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Jeffrey Mount,
Brian Gray,
Karrigan Bork,
James E. Cloern,
Frank W. Davis,
Ted Grantham,
Letitia Grenier,
Jennifer Harder,
Yusuke Kuwayama,
Peter Moyle,
Mark W. Schwartz,
Alison Whipple, and
Sarah Yarnell
with research support from Gokce Sencan

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A Path Forward for California's Freshwater Ecosystems

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Technical appendices to this report are available on the PPIC website.

Policy recommendations from this report are available on the PPIC website.

SUMMARY

Californians rely on freshwater ecosystems for many things: water supply, hydropower, recreation, fisheries, flood risk reduction, biodiversity, and more. These ecosystems—and the social, economic and environmental benefits they provide—are part of the state's natural infrastructure. But they are changing in undesirable ways in response to water and land use, pollution, introduction of non-native species, and a changing climate. Declines in native biodiversity are the most direct measure of these changes, with numerous species now protected by state and federal endangered species acts (ESAs) and many times more likely to need protection in future.

For the past 40 years, the ESAs have played a prominent role in managing the state's freshwater ecosystems. While this approach has prevented extinctions, it also places an emphasis on reducing harm to listed species, rather than improving overall ecosystem condition necessary to recover their populations. And these laws are not forward-looking enough to help species adapt to changing climate and reduce future species listings. This approach also fuels controversy and litigation due to perceptions about trade-offs between species protection and economic uses of land and water.

To maintain the benefits that Californians derive from their freshwater ecosystems—and arrest the decline of native biodiversity—a new approach is needed. We recommend that the state adopt the principles and practices of ecosystem-based management. This involves the simultaneous management of water, land, and organisms to achieve a desired ecosystem condition that benefits both native biodiversity and human well-being. The goal of ecosystem-based planning is to develop a shared vision for the ecosystem, agreement upon a common set of facts, and a unified plan to achieve it. We are not proposing major reforms to state or federal endangered species acts. Rather, we recommend a shift in the way these acts are implemented.

Ecosystem-based management relies on robust governance frameworks that are transparent, collaborative, and supported by science and secure funding. Many programs are starting to adopt its principles and practices, but much more needs to be done. Actions needed to achieve ecosystem-based objectives include setting aside water budgets for the environment and using this water to improve ecosystem condition and create multiple benefits. Binding comprehensive agreements between regulatory agencies, stakeholders, and water users—developed as part of sustainable watershed management plans—should guide implementation. These plans can be used to align agency actions and permitting and can be adopted by the State Water Board as water quality control plans.

California needs to change course in how it manages freshwater ecosystems to protect the many beneficial uses they provide. Ecosystem-based management offers a more comprehensive, flexible, and adaptive approach, and one that is compatible with existing laws. We believe this approach is better able to improve ecosystem outcomes that benefit both people and nature and respond to today's challenges while preparing for an uncertain future.

Introduction

Water in California is managed to meet an array of objectives that are often in tension. This includes water supply, hydropower, recreation, flood risk reduction, fisheries, and the preservation of native biodiversity—particularly species that are at risk of extinction and protected by state and federal statutes. All of these objectives depend to some degree on the condition—or state of health—of the diverse array of freshwater ecosystems within the state's rivers, lakes, wetlands, and estuaries.

Despite the connections between healthy freshwater ecosystems and the multiple uses that depend upon them, environmental management, permitting, and planning often focus narrowly on impacts to species listed as threatened or endangered under state and federal endangered species acts (ESAs). The trade-offs between water project objectives and listed species often lie at the root of controversy over water management activities. This narrow, project- and species-specific approach has failed to arrest the decline in native biodiversity (Moyle, Lusardi, and Samuel 2017). It also has failed to maximize the multiple social and economic benefits derived from these ecosystems.

But this is starting to change. Recent California legislation—including the 2008 Flood Protection Act, the 2009 Delta Reform Act, and the 2014 Sustainable Groundwater Management Act—have declared management to achieve multiple objectives, including ecosystem health, to be state policy. This goal is also central to Governor Newsom's executive order requiring state agencies to develop a portfolio of actions to increase resilience of California's water management systems. But shifting away from the historical approach—focused principally upon permitting and mitigating project/species trade-offs—is proving difficult to accomplish.

In this report we build upon increasing interest in multi-objective approaches to management of freshwater ecosystems (see recent summary in Diringer 2019). To be clear, we are *not* proposing major legislative reforms to state or federal ESAs or other foundational environmental legislation. Rather, we are recommending a shift in the way these acts are implemented in order to improve ecosystem outcomes that benefit both people and nature and anticipate an uncertain future. We propose that water managers in California adopt ecosystem-based principles and practices wherever possible. This sets improving freshwater ecosystem health—and the multiple benefits derived from those ecosystems—as a top priority, rather than focusing narrowly on mitigating project impacts to species protected by state and federal laws.

We begin by describing the principles of freshwater ecosystem-based management, including management and governance frameworks and actions. We then describe why this approach is likely to produce better outcomes and reduce controversy when compared to current project- and species-specific approaches. Next we examine the feasibility of achieving ecosystem-based objectives under existing water quality, water rights, and endangered species laws, and find that current statutes either allow or promote this approach. We then examine ecosystem-based efforts that are currently underway in California and offer recommendations for how to build on this progress. Finally, we describe how to develop sustainable watershed management plans—a promising way to organize and implement ecosystem-based management. Technical appendices provide further details on the legal issues associated with ecosystem-based management, and case studies of current examples of this approach. Policy recommendations from this report are summarized here.

This report builds on research into ecosystem management and institutional responses during the 2012–16 drought in California (Hanak et al. 2015; Mount et al. 2017, 2018) and the Millennium Drought in Victoria, Australia (Mount et al. 2016). The report was informed by a May 2019 workshop involving the author team and roughly 30 representatives of federal, state, and local agencies, academic experts, and members of the water user and environmental non-profit communities.

Current Freshwater Ecosystem Management Is Not Working

California's diverse freshwater ecosystems are an essential part of the state's natural infrastructure and provide an array of social and economic benefits. Numerous state and federal agencies regulate the various uses of these ecosystems with the goal of preventing their degradation while balancing competing interests.

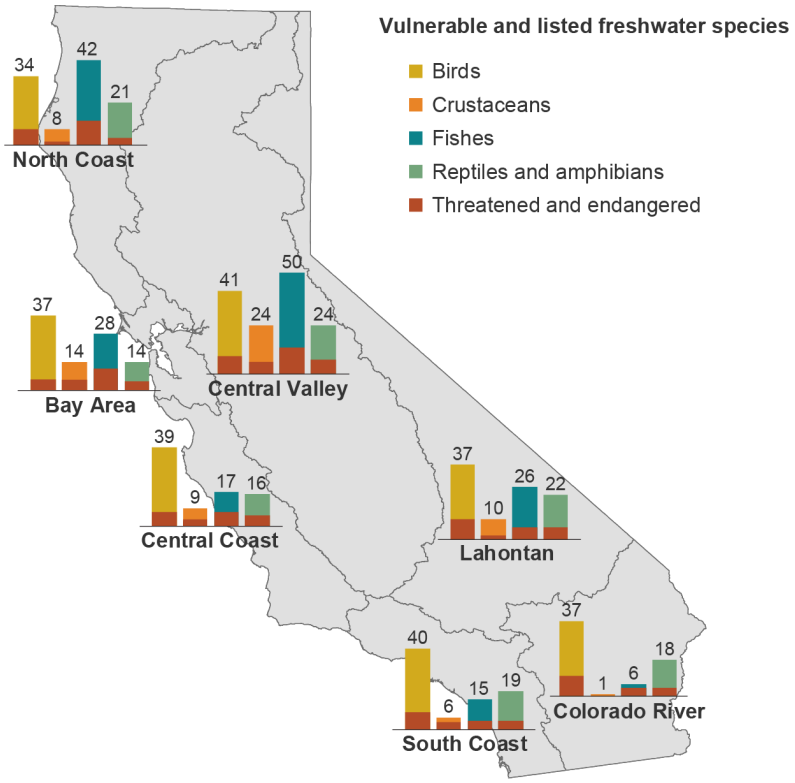
One particularly thorny problem has been the long-term decline in the state's freshwater native biodiversity.[1] An indicator of this decline is the status of species listed as endangered or threatened under state and federal ESAs. More than 100 freshwater-dependent species of plants and animals are currently listed for protection in freshwater ecosystems throughout the state. Although actions to protect these species have prevented extinctions, few show signs of recovery (mirroring a national trend), and many have disappeared from rivers and streams that they historically occupied (Bean 2009, Evans et al. 2016).[2]

The number of ESA-listed species understates the scope of the challenge of managing freshwater ecosystems, however. A recent study by Howard et al. (2015) demonstrated that freshwater species vulnerable to extinction due to declining ecosystem health are much greater than those currently protected by ESAs. All of the state's hydrologic regions have both listed species and numerous vulnerable species (Figure 1). During the 2012–16 drought, 18 fish species came close to extinction in parts of their historic range and remain highly vulnerable to future drought (Figure 2). Half of these fishes are *not* currently protected by the ESAs.[3]

[1] We use *native biodiversity* to refer to the variety of organisms, including their genes and ecosystems, that are native to California. Biodiversity in some areas is high because it is a mix of native and non-native species. Some non-native species have become invasive, outcompeting natives and disrupting ecosystem processes.
[2] Only two species of fish native to California (along with Oregon) —the Modoc sucker and the Oregon chub—have been federally delisted since the ESAs were enacted. The status of listed species is maintained and updated periodically by the California Department of Fish and Wildlife. Federal listed species are maintained by the US Fish and Wildlife Service. There is often pressure not to delist species because of the potential loss of funding for conservation efforts (Gerber et al. 2016).
[3] New listings of species can be done directly by the fish and wildlife agencies or in response to citizen petitions. In recent years, state and federal regulators have slowed the pace of listings. There is no evidence that this is because of better conditions or improved conservation actions. Rather, this appears to be a choice to avoid the costs and disruption of new listings.

