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Climate Resilience Metrics – Putting Them to Work in California

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CLIMATE RESILIENCE METRICS – PUTTING THEM TO WORK IN CALIFORNIA

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"If a measurement matters at all, it is because it must have some conceivable effect on decisions and behavior. If we can't identify a decision that could be affected by a proposed measurement and how it could change those decisions, then the measurement simply has no value"[1]

I. WHY DO WE NEED TO TRACK RESILIENCE?

Measuring, evaluating, and monitoring resiliency efforts – whether at the local, state, or national level – is an unprecedented challenge with many unresolved questions. How do we know when successful resiliency has been reached? What does success look like? How can we monitor whether or not interventions are on track and delivering results? These are critical questions that give purpose to the role of monitoring and evaluation in climate resilience (often referred to as climate adaptation).

As the impacts of climate change have become more frequent and widespread, and as society begins to respond, our ability to accurately measure progress towards climate and resilience goals will continue to become more important. In recent years, there have been an increasing number of efforts from state and local agencies, academics, and nonprofit

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[1] Douglas A. Hubbard, HOW TO MEASURE ANYTHING: FINDING THE VALUE OF "INTANGIBLES" IN BUSINESS (2nd ed. 2010).

organizations to both define climate resilience and to develop targets to assess our progress towards climate resilience goals.[2] Although we have many greenhouse gas (GHG) mitigation examples to look to for guidance definition (such as California Global Warming Solutions Act (AB 32)), climate resilience is an emerging field with diverse and unique impacts to measure and track, many of which cannot be captured with the precise numbers used to measure GHGs.[3] This provides an opportunity to take advantage of existing efforts and induce future innovation.

Building on climate adaptation goals defined in climate policy, this paper identifies examples of performance-based metrics to measure and track the effectiveness of climate risk reduction and resilience actions in California in order to inform developing state policy and guidance on resilience metrics. After a brief review of California's climate goals, a set of guiding principles are proposed for metric development. An overview of the current discourse on resiliency metrics follows and the paper concludes with a set of recommendations for the state as it moves forward in the development of metrics.

II. Definitions and Context

Before discussing how to measure resilience, we must first have a common understanding of the term. There are many definitions of resilience. For purposes of this paper, we use these three definitions:

President Obama's Executive Order: The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.[4]

U.S. Global Change Research Program: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.[5]

Ecosystem Resilience: In addition to the above two general definitions, this paper also refers to "ecosystem resilience," which is defined as the capacity of an ecosystem to tolerate disturbance without collapsing and rebuild itself when necessary.[6]

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[2] The author, Alexandra Leumer, has personal knowledge of this fact through observations while working in the field.

[3] Assemb. B. 32 2006 (Ca. 2008), http://www.arb.ca.gov/cc/ab32/ab32.htm.

[4] Fed. Reg. 78, 215, Exec. Order 13653, 66817, 66817-66824 (Nov. 2013).

[5] U.S Global Change Research Program, http://www.globalchange.gov/climate-change/glossary#Resilience (last visited Feb. 21, 2016).

[6] Resilience Alliance, http://www.resalliance.org/index.php/resilience (last visited Feb. 21, 2016).

A. Metric vs Indicator vs Measure

The definitions of the terms 'indicator', 'measure' and 'metric' vary across sectors and are often used interchangeably, though there are subtle differences. A **measure** is a value that is quantified against a standard (for example, acres, feet). According to the definition adopted by USAID, an **indicator** is: *"A quantitative or qualitative variable that provides reliable means to measure a particular phenomenon or attribute"*.[7] A **metric** is a calculated or composite measure or quantitative indicator based upon two or more indicators or measures.[8] Metrics help to put a variable in relation to one or more other dimensions; for example, yearly growth in urban green space for a certain period of time. In climate change adaptation there are not many agreed upon universal standards and so 'measures of success' will often be indicators.[9] For the purposed of this report, these terms are used interchangeably.

B. Types of Indicators

Output indicators measure the quantity and quality of the goods and services delivered by the program.[10] For example, number of urban trees planted in a city.

An **outcome-based approach** seeks to define an explicit outcome, or end point, of the adaptation action such as "increased resilience of California forests to climate-related impacts."[11]

Process indicators capture progression towards the achievement of an outcome (e.g. resilience to drought or wildfires), but do not guarantee or measure the final outcome itself.[12] For example draft adaptation strategy is completed. Process indicators are often used in the context of adaptation as we have often not yet reached the point where the outcome of adaptation can be evaluated and hence it can be challenging to apply a purely outcome-based approach.

