Resilience Metrics White Paper

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Introduction

The Integrated Climate Adaptation and Resiliency Program (ICARP), established through Senate Bill 246 (2016; Wieckowski), is a critical tool in California's strategy and leadership on climate adaptation and resilience. ICARP is charged with developing a cohesive and holistic response to the impacts of climate change by coordinating state and local adaptation efforts to expeditiously advance implementation. Through the enabling legislation, ICARP is centrally focused on efforts that advance climate equity and support integrated climate strategies, or those strategies that benefit both greenhouse gas reductions and adaptation. Senate Bill 246 established two driving components of ICARP: the development of an Adaptation Clearinghouse (http://resilientca.org) and the formation of a Technical Advisory Council or TAC (http://opr.ca.gov/planning/icarp/tac).

The Climate Resilience Metrics Workgroup is housed under the TAC and was formed to invite experts from around the world, support and collaborate with existing state efforts, and share findings and engage with the public. As an input into discussions with the workgroup, this white paper will begin to share the current landscape of adaptation metrics – strengths in the California case, gaps in resilience metrics generally, and suggestions for a final product for the workgroup. The objective of this paper is to appropriately frame four important goals in developing resilience metrics:

1. identifying needs for adaptation,
2. tracking implementation of actions,
3. guiding allocation of resources,
4. and assessing achieved results for state planning purposes.

This white paper synthesizes research documents and guidance from ICARP and other state programs, state and local plans, actions and activities and academic literature and analysis.

Placeholder: key findings/TAC WG Recommendations

Definitions

There are many peer-reviewed and vetted definitions for terms in the fields of adaptation and resilience. In its impact report, ICARP outlines the consensus definitions California uses for climate adaptation, resilience, and mitigation, vulnerable communities and equity, and points to other key state resources with a glossary of California-endorsed definitions.[1]

For defining climate and resilience metrics, indicators, and other terms to connote ways of measuring climate adaptation and resilience, there are also countless definitions and part of the work ahead for the workgroup will be to settle on an operational definition for some of these terms used.

While presented as a purpose statement, the 2018 update to Safeguarding states that metrics should be developed to track progress in the following areas:

1. Changing Climate Conditions: Once key risks are identified; metrics should be identified to track the progress and occurrence of change.

2. Resilience Outcomes: Metrics should be developed that track the performance of a plan or investment, both in terms of resilience to climate change and in meeting management objectives. Metrics should track proactive action taken by the state to enhance resilience, as well as the effect of past actions.

Another example, or approach to defining "indicators" comes from the California Tahoe Conservancy's integrated vulnerability assessment:

*An **"indicator"** refers to a characteristic used to describe something.*

- *An indicator can consist of a process, or a condition.*
- *However, given the difficulty of directly measuring many processes, for our discussions we propose (1) using the term "indicator" to refer to a site-specific condition at a given moment, and (2) that using multiple indicators taken together (especially when measured over time) can approximate a process.*
- *Indicators can be Output or Outcome focused.*
    - *Outcome-based metrics represent a specific, observable and measurable indicator of an outcome.*
    - *Output-based metrics measure the inputs to a given system and may be used to share progress on an outcome-based metric. These two metrics, taken together, may holistically be thought of as impacts.*[2]

[1] Integrated Climate Adaptation and Resiliency Program, Impact Report and 2020 Program Recommendations. Retrieved on June 5, 2020: http://opr.ca.gov/docs/20200427-ICARP_Impact_Report.pdf

[2] Grunwaldt, Alfred; Salinas, Andrea, Measuring Climate Resilience: A Common Framework to Take the First Step, (2019). Retrieved on May 29, 2020: https://blogs.iadb.org/sostenibilidad/en/measuring-climate-resilience-a-common-framework-to-take-the-first-step/

*Also from the California Tahoe Conservancy's integrated vulnerability assessment: Measuring an indicator implies identifying an appropriate unit of measurement (a **"metric"**), and then creating or utilizing a corresponding data set.*

- *In practice, the data available for different landscapes varies greatly.*
- *The ability to combine multiple indicators to approximate a Desired Landscape Outcome (DLO) allows different landscapes to draw on the data available to them, yet still speak to the same DLO, and compare themselves.*
- *In some cases, an indicator and metric may be identical (e.g., trees per acre). And in some cases, complex indicators may combine multiple metrics and data sets.*

Placeholder: TAC recommended definitions for metrics, indicators, and other key terms.

Overview of Resilience Metrics

California's continued efforts to develop a cohesive and integrated climate resilience and adaptation framework draw from a suite of existing programs, policies, research, and place-based actions, all of which are foundational to developing a suite of actionable resilience metrics. For example, ICARP hosts the Adaptation Clearinghouse (www.resilientca.org), an online resource for policymakers and others working to address the effects of climate change, housing numerous case studies, state guidance, local plans, and tools and data in measuring California's response to climate change. As a formational document in the resilience and adaptation space in California, the 2018 Update to the Safeguarding California Plan (Safeguarding) closes with an explanation of how adaptation progress will be tracked and reported on, as well as a look ahead to important adaptation initiatives. Its appendices cover a series of proposed metrics to evaluate climate impacts and state government adaptation responses, an overview of how research in California's Fourth Climate Change Assessment will inform Safeguarding California's policy recommendations, a glossary of terms, and a guide to the acronyms used in the document. Given Safeguarding's place in adaptation and resilience discussions in California, this is a key input to this workgroup.

In addition, Cal-Adapt provides wide-ranging datasets on how climate change might affect California. California's Office of Environmental Health Hazard

Assessment (OEHHA) releases a periodic report on indicators of climate change in California, with the most recent version released in 2018. While, this sample of resources makes clear that California is well positioned to continue and expand its leadership in resilience metrics work, additional work is needed to synthesize the current state of play for.

In order to approach the new and substantive topic area of resilience metrics, we suggest using the existing and foundational elements of the state's resilience framework, including the ICARP Vision and 2018 Safeguarding, to organize this effort into three systems: Natural, Built, and Social.

Naturally, there are linkages between these systems, and areas where these systems are synonymous. Indeed, some metrics might be valuable for multiple systems. For example, in Appendix B of Safeguarding, the "climate events" metric – defined as "amount in millions of dollars…this amount will grow as climate change accelerates, further stressing transportation assets and the system at large"[3] - could be applied as an economic metric with application across a natural, social, or built context.

While organizing metrics into these three systems provides consistencies with the state's current frame, there may be additional cross-sectional metrics and topics TAC members may wish to include as part of each system. Two we wish to mention for TAC consideration and feedback are the degree to which each system is affected culturally and economically. In terms of economic systems, we might consider the vulnerability (and resilience) of our economy to climate change, the readiness of the financial sector to fund resilience actions in California, and more. There may be additional priority topics, beyond economics and culture, that should be included within each system.

