under variable and extreme conditions, such as

flood events or drought. Invasive species also tend to produce large numbers of seeds or young and are capable of long distance dispersal; or have the ability to outcompete native species (especially plants that require no pollination or seed development).

Californians have benefited from the introduction of plant and animal species necessary for food or other human pursuits; however, there are many other introduced species that can wreak havoc on the state's environment and economy. Invasive species threaten the diversity or abundance of native species through competition for resources, predation, parasitism, interbreeding with native populations, transmitting diseases, or causing physical or chemical changes to the invaded habitat. Through their impacts on natural ecosystems, agricultural and other developed lands, water delivery and flood protection systems, invasive species may also negatively affect human health and/or the economy. Examples of direct impact to human activities include the clogging of navigable waterways and water delivery systems, weakening flood control structures, damaging crops, introducing diseases to animals that are raised or harvested commercially, and diminishing sport fish populations.

Changes to Community Composition and Interactions

Warming has already impacted the seasonal timing of biological events in California, including flowering times, leaf emergence, fall bird migration, and insect emergence[9]. In addition, interactions between climate change, habitat fragmentation and agricultural practices may have critical impacts on pollination services for crops and wild plants. A change in composition can disrupt biological interactions and impact ecosystem dynamics by displacing existing biological interactions and replacing it with another. For example, an earlier occurrence of flowering may result in futile reproduction efforts for pollinators if they are unable to adjust quickly to the change in availability of resources. Changes in pollinator activity will affect dependent species throughout the natural and human food chain.

It is important not to over generalize individual species responses to climate change as either adapting to warmer temperatures or moving to higher latitudes or altitudes[10]. Expected range shifts in response to precipitation and temperature changes may differ[11], and responses to novel climates are difficult to predict. California's complex topography will allow for small-scale changes in slope or aspect as a means of tracking a species preferred climate, and–due to the influence of the ocean–range shifts west and downhill, towards the coast, may occur for some taxa. Furthermore, the state of downscaling global climate model to meaningful ecological scales is still lacking in predictive ability at fine spatial scales.

Ecosystem Services:

Biodiversity in natural ecosystems and working landscapes supports a wide range of ecosystem services that sustain human well-being and the economy of California. Ecosystem services are simply defined as the benefits people obtain from ecosystems[12]. These include carbon sequestration, forage production, timber production, water storage and filtration, crop pollination, soil fertility, fish and game habitat, tourism, recreation and aesthetic values. Ecosystem services can be categorized as **provisioning services** (food, water, timber, and fiber), **regulating services** (the regulation of climate, floods, disease, wastes, and water quality), and **cultural services** such as recreation, aesthetic enjoyment, and spiritual fulfillment; and **supporting services** such as soil formation, photosynthesis, and nutrient cycling. (Millennium Ecosystem Assessment 2005).

Warming, changes in precipitation and increases in extreme events (drought, storms, heat waves, etc.) are expected to alter many ecosystem services, due to impacts on biodiversity and on the structure and functioning of ecosystems[13]. Changes in the geographic distribution of individual species and major habitats will alter the distribution of ecosystem services across the state. For example, potential conversion of conifer forest to evergreen woodlands, forecast for regions of the Sierra Nevada and northern Coast Ranges, would reduce and redistribute timber production. Reduced snowpack, changes in water flows, expansion of reservoirs, and warmer water temperatures will impact freshwater ecosystems, with likely negative effects on many native species. Conflicts between human water uses and management of game and non-game fish populations are expected to increase under future climates.

While demands for ecosystem services such as food and clean water are growing, climate change and other anthropogenic forcings are reducing the capacity of ecosystems to meet these demands (MEA 2005). "By the end of the twenty-first century, climate change and its impacts may be the dominant direct driver of biodiversity loss and changes in ecosystem services globally." (MEA 2005). Managing natural resources within an ecosystems services framework that explicitly acknowledges linkages between ecosystem processes and consequent outcomes to human welfare may be the most effective and economically viable means for protecting people from unsafe drinking water, flooding, and climate change[14] and maximizing conservation of biodiversity[15].

Carbon sequestration is of special interest due to its importance as a tool to offset GHG emissions and contribute to mitigation of global climate change. Proper management of California's ecosystems, including forests, open spaces, and wetlands, may provide significant capture and sequestration of greenhouse gases while simultaneously providing habitats necessary for the long-term conservation of California's biodiversity. As an example, tidal marsh restoration provides protection against erosion, flood control, habitat for many endangered or threatened species, and carbon sequestration services. Hotter and drier climates are projected to cause significant declines in carbon storage in standing tree stocks, and reduced extent of productive conifer forest vegetation[1]. Increased wildfire is also likely to reduce above- and below-ground carbon storage by forests, though the effects will depend on forest management practices[16]. Carbon sequestration represents a critical interface of climate mitigation and adaptation strategy in relation to biodiversity conservation, forest management, and wildfire; the potential contribution of non-forest ecosystems (grasslands, shrublands rangelands, chaparral, and wetlands) is poorly understood and deserves greater attention. Adaptation strategies that simultaneously enhance biodiversity conservation and ecosystem services are critically important to promote sustainable natural ecosystems and human well-being.

B. Precipitation Changes and Extreme Events

Changes in Stream Flow

Flowing water is important because it moves organic material and energy[17]. This movement facilitates the exchange of nutrients between aquatic and terrestrial areas. In terrestrial areas, aquatically derived nutrients help support vegetation and wildlife[18]. Emerging aquatic insects are prey for birds and bats foraging and breeding in riparian areas[19]. Equally important, flowing water moves terrestrial organisms and detritus, which play an important role in aquatic food webs[20].

Current projections for California suggest that precipitation and temperature events will be more extreme. For example, more frequent and intense heat waves can impact heat-sensitive species, reducing fitness and increasing mortality. With more precipitation falling as rain (less snow pack), river flows during the winter and spring seasons will be greater; while reduced snowfall in the winter will result in reduced snowmelt and subsequently lower stream flows during summer months.