FIGURE 1

Many freshwater-dependent species in California are already listed as threatened or endangered, and many more are vulnerable to extinction

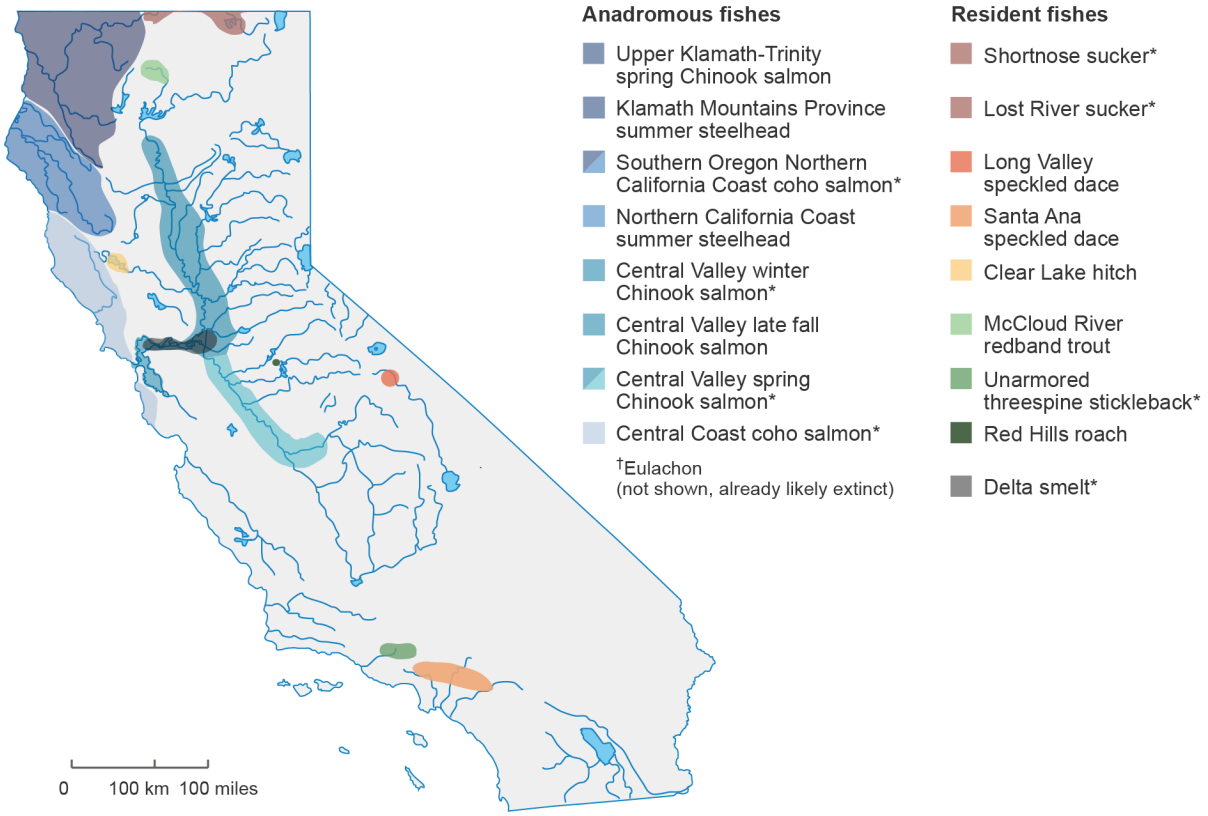


SOURCE: Adapted by the authors from Howard et al. (2015).

NOTE: The figure depicts species that are vulnerable to extinction but not listed, or already listed as either threatened or endangered under ESAs, in each hydrologic region. Many species are present in more than one hydrologic region. The total number of listed species shown is 65, with another 179 vulnerable to extinction. One listed mammal—not shown in this figure—occurs in the Colorado River region. The figure also does not depict plants, insects, or other invertebrates, 47 of which are listed, and 600 of which are vulnerable to extinction.

FIGURE 2

Many freshwater fishes are at high risk of extinction during the next severe drought



SOURCE: Hanak et al. (2015).

NOTE: This figure shows the ranges of 18 species considered highly vulnerable to extinction if the hot, dry conditions of the last major drought had persisted. Species marked with asterisks are listed as threatened or endangered. The drought ended in 2017, reducing the immediate threat. However, droughts of the future are likely to be increasingly severe as the climate warms, increasing the likelihood of extinctions (Cloern et al. 2011, Mount et al. 2018, Ullrich et al. 2018).

The overall decline in native biodiversity is exacerbated by changing conditions (Chornesky et al. 2015). Continuing pressures from growth in population and the economy—including discharge of pollutants, demand for water, flood control, and changing land use—are altering ecosystems. The introduction of numerous non-native species is dramatically changing the state's freshwater ecosystems, often at the expense of native species.

Climate change is also a driver of change (Moyle et al. 2013; Mount et al. 2018). Rising temperatures, declining snowpack, longer dry seasons, more-variable precipitation, and rising seas are increasing the number of freshwater-dependent species vulnerable to extinction and pushing those most at risk closer to the brink. Some species—particularly those that are temperature-sensitive—are unlikely to survive in their historic range. Recent work by Moyle, Lusardi, and Samuel (2017) highlights how much this will affect California's salmon and trout species, with as many as half likely to go extinct by the end of the century. Although federal and state regulatory agencies recognize these problems, species recovery plans generally emphasize restoring or improving critical habitat under current conditions. Recent revisions of federal ESA regulations even seek to de-emphasize management actions that anticipate future conditions.[4] Moreover, although the expected effects of growing

[4] Proposed revisions of federal ESA regulations in 2019 by the US Fish and Wildlife Service and the National Marine Fisheries Service would prohibit consideration of climate change impacts in listing species and developing recovery plans.

population and climate change on ecosystems are analyzed in many California planning documents (e.g., California Biodiversity Initiative 2017), existing laws and regulations do not adequately address the challenges of conserving listed or vulnerable species in the face of change.[5]

For the past 40 years, state and federal ESAs have played a prominent role in the management of freshwater ecosystems in the state. Most listed species have recovery plans prepared by state and federal fish and wildlife agencies that identify a broad suite of actions needed to recover species populations. Yet permitting activities under ESAs, along with on-the-ground conservation actions, usually focus narrowly on mitigating the impacts of individual water management projects on listed species. This has created a piecemeal, project- and species-specific approach to ecosystem management. Moreover, it has placed an emphasis on reducing harm to listed species, rather than improving overall ecosystem condition necessary to recover their populations (Box 1). Finally, this approach fuels controversy and litigation due to perceptions about trade-offs between species protection and economic uses of land and water.

The heavy reliance upon ESAs to manage freshwater ecosystems—and native biodiversity in general—is not working. This is in part due to the limitations of the acts themselves. They are specifically designed to prevent extinction and, if possible, promote recovery of a narrow range of species. They are not designed or implemented to manage ecosystems for multiple objectives, and they are not sufficiently forward-looking in ways that adapt to changing climate and reduce future species listings (Doremus 2010).

In the following section we describe how ecosystem-based management would work for California's freshwater ecosystems.

An Alternative Strategy: Ecosystem-Based Management

Since the inception of modern environmental regulations, there have been numerous calls for more holistic approaches to freshwater management that do not focus on regulating a narrow range of species or their stressors (Bean 2009; Evans et al. 2016; Williams et al. 2019). A common theme is the observation that ecosystems in good condition provide an array of ecological, social, and economic benefits that improve human well-being and are broadly protective of native biodiversity.[6] These benefits include costs avoided (e.g., reductions in flood risk, lower water treatment costs, and reduced regulatory disruption associated with endangered species listings). Management that maximizes multiple objectives—rather than narrowly managing for water supply, for example—has the potential to produce higher net benefits.

