A 2018 Ballot Measure Analysis for Voters: The CA Water Bond and its Impact on Scientific Research from a Biology Perspective

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I. Introduction

The 2018 California (CA) Water Bond is a ballot measure that has a total cost of US$17.3 billion over 40 years; US$8.877 billion would be spent immediately, and the interest would accumulate to US$8.4 billion. CA has the fifth largest economy in the world, and two of the largest economic drivers are the agricultural cash-crop value and the agricultural export-value (Meral 2017). CA's agricultural economy relies on a stable ecosystem. The loss of key ecosystem services, such as the pollination of plants and nutrient cycling, could mean the collapse of entire agricultural industries and a shock to CA's economy. In 1997, the global economic impact of ecosystem services was estimated to be at least US$33 trillion per year (Costanza et al. 1997). Notably, a main objective of the 2018 CA Water Bond is to conserve natural resources to help mitigate environmental damage in CA.

CA's economy requires a stable environment that bolsters its large agricultural industry, but indicators show that human-made actions contribute to the environmental crisis. Globally, animal extinction rates are some of the highest in history, as 322 species of terrestrial vertebrates have become extinct since 1500, and there has been a 25% decline in abundance (Steffen et al. 2011). A total of 67% of invertebrates, which includes pollinators, have shown a 45% decrease in abundance (Dirzo et al. 2014). Likewise, important ecosystems, such as wetlands and their carbon, nitrogen, and phosphorus cycles, have been disrupted in CA and across the world (Pievani 2014), negatively influencing ecosystem services (Waters et al. 2016). With immense economic power and diverse geographical landscape, research spending on the conservation of CA's environment could help conserve similar types of global ecosystems.

Passing the 2018 CA Water Bond funds timely ecosystem conservation efforts of species and habitats. Large-scale rehabilitation and conservation projects are possible in CA through bonds. Recent scientific research has made progress in biology fields that could help conserve essential ecosystem services, bolster plant productivity during environmental stress, and rehabilitate species. The purpose of this piece is to provide voters with information on how this ballot measure could impact biology fields related to bioengineering, monitoring, and conserving CA's ecosystems.

II. Scientific Research Impacts

Although some funds from the 2018 CA Water Bond are already allocated, biological research programs would be competing for some of the remaining funds. Some of the more recent breakthroughs and future directions that would benefit from this funding are discussed below.

ii.i. Plant Biology Research

Plants are now being engineered with genetic tools to strengthen resiliency, increase productivity per acre, and allow real-time monitoring of stresses by computers. Research into molecular mechanisms of environmental stress allows genetically engineered plants to withstand extreme environmental conditions (Nuccio et al. 2018). The main limitation of these genetic methods is that the species must be genetically manipulatable, which is not true for most crop plants (Cardi, D'Agostino, and Tripodi 2017).

New technologies are being developed to circumvent the need to develop genetic tools for individual plant species.

Nanotechnology aims to work with any plant by applying nano-scale devices that emit signals. For example, plant stress induced by drought can be monitored in real time (Koman et al. 2017). Nanotechnology-enabled plants are capable of sensing specific chemicals found in the soil, emitting an optical signal detectable by cameras, and then emailing researchers an alert (Giraldo et al. 2014). The future of plant agriculture could be fields of plants that can individually signal specific nutrient needs or environmental stresses, allowing for higher plant productivity and resiliency to stress.

ii.ii. Ecology Research

Ecology-based funding is crucial to see how CA's agricultural industry will influence the environment and how the global climate will impact CA's economy in the future. Ecology, the study of how organisms and nutrients cycle within an ecosystem, seeks to monitor environmental changes and highlight unexpected environmental services that organisms provide. For example, robust microbial soil diversity increases plant biodiversity and total productivity (van der Heijden et al. 1998). By genetically modifying these microbial communities, researchers have manipulated a plant's response to environmental factors, which could improve yields in harsh conditions (Herrera Paredes et al. 2018). Although these diverse microbial communities can increase plant productivity, their unexplored genomes may have broader implications outside of the agricultural sector and deserve additional research.

Recent breakthroughs in high throughput DNA sequencing, such as Illumina-based sequencing-by-synthesis, have allowed researchers to study microbial genomes extensively. For instance, researchers can analyze a microbe's genomic ability to make new natural chemicals that could transform medical, agricultural, and material industries (Smanski et al. 2016). Surveying these microbial communities for novel drugs or chemicals, however, is only possible if they have not become extinct, further warranting conservation projects.

ii.iii. Conservation Research

Funds from the 2018 CA Water Bond are allocated to three specific projects that are aimed at building infrastructure to address the drought-related issues rampant throughout the state and conserve natural resources. First, to mitigate precipitation volatility, water resources can be conserved and moved more effectively throughout the state with new water conveyance projects (Swain et al. 2018). Second, projects are aimed to provide universal water access to minority communities that have not had equal access to resources previously due to a variety of socioeconomic factors (Ramirez and Stafford 2013; Balazs et al. 2011). Third, water quality can be improved by decreasing the number of nitrates contaminating groundwater via agricultural runoff (Rosenstock et al. 2014). Hence, engineering ways to conserve natural resources can be done alongside efforts to conserve CA's ecosystem diversity and productivity.