One of the first species groups impacted by stream flow change will be fish. Fish reproduction is affected by stream flows in several ways. Increases in winter runoff and earlier spring peak flows are likely to lead to increases in the number of flooding events during these seasons. Early-spring, high-runoff periods or flooding may occur during egg incubation periods for many fish species, thus impacting reproduction. High stream flow could additionally shift streambed gravel, and heighten the risk of damage to incubating eggs; while the emergence of juveniles can be displaced, undermining the reproductive success of species.[21]

Mosquitoes will proliferate in areas where flooding combines with higher springtime temperatures. If these areas are chemically treated to protect human health, non-target invertebrates that feed fish and other aquatic species will be affected. Introduced toxins will have unintended consequences for the entire food chain. (See also Public Health chapter for additional information on climate change impacts to public health.)

As a result of a decrease in snow pack and earlier snowmelt, stream flows are expected to be lower during the summer months and extending into the fall. In addition, reduced stream water depth and higher air temperatures will increase stream water temperatures, to levels that are potentially unhealthy for coldwater fish. Salmonids are temperature-sensitive and rely on precipitation and snow melt. The projected changes in inland water temperatures with changing seasonal flows is projected to place additional stress on these species (Figure 5.3), contributing to the need for increased resources for monitoring and restoration efforts. It is common for adult fish migrating to spawning grounds to encounter obstacles that require high flow conditions in order to pass. If climate change results in reduced stream flows this could impede or halt their progress. A delay in the arrival to spawning grounds may decrease reproductive success and increase fish mortality. Repeated low stream flows during spawning migration periods may naturally select against large adult body sizes.[22]

The projected changes in temperature and precipitation patterns will also affect the distribution and longevity of available surface water. Changes in the composition and structure of riparian communities may result from changes in precipitation and flow and could contribute to increased management conflicts as the needs of humans and wildlife compete for limited resources. Changes in temperature and precipitation associated with climate change may lead to less stored water and will have a direct effect on the survival of aquatic species and the preservation of wetland habitats.[23]

Other factors impacting aquatic species may be exacerbated by changes in precipitation including the timing and amount of river and stream diversions, temperature changes and pollution or sediment load. Alterations in timing and magnitude of high or low water events could impact riparian vegetation and the species that depend on it[24]. Of the 11 California Partners In Flight focal riparian bird species that have suffered population declines over the past 50 years, seven prefer to nest in early successional riparian habitat, particularly willow/alder shrub habitats with dense understory cover (RHJV 2004). One species (Bank Swallow) depends on regular high-water events to create exposed riverbank sites for nesting, but abrupt changes in water level during breeding can cause total reproductive failure (RHJV 2004). To flourish, early successional habitats depend upon natural hydrology, including flooding, soil deposition, and point bar formation, for establishment[25]. Seed dispersal and natural tree regeneration and growth can be compromised due to the absence of high peak flows or seasonal fluctuations in water levels[26].

BIODIVERSITY AND HABITAT IMPACTS DUE TO PRECIPITATION CHANGES

- Stream Flows - Impact to Fish Passage
- Distribution/Longevity of Surface Water, Impact to Wildlife
- Changes in Riparian Communities and Structure
- Decreased Water Availability – Fish, Wildlife, and Plants
- Water Temperature, Pollution and Sediment Load Changes
- Impacts to Water Dependent Species
- Surface Water Allocations - Impact All Water Users (humans & wildlife)
- Increased Susceptibility to Pests, Disease, Wildfires & Invasive Species
- Habitat Conversions - Changes in Biodiversity

Floods and Droughts

Aside from the impacts of high-runoff events and flooding on stream habitats and fish populations, periodic floods have always been a part of the formation of landscapes and ecosystem processes. Species and ecosystems in riparian habitats are largely adapted to such events. Many California land use decisions, however, have created conditions that have separated streams and rivers from their historical floodplains through either construction of levees, development on floodplains, or both. These activities reduce the adaptive capacity of remnant riparian ecosystems, especially if flooding is projected to increase in late winter and spring as a result of climate change. When riparian habitats are adjacent to urbanized areas, increased flooding can burden these ecosystems with heavier and sometimes more toxic sediment deposits. In the highly developed coastal floodplains, where storm-related coastal flooding may coincide with high tides and stream runoff,

ecosystems will face great challenges. Likewise, the projected increase in drought conditions will further impact stream and terrestrial habitat quality as well as the adaptive capacity of ecosystems to continue to provide their goods and services.

Prolonged periods of drought can make ecosystems vulnerable to pests, non-native species invasions and frequent and intense wildfires. Moreover, reduced rainfall and snowmelt will lead to less water infiltrating the soil, stressing plants and animals. This reduced infiltration rate will also diminish groundwater recharge. Lowered levels of groundwater, combined in coastal areas with saltwater intrusion, will exacerbate dry conditions and further stress species and habitats. As an example, likely reductions in precipitation and higher variability in precipitation, both within and among years are likely to reduce survival of young seedlings, which are particularly susceptible to drought stress and has serious implications for the ability of ecosystems to recover from disturbance both natural and by active restoration (See also Forestry sector). Together, all these changes in water availability can cause landscape transformations as conditions select for species that require less water (see the Water chapter for more discussion on climate change impacts on freshwater ecosystems and species).

Wildfires

Fire plays an important role in the condition, function, and distribution of many of California's natural habitats and has done prior to and since human settlement. Aspects of fire regime, frequency, intensity, severity, magnitude, and pattern, have fluctuated over time. Since the 1980s, the state has recognized apparent changes in the frequency, intensity, and duration of wildfire, especially in conifer-dominant ecosystems in the Sierra Nevada and chaparral ecosystems in coastal and interior southern California.. Land-use, land management, and fire suppression policies, particularly in conifer forest and chaparral communities, are thought to have affected attributes of fire regimes throughout human history. In recent years, researchers have determined that changes in climate have had an important role in altering fire regimes. Current information suggested an extension of the fire season and increasing the number of large wildfires, as well as wildfire intensity. Particularly, higher spring and summer temperatures and earlier spring snowmelt are thought to have contributed to these changes.[27] Wildfire occurrence statewide could increase from 57 percent to 169 percent by 2085 under the A2 (higher) emissions scenario and by more than 100 percent in most northern California forest in all SRES A2 scenarios by 2085[28].