There are numerous definitions of ecosystem-based management, often tailored to the specific resource or use in question. For California's freshwater ecosystems, it involves the simultaneous management of water, land, and organisms to achieve a desired *ecosystem condition* (Box 1) that benefits both native biodiversity and human

[5] Mount et al. (2017) examined the response of state and federal agencies to the 2012−16 drought. With some exceptions, the authors found a general lack of planning for the high temperatures and sustained low flow conditions of this drought, resulting in ad hoc and uncoordinated responses. Ullrich et al. (2018) demonstrate that this type of drought will become the norm, rather than the exception, by the mid-21st century.

[6] Some of these benefits—often described as "ecosystem services"— can be assigned economic value (e.g., MEA 2005; Gilvear et al. 2013). There has been extensive research on how to attribute the full economic value to these benefits, including the economic value of goods and services created by freshwater ecosystems, costs avoided (such as floods or additional water treatment), and social values (La Notte et al. 2017). One challenge is that many of these services do not have explicit market prices, even though they provide clear benefits to society. The use of ecosystem service valuation as a way to set policy and priorities remains a work in progress, more advanced in some places, particularly the European Union.

well-being. Ecosystem-based management integrates human activities and uses (e.g., water supply and quality, flood control, hydropower generation, recreation, etc.) into the setting of ecosystem goals and objectives and emphasizes actions that produce multiple benefits.

Box 1: Ecosystem Condition

Ecosystem-based management seeks to improve ecosystem condition—often referred to as ecosystem health—for native biodiversity and various human uses of fresh water and connected lands. Ecosystem condition is defined by ecosystem *structure* and *function*.

- **Structure** refers to the physical and biological features of an ecosystem. This includes structural habitat, such as gravel bars, channels, riparian corridors, floodplains, and wetlands. It also includes plant and animal communities that make up the food webs of these habitats.
- **Function** refers to processes that support and interact with the ecosystem structure. This includes processes that typically vary over space and time, such as flow, water quality, temperature, nutrient cycling, productivity of food webs, and sediment transport.

In freshwater ecosystems, both structure and function are constantly changing with changes in seasons, weather, tides, and flows. And in most watersheds, ecosystem functions connect over broad scales; what happens upstream impacts what happens downstream. For example, ecosystem function in estuaries is affected both by the watershed that controls inflow to the estuary, by the tides and freshwater flows that drive circulation within the estuary, and by ocean conditions that affect organisms that make use of the estuary.

The focus of ecosystem-based management on a desired condition also recognizes societal values as critical for establishing management goals and objectives, and for creating appropriate metrics to measure compliance and assess achievement. This does not mean that basic environmental standards—including those for water quality and endangered species—are abandoned. Rather, those standards are folded into a broader set of management objectives that focus on improving ecosystem condition. This approach provides a better alignment between economic and social uses of the ecosystem and management for species conservation objectives, creating greater net benefit overall. It also lowers the perceived cost of listed species protection by providing a broader array of benefits from management actions.

It is important to highlight the differences between ecosystem-based management and other, often similar approaches. For example, *ecosystem management* seeks to manage the ecosystem for species conservation goals and objectives, such as resilient populations of native plants and animals. This is accomplished principally by constraining land and water use and often uses recovery of protected species as a primary objective. In contrast, ecosystem-based management integrates human uses into the setting of conservation goals and objectives, balancing the uses of the resource. Ecosystem-based management also differs from Integrated Water Resources Management (IWRM), which focuses principally on coordination and funding of local water management projects while managing their impacts on ecosystems.

We next describe some key elements that are needed to incorporate ecosystem-based management into practice.

Freshwater Ecosystem-Based Management in Practice

The practice of ecosystem-based management is not new (Long et al. 2015; Holland et al. 2012). It is already the guiding approach in some settings in the United States, including federally managed headwater forests and marine ecosystems (Franklin et al. 2018; Levin and Lubchenco 2008; Marshall et al. 2018; Wondolleck and Yaffee 2017). The approach is less frequently used for freshwater ecosystems, however, particularly where there is controversy over managing critical habitat for ESA-listed species. A prominent exception is the extensive work in the Everglades and the Kissimmee River in Florida, where managers have been attempting to implement ecosystem-based management for decades (Harwell et al. 1999; Sklar et al. 2005; LoSchiavo et al. 2013). And versions of it are practiced in Europe and other parts of the world (Rouillard et al. 2018). Here we describe a planning and governance framework and a set of management actions specific to freshwater management; these are based on author experience on these issues and extensive consultation with practitioners and stakeholders.

A Planning and Governance Framework

At the heart of successful ecosystem-based management programs are robust, collaborative planning and governance processes. Such processes include inputs from key constituencies, experts, and agencies to develop a shared vision for the ecosystem and agreement upon a common set of facts. Even where disagreements are not fully resolved, consultation and collaboration reduce the potential for conflict and litigation, particularly if the plans identify ways to resolve scientific and management disputes.[7]

Ecosystem-based planning is the forum for the difficult task of priority setting. All resource management involves trade-offs. But focusing on project-related, species-by-species habitat mitigation fails to fully capture the complexity of the problem, or the potential array of solutions. Ecosystem-based planning allows for a transparent evaluation of how to employ resources in ways that create the greatest return on investment. This encourages a more accurate and nuanced understanding of the multiple benefits of healthy ecosystems, rather than overly simplistic "farmers versus fish" debates. Plans seek to not only protect species that are already listed, but also avoid future listings and, where possible, improve the quality and reliability of human uses of the ecosystem. And because freshwater ecosystems are changing and new knowledge is constantly being created, plans must be living documents that are both flexible and anticipatory, following the well-established tenets of adaptive management.[8]

Ideally, ecosystem-based planning and governance should be negotiated. As outlined later in this report, comprehensive agreements should be developed that are legally binding and can be adopted by regulatory agencies. At minimum, the agreements should include the following:

- **Desired ecosystem condition, benefits, and beneficiaries.** The first step in ecosystem-based planning is defining the desired ecosystem condition that provides an array of social, economic, and environmental benefits. This requires extensive stakeholder and expert engagement to develop a narrative that can guide management. Ecosystem benefits and beneficiaries should be made explicit to allow for informed priority setting, assessment of trade-offs, and the identification of actions that can create multiple benefits.[9] The

[7] For example, efforts to restore the Everglades have included development of a robust planning and governance framework that is inclusive of many interests. This is summarized well in Harwell et al. (1999).

[8] Earlier PPIC work on this issue (Mount et al. 2017) recommended a combination of multi-year watershed plans and annual watering plans that describe water and ecosystem management actions and priorities for the next water year, depending on hydrologic conditions. Watering plans have proven successful in managing drought-stressed ecosystems in parts of Australia (Mount et al. 2016).

[9] In our view, it is not necessary to conduct a full ecosystem services valuation assessment. Given the large uncertainties in setting values for some services—particularly many of the public trust values of freshwater ecosystems—it is likely sufficient to identify and qualitatively describe benefits and beneficiaries. This approach is used in the Puget Sound Partnership, where all actions—including species conservation and water management—are linked by narrative to beneficiaries.

most important—and controversial—elements will be identification of actions needed to achieve desired ecosystem condition and who will be responsible for implementation and funding. Finally, to meet permitting requirements, plans should seek to incorporate narrative objectives of existing water quality and ESA regulations (discussed below).

- **Metrics and performance measures**. The setting of metrics and time-specific performance measures clarifies objectives and priorities and is likely to be required for needed permits. Metrics will often include population conditions of "focal species"—the plants and animals that are useful indicators of ecosystem health—or groups of species with similar requirements.[10] In most cases, metrics will target ecosystem structure—including composition of plant and animal communities—and function. Metrics will vary depending on the setting (e.g., mountain streams versus rivers with large floodplains), but will typically include habitat diversity, quality and connectivity, food web productivity, biodiversity, frequency of harmful algal blooms, water temperature, flow regime, etc. Additionally, it is important to reaffirm responsibilities and timelines (e.g., which agency or entity will fund and implement habitat and water management improvements).
- **Scientific support**. Strong scientific support programs are needed to implement ecosystem-based plans. Research and monitoring should be organized around testing management hypotheses, reducing scientific uncertainties, and measuring progress toward performance measures.[11] It is essential that the science be collaborative. This reduces the risk of combat science—i.e., science and information narrowly developed to support a pre-existing legal or political position or to cast doubt on conclusions of others—and the inevitable litigation that follows (Cloern and Hanak 2013; Hanak et al. 2011, 2013). New collaborative science programs may need to be developed to support transparent regulatory decision making and ecosystem management.[12]
- **Regulatory alignment with transparent governance and administration**. Management of ecosystems for multiple benefits typically goes well beyond the purview of a single agency. Ecosystem-based management can provide a framework for aligning agency priorities and permitting actions under a single program, which will reduce complexity and cost for both regulators and the regulated community.[13] For this to occur, there has to be a collaborative governance program (some examples described below). This program should include stakeholders and agency representatives, and it should identify responsibilities within overlapping jurisdictions. The governance program also oversees the acquisition and administration of funding, along with the allocation of water and restoration of structural habitat within legal constraints.

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[10] In many freshwater ecosystems population levels of listed species are so low that their abundance is not a reliable indicator of ecosystem condition. This is a roadblock to monitoring progress in the Sacramento–San Joaquin Delta, where population numbers of listed smelt are too low to determine whether water management actions are improving conditions.