Proxy indicators are (more) easily-measureable "stand-ins" for concepts or variables for which data is unavailable. The proxy indicator should be

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[7] *Glossary of Evaluation Terms*, Office of the Director of U.S. Foreign Assistance, http://pdf.usaid.gov/pdf_docs/PNADO820.pdf, (last visited Feb. 21, 2016).

[8] Dennis Bours, *What's in a name? On indicators, measures and metrics*, Climate-Eval (2014),.

[9] *Id.*

[10] Indicators: *Definition and Use in a Results-Based Accountability System*, Harvard Family Research Project, http://www.hfrp.org/publications-resources/browse-our-publications/indicators-definition-and-use-in-a-results-based-accountability-system (last visited Feb. 21, 2016).

[11] UKCIP, *Evaluation Criteria,* http://www.ukcip.org.uk/wizard/adaptme-toolkit/measuring-performance/evaluation-criteria/#.VpWcovkrKUk (last updated Aug. 12, 2015).

[12] *Id.*

highly correlated with what it is trying to achieve – even if it is not an exact measure of the concept or outcome itself.[13] Using the example above, urban tree canopy cover can be a proxy measure for a city's resiliency to higher heat days.

C. Challenges in Drafting Indicators

There are a numbers of challenges in drafting metrics and indicators. The temporal complexities and issues with scale are two of the most prominent.

Scale: The appropriate scale(s) to measure resilience is often unclear (system level, species, global, local, state, etc.) and data needs and availability can vary greatly.

Temporal: It is hard to estimate threats and ability to respond over a long time horizon and with moving and dynamic baselines. Communities are acting now while anticipating an unknown but different future. Further, there are no clear end points —"resiliency" is a moving target and a process of continual adjustment and therefore often must rely on proxy and process measures.

Monitoring and Updating: Given limited staffing and resources, ongoing monitoring and updating metrics can be a challenge. Updating the metrics is especially important given the changing climate can affect the desired goals and outcomes. Monitoring is also essential to ensure progress is in fact being made.

Defining the Goal: Often the challenge is defining the goal. To be effective, metrics should be tied to specific goals in order to achieve results, and the goal should be clearly defined before the metrics are created.[14]

D. California's Climate Goals

California's climate goals are captured in a number of plans and guidance documents. The most comprehensive set of goals are outlined in the 2014 Safeguarding California Plan (SCP),[15] an update to the 2009 California Climate Adaptation Strategy, produced by the California Natural Resources Agency, in coordination with other state agencies.[16] The SCP summarizes climate change impacts and provides over-arching,

[13] *Id.*

[14] The author, Alexandra Leumer, has personal knowledge of these facts through extensive research and work in the field.

[15] *Safeguarding California Plan*, California Natural Resources Agency, http://resources.ca.gov/climate/safeguarding/ (last visited Feb. 21, 2016).

[16] *2009 California Climate Adaptation Strategy*, California Natural Resources Agency, http://resources.ca.gov/docs/climate/Statewide_Adaptation_Strategy.pdf (2009).

cross-sectoral guidance for state agencies, as well as adaptation strategies across nine sectors (including biodiversity and habitat, public health, and forests).

> The state has an important role to play in enabling efforts to reduce climate risk, helping climate risks become a mainstream policy consideration, and ensuring that all state agencies are taking climate risks into account. State agencies need to consider climate change in their normal day-to-day business and operations.[17]

As the state begins to implement these strategies, it is important to track progress and successes.

As a complimentary effort, the California Governor's Office of Planning and Research (OPR) has updated the State's Environmental Goals and Policy Report (EGPR), which encompasses climate resilience, health, economy, innovation, and equity goals that are to be incorporated into planning at the state, regional, and local level.[18]

II. INDICATORS IN ACTION: HOW INDICATORS ARE ALREADY BEING USED

There is a vast amount of work on resiliency metrics being done at a variety of scales, from international to project level.[19] This paper focuses on actions at the state or regional level. The focus is to given metrics that capture the important role natural resources play in making communities and ecosystems more resilient to climate change while providing the dual benefit for greenhouse gas (GHG) mitigation. The paper also prioritizes examples of existing metrics, as they are readily available without additional funding since the data sources are in place.

The following examples highlight metrics that are being used on a variety of scales (including local and regional), but that have potential at the state level, where there are the most near-term opportunities to establish metrics. The examples focus on capturing the resilience of cities, public health, and ecosystems, with ecosystem/landscape resilience metrics given greater attention.

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[17] *Safeguarding California Plan*, CALIFORNIA NATURAL RESOURCES AGENCY, 10, http://resources.ca.gov/climate/safeguarding/ (last visited Feb. 21, 2016).