In one climate change scenario, potential fire fuels can build up during wet years when plant production is high. Preconditions for catastrophic wildfires will occur if ensuing weather conditions include decreased precipitation or drought that dries out the accumulated fuel. Large scale and intense wildfires could result in vegetation and habitat alterations, resulting in displacement of local species for variable amounts of time, sometimes years or complete extirpation. In addition, the recruitment of invasive grass species in fire-disturbed areas can increase fine fuel loads, resulting in greater fuel continuity, frequency, and rate of spread.[29]

Most California vegetative communities experience fire on a regular basis, but it is essential to take note that historical fire regimes differ enormously between different vegetation types, and these differences lead to very different management challenges. Exclusion of fire or altering its regional fire regime attributes will alter the systems and both eliminate animal species and change, if not decrease, existing biodiversity. Some of the wildlife benefits of wildfire include the (1) recycling of dead and downed vegetation and creation of new deadwood and snags,[ii] (2) cycling of soil nutrients, (3) removal of excess, woody vegetation which provides for herbaceous plants and younger plants to grow and new and palatable vegetation for herbivores, (4) opening up of the under story for browsing for larger wildlife species, and (5) creation of tree holes utilized by cavity-nesting birds, bats, and arboreal mammals. These benefits are typically derived from low- to moderate intensity fires, and in some cases, depending on the vegetation community, infrequent, high-intensity fires. However, benefits are not derived from the

[ii] One of the most crucial habitat elements for woodland and forest invertebrates, vertebrates, and fungi.

more frequent, high intensity wildfires that California has experienced in recent years, especially in conifer systems in the western Sierra Nevada and chaparral systems in southern California.

More frequent fires help manage fuel loads in forested communities. However, some lands do not behave this way ecologically and will not survive the increase in fire frequency that has occurred and is likely to be exacerbated by climate change. For example, in southern California coastal and interior chaparral (including coastal sage scrub communities) increased fire frequency is the primary threat to maintaining ecological integrity and ecosystem services over time. These systems are adapted to a fire return interval of 60-150 years[30] on average and too frequent fire has been shown to cause habitat type conversion in addition to increasing pathways for invasive occurrences. This altered frequency has resulted from an increase in the human presence at the wildlife urban interface and associated increase in the anthropogenic ignition combined with extreme wind events. Because of this, management strategies for fire in southern California chaparral and areas of similar circumstance might need to focus on ignition prevention.

Vegetation and wildfire management, including mechanical vegetation reduction, prescribed fire, use of wildland fire, and restoring lands post-wildfire, have to consider the current fire regime operating in the vegetation type and ecological zone and the desired fire regime. The “right kind of fire” is the fire that will enable a vegetation community to sustain itself within all the other ecological considerations [soil dynamics, hydrology, biotic community, weather and climate, etc.). How vegetation fuels management is done and how fire prevention activities are carried out should always focus on being able to re-establish the landscape to support an appropriate, acceptable fire regime. Strategies related to fire must consider these differences, focusing on the idea of the 'right kind of fire' in different systems. For example, California State Parks burns under controlled conditions about five percent of what they deem necessary. Prescribed burning in many forested areas, including old growth, is not possible until heavy understory fuel accumulations have been reduced manually or by mechanical means before burning takes place. Regulatory requirements, e.g., air quality and listed species protection, can also impact or reduce prescribed burning activities.

When it comes to current vegetation community and fuel condition versus desired vegetation and fuel conditions, land managers [fire, fuels, etc.] should have a plan that can be used over a period of time to alter conditions as appropriate within fiscal, time, management, and ecological constraints. This type of integrated fire and fuels management and planning are important given climate change concerns. Agency(ies) should have a land management plan that clearly articulates how and when vegetation will be altered in order to achieve a level of composition and structure that is both viable ecologically [including fire regime] and socio-politically. As an example, the Department of Fish and Game, includes a fire and fuels management section within land management plans for all properties owned or managed by the Department.

Fire prevention and natural resource managers across the state must work together to support key fuels management measures to find a balance between protecting the public, existing infrastructure, and the essential ecological role that fires play in ecosystems (see the Forestry chapter for additional information on climate change impacts on forests and wildfire).

C. Sea-level rise

California’s coastal areas include a variety of habitats that range in their characteristics from purely aquatic, to semi-aquatic, to terrestrial. All habitats are influenced by periodic flooding by tidal waters, rainfall, or runoff. These wetlands, dunes, and rocky habitats are home to a vast number of organisms, including many endangered species. During certain periods, wetlands harbor juveniles of numerous aquatic species including fish and shellfish. Wetland habitats from the Sacramento Valley southward to

the Salton Sea and the tidal marshes of San Francisco Bay also provide essential wintering habitat for hundreds of thousands of birds as they migrate north and south along the Pacific Flyway. Humans additionally benefit from the ability of healthy wetlands to buffer storm impacts, reduce shoreline erosion, improve water quality, and provide beautiful areas for recreation.[31]

Located between sea and land, coastal habitats have developed as a result of dynamic changes over time. Accelerating sea-level rise may overwhelm their natural capacity to keep up and concurrent stresses and pressures due to development and land use decisions further threaten these habitats. Existing stresses include ongoing discharge of organic wastes fostering eutrophication, legacy of organic pollutants and other toxic substances, pathogen loading, sediment and freshwater delivery alteration, thermal pollution, direct wetland infill and destruction with subsequent habitat loss, bottom disturbance from fishing practices and recreational boating, extraction of living and non-living material and influx of invasive species.[32] Thus, the biodiversity and habitats of coastal areas may be particularly impacted by sea-level rise and other climatic changes.

Some coastal habitats, such as wetlands and dune habitats can become permanently inundated and eroded if sea level rises faster than these ecosystems can move inland. Moreover, inland migration is frequently hindered by development such as bulkheads, seawalls, roads, and buildings. Continued growth and development in coastal areas will only increase the direct pressure on remaining habitats and make inland migration more difficult. Sea-level rise, especially at the increasing rates projected for the 21st century, may result in the loss of substantial areas of critical habitat for a variety of coastal species.[33]

The degradation of sensitive ecosystems can be brought about not just by higher sea levels but also by other climate changes, including higher temperatures and changes in precipitation patterns, which together can facilitate the establishment of invasive species such as European beach grass. Both aquatic and terrestrial coastal ecosystems may thus see further increases in problems with invasive species.[34]

Sea-level rise will also result in salt water intrusion into fresh water resources near the coast, reducing the amount of fresh water available for plants, wildlife, and competing agricultural and metropolitan uses. Species with greater salt tolerances may have a selection advantage where habitats can naturally transform, without human interference. Sea-level rise, in conjunction with coastal storms, may also lead to coastal flooding that extends further inland, thus increasing the risk of pollution, runoff, and sedimentation in fresh water sources of previously unaffected areas. This degradation of fresh water in near-coastal areas may aggravate conflicts over water for human uses versus ecosystem and species needs.