[11] An exemplary science program proposal that addresses research and monitoring to support management hypotheses is contained in One Delta, One Science—A Path for Building Common Knowledge. This program—still undergoing revisions—addresses the complex information needs for managing the Sacramento–San Joaquin Delta ecosystem.

[12] The Southern California Coastal Water Research Project is one model for how to organize collaborative science, principally for water quality issues. For other alternatives, see Gray et al. (2013) and Mount (2018).

[13] In a review of the challenge of managing multiple stressors in the Delta, Hanak et al. (2013) documented how difficult it is to meet multiple and often conflicting regulatory requirements for managing ecosystems. To do comprehensive work, efforts in the Delta need permits from 11 different state agencies and 8 federal agencies, along with numerous local agencies (see Table 4 in Hanak et al. 2013). Attempts to remove four dams on the Klamath River is another example of the challenge of permitting. The director of the Klamath River Renewal Corporation has noted that the number and complexity of permits to remove the dams exceeds those required to build a new dam in California, such as the proposed Sites Reservoir to store water from the Sacramento River (Pottinger 2019). As this example highlights, permitting systems are better at mitigating harm from new construction than they are at improving ecosystem condition where land and water resources have already been developed.

- **Reliable funding**. Of the many challenges facing ecosystem-based management, securing a source of reliable and adequate funding may be the most difficult. The environment is often a "fiscal orphan," reliant on bond funds and fees that are difficult to acquire (Hanak et al. 2014, 2018). Plans must identify amounts and sources of funding for all phases of implementation, including investments in habitat improvements, ongoing operations and maintenance, science and monitoring, and administration.

Management Actions

Managing ecosystems requires a broad, coordinated set of actions that go beyond traditional project-specific, single-species approaches. Under current approaches, regulatory emphasis too often focuses on managing only one component of the ecosystem (e.g., flow), rather than managing the many factors that affect structure and function. Five types of actions—managed simultaneously—are needed:

- **Establish ecosystem water budgets**. The most contested aspect of freshwater ecosystem management is determining the amount of water allocated to the environment. Today, this is commonly done by setting minimum instream flows to meet water quality objectives for human uses and life history needs of listed species. Over time, regulatory processes have tended to augment these minimums as ecological conditions decline, creating uncertainty for water availability for human uses. An alternative approach is to create ecosystem water budgets (Box 2). These budgets—similar to water rights for the environment—allow managers to flexibly allocate, trade, and store water to improve ecosystem condition during drought.
- **Connect structural habitat to functional flows**. Natural flow in rivers and estuaries varies seasonally and between years. This variability is essential to maintaining ecosystem condition and is fundamental to native species' habitat needs (e.g., Poff et al. 2010; Arthington 2012, Williams et al. 2019). Using ecosystem water budgets to create "functional flows" can reintroduce seasonal flow variability—such as winter pulses, spring snowmelt, and summer low flows (Figure 3)—to support a range of important physical, chemical, and biological processes (Yarnell et al. 2015; Poff 2017; Thompson et al. 2017). However, in highly impacted ecosystems it is insufficient to just apply water more strategically (although it often helps). To improve ecosystem condition and to make the most efficient use of ecosystem water, it is also necessary to connect flows to landscapes. Modifications of channels and their surrounding landscapes to reconnect flows to marshes, floodplains, and wetlands improves both structure and function of ecosystems (Whipple and Viers 2019). Without these improvements, providing more water may be insufficient for improving ecosystem outcomes.
- **Manage water quality and quantity together**. Increasing the volume of water allocated to ecosystems will be less effective if the quality is inadequate. Water quality characteristics—including temperature, salinity, nutrients, and other contaminants—change with variation in flow. This can reduce the ecosystem benefits of flow and habitat investments and threaten human health.[14] There are many ways to improve water quality, including operating reservoirs to preserve cold water; improving treatment of wastewater and urban stormwater runoff; reducing runoff of salts, pesticides, fertilizers and other contaminants; and re-establishing wetlands and riparian forests to receive and reduce contaminants.
- **Actively manage native and non-native species**. California's freshwater ecosystems support numerous non-native plants and animals. Many are fully integrated into these ecosystems and perform important

[14] For example, California is seeing a significant increase in the occurrence of harmful algal blooms in rivers, reservoirs, and estuaries. This may be due to a combination of changing nutrient content, increasing water temperatures, and altered flows. This is a global phenomenon well described by Paerl et al. (2011).

ecological functions. Some have become so abundant they are "invasive"—altering conditions to the detriment of ecosystems and human uses. Others are game species of cultural importance, valued by society (Bork 2018). Management of invasive species will be integral to achieving the desired ecosystem condition. But given the scale of alteration in the state's ecosystems, freshwater species will require indefinite and sustained management interventions, including catch regulations, hatcheries, species relocations, and assisted migrations to avoid extinctions and recover populations.

- **Manage at the appropriate scale**. It is important to remember that ecosystems function at large scales that depend on dynamic physical and biological connections. Actions taken upstream—such as species management, land use change, diversions, storage, or water quality management—affect structure and function downstream. For this reason, in many locations the watershed is the optimal scale for planning and implementation. This allows for managing different parts of the ecosystem for different objectives.[15]

Box 2: Ecosystem Water Budgets

Central to ecosystem-based management is the ability to flexibly deploy environmental water to improve ecosystem structure and function. The current approach, which focuses mostly on setting minimum instream flow and water quality standards, does not allow for this. Ecosystem water budgets (EWBs) offer significant improvements to address this challenge.

An EWB is a volume of water allocated to the environment. This water should be managed by an ecosystem trustee or other individual with both the responsibility and authority to allocate the EWB in the most efficient way to meet ecosystem objectives while reducing impacts on other water users. Critically, the EWB should have the status of a priority water right, allowing the trustee to store and use water in surface reservoirs and aquifers and to trade water with other users.

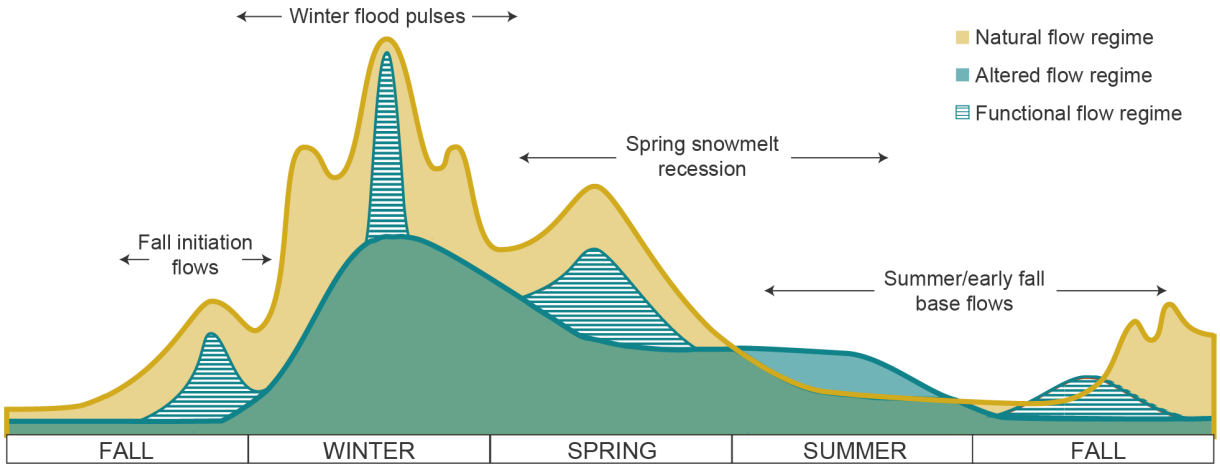
Establishing an EWB for a watershed creates assurances for stakeholders, regulators, and water users about environmental allocations. Most importantly, it integrates ecosystem and water management by giving the environment an asset—the EWB itself—along with a seat at the table.

See Mount et al. 2017 for a more complete description of the EWB concept.

[15] The scale of action required depends largely on the issues being addressed. For example, in parts of California where large, multi-purpose reservoirs determine flow and water quality, these reservoirs mark the upstream limits for some management actions—such as ecosystems supporting ocean-going salmon and steelhead. Conversely, efforts to improve conditions in montane lakes, such as those above dams in the Sierra Nevada—may appropriately focus solely on the lake and its adjacent watershed. The scale for managing estuaries can be very large, including both the watershed that feeds into them and their connections to ocean conditions.

FIGURE 3

Ecosystem water budgets can be used to create functional flows



SOURCE: Modified from Mount et al. (2017).

NOTES: This figure illustrates types of strategic functional flows that could be created with an ecosystem water budget. The hatched blue areas depict flow augmentation through releases from storage or reduced diversions to mimic key elements of the natural flow regime. These flow pulses promote biological responses, such as cues for reproduction or migration, and dispersal of organisms and seeds. They also help shape structural habitat through erosion and deposition of sediment.