[18] *A Strategy for California @ 50 Million*, The Governor's Environmental Goals and Policy Report, https://www.opr.ca.gov/docs/EGPR_Nov_2015.pdf (last visited Feb. 21, 2016).

[19] The author, Alexandra Leumer, has personal knowledge of these facts through extensive research and work in the field.

A. Ecosystem/Landscape Resilience

1. The Nature Conservancy: Resilient California Ecosystems[20]

In one system, The Nature Conservancy (TNC) defines a resilient site as one that has characteristics (microclimatic buffering and connectedness) that maintain ecological functions and will likely sustain a diversity of species.[21] Criteria were grouped in three categories:

1. Landscape diversity: topography, elevation range, and the density and configuration of wetlands.
2. Landscape permeability: measure of landscape structure: the hardness of barriers, the connectedness of natural cover, and the arrangement of land uses.
3. Combined Resilience Factors: landscape diversity and the local connectivity scores were combined into an integrated resilience score. The integrated score is useful for mapping the areas where those factors combine to create high resilience, but users are also encouraged to look closely at the individual factors as they reveal interesting and different information about the landscape.[22]

In California, TNC has documented how existing conservation areas have helped prepare California for climate change by providing opportunities and options for species to redistribute and find accessible suitable habitats. It has also identified additional steps needed to make landscapes more resilient.[23] In doing so, it compiled a list of criteria for resilient ecosystems, mapping them on a one kilometer grid and overlaying it with a map of protected land in the State.

Measures include:

1. Microclimate diversity/variation,
2. Distance to stable water sources,
3. Existence of riparian corridors, and

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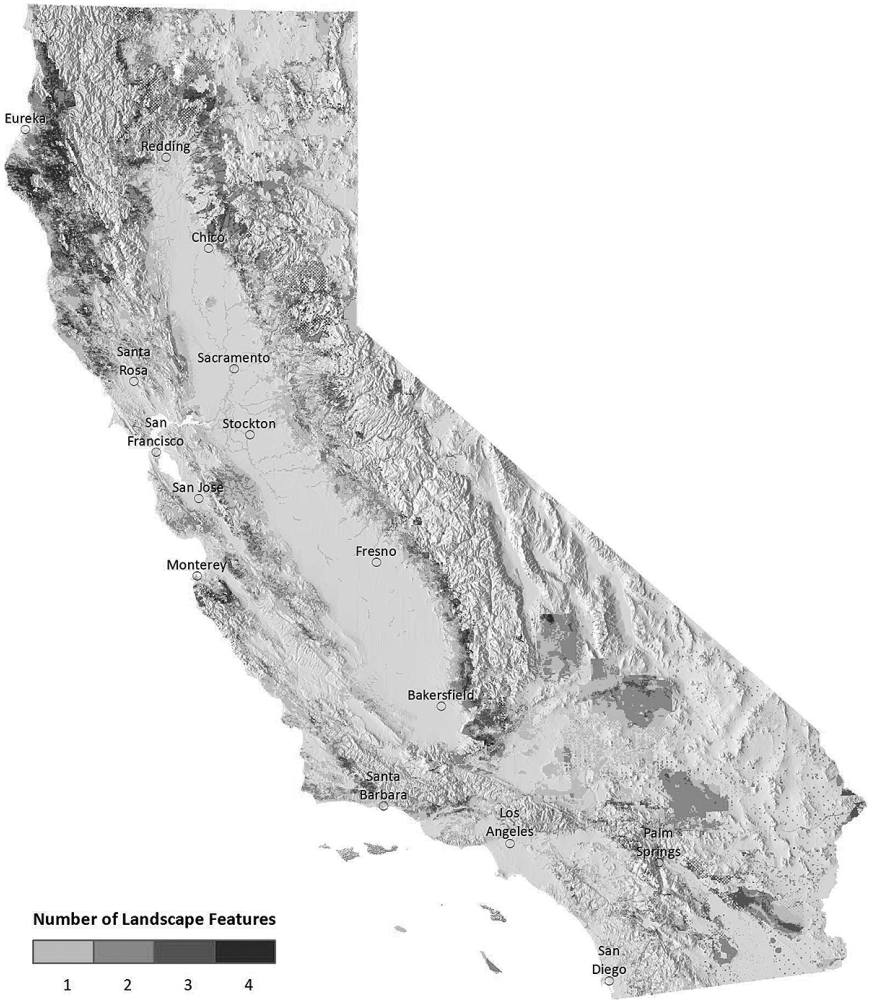
[20] Kirk Klausmeyer, Dick Cameron & Scott Morrison, *Laying the Foundation: How Existing Conservation Areas Have Helped Prepare California for Climate Change*, The Nature Conservancy (July 2013), http://scienceforconservation.org/dl/Laying_the_Foundation_TNC_CA_Science_July_2013.pdf.