The following sections, while still in draft form, include: (1) an initial definition for each system; (2) a literature review of the current state of resilience metrics; and (3) recommendations on proposed or useful metrics for consideration. The goal is to develop a baseline and discussion guide for future workgroup discussions. In coordination and collaboration with the TAC, we hope to build out each section prior to workgroup meetings on specific systems to provide a more complete survey of the literature and metric possibilities.

Resilience Metrics for Natural Systems

[3] Safeguarding 2018, Appendix B. Retrieved on June 5, 2020: https://resources.ca.gov/CNRALegacyFiles/wp-content/uploads/2017/05/DRAFT-Safeguarding-California-Plan-Appendix-B.pdf

Draft Definition of Resilient Natural Systems: In a March 2019 PowerPoint to the TAC, a suggested draft definition for resilient natural systems is that "natural systems adjust and maintain functioning ecosystems in the face of change."[4]

Literature Review

Metrics for resilience in the context of ecology have been broadly described as those measuring "the capacity of an ecosystem to maintain its state and recover from disturbances."[5]

The metrics discussion in relation to natural systems has been characterized by difficulty "...in evaluating how ecosystem responses to disturbances and stressors vary over large heterogeneous landscapes..."[6] Thus, until recently, resilience metric literature has focused on theory and definitions underpinning a possible effort to create and monitor climate resilience in ecosystems. [7][8][9]

Some authors are now beginning to apply theory and definitions, like the definition above, to assert a framework for ecological resilience metrics. For example, one author asserts an effort to apply a management strategy for remediating the sagebrush biome amid climate change and human impacts on the ecosystem. [10]

First, the author posits to first define management goals – is it to remediate habitat? Increase overall resilience? Preserving a keystone species? Upon defining management goals, the author then suggests finding outcome-based indicators to assist in measuring that ecosystem. In the case of the sagebrush ecosystem, the author recommends indicators like "soil temperature and moisture regimes...[that] closely reflect climate and vegetation patterns."

Metrics

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[4] ICARP TAC, Draft Outline Vulnerability Assessment Framework, (2020). Retrieved on June 4, 2020: http://opr.ca.gov/meetings/tac/2019-03-22/docs/20190322-7_DRAFT_outline_Vulnerability_Assessment_Framework.pdf

[5] Ingrisch, Johannes, Bahn, Michael, Trends in Ecology & Evolution, April 2018, Vol. 33, No.4.

[6] Chambers JC, Allen CR and Cushman SA (2019) Operationalizing Ecological Resilience Concepts for Managing Species and Ecosystems at Risk. Front. Ecol. Evol. 7:241. doi: 10.3389/fevo.2019.00241

[7] Gunderson, L. H. (2000). Ecological resilience – in theory and application. Ann. Rev. Ecol. Syst. 31, 425–439. doi: 10.1146/annurev.ecolsys.31.1.425

[8] Gunderson, L. H., Allen, C. R., and Holling, C. S. (2010). Foundations of Ecological Resilience. New York, NY: Island Press.

[9] Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., and Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. Ecol. Soc. 15:20. doi: 10.5751/ES-03610-150420

[10] Chambers JC, Allen CR and Cushman SA (2019) Operationalizing Ecological Resilience Concepts for Managing Species and Ecosystems at Risk. Front. Ecol. Evol. 7:241. doi: 10.3389/fevo.2019.00241

As a potential starting point to think through natural system metrics in California, OEHHA has developed a set of potential indicators through their Indicators of Climate Change Report[11] which highlights impacts of climate change on natural systems. Depending on location, type of resilience project, and more, there is historical data to compare to future data points in areas like Sacramento fall-run Chinook salmon abundance, migratory bird arrivals, and small mammal and avian range shifts.

Additional organizations in California have also provided interesting methodologies in considering resilience metrics for this system. In its Integrated Vulnerability Assessment for the Tahoe Basin, the California Tahoe Conservancy has laid out a potential methodology for considering vulnerability for the basin.[12] For example, Appendix A of the Vulnerability Assessment lays out a potential scoring method for rating vulnerability of an ecosystem – offering a potential path forward for localities to judge whether their natural systems are resilient – or not.

Placeholder: possible California-specific natural system resilience metrics

Resilience Metrics for Built Systems

Draft Definition of Resilient Built Systems: Infrastructure and built systems withstand changing conditions and shocks, including changes in climate, while continuing to provide essential services.[13]

Literature Review

According to the literature, metrics for built infrastructure resilience have been focused on several key outlets: First, limiting or preventing damage to building stock due to catastrophic events; second, limiting or preventing loss of human life due to catastrophic events; and third, 'future-proofing' built systems to prevent loss of life or property from the effects of climate change. These three challenges can be described as the difference between sudden and slow onset disasters due to climate change.

In considering the first and second challenge – preventing loss of life or property in the context of climate change today or in the near future – there have been

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[11] 2018 Climate Change Indicators – Summary. Retrieved on May 22, 2020: https://oehha.ca.gov/media/downloads/climate-change/report/2018indicatorssummary.pdf

[12] Integrated Vulnerability Assessment of Climate Change in the Lake Tahoe Basin, (2020). Retrieved on May 22, 2020: https://tahoe.ca.gov/wp-content/uploads/sites/257/2020/04/Integrated-Vulnerability-Assessment-of-Climate-Change-in-the-Lake-Tahoe-Basin_2020.pdf.

[13] ICARP TAC, Draft Outline Vulnerability Assessment Framework, (2020). Retrieved on June 4, 2020: http://opr.ca.gov/meetings/tac/2019-03-22/docs/20190322-7_DRAFT_outline_Vulnerability_Assessment_Framework.pdf

steps taken by state organizations in hardening built infrastructure, like utilities, building stock, and more.

As examples of possible metrics for discussion, the California Public Utilities Commission (CPUC) is considering the costs and benefits of increasing resilience in the electricity sector – a key aspect of resilience in built systems.[14] In noting the vulnerability of customers, CPUC states that "[t]he vulnerability of communities is also a key consideration. Most local governments are conducting adaptation plans according to their own assessed vulnerabilities and it is essential to partner with those organizations to understand where synergies lie."[15] The report further notes Department of Energy guidance on resilience plans, urging utilities to consider: "costs of climate change impacts, costs of climate resilience solutions, and benefits of climate resilience solutions in considering whether or not to take a resilience action."[16]

As a further example, in 2014 the Department of Energy considered guidance by the Sandia National Laboratories on Resilience Metrics for Energy Transmission and Distribution Infrastructure.[17]

As part of this effort, the work defines a possible analysis process for resilience measurement. Their process is thus: "Define resilience goals -> Define System and Resilience Metrics -> Characterize Threats -> Determine Level of Disruption -> Define and Apply System Models -> Calculate Consequence -> Evaluate Resilient Improvements." [18]