Reasons to Adopt Ecosystem-Based Management

The decline in biodiversity of native freshwater-dependent species in California reflects undesirable changes in freshwater ecosystems. The causes are many, but the current approach to managing freshwater ecosystems—with its focus on mitigating the impacts of individual projects on a narrow range of listed species—is failing to arrest this decline. The consequences are broad. At minimum, declining biodiversity will be highly disruptive to water management, particularly as more and more species are pushed to the brink of extinction. More generally, the decline in ecosystem condition impacts multiple social and economic uses of water in the state.

We see at least four advantages to ecosystem-based management over current strategies:

- **Adaptable.** Ecosystem-based approaches allow managers to respond to opportunities, such as wet periods where environmental water can be stored for future use, or drought emergencies where stored water can be deployed to reduce impacts on habitat. The approach makes it easier to incorporate new science and understanding into management operations, and to conduct adaptive management experiments. Finally, unlike many current regulatory and conservation efforts, ecosystem-based planning can be inherently forward-looking, taking into account future conditions driven by climate change and population growth.
- **Reduces new listings**. The overall decline in native biodiversity is associated with changing ecosystems that impact a diverse array of plants and animals. The best approach to address this—and most efficient use of resources—is to focus on improving overall ecosystem condition, a fundamental tenet of ecosystem-based management.[16] This does not remove the need to continue efforts to recover species that are already

[16] Auerbach and BenDor (2015) provide a useful summary of freshwater ecosystem management designed to avoid new ESA listings.

listed. But recent research has shown that providing a mix of habitat—rather than focusing narrowly on critical habitat that is ideal for listed species—promotes species recovery better and improves overall ecosystem condition (Heirs et al. 2016).

- **Integrates human uses into ecosystem management**. Water management and regulation in California tends to view ecosystem health as a constraint on the uses of water and the development and operation of water projects. Ecosystem-based management instead seeks to integrate diverse social and economic uses of these ecosystems to improve both human well-being and ecosystem condition. It identifies the many benefits and beneficiaries of healthy ecosystems, and establishes the important discussion of trade-offs, moving away from overly simplistic, binary choices (i.e., people versus nature). Its governance structures are inclusive and engage a wide range of stakeholders, which can reduce conflict and litigation, particularly if comprehensive agreements are negotiated. Finally, the environment—by holding assets such as ecosystem water budgets—becomes a partner in water management, rather than just a constraint.
- **Aligns agency priorities and actions**. Many federal, state, and local agencies have project or regulatory responsibilities for water and ecosystem management (described below). This is often identified as one of the most costly and time-consuming impediments to on-the-ground actions to improve ecosystem condition. Although there has been considerable progress in streamlining some permitting and implementation, this remains a major challenge with significant room for improvement (Hanak et al. 2011; Robins et al. 2019).[17] Ecosystem-based planning creates the opportunity to organize and align regulatory permitting, monitoring, and management actions under a single plan.

Despite all these advantages, there are many challenges to implementing ecosystem-based management programs. A major concern is whether ecosystem-based management is permissible under the laws that govern water quality and endangered species. We next examine key laws that may facilitate or constrain this approach.

Ecosystem-Based Management and Current Law

Many laws regulate the management of freshwater ecosystems. Most germane to this report are California's Porter-Cologne Act—the principal law that governs water quality and flow—and state and federal ESAs. A range of other state and federal laws also affect ecosystem-based management, principally through permitting for restoration efforts (Box 3). A more thorough analysis of these laws is contained in Technical Appendix A.

Water Quality and Water Right Laws

The Porter-Cologne Act grants the State Water Board ("the board") and the nine regional water quality boards authority to set water quality standards that protect the multiple beneficial public uses of California's waters. The boards' powers are broad and flexible, allowing them to define economic, social, and ecological objectives; set priorities and timelines for actions; and regulate water diversions, water use, and discharges of pollutants. This

[17] Progress is being made to streamline and simplify permitting. For example, the State Water Board has filed a Notice of Preparation for a General Order to streamline water quality certifications for aquatic habitat restoration projects. And a recent review by Robins et al. (2019) demonstrates considerable opportunity to reduce agency overlap and conflicting priorities.

allows the boards to set water quality criteria based on ecosystem condition—a fundamental criterion of ecosystem-based management. These criteria are established in regional water quality control plans that must be periodically renewed, allowing for adaptive management.[18] The US Environmental Protection Agency (EPA) reviews these plans to determine whether they comply with the federal Clean Water Act.

The public trust doctrine and reasonable use mandate of Article X, Section 2 of the California constitution reinforce the state's authority to regulate using ecosystem-based management principles. Through a series of cases, the courts have affirmed the state's responsibility to manage water to meet an array of public needs, including the condition of freshwater ecosystems. This includes determining what uses of water are reasonable when attempting to balance multiple and competing demands. The state board can change the terms of water rights—including volume, timing, and place of diversion—to protect instream uses and public trust values. It also has the power to set aside blocks of water that can be used as ecosystem water budgets to meet these objectives.

The water quality and water rights laws therefore can incorporate the principles of ecosystem-based management (Technical Appendix A). Under these laws, the state board has authority to require functional flows and to create ecosystem water budgets. In certain situations, the board also can require water right holders to make structural habitat improvements. The board has exercised this authority sparingly, however—an approach that foregoes a crucial part of ecosystem-based management: concurrent management of flow, water quality, and structural habitat to make the most efficient use of water allocated to improve ecosystem condition.[19]

State and Federal Endangered Species Acts

Since their inception, the ESAs have prevented the extinction of all but a handful of California's most at-risk aquatic and terrestrial species. But their focus on listed species makes them an inadequate tool for managing for overall ecosystem health and the multiple benefits derived from freshwater ecosystems. Moreover, administration of these acts tends to seek narrowly prescribed actions that limit discretion in decision making and the necessary flexibility for adaptively managing ecosystems.

Yet the ESAs do not preclude the adoption of ecosystem-based strategies. Indeed, in some watersheds—particularly those with multiple listed species—ecosystem-based management may represent the best means of achieving the objectives of the ESAs.

As background, both the state and federal ESAs prohibit the unauthorized "taking" (e.g., killing, capturing, harming) of any protected species as well as actions that could place the species in jeopardy of extinction, including degradation of habitat considered critical. In addition, the federal act requires federal agencies that operate, license, or fund water development projects to consult with the regulatory agencies responsible for administering the ESA—the National Marine Fisheries Service and the US Fish and Wildlife Service—to ensure that their activities do not jeopardize the existence of listed species or adversely modify their critical habitat. These consultations typically result in "biological opinions," which guide project operations to comply with these strictures. The biological opinions and take limitations may affect other regulatory decisions, including water quality decisions by the state and regional boards, in ways that are in tension with the broader objectives and more flexible strategies of the water quality laws.

[18] By law, water quality control plans must be reviewed (and, if appropriate, updated) every three years. In practice this rarely occurs given the administrative complexity involved.
[19] The most prominent example where the board has used this authority is Mono Lake (see Technical Appendix A).

On the surface, ESA provisions could pose an impediment to ecosystem-based management. Yet, the state and federal ESAs contain regulatory flexibility that allow water projects to operate consistent with the take limitations. Both statutes also emphasize the need to protect habitat—specifically, the ecosystems that listed species depend upon. Finally, state and federal law authorize the creation of conservation plans and other programs that address ecosystem condition for multiple species, including species that are candidates for future listing.

The federal ESA provides for the creation of Habitat Conservation Plans (HCPs) that allow for incidental take of listed species that occurs during project operations and maintenance. These can be crafted to protect multiple species (including species that are not yet listed but are deemed vulnerable) and their habitat, which in turn requires a broader focus on ecosystem conditions. Similarly, California law authorizes the development of Natural Community Conservation Plans (NCCPs) that provide for comprehensive conservation of multiple wildlife species, including species not currently protected by ESAs. These plans are more focused on ecosystem condition with the goal of conserving native biodiversity, rather than protecting specific species. The Natural Community Conservation Planning Act, which authorizes NCCPs, calls for conservation actions to be compatible with economic development and other human uses of land and water.[20]

HCPs and NCCPs provide a way to set broad conservation objectives that are better aligned with ecosystem-based management. Yet, despite important exceptions, these tools are seldom used for freshwater ecosystems. Even fewer programs are forward-looking, crafting and implementing plans to protect species that are not currently listed but are at risk of listing as climate and other conditions change. As described below, one notable exception is the Upper Santa Ana River HCP, currently under development, which includes these important features.

Despite their advantages, HCPs and NCCPs also face important constraints: they are difficult to negotiate and it can take many years to acquire necessary permits. Some parties—including the fish and wildlife agencies and some environmental groups—have been reluctant to risk granting long-term regulatory commitments needed to engage land and water users in these agreements.[21]

Nevertheless, HCPs and NCCPs offer opportunities to engage in holistic management of ecosystem condition—rather than on habitat for single species—in setting overall conservation objectives. The challenge is twofold: first, how to make these plans easier to accomplish; and second, how to better align them with water quality control plans and other permitting processes. We describe some examples of current progress in meeting this challenge in the following section.