There will also be shifts in the type and location of agriculture as saltwater intrudes into coastal aquifers and natural recharge of groundwater resources decreases with the drying climate. Water transfer and management impacts may become increasingly complex, as there may be impacts to hydropower and hatchery project operations as well as water diversion projects.

Changes to the timing and intensity of freshwater input may impact marine and near shore populations through increased runoff resulting in pollution and sedimentation contamination and shifts in urban growth and development will place new or increased pressure on existing coastal resources and available habitat. Inundation of coastal infrastructure could cause widespread pollution and contamination further jeopardizing marine and near-marine environments. Changes in ocean circulation and ocean warming will impact pelagic species distribution and community structure. In addition, ocean acidification could impact shellfish species as well as their prey base. Protected areas such as ecological reserves, wildlife areas, undesignated lands, mitigation sites and easements could also be affected, and require management decisions that protect California's natural resources. These challenges and many more will require close coordination with those entities implementing the oceans and coastal adaptation strategies. Please refer to the Oceans and Coastal Resources chapter for additional information.

Monitoring and Adaptive Management

Adaptive management is a key element of implementing effective conservation programs especially in light of some of the uncertainties associated with climate change. Natural communities, ecosystems, species population dynamics, and the effects of stressors on the environment are inherently complex. Wildlife and resource managers often are called upon to implement conservation strategies or actions based upon limited scientific information and despite considerable uncertainties.

Adaptive management combines data from monitoring species and natural systems with new information from management and targeted studies to continually assess the effectiveness of, and adjust and improve, conservation actions. It is important to keep in mind that the outcomes of management interventions in the face of climate change differ markedly in their predictability and while some management strategies will be robust to different future climates, others will not. Successful management will require strategies in which management actions are coupled with monitoring to provide informative feedback loops however, despite uncertainties in future projections; managers can begin to actively address climate change now[35]. .California's Wildlife Action Plan summarizes an approach to adaptive management and addresses the steps and considerations needed to design a monitoring program in an adaptive management context.[36] California's Wildlife Action Plan also provides a framework for establishing monitoring programs central to the implementation specific climate change adaptation strategies detailed in this document.

D. Risks for Biodiversity and Habitats

In summary, some of the current and future climate change impacts to biodiversity expected in California include:

- Temperature-sensitive terrestrial plant and animal species must adapt to warmer temperatures within their existing ranges and/or shift their geographical range in response to climate changes. These shifts may occur towards higher latitudes, higher elevations, cooler coastal environments, or local microclimatic refuges, depending upon interactions with precipitation, topography and soils, and species behavioral and life history characteristics.

- The amount of additional warming expected in California in the future may exceed the tolerance of some species, particularly endemic ones. Where relocation access is blocked off by natural landscape features or human development, species will need corridors to establish habitat connectivity or face a growing risk of extinction.

- Similar stresses and barriers apply to aquatic species, but their migratory limitations may be greater.

- The problem of invasive species is likely to become even more challenging in the future, as invasive species are typically more competitive than native species especially in damaged/degraded environments.

- Species migration/movement and invasions, along with changes in behavior of climate-sensitive species, will alter species interactions and community dynamics; these changes may have negative effects on critical ecosystem services.

- Changes in precipitation patterns will alter stream flow and severely affect fish populations during their life cycle. Low-flow conditions and higher stream flow temperatures are particularly threatening to coldwater fish.

- Human activities across the state have reduced the ecological integrity of many areas as well as the levels of biodiversity. Climate change will act synergistically with existing stressors to have an even greater impact on already stressed ecosystems.

- Longer fire season trends over the last three decades and increased numbers of large, intense wildfires are projected to continue, increasing the risk of vegetation and habitat conversion, spread of invasive species and losses in biodiversity, and ecosystem goods and services.

- Accelerating sea-level rise, especially at the increasing rates projected for the 21st century, may result in the loss of substantial areas of critical habitat for a variety of coastal species. Both aquatic and terrestrial coastal ecosystems may see growing problems with invasive species.

- Sea-level rise will result in salt water intrusion into fresh water resources near the coast and reduce the amount of fresh water available for plants, wildlife, and competing agricultural and metropolitan uses.

- The preservation of healthy, resilient ecosystems with a rich plant and animal biodiversity is critical to the health, safety, and welfare of human populations. Human development has already reduced, degraded, and fragmented natural communities. This alone threatens the survival of individual species and some rare ecosystems.

BIODIVERSITY & HABITAT IMPACTS DUE TO SEA-LEVEL RISE

- Inundation of Permanent Coastal Habitat
  - Alteration of Dune Habitat & Coastal Wetlands
  - Coastal Habitat Loss of Migratory Birds, Shellfish & Endangered Plants
- Reduction of Fresh Water Resources Due to Salt Water Intrusion
- Sedimentation Increases May Increase Pollution and Run Off
- Degradation of Aquatic Ecosystem
- Increase in Invasive Species
- Competition for Coastal Land Areas
  - Shifts in Urban Growth and Development
  - Agricultural Relocation
  - Alterations of Ecological Reserves, Wildlife Areas, Undesignated Lands, Mitigations Sites & Easements
- Groundwater Recharge & Overdrafting
- Water Management & Water Transfer Conflicts
- Reduction in Wetland Habitat on Commercial and Sport Fisheries

Biodiversity and Habitat Adaptation Strategies

Introduction

The impacts of climate change will be significant and far reaching; requiring coordinated and targeted efforts to protect California's biodiversity. The adaptation strategies developed for this document provide a roadmap of actions that help maintain and restore processes that enhance ecosystem function and protect California's rich biodiversity. Existing stressors such as growth and development, water management conflicts, invasive species, and other widespread stressors identified in California's Wildlife Action Plan will act synergistically with climate change.[37] Investing and implementing these strategies will increase the capacity to deal with uncertainty and ensure that California's natural resources are maintained for generations to come. The state agencies that participated in the Biodiversity Sector Working Group (Department of Fish and Game and State Parks) developed the following strategies and are committed to implementing these strategies as capacity and resources allow. The strategies detailed in this document are part of a more detailed effort that can be reviewed on the Department of Fish and Game's climate change web page.[38] Please note that the strategies developed for this document generally address all natural areas above high tide. The continuum of habitat below high tide includes bays, estuaries, coastal wetlands and open ocean waters were not included (for additional information see the Oceans and Coastal Resources chapter).