Invasive species are organisms that have migrated, often aided by human travel, into new ecosystems where they have no natural predators. These invasive species can wreak havoc on entire ecosystems and have negative impacts on human health. For example, based on environmental conditions, mosquito vectors can flourish in new geographic areas and transport life-threatening pathogens. Using innovative gene editing technologies that can target specific species, researchers are now attempting to stop the spread of *Anopheles stephensi* mosquito populations that transmit the parasite *Plasmodium falciparum* (Gantz et al. 2015). New conservation efforts help preserve ecosystem genetic diversity by specifically removing harmful species.

III. Bond Project Highlights

Several conservation and rehabilitation projects already have allocated funds within the 2018 CA Water Bond.

iii.i. Salton Sea Habitat Preservation

The Salton Sea is an example of an out-of-balance ecosystem resulting from poor ecological planning and conservation. CA's largest lake is now a potential health hazard to all residents of southern CA. In 1905, the current Salton Sea was formed by an accidental flooding event from the Colorado River ("Background Information on the Salton Sea" n.d.). As a terminal lake with no outflow, a substantial portion of the water in the lake evaporated and created a hypersaline environment. Fish were placed into the newly formed lake, but without ecosystem services to break down detritus, hordes of fish skeletons routinely washed on shore (Upadhyay et al. 2013). Although incomplete nutrient recycling harms the Salton Sea's sustainability, some animals still require the habitat to survive.

A strong case persists to preserve and rehabilitate the Salton Sea. As one of the largest wetland habitats in CA, over 400 migratory and native bird species use the Sea for habitat (Shuford et al. 2002). Hazardous dust exposed because of evaporation has already caused health problems for nearby residents. If the lakebed is exposed completely, it has the potential to spread harmful dust from San Diego to Los Angeles. In April 2018, US$280 million in funding was secured for the Salton Sea Management Program ("Funding Secured for Salton Sea Management Plan" 2018) for the restoration of the Salton Sea ecosystem, and restoration methods are currently being researched (Upadhyay et al. 2013).

iii.ii. Salmon Population Rehabilitation

The salmon population restoration projects proposed by the 2018 CA Water Bond attempt to rehabilitate once-native populations. Chinook salmon were once so populous in CA's Central Valley that a genetic screen from 1991 through 1997 showed a significant genetic divergence between different breeding events (Banks et al. 2000). A key aim for the CA Water Bond-funded salmon projects will be re-creating this rich genetic diversity of salmon populations in CA, which can also benefit nearby ecosystems.

Fish populations are crucial for nutrient cycling within marine systems. Species' migration between two ecosystems – like salmon breeding in freshwater and spending most of their lives in the ocean – plays a key role in maintaining population equilibriums. When one species disappears, there is a "trophic cascade," an ecological term to describe the effects on the entire ecosystem. For example, when sea otters were hunted for their fur in Alaska, native fish populations plummeted unexpectedly. Researchers found that with the sea otters removed, the abundant sea urchins ate more kelp that was anchored to the ocean floor. When the unanchored kelp then floated to the ocean surface, fish did not have the dense kelp forests for protection and reproduction (Estes and Duggins 1995). Based on these ecological principles, bringing back native salmon populations would have a dramatic impact on both marine and inland ecosystems.

For the newly-established salmon populations to thrive, they must have genetic diversity within their population. Insufficient genetic diversity means that salmon populations, and in turn the entire CA ecosystem, may be vulnerable to environmental stressors (e.g., single virus, extreme weather conditions) and face elimination. For example, researchers estimate that low genetic diversity within the sockeye salmon population in Bristol Bay, Alaska, would produce low stock numbers and cause fisheries to close ten times more often (Schindler et al. 2010).

IV. Discussion

CA residents have an opportunity to vote on the 2018 CA Water Bond that would address some of the largest long-term challenges that we face as humans. Over time, the cost of this bond pales in comparison to the economic value that a healthy and stable ecosystem provides to CA's agricultural economy, by increasing plant productivity and providing valuable ecosystem services. Therefore, CA's future economic stability is intimately tied to environmental health. Since increasing genetic diversity is the best way to uphold environmental health, conserving biodiversity in CA has incredible intrinsic and fiscal value for future generations. By continuing to invest in scientific research, CA could also develop innovative technologies to mitigate and reverse environmental harm attributed to human-made actions.

Scientific research is creating more resilient plant agricultural species, bettering our understanding of how nutrients flow within an ecosystem, and developing new methods to rehabilitate biodiversity. Creating ecosystems that can withstand the human-made environmental crises will be a major factor in whether the current CA economy will be sustainable in the future. Money from the 2018 CA Water Bond that is not already allocated should be incorporated into research and development that increases the resiliency of CA's ecosystems for future generations.

From a research biology perspective, a vote in favor of the 2018 CA Water Bond is supported by decades of research in diverse disciplines. Voting against this bond would be detrimental to continuing CA's conservation efforts for environmental protection, and thus abandoning decades of biology research, moral obligations of improving our environment for future generations, and opportunities to discover new frontiers in science. CA voters have a chance to secure the future of CA's environmentally-enabled economy, preserve valuable species that provide critical ecosystem services, and bolster technological development that may significantly contribute at the global scale.

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