[20] State and federal law also recognize Safe Harbor Agreements, which protect landowners and water operators who invest in conservation actions against the risk of future listings and more stringent regulatory requirements that may result from the recovery of listed species. In addition, although rarely used, the federal government will permit multi-species Candidate Conservation Agreements (CCAs) and Candidate Conservation Agreements with Assurances (CCAAs), that put in place actions to avoid future listings by protecting ecosystems while providing protection for landowners and water users. See Technical Appendix A for a discussion.

[21] The efforts to develop the Bay Delta Conservation Plan (an HCP/NCCP for the Sacramento–San Joaquin Delta) illustrate the complexity of securing these agreements. The goal was to develop a comprehensive, multi-species conservation plan for the Delta that would permit the construction of tunnels to divert water from the Sacramento River and deliver it to the Central Valley Project and State Water Project pumps in the south Delta. This program collapsed when federal fish and wildlife agencies refused to grant a 50-year permit due to uncertainties about the project (Mount et al. 2015). An added complication is that under the federal ESA, federal projects like the Central Valley Project do not generally qualify for HCP status. This issue was unresolved at the time of the collapse of the effort.

Box 3: Other Relevant Laws for Ecosystem-based Management

In addition to the Porter-Cologne Act and ESAs, a variety of other laws and regulatory programs affect ecosystem-based management strategies. In alphabetical order, here are a few of the most important.

California Fish and Game Code § 5937. Requires all dams to bypass or release sufficient water "to keep in good condition any fish that may be planted or exist below the dam." The State Water Board (with the California Department of Fish and Wildlife) has broad power to decide how best to restore and protect various fish species, and it could employ multi-benefit approaches to make this determination.

Clean Water Act § 404. Requires a permit, issued by the US Army Corps of Engineers, for the discharge of dredged or fill material into the "waters of the United States." The corps consults with fish and wildlife agencies on permit applications. Permit applicants must also obtain state § 401(a) certification and the corps must include state water quality criteria and other conditions imposed by the board.

Federal Power Act and Federal Energy Regulatory Commission (FERC) Licensing. All non-federal hydroelectric power projects must be licensed by FERC, which must give "equal consideration" to power production, energy conservation, recreation, and the protection, mitigation, and enhancement of fish and wildlife. This directive promotes multi-benefit, ecosystem-based approaches. Under the federal Clean Water Act § 401(a) the board must certify that the license will comply with state water quality standards.

Habitat Restoration and Enhancement Act. An expedited approval process for small-scale habitat restoration projects. Projects must be voluntary, and the board must certify that the project qualifies under § 401 General Water Quality Certification for Small Habitat Restoration Projects. Approval can include incidental take authorization in lieu of a permit under the California ESA, but not the federal ESA.

Lake or Streambed Alteration Agreements (LSA). Required for projects that alter natural flow or change the bed and banks of rivers and lakes, including for most habitat restoration activities, unless the project is authorized under the Habitat Restoration and Enhancement Act (see below).

NEPA and CEQA. The National Environmental Policy Act (NEPA) requires the preparation of an environmental impact statement for major federal actions that may "significantly affect the quality of the human environment." The California Environmental Quality Act (CEQA), the state counterpart to NEPA, requires state and local agencies to prepare an environmental impact report to identify effects of a project, alternatives to it, and whether effects can be mitigated.

Regional Conservation Investment Strategies (RCIS). Encourages voluntary conservation actions to conserve focal species through regional restoration strategies. The act does not impose regulatory requirements. However, where an RCIS is established, compensatory mitigation credit agreements can be developed under CEQA, California ESA, and LSA if it is in line with the RCIS.

Sacramento–San Joaquin Delta Reform Act. Created the Delta Stewardship Council (DSC) and directed it to prepare a Delta Plan to achieve the coequal goals of "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem." Plan objectives include: maintenance of flows to support the estuary, improvement of water quality, restoration of habitat, promotion of water conservation and water use efficiency, and evaluation of new water supply infrastructure.

Sustainable Groundwater Management Act. Requires groundwater sustainability agencies to prepare and implement plans to achieve sustainable groundwater management by the early 2040s. The act prohibits actions that can cause significant and unreasonable "undesirable results." This includes actions that adversely affect groundwater-dependent freshwater ecosystems.

Current Progress in Ecosystem-Based Management

Federal, state, and local agencies are already including elements of ecosystem-based management in some of their species and water management programs. For example, efforts by the State Water Board (2019) to develop a water quality control plan for the Sacramento–San Joaquin Delta adopt many of the principles of ecosystem-based management, including setting aside a block of water for the environment (similar in concept to an ecosystem water budget) and promoting voluntary agreements.

To evaluate progress in ecosystem-based management, we reviewed 12 water and habitat management programs across California (Figure 4). All address key aspects of ecosystem-based management and offer potential (if incomplete) models for future programs. For each program, we made a subjective evaluation of how well its efforts adhered to the management framework and actions outlined above. These programs are summarized below. Technical Appendix B includes a more complete summary and sources for additional information.

- **Central Valley Flood Protection Plan** (2017). A plan for managing flood risk in the Central Valley that makes a notable effort to integrate ecosystem improvement into flood control projects.
- **Central Valley Wildlife Refuges** (1992). A management program for wetlands in the Central Valley, involving federal, state, and local agencies and environmental groups, focused primarily on waterbirds. This project offers a model for regional coordination among diverse entities and includes a water budget for the ecosystem.
- **Delta Plan** (2019). A management plan required by the Delta Reform Act (2009), which seeks to balance the goals of water supply reliability and ecosystem health. The plan takes a unique approach to describing a desired ecosystem condition.
- **Green Diamond Aquatic Habitat HCP** (2007). A species conservation program to support habitat restoration and reduce impacts of logging on North Coast rivers containing multiple listed species of fish and amphibians. Although protecting listed species is a goal, the program takes an ecosystem approach to management.
- **Kern Water Bank Authority HCP/NCCP** (1997). A program to manage wetlands and terrestrial habitat within the area of the Kern Water Bank to support multiple listed species. One of the older HCP and NCCPs in the state, the effort integrates intermittent wetland habitat with water storage operations.
- **Lower Colorado River Multi-Species Conservation Program** (2005). An HCP led by the US Bureau of Reclamation that seeks to recover multiple federally-listed aquatic and terrestrial species. This comprehensive program conducts extensive species management and commits to avoiding future listings.
- **Mono Basin Restoration Program** (1998). A program to restore ecosystems in the Mono Basin, based on court orders, a settlement agreement, and a State Water Board decision. This landmark program manages a comprehensive suite of public trust values based on improving ecosystem condition.
- **Putah Creek Restoration Program** (2000). Based on a settlement agreement, this program seeks to improve ecosystem conditions in lower Putah Creek through changes in flow regime and habitat management. The effort is widely recognized for its community involvement and success at habitat restoration using functional flows.
- **San Joaquin River Restoration Program** (2012). This program, based on a settlement agreement, seeks to improve ecosystem conditions on the San Joaquin River. Although primarily focused on spring-run Chinook salmon, the program benefits a wide range of species and includes a water budget for the ecosystem.
- **Upper Santa Ana River HCP** (2019). A draft HCP that seeks to improve ecosystem conditions for a broad range of species and support permitting for all water management-related activity in the watershed.

This is perhaps the most comprehensive ecosystem-based approach of the programs reviewed here and may be a model for management of highly urbanized watersheds.