[14] California Public Utilities Commission. Climate Adaptation in the Electric Sector: Vulnerability Assessments & Resiliency Plans, (2016). Retrieved on May 22, 2020: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Climate%20Adaptation%20Plans.pdf

[15] California Public Utilities Commission, Climate Adaptation in the Electric Sector: Vulnerability Assessments & Resiliency Plans, (2016). Retrieved on May 22, 2020: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Climate%20Adaptation%20Plans.pdf

[16] California Public Utilities Commission, Climate Adaptation in the Electric Sector: Vulnerability Assessments & Resiliency Plans, (2016). Retrieved on May 22, 2020: https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(2014_forward)/PPD%20-%20Climate%20Adaptation%20Plans.pdf

[17] Sandia National Laboratories, Resilience Metrics for Energy Transmission and Distribution Infrastructure, (2014). Retrieved on June 4, 2020: https://www.energy.gov/sites/prod/files/2015/01/f19/QER%20Workshop%20June%2010%202014%20Posted.pdf

[18] Sandia National Laboratories, Resilience Metrics for Energy Transmission and Distribution Infrastructure (2014). Retrieved on June 4, 2020: https://www.energy.gov/sites/prod/files/2015/01/f19/QER%20Workshop%20June%2010%202014%20Posted.pdf

In defining the placement of this workgroup in the process above, we can look particularly at the first two steps – defining our goals, and defining the system and metrics. These are two important considerations for the TAC.

A further consideration of built systems for review by the TAC is not just surrounding catastrophic events, but also slow-onset events that may take decades to prevent. For instance, a commonly-reported example of a slow onset event is sea-level rise. As an example of how locations are already beginning to think through pricing such an event, the San Francisco Bay Area has reported the potential that an area "of 125 to 429 km^2 will be vulnerable to inundation, as opposed to 51 to 413 km^2 considering sea-level rise alone."[19] Responding to concerns of coastal inundation, the San Francisco International Airport submitted a feasibility study to the Board of Supervisors for a shoreline protection project.[20] Analyzing slow-onset events like sea level rise as part of adaptation metric is a gap in current metrics, which focus on short-term projects, and have a wide disparity of potential impacts forecasted into the future.[21][22]

Placeholder: possible California-specific built system resilience metrics

Resilience Metrics for Social Systems

<u>Draft Definition of Resilient Social Systems:</u> All people and communities respond to changing average conditions, shocks, and stresses in a manner that minimizes risks to public health, safety, and economic disruption and maximizes equity and protection of the most vulnerable.[23]

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[19] Shirzaei, Manoochehr, Burgmann, Science Advances: Global climate change and local land subsidence exacerbate inundation risk to San Francisco Bay Area (2018). Retrieved on May 22, 2020: https://advances.sciencemag.org/content/4/3/eaap9234.

[20] San Francisco International Airport: Airport Shoreline Protection Project (2019). Retrieved on May 22, 2020: https://sfgov.legistar.com/View.ashx?M=F&ID=7513892&GUID=EC2CED9E-FB3A-4A25-930E-D481824BE6AD

[21] Scripps Institution of Oceanography. Probabilistic Scenarios of Sea Level Rise (SLR) along the California Coast: A Product of the California 4th Climate Assessment, Page 8. (2016). Retrieved on May 29, 2020: http://trnerr.org/wp-content/uploads/2016/11/Cayan_SeaLevelRise_CoSMoSMeetingSanDiego_17Nov2016.pdf

[22] Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust, April 2017. Retrieved on May 29, 2020: http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

[23] ICARP TAC. Draft Outline Vulnerability Assessment Framework. (2020). Retrieved on June 4, 2020: http://opr.ca.gov/meetings/tac/2019-03-22/docs/20190322-7_DRAFT_outline_Vulnerability_Assessment_Framework.pdf

Literature Review

According to surveyed literature, there are several key areas for measuring social systems in response to climate impacts. The first is around community resilience to hazards – from immediate hazards like wildfires, to slower onset disasters like drought or sea level rise.

According to Chapter 5 of OPR's 2017 General Plan Guidelines, community resilience "refers to the ability of a community to respond, recover, and adapt, and do so dynamically. It is directly related to equity."[24] Assessing the impact and risk to community resilience has been the subject of several metric efforts, including the Natural Hazard Resilience Screening Index (NaHRSI) and Integrated Community Based Risk Reduction (CBDRR), which have both sought to organize thinking around resilience efforts as a community effort.

In the case of NaHRSI, the goal is to conduct a landscape analysis of the resilience in communities. Considering indicators from natural systems, built environments, governance, and risk management, NaHRSI aims to integrate systems that individuals and communities' interface with on a daily basis to create a human-centered metric for risk and resilience.[25]

As a further example, CBDRR has been used to categorize risk in villages in Indonesia, including a longitudinal study from 1998-2017.[26] In the context of the Maldives, CBDRR has been used at a national scale to develop a strategy for disaster risk management focused around indicators surrounding institutional arrangements, financial resources, human capacity, partnerships, and technical capacity.[27]

Another key consideration in the effect of climate change on social systems is climate change's unequal impacts on vulnerable and disadvantaged communities. Climate vulnerability describes the degree to which natural, built, and human systems are at risk of exposure to climate change impacts.

"Vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with,

[24] Governor's Office of Planning and Research. Chapter 5, Equitable & Resilient Communities. Page 201. Retrieved on May 27, 2020: http://opr.ca.gov/docs/OPR_C5_final.pdf
[25] Summers, J. K., Harwell, L. C., Smith, L. M., & Buck, K. D. (2018). Measuring community resilience to natural hazards: The Natural Hazard Resilience Screening Index (NaHRSI)—Development and application to the United States. GeoHealth, 2. https://doi.org/10.1029/2018GH000160

[26] Lassa, Jonatan, et al. Twenty years of community-based disaster risk reduction experience from a dryland village in Indonesia. (2018). Retrieved on May 27, 2020: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6014115/.
[27] National Community Based Disaster Reduction Framework, Maldives. Retrieved on May 27, 2020: http://ndmc.gov.mv/assets/Uploads/National-CBDRR-Framework.pdf

adapt to, or recover from climate impacts. These disproportionate effects are caused by physical (built and environmental), social, political, and/or economic factor(s), which are exacerbated by climate impacts. These factors include, but are not limited to, race, class, sexual orientation and identification, national origin, and income inequality."[28]

Climate vulnerability is closely linked with climate equity and environmental justice (EJ) which is enshrined in California Code GOV § 65040.12 as, "the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies."[29]

Measuring efficacy of policies in reducing climate vulnerability and following EJ principles is an important component of searching for climate resilience metrics. For example, the Environmental Protection Agency (EPA) has released technical guidance for assessing EJ in regulatory analysis. In their guidance EPA has noted the following recommendations for mainstreaming EJ, including:

"When achievable, analysis should present information on estimated health and environmental risks, exposures, outcomes, benefits, and other relevant effects disaggregated by income and race/ethnicity. When such data are not available, it may still be possible to evaluate risk or exposure using other metrics (e.g., prevalence of affected facilities as a function of race/ethnicity or income, evidence of unique or atypical consumption patterns or contact rates) in a scientifically defensible way."[30]

California has applied some of these lessons in its own case studies and workplans by agencies. For example, the 2017 General Plan Guidelines[31] includes a chapter on equitable and resilient communities (Chapter 5) and healthy communities (Chapter 6). Chapter 6 includes recommended policies depending on jurisdiction, including, for example, the County of Marin which has a provision stating that, "[City, County] shall plan for the public health implications of climate change, including disease and temperature effects."[32]

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[28] CA Office of Planning and Research. Defining Vulnerable Communities in the Context of Climate Adaptation, Page 2. Retrieved on May 29, 2020: http://opr.ca.gov/docs/20180723-Vulnerable_Communities.pdf

[29] See here for more information: https://codes.findlaw.com/ca/government-code/gov-sect-65040-12.html.

[30] Environmental Protection Agency, Technical Guidance for Assessing Environmental Justice in Regulatory Analysis, Page 13 (2016). Retrieved on May 28, 2020: https://www.epa.gov/sites/production/files/2016-06/documents/ejtg_5_6_16_v5.1.pdf

[31] Governor's Office of Planning and Research, General Plan Guidelines: 2017 Update. Retrieved on May 27, 2020: http://opr.ca.gov/planning/general-plan/guidelines.html

[32] Governor's Office of Planning and Research. 2017 General Plan. Chapter 6, Healthy Communities, Page 217. Retrieved on May 27, 2020: http://opr.ca.gov/docs/OPR_C6_final.pdf

Separately there are a wide variety of potential indicators and tools to assist planning and research in forecasting indicators to consider long-range impacts of climate change on communities. For example, the Department of Water Resources has released two data explorers on water shortage and drought risk projected into the future.[33] The California Heat Assessment Tool projects how extreme heat might impact communities in the state, and includes indicators around social vulnerability, human health, and climate science data points.[34][35]

Placeholder: possible California-specific social system resilience metrics

Resilience Metrics Gaps

There are certainly caveats in the efficacy of current metrics for resilience and adaptation. Namely, as a theoretical start to assessing the gaps in resilience metrics, there are five key broad categories of challenges/gaps in achieving a single set of metrics usable across California's jurisdictions and sectors.

First, the availability of data – despite being a relative strength in California, data availability is unfinished and uneven. Particular strengths surround physical climate risk indicators with tools like Cal Heat, OEHHA's Indicators Report, and Cal-Adapt, among others.

Second, indicators for one sector might be wholly different than another sector, or data tools may be reliable for only a single sector or geographic area.

Third, indicators for climate resilience actions might lag behind the effects of climatic impacts – or, the climatic impacts might be so great that it results in outliers from average metric, distorting the overall picture. We speak specifically of "fat-tailed uncertainty", in that some climatic impacts might be so devastating or unexpected (residing on the outskirts of a normal distribution of impacts), that society might choose to either bear any burden to prevent such needs or decide that in avoiding such burdens they remove capability to adapt in other areas or sectors.[36]

Fourth, relying on a single metric or index for use across sectors or scales may not provide significant or meaningful insight. For example, there may be some

[33] CA DWR. Appendix 2. Drought and Water Scoring: California's Small Water Supplier and Self-Supplied Communities. Retrieved on May 29, 2020: https://dwr.maps.arcgis.com/apps/MapSeries/index.html?appid=3353b370f7844f468ca16b8316fa3c7b

[34] California Heat Assessment Tool: https://www.cal-heat.org/explore.

[35]

[36] Weitzman, Martin, Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change. Retrieved on May 29, 2020: https://scholar.harvard.edu/files/weitzman/files/fattaileduncertaintyeconomics.pdf

metrics that when presented at a state-wide scale, do not provide useful meaning to policy or funding decisions. Therefore, some metrics, may provide the most utility at a regional or sub-regional scale only, adding complexity to developing a suite of state-wide resilience metrics.

Fifth, there is danger in using measurements of mitigation actions for resilience and adaptation actions. The danger lies primarily in two aspects of mitigation actions that are not always present in adaptation and resilience actions. These two aspects are:

- universal applicability – an action is equally applicable in all contexts, at all geographical levels, and for all types of interventions.[37]
- uniform effect - each "ton" of avoided effects is the same irrespective of location or how much is reduced by one intervention.[38]

For example, one may be able to measure two identical mitigation actions in two separate countries in two separate contexts, and know that the reduction in CO_2 emissions is the same no matter that geography or context.

Meanwhile, in adaptation actions – we are operating from fundamentally different baselines. Adapting one sector or geography might be 'better' – or not; one must first ascertain the baseline for each geography and sector and determine that baseline before proceeding to a comparison.

These gaps are not shared to dissuade workgroup efforts, but rather to frame challenges faced by jurisdictions, researchers, and governments in formulating resilience metrics that will be useful for years to come.

Conclusion

Forthcoming.

[37] Adaptation Metrics: Perspectives on Measuring, Aggregating, and Comparing Adaptation Results. Page 33: https://resilientcities2018.iclei.org/wp-content/uploads/UDP_Perspectives-Adaptation-Metrics-WEB.pdf

[38] Adaptation Metrics: Perspectives on Measuring, Aggregating, and Comparing Adaptation Results. Page 33: https://resilientcities2018.iclei.org/wp-content/uploads/UDP_Perspectives-Adaptation-Metrics-WEB.pdf

Appendix B: Measuring Climate Change Adaptation

Changing climate conditions necessitate an adaptive management approach. An adaptive management approach is informed by tracking changing climate conditions and the performance of a plan or project. Building check points into a project or plan timeline can help to create a system for regular review and, if needed, adjustments.

Developing a robust set of metrics to track progress and identifying points – either in process, design, or operation – where adjustments can be made is a key part of an adaptive management approach. Ongoing and inevitable climate impacts require changing processes that have been static, and state agencies need to develop metrics, report regularly on changing conditions and state performance, and incorporate lessons learned for more effective interventions.

Metrics should be developed from the outset of the project or plan, and should capture the performance outcomes, changing climate conditions, and overall climate awareness of programs and policies implemented by state agencies. Regular reporting is a key component for ensuring transparency and accountability in state operations and establishing trust in the efficacy and effect of climate adaptation initiatives. Metrics should be developed to track progress in the following areas:

1. Changing Climate Conditions: Once key risks are identified, metrics should be identified to track the progress and occurrence of change .
2. Resilience Outcomes: Metrics should be developed that track the performance of a plan or investment, both in terms of resilience to climate change and in meeting management objectives. Metrics should track proactive action taken by the state to enhance resilience.