Climate Change Adaptation Strategies to Conserve California's Biodiversity

- Create a large scale well connected, sustainable system of protected areas across the State.
- Manage for restoring and enhancing ecosystem function to conserve both species and habitats in a changing climate.
- Adjust management actions as appropriate for threatened and endangered species
- Prioritize research needs and pursue collaborative partnerships with the research community to ensure that the best available science is informing management actions.
- Re-evaluate existing policies and programs to incorporate climate change and seek regulatory changes as appropriate
- Pursue endeavors that will support implementation of the strategies including funding, capacity building, collaborative partnerships, and education and outreach.

The Biodiversity/Habitat adaptation strategies provide a range of goals and objectives to help conserve biodiversity in the face of a changing climate. Detailed planning and subsequent actions are needed to implement these strategies. Before meaningful action can be undertaken, the Departments under the Natural Resources Agency should evaluate existing programs and projects that might contribute to the overall goals detailed in the following strategies and actions and carefully examine adaptation strategies in other sectors that may enhance or detract from the facilitation of biodiversity adaptation. Examples include long-term collaborative efforts that will help the state reach its goal of preserving and sustaining the largest possible array of biological diversity and habitat in all ecological regions of California. In the face of a changing climate it is imperative that Departments work to maintain healthy, connected, genetically diverse populations; improve and enhance ecosystem function of existing habitats; reduce non-climate stressors on ecosystems; develop adaptive management models for game and commercial species management; and adopt adaptation approaches that reduce risks to species and habitats while providing adequate time for species evolution and development if appropriate.

At the heart of these strategies is the need to create and maintain a network of reserve areas across the state that builds on existing conservation investments (e.g., acquisitions, easements), and provides refuge areas, and aids the movement of species within reserve areas as they adjust to changing conditions associated with climate change. Establishing a system of priority sustainable habitat reserves should provide for protection of habitat in all nine ecological bioregions identified in California's Wildlife

Action Plan. Reserves should represent to the extent practical all aspects of ecosystem structure, composition, and function within aquatic, terrestrial, and near-shore marine habitats. In addition, any effort to establish a system of priority reserve areas should follow the basic principles of reserve design that will provide protection for species in the interim before species migration/movement due to climate change is wholly understood. In the future, a reexamination of the reserve system and species movement must take place and modifications for future protected areas identified.

The reserve system is intended to provide connectivity for species movement between current and future suitable habitats (primarily within each identified reserve), while also accommodating range shifts of regionally-limited native plant species, and offering protection from catastrophic loss (e.g., through fire, flood, disease, invasive species). Climate change corridors should facilitate movement and incorporate temperature, soil and elevational gradients that benefit a suite of species. Management and restoration efforts on the network of reserve areas should be elevated in priority and focus on reducing the environmental stressors on plant and animal species and habitats.

Reserve system areas should be identified in the near-term for use in current and future land use planning efforts. It is important to acquire and protect habitat linkages found within and around designated reserve areas. Other important acquisitions may include acquiring fee title or conservation easements that focus on but are not limited to the following parameters: (1) increase soil, latitudinal and elevational gradients, (2) accommodate movement and migration of multiple endemic species, (3) reduce outside threats by improving reserve boundary configuration, and (4) protect evolutionary hotspots. Individually or collectively all these measures increase the overall protected area and provide for greater heterogeneity.

Identifying, improving, and connecting these reserve areas will help maintain and increase ecological integrity and provide healthy, resilient habitat and refuge areas to help species persist in a changing climate. For some species these areas may allow them to adapt to new conditions associated with climate change. Adapting to climate change through evolutionary change is an important factor affecting the fate of many plant and animal species. The success of the strategies identified in this document will be in part driven by when and how species may adapt or adjust to their surroundings. A better understanding of natural rates of adaptation through evolutionary change may permit effective management strategies that will help species persist and guide future conservation activities and investments. Species are pushed more rapidly to change where strong natural selection is working in a single direction. However, it is unknown if a single climate change factor will be strong enough to push rapid adaptation. For example, higher temperatures and drought stress may not exert similar selection pressures. Rapid evolutionary change provides a greater chance of species survival and is an important factor in establishing strategies for adaptation of biodiversity and habitat.

Adaptation Strategies and Actions

Over the last year the Department of Fish and Game and California State Parks have made climate change a priority in addressing the complex and large scale challenges needed for conserving biodiversity and habitat. Both of these Departments are an important part of the climate change solution and are working collaboratively with stakeholders to create strategies for addressing climate change impacts while responding to public needs. Initial planning efforts will lay the ground work for achieving the goals of these strategies as efforts are made to help species persist in a changing environment. As a first step, the Department of Fish and Game and California State Parks are committed to building upon the existing frameworks and programs, addressing internal policies related to regulatory responsibilities, and communicating openly with our partners and the public.

To this end, the Department of Fish and Game has created a new climate change advisor position to coordinate the Department's activities. Efforts are also underway at California State Parks (pending available funding) to develop a similar staff position. To meet the growing activities surrounding climate change, existing staff have been tasked with new climate change responsibilities and in some cases have been redirected to work on climate change issues.

The following climate adaptation strategies include both near-term actions which have been either identified, proposed, initiated, or can be completed by 2010. The long-term actions include those recommendations that will require additional collaborative efforts with multiple state agencies, as well as sustainable funding and long-term state support.