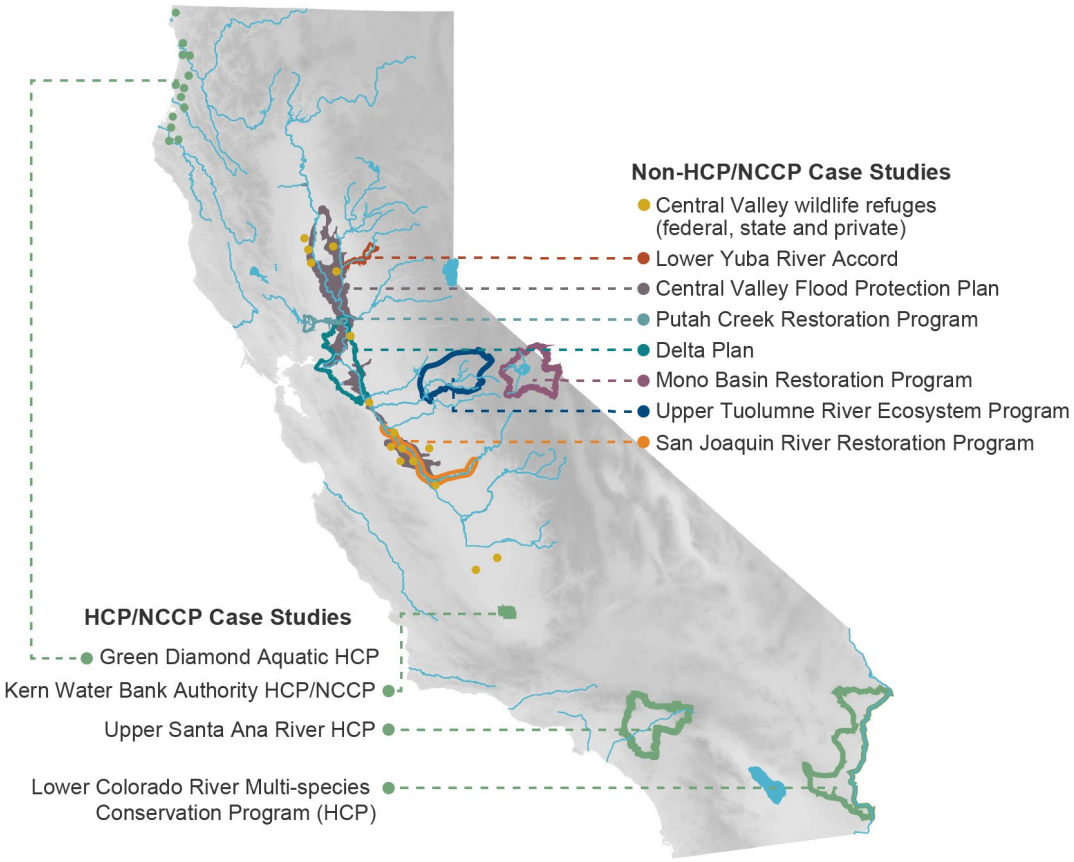
- **Upper Tuolumne River Ecosystem Program** (2006). A program to integrate ecosystem restoration with water and hydropower management below Hetch Hetchy reservoir. The project is considered a model of multi-benefit management.
- **Lower Yuba River Accord** (2008). A settlement agreement adopted by the board that seeks to improve river conditions for anadromous fish on the lower Yuba River while balancing water supply and flood management needs. The accord is widely recognized as a model for cooperative, multi-benefit water management and has expanded beyond its early focus on listed species.

The impetus for all but two of these programs was the need to acquire permits for changes in operations and maintenance of water infrastructure. Most also involved settlements following litigation with regulatory agencies, third parties, or both. The exceptions—the Delta Plan and the Central Valley Flood Protection Plan—were responses to legislative directives that set multi-benefit management as a priority.[22]

This pattern highlights how the goals and objectives for managing freshwater ecosystems in California are still principally shaped by the need to acquire ESA and water quality permits or respond to litigation. Although there is progress toward ecosystem objectives in these programs, too often parties focus solely on actions sufficient to secure a permit to harm species listed under federal and state ESAs. In our view, this is a fundamental weakness in California's approach to ecosystem management, and a missed opportunity to improve freshwater ecosystems to create broader social, economic, and environmental benefits and to adapt to an uncertain future. Steps can be taken to improve existing programs and encourage more comprehensive ecosystem-based management plans.

[22] Neither program is currently requesting permits (although the flood control plan seeks eventually to aggregate permitting into a single program), but both have gone through CEQA review.

FIGURE 4
Locations of case studies in ecosystem-based management



SOURCE: Developed by the authors from multiple sources.

A Way Forward: Sustainable Watershed Management Plans

In an earlier PPIC report examining environmental management during the 2012−16 drought, the authors recommended that California promote the development of watershed-level ecosystem plans (Mount et al. 2017). This recommendation was based on the conclusion that most freshwater ecosystem management during the drought crisis was reactive, ad hoc, and poorly organized. Actions to manage ecosystems—usually focused on listed species—were less effective than they could have been, and the process created unnecessary controversy. By committing to pre-drought planning, managers and stakeholders can set priorities, identify trade-offs, and create water allocation and habitat plans to better mitigate impacts and provide greater certainty for freshwater ecosystems and the water user community.

We expand here on that recommendation—and build upon progress outlined in the previous section—with the suggestion that the state promote *sustainable watershed management plans*. These plans would incorporate the principles of ecosystem-based management, including the management framework and actions described above.

The state—with support from the legislature—could take one of two approaches to promote investments in this type of planning: incentivize willing coalitions of stakeholders and water managers who commit to develop watershed plans that can be adopted by regulatory agencies; or require it, using the model of mandatory groundwater basin planning under SGMA.

Incentivized Sustainable Watershed Management Planning

We recommend the State Water Board—with its broad water quality and water rights authorities—take the lead in promoting sustainable watershed management plans. In consultation with other state and federal regulatory agencies, the board would provide guidance, technical support, and oversight for plan development. The process should include these objectives:

- **Establish criteria for development of sustainable watershed management plans**. The board would set the goals and objectives for the plan based on the principles of ecosystem-based management described in this report. The board also would give guidance on creating a management framework and a robust, inclusive planning process that identifies the benefits and beneficiaries of improved ecosystem conditions. This should include broad representation from local water and land use planning agencies, tribal representatives, environmental groups, state and federal regulators, and other stakeholders.
- **Encourage the development of comprehensive agreements.** These agreements would be between the regulatory agencies, water right holders, and water management agencies (e.g., wastewater dischargers, flood management districts, and others), and would be negotiated with the involvement of other key stakeholders. Integral to this effort would be the negotiation of ecosystem water budgets and other management actions and financial commitments (see Box 4 for an example of on-going efforts to negotiate comprehensive agreements—termed voluntary agreements in that effort—for the Sacramento–San Joaquin Delta). By involving multiple agencies in the process, this approach can be used to align permitting for ecosystem and water management actions under a single, coordinated plan.
- **Establish timelines for plan development**. The board would also establish a schedule for developing and implementing the plan and for periodic revisions to meet regulatory requirements. For example, the board might allow five years to develop a plan, with an additional 20 years for implementation, with revisions every five years.[23]
- **Adopt agreements as water quality control plans**. If sustainability plans—incorporating comprehensive agreements—meet the goals and objectives for ecosystem condition and existing state water quality laws, the board could adopt the plan as the water quality control plan for the watershed or incorporate it into the existing water quality plan (Box 4). Where ESA-listed species are involved, plans should seek to eventually meet HCP/NCCP requirements for habitat management and incidental take of listed species, or use other instruments—such as Safe Harbor Agreements—as appropriate (see footnote 20).

The legislature could assist the board's implementation of this policy by providing funding and directing other state agencies—including the California Departments of Water Resources (DWR) and Fish and Wildlife (DFW)—to offer technical support to develop the sustainable watershed management plans. To make this support most effective, funding should be contingent upon developing a plan capable of obtaining necessary regulatory

[23] We suggest 20 years for implementation to allow the parties and the board to evaluate the objectives and policies of the plan over several wet and dry cycles. As with SGMA, a more frequent process of plan revisions—such as every five years—would allow for adjustments along the way.

approvals within a defined timeframe. The existing regulatory framework would serve as a backstop if efforts fail to produce a sustainability plan.

This incentivized approach will work best in watersheds where there are willing coalitions seeking to develop plans that improve conditions and provide regulatory relief.

Box 4: Voluntary Agreements and the Delta Water Quality Control Plan

At the time of this writing (fall 2019), a large, complex effort is underway to establish a revised water quality control plan for the Sacramento–San Joaquin Delta and its watershed. The uses and regulation of Delta waters are highly contested, and long-term solutions have proved elusive. The State Water Board (2019) proposed a suite of changes in operations that would increase environmental flows in watershed tributaries and the Delta to improve conditions for native fishes, principally salmon and steelhead, and other beneficial uses. The board approved the first phase of the revised water quality control plan—which focuses on the San Joaquin River—in December 2018, with the anticipation that a full plan including the Sacramento River and the Delta will be approved in late 2019.

The water user community—along with the California Natural Resources Agency, California EPA, and various nonprofit groups—has been trying to craft agreements that the board can adopt in lieu of the revised plan. Termed "voluntary agreements," they seek to reduce the impacts of diversion reductions to the water user community while still meeting the biological objectives set forward by the board, principally through major investments in structural habitat and modest increases in water for the environment.

The draft voluntary agreements—like the board's proposed approach—are more limited in scope than what we envisage for ecosystem-based management, and there are reasonable disagreements over proposed new water for the environment and habitat restoration. Yet in several respects, the draft agreements follow much of the management framework and actions outlined above. Common elements include commitments to a combination of investments in structural habitat, flexible use of water for functional flows, collaborative governance and science to support adaptive management, and funding by water users to support science and the acquisition of additional water for ecosystem purposes. Whether these agreements will be successful remains to be seen, but the framework shows promise.