This appendix presents conceptual metrics for review and comment. These metrics measuring the changing climate and resilience may serve as the foundation for efforts to integrate more comprehensive tracking and evaluation in future updates to the *Safeguarding California Plan*.

Changing Climate Conditions Metrics

Climate Impact Metric	Context and Rationale
2016 Estimated Average State and Local Disaster Recovery Costs per Fire Management Assistant Grant (FMAG) Declared Wildfire	The extreme and unpredictable wildfire behavior challenges the State's ability to quickly mobilize sufficient resources and personnel in wildfire emergencies, thus increasing the cost of these disasters and demonstrating the immense financial burden climate change has on the State's response efforts. These are response costs to FMAG declared only fires; there were an additional 5,687 fires in 2016.
Number of Critical Infrastructure Interruption Scenarios	Climate change continues to increase the likelihood of extreme heat events as well as drought, which could lead to or exacerbate utility and other disruptions to lifeline systems. Interruptions to critical infrastructure, such as the energy, dams, and agriculture sectors, threaten lives and water, food, and health security for California constituents; particularly among access and functional needs populations who are disproportionately impacted during interruptions.
Increase in Cooling Degree Days (CDD) since 1950	Energy demand for space cooling is approximately proportional to CDD. Since 1950 CDD has increased by about 49% with sharper increases in 2014 and 2015 (see Figure 1).
Decline in Heating Degree Days (HDD) since 1950	Energy demand for space heating on cold days is approximately proportional to HDD. Since 1950 HDD has decreased by about 19% with sharper decreases in 2014 and 2015.
Trend of significant weather-related energy disturbances	Climate change is projected to increase extreme weather events, which may lead to increased significant weather-related energy disturbances. This metric can indicate whether climate change is impacting the reliability of the state's energy system, and indicate needed responses.
Trend of hydropower generation in the summer months	Climate change is expected to reduce hydropower generation in the summer months. There is a downward trend since the early 2000s driven mainly by reductions in wintertime precipitation. Hydropower can ramp up and down to help balance the grid and it is an important low cost source of electricity in the summer.
Average annual extreme heat Land Surface Temperature (LST) difference between urban and rural areas	The urban heat island effect leaves our urban communities more vulnerable to the compounding negative health impacts and system disruptions caused by higher temperatures, when compared to more rural communities. The concentration of heat in urban areas, caused by a "combination of heat-absorptive surfaces (such as dark pavement and roofing), heat-generating activities (such as engines and generators), and the absence of vegetation (which provides evaporative cooling)", exacerbates existing disparities, especially for disadvantaged communities. While this metric does not provide a disaggregated assessment of vulnerability within urban communities, it demonstrates how urban land use, transportation, and design decisions can either mitigate or exacerbate the risks that increased temperatures pose.

	The State should continue to incentivize and invest in land use and infrastructure strategies that reduce the urban heat island effect and minimize, to the extent feasible, the difference in Land Surface Temperature between urban and rural areas.
Number of residents who are members of vulnerable populations in hazard areas	This metric may be able to capture whether expanding hazard areas due to climate change are disproportionately impacting vulnerable populations and inform State responses. We know climate change will exacerbate existing environmental hazards for the most vulnerable in society, so spatially tracking the expansion of risk and vulnerability will be important.
Households in "at-risk" toxic site exposure areas	Climate change increases the risk of disruption and damage to critical infrastructure across the state, including toxic sites. For example, toxic sites along the California coast are at increased risk of flooding and inundation due to sea level rise. Further, communities living in proximity to these sites face an increased threat of exposure to toxic substances.
Heat deaths, hospitalizations, and emergency room visits	This metric is aimed at evaluating the effects of increasing temperatures across the state. As hot days hot nights and heatwaves have become more frequent the emergence or increase in heat-related deaths, hospitalizations or emergency room visits could be an indicator to communities that are vulnerable to heat-exposure.
Rate of allergic disease-related hospitalizations and emergency room visits	As climate change continues, it is expected that extreme temperature days and weather patterns will increase in occurrence. A changing climate can alter the production, allergenicity, distribution, and seasonal timing of aeroallergen. High pollen concentrations and longer pollen seasons can increase allergic disease burden.
Rate of asthma diagnoses and emergency room visits	This health outcome metric can be used to document and evaluate the contribution of environmental hazards on asthma emergency room visits. Subsequently, this information could be used to design, implement, and/or evaluate new interventions. Changes in climate, particularly extreme heat events, interact with air quality, which can increase vulnerability to poor air quality and allergens that have negative impacts on asthma.
Human cases of reportable vector-borne diseases	Changes in temperature, precipitation, and humidity can greatly impact the transmission of vector-borne diseases (i.e. Lyme disease, West Nile Disease, Zika), with relation to disease incidence and vector range. Collecting information on vector-borne diseases will allow for detection of changes that may be related to climate change.
Days with unhealthy air quality across state as aggregate or in an indicator area	As climate change continues, it is expected that air quality is to worsen. Air quality provides information on the concentrations of pollutants in the outdoor air. Health effects from unhealthy air quality can include respiratory disease, cancer, heart disease, and stroke.
Disaster funds disbursed to fix transportation assets after	This metric shows the cost of protecting state highway infrastructure. Historic climate related impacts have already cost

climate events (flood, wildfire, landslide)	the state millions of dollars, and this amount will grow as climate change accelerates, further stressing transportation assets and the system at large. Early adaptation measures could save the state a significant amount of money.
Miles of transportation network impacted by wildfire	Under future climate projections, drought and higher temperatures are projected, which will exacerbate wildfire conditions. Wildfires not only have the potential to damage roadway infrastructure but also threaten homes, businesses, and human life. This metric, when analyzed over time, will assist transportation agencies in understanding the speed and extent of increase in impacts from climate change.
Miles of transportation network impacted by coastal and/or inland flooding	Transportation assets are vulnerable to the impacts of sea level rise – the greatest threat to infrastructure. Coastal and inland flooding pose potentially significant damage to the state transportation system. This metric, when analyzed over time, will assist transportation agencies in understanding the speed and extent of increase in impacts from climate change.
Miles of transportation network impacted by precipitation-induced landslides	This metric, when analyzed over time, will track changes in the most consistent impact to transportation infrastructure. Caltrans has been studying and identifying areas at risk of landslides for years – a major risk that will increase with more intense precipitation events expected under future climate projections.
Snow water content compared to average	This metric is important because California agriculture is reliant on irrigation water. Several metrics of precipitation are relevant to agricultural water supply: reservoir conditions, average regional precipitation, winter snowpack, snow water content and surface water deliveries. Due to uncertainty in models of future California precipitation trends, it is difficult to anticipate how water availability will change by 2050. Many models agree the drought is likely to be more common and more severe.
Drought-related idled land	This metric is important because drought-related idled land represents a manifestation of agricultural vulnerability to climate change (as well as other stressors such as changes in markets, regulations, and input costs). The Center for Watershed Science at the University of California assessed the economic impact of the ongoing drought in 2016 on California agriculture. The authors determined that in 2016, 6.6% more land was fallowed due to the drought than would be idle in an average precipitation year. This translates to lost jobs and income.
Cumulative winter chill hours (hours less than 45° F)	This metric is important because certain types of fruit and nut trees are especially impacted by warming winter temperatures. Warm winters can lead to incomplete winter dormancy and sporadic blooms in the spring months. The negative impact of reduced winter chill is projected to grow. By 2050, winter chill hours could be half of observed hours in 1950.
Heat stress impacts to crop and livestock	This metric can track extreme heat events as well as the response of the agricultural sector to extreme heat through producer surveys