Adaptation Strategies and Actions

Strategy 1: Establish a System of Sustainable Habitat Reserves

The intent of this strategy is to identify and improve a statewide landscape reserve system to protect the maximum number of representative plant and animal species in California. The system should include relatively large (e.g., 150,000 plus acres), if possible, reserves in all ecological regions. This size should be adequate to support the maintenance of ecological processes and entire ecosystem function and populations of target species. It is a fair assumption that larger reserves generally have greater carrying capacity and built-in connectivity between included habitats, however, the potential contribution of a mosaic of smaller interconnected reserves is significant, with increased attention to the biodiversity value of intervening working landscapes; in many places, such a network may be the only feasible alternative left due to habitat fragmentation. Reserves should include federal, state, local and nonprofit protected habitat areas and matrix lands consisting of working landscapes (i.e., industrial timberland, agricultural lands, and rangelands) conservation easements, and mitigation lands. Conservation priorities will need to consider sites that have landscape features that are better able to buffer the projected changes in climate. Examples of these types of landscape features include, but are not limited to climatic and elevational gradients; microclimates; groundwater resources; and low fragmentation. Each reserve should include a core area(s) of protected, heterogeneous habitat, including representative aquatic and terrestrial environments..

Near -Term Actions:

- **Organization of Collaborating Entities** – Initiate the development of a working structure that would include a facilitator and key entities (including a scientific panel) that will work together to identify a statewide reserve system and provide scientific expertise. Participants should be from the major land management and acquisition entities around the state, and federal and multi-organizational partnerships including but not be limited to the State Department of Fish and Game, State Parks, State Coastal Conservancy, the National Park Service, U.S. Forest Service, U.S. Fish and Wildlife Service, US Geological Survey, Bureau of Land Management, academia including the University of California Natural Reserve System, representatives of working landscapes, and the Nature Conservancy and other conservation partners. In addition, multi-organizational partnerships provide important opportunities to engage and help achieve goals including the USGS Global Change Science Strategy, USFWS Climate Change Strategic Plan, and the Bay Area Ecosystem Climate Change Coalition.

    a. **(See Strategy 4.a)**

        i. **Incorporate Latest Science** – Participants identified in strategy 1a should establish policies, priorities, and actions based upon the best available science and incorporate new scientific information into adaptive strategies (iterative approach) when available. Give research priority to monitoring keystone species, selected species, species interactions and the influence of abiotic ecosystem components on species adaptation or movement relative to reserves and unprotected lands.. In addition pursue opportunities to centralize database management and increase information sharing.

        ii. **Incentives for Private Conservation** – Participants identified in strategy 1a should provide, where feasible, incentives for the conservation of private lands and working

landscapes (including the creation and maintenance of habitat on private lands) and prioritize those at greatest risk.

b. **Best use of California's Wildlife Action Plan (Action Plan)** – The Action Plan is already proving to be an important blueprint for how the Department of Fish and Game will address future and current climate change challenges and will play a significant role in identifying a course of action.

c. **Setting Priorities for Conservation** – The Department of Fish and Game's Areas of Conservation Emphasis (ACE) mapping effort involved a statewide prioritization of areas considered to be of highest conservation value. The ACE effort is still in its preliminary mapping phase but is intended as a tool to directly support efforts to create a system of priority sustainable habitat reserves across California. The ACE mapping effort will to the extent practical incorporate climate change projections and vulnerabilities. In addition, the ACE can be used in conjunction with other mapping efforts to identify areas overlooked within biological subregions to ensure representative examples of every ecotype have been accounted for. This effort will also help identify linkages and corridors that will help aid species movement and migration. The Department of Fish and Game is committed to continuing coordination with our conservation partners as the final ACE maps are developed and informing all levels of government to better build collaboration and focus resources to the highest priorities. Additional conservation priorities will include consideration of California State Parks reports identifying Key and Representation Parklands and Key Watersheds. These areas have been found to be the most significant habitat areas that are linked to other large blocks of protected habitat. TNC's priority conservation areas should be included in the overall review of conservation strategies in all ecoregions.

Long -Term Actions:

d. **Update Existing Statewide Priorities** – Each entity in the above strategy should consider updating existing statewide planning priorities as appropriate to contribute to the design of a state reserve system. Statewide planning efforts include California's Wildlife Action Plan, Areas of Conservation Emphasis mapping effort (Department of Fish and Game), Natural Communities Conservation Planning (Department of Fish and Game), key and representative large natural parks (DPR), and statewide portfolio areas (The Nature Conservancy).

e. **Reserve Design** – Collaborating entities should use public ownership and other protected area maps and priority areas in efforts to design reserves in all ecological regions.

f. **State Agency Review** – Review of draft reserves and the connectivity corridors should take place with key state agencies and their associated departments such as the California Natural Resources Agency, the Department of Transportation, the Department of Food and Agriculture, CAL FIRE, and the Department of Water Resources to ensure the adaptation plans from each department are complementary. Where synergies exist, focus would be on utilizing resources efficiently. Where potential conflicts in plans and their implementation exist, solutions should be negotiated to provide maximum flexibility for adaptive responses.

g. **Regional Review** – Review of draft plans for location of reserve areas should take place with key regional conservation planning groups in all regions. In addition, for each reserve participants should assess risk of habitat conversion, general condition and integrity, methods for land protection, and public access.

h. **Ratification** – Final design should be adopted by state and federal land management and acquisition agencies of the California Biodiversity Council. In order to better facilitate improvement and focus of the reserves over time, lead agencies should be identified for each reserve.

i. **Develop implementation incentives for participation by private landowners and local land use agencies** – Pursue incentives to increase participation in implementation by private landowners and regional and local land use authorities. Private landowners are often able to effectively and efficiently provide critical habitat on working landscapes and are a key component of this strategy.

j. **Improve Reserve System Functionality** – Support research that indicates how to improve ecological integrity in reserve areas through acquisition or other forms of land protection that do the following: provide internal and external connectivity, increase soil elevational or latitudinal gradients, protect private lands from habitat conversions, enlarge the reserve consistent with endemic species movement, improve configuration of protected lands, and protect evolutionary hot spots.

k. **Adaptive Management-Review of Reserve System** – Periodically the state will need to evaluate and review the long-term success of the Statewide Reserve System in conserving species and new habitat configurations associated with climate change. Determine degree of success of reserves and their improvements in light of keystone species movement as well as monitoring population numbers and viability. This kind of monitoring will be key to understanding what is and is not working to inform management actions and make decisions about whether to adopt new strategies, e.g., modifications to reserve system as appropriate.

l. **Remove Federal Barriers** – Pursue modifications to laws, regulations and practices that provide barriers to linking protected areas especially those that impede the National Park Service, U.S. Forest Service and U.S. Fish and Wildlife Service from land acquisition that creates important landscape linkages and improves the reserve system beyond Congressional boundaries and encourages federal assistance that would strengthen the landscape reserve system.