Mandated Sustainable Watershed Management Plans

A second option would be for the legislature to mandate—rather than incentivize—the development of sustainable watershed management plans. This process could be modeled on SGMA, which requires that water users in priority basins achieve sustainable groundwater management by the early 2040s. Water users self-organize into groundwater sustainability agencies (GSAs), which in turn prepare and administer groundwater sustainability plans (GSPs). If an agency either does not prepare an acceptable plan or fails to meet sustainability

goals, SGMA authorizes the State Water Board to draft its own plan for the basin, which may include limits on pumping and fees to support management actions.[24]

Sustainable watershed management plans—modeled after GSPs—could take many forms, but they should include all elements of the incentivized planning approach described above, including the board setting criteria for the plans, encouraging comprehensive agreements, setting timelines, and adopting plans that meet water quality control plan goals and objectives. Mandated planning and management, however, would require two additional elements:

- **Designated priority watersheds.** The board—in consultation with DWR and DFW—would determine which watersheds will be required to develop sustainable watershed management plans. The legislature would set the criteria for designating priority watersheds, while the board would determine the boundaries of the planning area. Water users and stakeholders would then self-organize to form sustainable watershed agencies, similar to GSAs under SGMA.
- **Consequences of failing to meet objectives.** Following the approach of SGMA, if a sustainability plan is insufficient or inadequately implemented, the board would exercise its authority to set biological and water quality standards and use its water rights authorities to achieve the plan's objectives. To be most effective at encouraging compliance, it would be appropriate for the board to adopt a provisional water quality control plan that will go into effect if sustainability plans are insufficient or not implemented.[25]

There are strengths and weaknesses to incentivized or mandated approaches to planning. Incentivized approaches are less controversial, but they will be employed successfully only in those watersheds where there are functional coalitions willing to take on the difficult process of planning, and leaders willing to champion the effort. Conversely, although mandated planning in critical watersheds is likely to improve conditions, this would create a significant administrative and financial burden on state and local agencies, water users, and other stakeholders. Both approaches—mandated plans in critical watersheds and incentivized plans in less critical watersheds—may be warranted.

An additional concern is the role of the federal government in sustainable watershed management plans. Although the state retains power over water rights and quality, it lacks the authority to compel the US Bureau of Reclamation, which operates the Central Valley Project, to participate in the development of these plans and to enter into comprehensive agreements. In addition, federal agencies like the US Fish and Wildlife Service, National Marine Fisheries Service, and US Army Corps of Engineers have independent permitting authorities. Short of new federal legislation, the goal should be to include federal agencies in all phases of planning in order to better align priorities and actions and, where possible, to streamline permitting.

[24] A complete description of SGMA and its requirements can be found at the Department of Water Resources' SGMA web page.

[25] In the ongoing negotiations over the water quality control plan for the Delta (Box 4), the board has adopted a plan for the San Joaquin River and identified a draft plan for the Sacramento River that clearly indicates the consequences of failing to achieve adequate voluntary agreements. This regulatory threat is an incentive for the parties to conclude an agreement.

Conclusion

California's freshwater ecosystems are changing in undesirable ways, contributing to the decline in native biodiversity, as well as increased flood risk, reduced water supply reliability, and declines in other ecosystem functions that affect people. Political arguments, litigation, and management remain focused on efforts to prevent extinction of listed species and to cope with trade-offs between water supply and listed species protection. This approach is unlikely to alter the trajectory of ecosystem decline, with all its undesirable social, economic, and environmental consequences. This report draws three principal conclusions:

- Ecosystem-based management is a better alternative than current approaches to freshwater ecosystem management. Many programs are starting to adopt its principles and practices, but much more needs to be done.
- Ecosystem-based management is consistent with applicable state and federal laws. Clean Water Act laws promote it and the ESAs allow for it. Agencies need to take advantage of this flexibility.
- Sustainable watershed management plans, backed by binding comprehensive agreements, are the best way to accomplish ecosystem-based management. These agreements can be adopted by state and federal regulators to meet Clean Water Act and ESA requirements and can align other agency priorities and actions.

Achieving ecosystem-based management does not require new state or federal legislation. It could be achieved simply by agencies changing their approach to implementation and by promoting coordination, streamlined planning and permitting, and alignment of goals and objectives. However, legislation to help incentivize or mandate sustainable watershed management plans would speed the effort and increase its likelihood of success.

Broadening the management focus from a species-by-species approach to one that addresses overall ecosystem condition—and maximizes the multiple benefits derived from ecosystems—will not happen quickly or easily. Negotiation of comprehensive agreements to guide this change will be neither simple nor without controversy. But California needs a new approach that sets broader ecosystem conservation priorities, seeks to avoid future ESA listings, makes it easier to adapt to changing conditions, and integrates human uses of the ecosystem. Ecosystem-based management is the best way to get there.

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ABOUT THE AUTHORS

Jeffrey Mount is a senior fellow at the PPIC Water Policy Center. He is an emeritus professor in the Department of Earth and Planetary Sciences and founding director of the Center for Watershed Sciences at the University of California, Davis. He is a geomorphologist who specializes in the study of rivers, streams, and wetlands. He has served on many state and federal boards and commissions that address water resource management issues in the West. He has published more than a hundred articles, books, and other publications, including the seminal book *California Rivers and Streams* (UC Press). He holds a PhD and MS in earth sciences from the University of California, Santa Cruz.

Brian Gray is a senior fellow at the PPIC Water Policy Center and professor emeritus at the University of California, Hastings College of the Law in San Francisco. He has published numerous articles on environmental and water resources law and coauthored a variety of PPIC reports, including the 2011 book *Managing California's Water: From Conflict to Reconciliation*. He has argued before the California Supreme Court and the US Court of Appeals in cases involving wild and scenic rivers, water pricing reform, takings, and water rights and environmental quality. He holds a JD from UC Berkeley, and a BA in economics from Pomona College.

Karrigan Börk is an acting professor of law at the University of California, Davis, and an associate director of the Center for Watershed Sciences. He researches and writes on issues at the intersection of science and the law. His past work includes publications on water law, administrative law, the Endangered Species Act, restoration and reconciliation, and management of nonnative species. He holds a PhD in ecology from the University of California, Davis, and a JD from Stanford Law School.

James Cloern is an adjunct fellow at the PPIC Water Policy Center. He retired in 2019 from a 43-year career at the US Geological Survey. His research is designed to understand how changes in estuarine-coastal ecosystems are driven by human activities and climate variability. He holds a PhD in zoology from Washington State University.

Frank Davis heads the biogeography lab at the Bren School of Environmental Science and Management at the University of California, Santa Barbara. His research focuses on the landscape ecology of California plant communities, the design of protected-area network, rangeland and farmland conservation, and the biological implications of regional climate change. He holds a PhD in geography and environmental engineering from The Johns Hopkins University**.**

Ted Grantham is an adjunct fellow at the PPIC Water Policy Center, a cooperative extension specialist, and an adjunct professor in the department of environmental science, policy, and management at UC Berkeley. He is the PPIC CalTrout Ecosystem Fellow. His research explores the effects of climate change and water management on freshwater ecosystems. He holds a PhD in ecosystem sciences from the University of California, Berkeley, and a BS in biological sciences from Stanford University.

Letitia Grenier is a senior scientist at the San Francisco Estuary Institute, where she co-directs the Resilient Landscapes Program. Her focus is working with partners to develop large-scale, nature-based solutions for restoring benefits provided by ecosystems against the backdrop of development and climate change. She holds a PhD in environmental science, policy, and management from the University of California, Berkeley and a BA in biology and film/video from Middlebury College.

Jennifer Harder is an associate professor at University of the Pacific, McGeorge School of Law where she teaches water, environmental, and administrative law. She was previously a partner at Downey Brand LLP, Sacramento, and served as law clerk to the Alaska Supreme Court. She is coauthor of *Cases and Materials on Water Law*, 9th ed. She holds a JD from the University of California, Davis.

Yusuke Kuwayama is a fellow at Resources for the Future (RFF) in Washington, DC. His primary research field is natural resource economics, with a focus on water resources and ecosystems. He holds a PhD in agricultural and applied economics from the University of Illinois at Urbana-Champaign.

Peter Moyle has been working on ecology and conservation of freshwater and estuarine fishes of California since he obtained his PhD from the University of Minnesota in 1969. He is author or co-author of numerous books and papers on the state's fishes, and is Distinguished Professor Emeritus in the Department of Wildlife, Fish and Conservation Biology and associate director of the Center for Watershed Sciences at the University of California, Davis.

Mark Schwartz is a professor in the department of environmental science and policy at the University of California, Davis. His research focuses on climate change impacts to ecosystems with a focus on natural resource decision-making support. His work largely focuses on conservation science with an emphasis on forested ecosystems. He holds a PhD in biology from Florida State University.

Alison Whipple is an environmental scientist in the Resilient Landscapes Program at the San Francisco Estuary Institute. She has an interdisciplinary background in hydrology and ecology and is focused on the science and decision-support tools for promoting physical and ecological processes in California's riverine and floodplain landscapes. She holds a PhD in hydrologic sciences from UC Davis.

Sarah Yarnell is an associate professional researcher at the Center for Watershed Sciences at the University of California, Davis. She conducts interdisciplinary research that applies understanding of river ecosystem processes to managed systems, with a focus on the development and maintenance of riverine habitat for native aquatic species. She is currently working with colleagues to apply a functional flows approach to the development of environmental flow criteria throughout California. She holds a PhD in hydrologic sciences from the University of California, Davis.

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Public Policy Institute of California
500 Washington Street, Suite 600
San Francisco, CA 94111
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F: 415.291.4401
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PPIC Sacramento Center
Senator Office Building
1121 L Street, Suite 801
Sacramento, CA 95814
T: 916.440.1120
F: 916.440.1121