	and annual crop reports. There are many published studies demonstrating the negative consequences of heat stress on livestock, including decreased production, reduced feed efficiency/intake, increased poultry mortality rates, and potentially poor immune function resulting in susceptibility to disease. Livestock producers monitor production and well-being closely and invest in adaption when factors like heat begin to have long term effects. On livestock operations adaption to heat usually involves mitigation via coolers, fans, sprinklers and shade, adjusting water pH, and potentially shifting breeding to include more heat tolerant species.
Species ranges	Individual species, both native and invasive, are expected to move across the landscape in response to changing climatic conditions. Observed changes in where species are found, (e.g. upward in elevation, or northward) can indicate shifts in species distributions associated with climate change. For wildlife, range shift data can also provide insight into the locations of important wildlife corridors needed to maintain connectivity as the climate changes.
Area of plant community types	This metric is aimed at capturing any increases or decreases in the total area of vegetative community types that may be associated with changing climatic conditions. Vegetative communities are often associated with habitat types that support certain species; changes in the underlying vegetation (or other habitat attributes) can have repercussions for the wildlife it supports and ecosystem services that it provides.
Species abundance and diversity	Climate impacts to individual fish, wildlife, and plant species can collectively alter broader natural community structure and composition. Tracking species diversity (number of species and their relative abundance in a given ecosystem) can serve as a measure of changing community dynamics (e.g. native versus non-native species diversity). Presence or relative abundance of plant and animal species in both aquatic and terrestrial environments can be monitored as part of this effort (e.g. key species population levels).
Fish and wildfire mortality events	Climate change will likely have a negative impact on the overall health of some fish and wildlife populations, and could result in increases in mortality events or overall extinction risk for some species. This metric would track mortality events to identify any trends that may be linked to changing environmental conditions or stressors brought about by climate change. This may include mortality events directly tied to climatic factors like heat stress and reduced water availability, or events that are more indirectly tied to climate change, such as the emergence or spread of existing diseases, pathogens and parasites.
Timing of life cycle events (phenology)	Climate change is altering the timing of life cycle events such as migration, leaf emergence, reproduction, pollination of native plants and crops, metamorphosis (i.e. transition from larvae to adult), and hibernation. These events can be tracked for certain species to

	identify patterns related to changing seasonal climate conditions.
Human-wildlife conflicts	Wildlife that is under stress due to climate change and other factors will search for alternate food, water, and habitat as necessary. This can result in conflicts between humans and wildlife. Monitoring human-wildlife conflict incident data will help us determine whether or not these occurrences are increasing in the face of climate change, and improve our understanding of impacts to the urban-wildlife interface.
Soil burn severity	Fire severity has been increasing beyond the historical norm. Surveyors in the 1800s wrote that large tree death from fire was an uncommon occurrence, and by the 1980s, approximately 20% of fire footprints were severely burned. By the early 2000s, high severity in fires over 500 acres in size increased to almost 30%, and the Rim Fire of 2013 and King Fire of 2014 were almost 40% and 50%, respectively. High severity burn patches were historically small, commonly under 10 acres in size, which allowed living trees on the edges to quickly reseed the burned area, and it created diverse habitat in a small area. In contrast to this healthy functionality, the King Fire had a single high-severity burn patch of over 30,000 acres in size and the Rim Fire had a high-severity burn patch over 50,000 acres.
Deforestation after wildfire	During the last decade, 700,000 of the 2.3 million acres of U.S. Forest Service forested lands affected by wildfire have been classified as deforested. This is equal to a deforestation rate of 30.43% on the lands affected by wildfire.
10-year average of acres burned	Over the last few decades, wildfires in California's conifer forests have grown bigger and have exhibited larger and larger uniform patches of severe fire.
Trend in acreage of elevated tree mortality	Five consecutive years of severe drought in California, a dramatic rise in bark beetle infestation and warmer temperatures are leading to historic levels of tree die-off. In total, a cumulative number of 102 million trees have died on California's forested lands since 2010. This scale of die-off is unprecedented in California's modern history, and millions more drought-stressed trees that are not yet dead are expected to die in the coming months and years. As stressors like heat, drought, pests, disease, and a rising snowline increase with climate change, California will continue to struggle with massive tree die-offs.
Average observed sea level rise in inches over the past century	Sea levels measured at stations in San Francisco and La Jolla have risen at a rate of 8 and 6 inches over the century, respectively. Sea level rise in California could lead to flooding of low–lying areas, loss of coastal wetlands such as portions of the San Francisco Bay Delta system, erosion of cliffs and beaches, saltwater contamination of drinking water, impacts on roads and bridges and harmful ecological effects along the coastline.
Number of Californians living in flood-prone areas	As of 2013, one in five Californians were exposed to the hazards of flooding in California. This metric captures the number of

	Californians living in the 500-year floodplain, and includes risks from tsunami flooding, engineered structure failure flooding, and coastal flooding.
Coastal ocean temperature change over the past century	Sea surface temperatures at La Jolla have increased by about 1.8° F over the past century at about twice the global rate. Warmer ocean waters contribute to global sea level rise and extreme weather events, and can impact the marine ecosystem and its populations.
Impact on fisheries of climate-impacted states of emergency	Climate change impacts are predicted to have direct physiological effects on marine fish, impacting species growth, reproductive capacity, and distribution, as well as indirect effects on marine fishery ecosystems, food webs, and habitats. Climate change impacts that will affect marine fisheries and food webs include changes in oceanographic processes which drive nutrient enrichment and primary productivity, changes in ocean temperature, changes in the timing of upwelling, and changes in dissolved oxygen concentrations. The role of direct and indirect climate impacts on marine fisheries and fishery states of emergency, such as the 2015 Dungeness crab fishery closure, will be investigated with this metric.
Oxygen concentration in California current	Dissolved oxygen concentrations in the ocean are an indicator for physical and biological processes within the marine environment. There was a significant decrease in dissolved oxygen in the California Current System from 1984 to 2006, and climate change models predict a continued decline in dissolved oxygen. This can lead to significant and complex ecological changes to marine ecosystems: in addition to the direct adverse effects of lower oxygen concentrations (hypoxia), shallower oxygen-deficient zones can also lead to a compression of favorable habitat for certain marine species and an expansion of favorable habitat for other species. Sampling and monitoring by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program provides data for this indicator.
Mean temperature departure, October through September	Temperatures are projected to increase due to climate change, providing an easily tracked observational record. Temperatures impact the type of precipitation that falls (rain or snow), evaporation rates, water demands by agriculture and people, water quality, as well as energy demands (which often require significant water use for generation). This impact is projected to grow; by 2050, average high temperatures are projected to be 3-4° F higher than mid-20th century.
Percentage of rainfall as total precipitation	As temperatures increase, the proportion of annual precipitation that falls as snow will decrease. A trend toward 'more rain, less snow' creates the need to adjust water management to accommodate the changes in precipitation timing and type. This impact is projected to grow as the climate warms, with year-to-year variability continuing, and the percentage of precipitation falling as rain increasing over time.
3-year average of Sacramento	Streamflow is captured by reservoirs for water supply and is a key