Strategy 2: Management of Watersheds, Habitat, and Vulnerable Species

Maintaining and restoring ecosystem function is a cornerstone of natural resource adaptation. As appropriate the State will need to determine whether to pursue actions that increase the resistance to climate change, promoting resilience, enable ecosystem responses, or realign restoration and management activities to reflect changing conditions[39]. Actions intended to resist climate change forestall undesired effects of change and/or manage ecosystems so they are better able to resist changes resulting from climate change. Resilience focuses on managing for "viable" ecosystems to increase the likelihood that they will accommodate gradual changes related to climate and tend to return toward a prior condition after disturbance. Response is an intentional management action intended to accommodate change rather than resist it by actively or passively facilitating ecosystems to respond as environmental changes accrue.

Realigning management activities focuses on the idea that rather than restoring habitats to historic conditions, or managing for historic range of variability the managing entity would realign "restoration" and management approaches to current and anticipated future conditions[40]. Since species will respond differently to climate change and strategies will need to evolve as research and monitoring produce new information the State will need to establish a clear process to identify priority species and systems for adaptation management projects as a short-term action and include an adaptive management response.

Near -Term Actions:

a. **Integrate Climate Change into Field Management** – Each land managing entity in the state should commit to reviewing and modifying current land and resource management objectives and practices to reduce environmental stressors and improve watershed conditions and ecosystem services on major holdings.

b. **California Wildlife Action Plan (Action Plan)** – Local, regional, and state wide land use and conservation plans should incorporate important regional actions to improve habitat and animal populations identified in the Action Plan. These actions should be considered priorities for implementation of stewardship efforts.

c. **Use and Improve Existing Conservation Efforts** – Department of Fish and Game's Natural Communities Conservation Program, Areas of Conservation Emphasis and mitigation banking should be continually supported as effective methods of identifying and protecting priority habitat areas. With appropriate resources these programs could use dynamic habitat-based models to improve identification of conservation areas.

d. **Field Restoration and Improved Protection** – Managers of conservation lands, including working landscapes, should continue restoration and other land stewardship practices. State and federal agencies should seek resources and expertise that will help them expand capacity to reduce environmental stressors, improve watershed conditions and restore ecosystem services on priority lands Reducing stressors includes but is not limited to:

   i. Eliminating or controlling invasive species
   ii. Restoring natural processes as appropriate
   iii. Maintaining natural disturbance regimes
   iv. Reduce unnatural sediment flows by improving drainage and maintenance of unpaved roads
   v. Remove barriers to terrestrial and aquatic species movement
   vi. Reduce risks of catastrophic wildfire
   vii. Reduce and/or control pollution from runoff and flooding.

e. **Restore Aquatic Habitat** – With appropriate resources prioritize conservation and management actions on aquatic systems (including but not limited to associated floodplains, riparian zones, springs, and marshes) for monitoring and restoration efforts that will reduce stress on species resulting from events associated with climate change (i.e., increased sedimentation from flooding events). Management actions to assist in the reduction of existing stressors include, but are not limited to:

   i. Maintain and increase genetic diversity of all native anadromous spawning runs
   ii. Protect cold water resources
   iii. Maintain habitat complexity
   iv. Connect river/streams and floodplains
   v. Protect high elevation alpine meadows, springs, and riparian areas
   vi. To the extent possible limit interaction between wild and hatchery fish
   vii. Temper unusual high and low flows
   viii. Restore estuaries, sloughs and marshes

Long-Term Actions:

f. **Managing Endemic and Other Priority Species** – Identify movement patterns of key species, especially latitudinal and elevational movement patterns in order to inform restoration and other stewardship activities that will aid in the conservation and management of species and habitats.

   i. Identify climate change impacts to declining and vulnerable species and integrate climate change adaptation strategies into their management.

   ii. Develop and implement recovery plans that analyze, among other factors, the effects of climate change on declining and vulnerable species and outline conservation strategies for their persistence and recovery under changing climate conditions.

   iii. Prioritize monitoring and research necessary to identify species threatened by climate change.

g. **Restoration Cost/Benefit Assessment and Climate Change** – Develop guidance for restoration practitioners to determine whether the objectives of large-scale restoration project take into account climate change scenarios and encourage the use of risk analysis to inform project planning and implementation.

h. **Minimizing catastrophic events and habitat conversions** – Develop management recommendations that minimize habitat conversions and other large scale losses from catastrophic events, including crown fire, flooding, invasive species, diseases, pests and pathogens.

i. **Establishing Priorities** – Develop criteria for determining where limited conservation resources should be placed in order to have the most benefit.

j. **Water: Enhance and Sustain Ecosystems** (see also Water Management Chapter)
   i. Water management systems should protect and reestablish contiguous habitat and migration and movement corridors for plant and animal species related to rivers and riparian or wetland ecosystems.
   ii. Flood management systems should seek to reestablish natural hydrologic connectivity between rivers and their historic floodplains.
   iii. The state should work with dam owners and operators, federal resource management agencies, and other stakeholders to evaluate opportunities to introduce or reintroduce anadromous fish to upper watersheds.
   iv. The state should identify and strategically prioritize for protection lands at the boundaries of the San Francisco Bay and Sacramento-San Joaquin Delta that will provide the habitat range for tidal wetlands to adapt to sea-level rise.
   v. The state should prioritize and expand Delta island subsidence reversal and land accretion projects to create equilibrium between land and estuary elevations along select Delta fringes and islands.
   vi. The state should consider actions to protect, enhance and restore upper watershed forests and meadow systems that act as natural water and snow storage.
   vii. The state should consider whether there are other geographic regions where these assessments should also be applied.

Strategy 3 - Regulatory Requirements

Near-Term Actions:

a. **CEQA Review/Wildlife** – The Departments within the Natural Resources Agency will continue to use the California Environmental Quality Act (CEQA) process to address the climate change impacts from projects on wildlife, including cumulative impacts.

b. **CEQA Review/Department Guidance** – The Department of Fish and Game will initiate the development of internal guidance for staff to help address climate adaptation and to ensure climate change impacts are appropriately addressed in CEQA documents

Long-Term Actions:

c. **Adaptive Capacity/CEQA Thresholds** – Based on climate change scenarios, the Department of Fish and Game should work to develop thresholds of significance for the adaptive capacity of species related to any direct, indirect and cumulative impacts of projects.

d. **Local Government Collaboration** – State Agencies that have regulatory authority and the Governor's Office of Planning and Research (OPR) should work with local land use planners and encourage local governments to adopt climate change adaptation actions for conservation, land use, research and regulatory measures.

e. **Sustainable Funding Mechanisms** – Achieve consistency in state and local regulations, general plans, and ordinances and develop sustainable funding mechanisms to support climate change planning efforts that focus on biodiversity conservation.
   i. The Natural Resources Agency and appropriate Departments should review and make recommendations to amend regulations to achieve consistency. This could be done through the Strategic Growth Council (SGC).
   ii. The state could work with local governments to develop consistency between state goals and local general plans and ordinances.
   iii. The SGC could develop funding programs to institute sustainable funding mechanisms to support climate change planning. The SGC may need to propose legislation to institute those funding mechanisms.

f. **Climate Change Models** – The state should continue to support climate change research and modeling efforts that support conservation and management of biodiversity in a changing climate. These kinds of modeling activities might include but are not limited to flow requirements for fish bearing streams that will help the Department of Fish and Game dedicate new instream flow requirements and develop new policies to address variances.

Strategy 4 - Research and Guidelines

Long-Term Actions:

Establish a Permanent Biodiversity Research Team – Appoint a permanent team of researchers and land managers to ensure that the best available science is used in management, restoration, and species protection. This team will be responsible for ensuring that state funded research is properly reviewed, annotated, and made publicly available to the conservation community and land use planners. In addition, the team will be responsible for identifying data gaps and research needs and coming up with a plan to deal with data management and finding ways to link ongoing and new monitoring and research efforts.

a. **Team activities and associated deliverables shall incorporate an open and transparent process that encourages stakeholder participation.**
   i. **Develop a technical Scientific Panel to facilitate credible use of climate, ecosystem and species data to inform planning** – Developing a new approach to reserve design for adaptation to climate change will require increased sophistication of the use of data. A Science Panel should be formed to determine data and criteria for the use of data as inputs into the planning process. The Science Panel would be formed of scientists from academia, state and federal agencies and non-profit organizations. This team will determine selected plant and animal species for long-term monitoring and help identify and establish monitoring protocols with objectives of determining rapid evolution if appropriate, range shifts that will inform adaptation efforts, or other key information that will inform management actions.

b. **Climate Change Monitoring** – With appropriate resources, Department of Fish and Game along with other sister state agencies should work together to develop a statewide, long-term monitoring effort that evaluates climate related changes affecting indicator species, populations, communities and ecosystems. Short and long term data from climate change monitoring is essential to the identification, assessment, selection, evaluation, and adjustment of adaptation strategies. The structure and application of a monitoring program will need to be clearly articulated and incorporate the contributions of citizen scientists.

c. **Climate Change Models** – The state should continue to support climate change research, including priority modeling efforts that clearly support conservation and management of biodiversity in a changing climate.

d. **Link Climate Change Science to Climate Adaptation** – Baseline data and impacts should be studied. For example, Save the Redwoods League and the CA Natural Resources Agency should track and monitor old growth forest responses to climate change and use the information to establish baseline records for potential landscape-level impacts.

e. **Prioritize Reserve System Related Research**
   i. Protected Area Planning
   ii. Species and community responses
   iii. Ecosystem services
   iv. Restoration efforts to increase connectivity and enhance ecosystem function
   v. Past effects of climate change

f. **Evolutionary Development** – While climate change and its impact on species are taking place rapidly, evolutionary change is generally unable to keep pace. However, recent research on genetics and evolution, illustrate examples where rapid change within generations is enabling species to adapt to new conditions. Research in the field of evolutionary biology will provide significant information to aid adaptation strategies in the future and should be integrated and funded to the extent possible.

Strategy 5 - Education and Outreach

Near-Term and Long-Term Actions:

a. **Public Outreach** – Given climate change and its associated impacts a commitment to ongoing public communication and outreach is essential, and should articulate the role of organizations in the protection of biodiversity.

b. **Citizen Scientists** - In order to pursue efforts to engage the public, build support to reduce impacts and support adaptation and mitigation strategies, citizen scientists should be engaged to help collect important information including but not limited to phenology observations, stream monitoring, and weather data. This will result in data collected across many locations with limited costs.

c. **Public Interpretation and Classroom Education** – A public education campaign on interpretation and climate change, developed by California State Parks includes ten priority components, and will help the 85 million visitors each year understand climate change. Elementary schools will be offered three programs that teach climate change, given the availability of funding. The Department of Fish and Game should pursue similar outreach and education initiatives to inform the public regarding the effects of climate change on natural environments and species. In addition, the State should provide materials to the extensive environmental education community of California,

Strategy 6 – Implementation of Adaptation Strategies

Near-Term and Long-Term Actions:

a. **Policy Development** – All state agencies should review existing policies, criteria, and directives to initiate adaptation measures in response to climate change impacts.

b. **Capacity and Continuity** – In order to accomplish and maintain actions associated with the adaptation strategies, new funding sources should be identified to support new full time permanent civil servant positions that are dedicated to climate change adaptation.

c. **Success Measurements** – Establish quantifiable and qualitative near-term targets, mid-term and long-term milestones to measure success.

d. **Implementation Timing** – The Natural Resources Agency should convene a group of stakeholders and state agency staff to identify sustainable funding for climate change adaptation, prioritize recommendations and opportunities for securing funding.

e. **Adaptive Management** – Adaptive management is a key element of implementing effective conservation programs especially in light of the uncertainties associated with climate change related impacts on natural resources. The State should establish a clear process to identify priority species and systems for adaptation management projects as a short-term action and include an adaptive management response. A statewide knowledge base should be pulled together as soon as possible with the assistance of the scientific community to support the State's efforts to employ an adaptive management framework.

f. **Cross Sector Cooperation** – Interagency cooperation and collaboration are critical to the implementation and long term success of the strategies particularly in regards to the overlap between biodiversity and habitat concerns and all other sectors of this report. In addition, this same spirit of collaboration needs to be extended to other partners and stakeholders that can provide the data, research, and support to help achieve these goals.