River runoff in April through July in percent of water year runoff	driver of aquatic ecosystem health. Year-to-year variability in streamflow is a natural feature of California's hydrology; all of the impacts listed above act to intensify this annual variability. For aquatic species, these impacts put stress on the amount, timing and temperature of the water. For supply, extreme variability in streamflow reduces reliability.

Resilience Outcomes Metrics

Government Response Metric	Context and Rationale
Percentage of Local Hazard Mitigation Plans that address climate impacts	The State needs to promote the incorporation of climate change resiliency strategies into local hazard mitigation plans and grants quickly to comprehensively address growing climate risk.
Amount of California's energy from renewable sources	With 27% of its electricity coming from renewable sources in 2016, California is ahead of schedule to reach the state's goals of 33% renewable energy by 2020 and on track to meet 50% by 2030. While renewable energy is also crucial for the state's efforts to reduce greenhouse gas emissions to mitigate the effects of climate change, renewable energy production also helps California be more resilient by creating a more diversified and distributed energy supply.
Gigawatt hours of energy saved by efficiency and conservation initiatives	Energy efficiency and conservation are key climate adaptation efforts to ensure system reliability, and also has great benefits for climate change mitigation and consumer savings. This metric combines efficiency gains from codes and standards, efficiency programs, and market and price effects to show the cumulative annual efficiency and conservation savings for electricity from 1990 through the present.
Reduction in rate of land consumed for development	The State's natural resources are an integral part of the State's climate programs. Healthy, well-maintained natural systems can provide significant climate mitigation benefits and can also provide resilience in the face of change. Natural infrastructure is the preservation and/or restoration of ecological systems, or utilization of engineered systems that use ecological processes, to increase resiliency to climate change and/or manage other environmental problems (AB 1482 and SB 379). The State continues to promote and support local land use and development strategies that preserve ecologically intact and functioning natural infrastructure systems and habitats. The State is also invested in promoting the use of natural and ecological processes and features that are engineered to supplement traditional built infrastructure (for example, water treatment facilities that utilize ecologically functioning wetlands).
Total funding available that directly considers and	Since climate change is already exacerbating existing

builds resilience to climate impacts	inequities and vulnerabilities, efforts to build healthy and equitable communities needs to be central to the State's adaptation strategy.
New units approved in hazard areas	This metric would help the State track whether existing land use and hazard avoidance guidance is effectively safeguarding Californians.
Community service hours that build directly build adaptive capacity in communities	California Emergency Response Team, California Conservation Corps service programs, and Civic Spark
Local jurisdictions with climate action plans, adaptation plans, general plans, and hazard mitigation plans that address climate, health, and equity for vulnerable populations	Senate Bill 379 requires local jurisdictions to address climate adaptation and resiliency strategies in their next revision of a local hazard mitigation plan, or in the safety element of the general plan (beginning in 2022, if the local jurisdiction has not adopted a local hazard mitigation plan). The bill requires the update to include goals, policies, and objectives based on a vulnerability assessment identifying the risks that climate change poses to the local jurisdiction. This is an opportunity to plan to reduce harms to vulnerable populations from climate change.
State agency plans (infrastructure, investment, operational) or grant guidance documents that a.) identify populations vulnerable to climate change health impacts, b.) plan to reduce vulnerability through increased provision of resources, services, jobs or technical assistance, and c.) engage vulnerable populations in making decisions about programs, policies or funding.	Executive Order B-30-15 requires State agencies to take climate change into account in their infrastructure and investment decisions, and mandates that vulnerable populations be protected the process. The State agency guidance to implement the Executive Order helps agencies a.) identify populations vulnerable to climate change health impacts, b.) plan to reduce vulnerability through increased provision of resources, services, jobs or technical assistance, and c.) engage vulnerable populations in making decisions about programs, policies or funding. This item will help monitor the degree of implementation of the Executive Order.
Climate change, housing, transportation or land use investment plans or programs that incorporate measures to prevent residential and economic displacement	Transit investments and other amenities such as improved housing options are often provided to improve livability and reduce the need to drive, thus reducing greenhouse gases. These strategies may inadvertently drive up median area income, property taxes, and rents. A possible result of such changes is that existing residents and small business owners may no longer be able to afford living or doing business in their neighborhoods, and will be forced to move farther away. Displacement has harmful effects on physical and mental health of children and adults, and most harms people with low incomes.

Change in tree canopy or impervious surface coverage	Increasing the amount of tree coverage has a number of benefits for climate change and our communities including reduction of air pollution, calming of traffic, reduction of neighborhood violence, and the reduction of storm water runoff, which decreases flood risk and soil erosion while improving water quality. Impervious surfaces often are dark-colored and thus absorb more heat, contributing to the heat island effect. They also do not allow water to infiltrate into the soil. Allowing water to infiltrate into soil reduces flooding, recharges ground water supplies, and filters water.
Low-income and senior housing units receiving weatherization and energy efficiency upgrades.	Weatherization and energy efficiency measures have many benefits for climate vulnerable communities including the reduction of: susceptibility to extreme heat and cold; energy consumption, which decreases power plant emissions and air pollution; utility costs allowing more to be spent on other needs; and health and safety risks within the home.
State-owned roads that have a climate change vulnerability assessment	This metric will inform stakeholders of the potential impacts to transportation infrastructure to make more informed decision-making.
"Complete Street" features built into transportation infrastructure projects	This metric will identify progress towards integration of complete streets strategies and features that provide resilient travel options that are not petroleum-based and increase physical activity. Complete street features include bike lanes, crosswalks, transit amenities, and other design and livability features. To keep pace with impacts like temperature rise in urban areas, state government should increase funding in areas with poor air quality over time.
Number of transit stops (including high-speed rail) providing service to vulnerable or low-income populations.	Public transit access increases overall resiliency by providing economic opportunity, reducing emissions, and offering evacuation routes during emergencies.
Number of transit stops that serve as emergency centers	This metric demonstrates the state's commitment to resilience of transit-dependent Californians by creating more emergency centers at transit stops. To keep pace with impacts like storm events, state government should increase over time.
Volume of water to be conserved through the State Water Efficiency and Enhancement Program projects over 10 years	This metric shows how California is investing in efficient irrigation practices to increase the state's resilience to water shortage. To keep pace with impacts like water insecurity, state government should increase funding over time and address other

	methods to maintain a secure water supply for human, environmental, and agricultural needs.
Healthy Soils Program projects	This metric shows how California is investing in soil health to increase the state's resilience by sequestering carbon and tapping into the multiple benefits of soil. To keep pace with impacts such as drought, California should increase funding for the healthy soil program. The funding of research, demonstration projects, and outreach to the agricultural community will all be needed actions.
Acres of farmland conserved through state agricultural conservation easement programs	This metric shows how California is investing to increase the state's resilience by conserving farmland. To keep pace with impacts like population growth, state government should continue to fund farmland conservation easements in an effort to promote sustainable growth and the multiple environmental benefits provided by farmland.
Percentage of species included in climate change vulnerability assessments	Climate change vulnerability assessments provide insight into which species may be at highest risk from climate impacts, and why. Ensuring that a broad range of species and especially special status species are represented in these assessments will constitute progress towards improving our understanding of projected climate impacts to fish, wildlife, and plants, and filling important gaps in scientific information.
Number of projects underway to implement 2015 SWAP conservation strategies with climate co-benefits	The conservation goals and strategies identified in the 2015 State Wildlife Action Plan (SWAP) were developed in part to address risks associated with climate change, and strategies have been directly linked to state and national climate adaptation strategies for fish, wildlife, and plants. SWAP implementation is an important vehicle for building robust and resilient ecosystems.
Percentage of conservation plans that include climate adaptation strategies or actions for fish, wildlife, plants, or ecosystems	Species and ecosystem-based approaches to conservation planning occur at multiple scales to conserve biological diversity in perpetuity. Incorporating climate adaptation science and strategies into these efforts is crucial to their success. This metric can serve as an indicator of state agency progress towards integrating climate adaptation into conservation plans and frameworks.
Acres of terrestrial and aquatic habitat restored through state agency-administered restoration grant programs and restoration on state lands	Restoration and enhancement of degraded ecosystems, and activities such as invasive species removal, can protect ecological function and increase ecosystem resiliency to climate impacts. This metric serves as a measure of the magnitude of

	on-the-ground actions being taken or supported by state agencies to generally promote adaptation by ensuring terrestrial, aquatic, and marine ecosystems are healthy and more likely able to cope with or adapt to change.
Number of state agency staff enrolled in climate-related education courses and other trainings	This metric can be used to evaluate progress towards increasing awareness of climate impacts to biodiversity and adaptation options by state agency staff working on natural resource issues.
Acres of forested land treated to reduce fire risk	In October 2015, Governor Brown declared a state of emergency and formed a Tree Mortality task force to help mobilize additional resources for the safe removal of dead and dying trees. The US Forest Service is a key member of this task force, and in 2016, reprioritized $43 million to help protect people from hazard trees and conditions created by dead and dying trees. CAL FIRE and its partners have removed more than 423,000 trees in 10 counties, inspected and cleared of dead trees nearly 52,000 miles of roads and powerlines, treated more than 26,000 acres, and created roughly 1,300 acres of fuel breaks to date.
Acres of private forests in easements	This metric will track the acres of forestland protected from conversion to non-forest easements through programs between landowners and land trusts or governance agencies, such as the Federal Forest Legacy Program and the California Forest Legacy Program.
Projects and programs that focus on sea-level rise and climate adaptation	Local Coastal Programs, projects that demonstrate innovative shoreline management, use green infrastructure, ready our fisheries management and fishing practices for climate change, and other climate resilience projects are being implemented across the state. This metric will track the number of such projects.
Acres of coastal wetlands and coastal habitat restored or protected	This metric will track the acreage of coastal wetlands, marshes, and critical habitat restored along the coast. Plans such as the 2015 update to the Baylands Ecosystem Habitat Goals, which offer recommendations for promoting healthy baylands in light of climate-induced erosion and inundation, can guide these efforts.
Percentage of coastal population living in area with vulnerability assessments, mapping, and/or local planning for sea level rise	This metric will track regional preparedness for sea level rise, including the percentage of coastal population living in areas that have incorporated sea level rise in Local Coastal Plans and local general plans and the percentage of the coast with

	vulnerability assessments and mapping.
People who receive training or information annually on coastal and ocean climate risks and adaptation planning	This metric will track participation in outreach events, webinars, and other trainings on coastal and ocean climate risks and adaptation planning.
Local progress in achieving water conservation	California is acting to increase the state's resilience through water conservation, which will help reduce the impacts of increased drought duration, intensity and frequency, as well as maintain a sustainable water supply. The state released its Water Conservation Plan public review draft in November, 2016. The plan implementing Governor Brown's Executive Order B-37-16 will be final in January, 2017. The EO ordered the state to move towards using water more wisely, eliminate water waste, strengthen local drought resilience, and improve agricultural water use efficiency and drought planning. Much progress has been made at the local level toward water conservation. The State should track these measures as a climate change metric, continue to set guidance and find more ways to address vulnerability.
Urban water use reduction	California is investing in water supply reliability and taking action to increase resilience through water use efficiency. Implementation of the Water Conservation Act of 2009 (SBX7-7) is achieving urban water use reduction statewide by 20 percent per capita by the year 2020, helping agricultural water suppliers with efficient water management practices, and responding to the Governor's call for Californians to reduce their water usage by 20 percent during the drought. This metric can show how the State is dealing with water supply reliability issues by addressing water outages/quality in rural communities and other efficiency efforts and outreach.
Percentage of Groundwater Sustainability Agencies that have attained sustainability	The state passed the sustainable Groundwater Management Act (SGMA) in 2014. To help adapt to climate change impacts, increased demand for groundwater, and changing streamflow and replenishment, the water sector is establishing process and approach for determining the extent and magnitude of climate change and sea level rise impacts to sustainable groundwater management practices at the groundwater basin level. Groundwater basin boundaries are set, Groundwater Sustainability Agencies (GSAs) are being formed, regulations have been adopted requiring GSAs to attain sustainability by 2042 or

	earlier and to consider changing climate conditions over the planning period and beyond, and SGMA Best Management Practices (BMPs) were released. Tracking progress on these actions as climate change metrics will show how California is investing in/acting to increase the state's resilience by managing groundwater sustainably. California faces the ongoing threat of undesirable results caused by groundwater depletion, and moving forward state government needs to further its work in managing and using groundwater in a sustainable manner, to support the implementation of groundwater sustainability plans.