[21] *Id*.

[22] Mark G. Anderson, Analie Barnett, Melissa Clark, Charles Ferree, Arlene Olivero Sheldon & John Price, *Resilient Sites for Terrestrial Conservation in the Southeast Region*, The Nature Conservancy 24, 38, 49 (2014), https://easterndivision.s3.amazonaws.com/Terrestrial/Resilient_Sites_for_Terrestrial_Conservation_In_the_Southeast_Region.pdf.https://easterndivision.s3.amazonaws.com/Terrestrial/Resilient_Sites_for_Terrestrial_Conservation_In_the_Southeast_Region.pdf.

[23] Kirk Klausmeyer, Dick Cameron & Scott Morrison, *Laying the Foundation: How Existing Conservation Areas Have Helped Prepare California for Climate Change*, The Nature Conservancy, 13 (July 2013), http://scienceforconservation.org/dl/Laying_the_Foundation_TNC_CA_Science_July_2013.pdf.

4. Proximity to coast.[24]



This data could be used by the state to measure and track resiliency of ecosystems across the state.

2. The Nature Conservancy: Conservation Metrics

The following metrics were proposed by TNC for use in the EGPR, which will guide the State's environmental goals and policies, and provide excellent proxy measures for ecosystem resiliency as well as a resilience against increased fire risk and a changing water supply.

[24] *Id* at 5-6.

Importantly, many of the metrics can be tracked using existing data sources. The following examples list a goal, followed by a metric, and the source of data.

1. Conserving habitat and open space: Acres or percentage of habitat and open space protected by land cover type (forest, scrub, grassland, etc.).[25]
2. Protecting biodiversity: percentage of species diversity in region under conservation management (weighted by special status and percentage of species range in study area (could be done just for rare, threatened, and endangered wildlife).[26]
3. Ensuring habitat connectivity: percentage of corridors with permeable habitat and infrastructure, to allow for species movement.[27]
4. Preserving farmland: Acres of farmland lost to conversion.[28]
5. Ensuring water quality and adequate quantity; protecting riparian areas: percent of groundwater basin or watershed changed to impervious surface; acres of groundwater recharge areas protected; percentage of stream courses on 303(d) list.[29]
6. Protecting wetlands: Percentage of wetland area protected.[30]
7. Reducing catastrophic fire risk and avoiding associated costs: Percentage of forests restored to natural fire regime.[31]

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[25] *About CPAD*, GreenInfo Network, http://www.calands.org/data (last visited Dec. 12, 2015); *CCED – California Conservation Easement Database*, GreenInfo Network, http://www.calands.org/cced (last visited Dec. 12, 2015).

[26] *Areas of Conservation Emphasis (ACE-II)*, Cal. Dep't of Fish & Wildlife, http://www.dfg.ca.gov/biogeodata/ace/ (last visited Dec. 12, 2015); *California Natural Diversity Database*, Cal. Dep't of Fish & Wildlife, http://www.dfg.ca.gov/biogeodata/cnddb/ (last visited Dec. 12, 2015); *California Wildlife Habitat Relationships*, Cal. Dep't of Fish & Wildlife, http://www.dfg.ca.gov/biogeodata/cwhr/ (last visited Dec. 12, 2015).

[27] *Habitat Connectivity Planning for Fish and Wildlife*, Cal. Dep't of Fish & Wildlife, https://www.wildlife.ca.gov/Conservation/Planning/Connectivity (last visited Dec. 12, 2015); *Science & Collaboration for Connected Wildlands*, SC Wildlands, http://www.scwildlands.org/ (last visited Dec. 12, 2015).

[28] *Farmland Mapping and Monitoring Program*, Cal. Dep't of Conservation, http://www.conservation.ca.gov/dlrp/fmmp (last visited Dec. 12, 2015).

[29] Land Cover Institute, *Get Land Cover Data*, U.S. Geological Surv., http://landcover.usgs.gov/landcoverdata.php (last visited Dec. 12, 2015); *Implementing Clean Water Act Section 303(d): Impaired Waters and Total Maximum Daily Loads (TMDLs)*, U.S. Envtl. Protection Agency, http://www.epa.gov/tmdl (last visited Dec. 12, 2015).

[30] *National Wetlands Inventory*, U.S. Fish & Wildlife Service, http://www.fws.gov/wetlands/ (last visited Dec. 12, 2015); *About CPAD*, GreenInfo Network, http://www.calands.org/data (last visited Dec. 12, 2015); *CCED – California Conservation Easement Database*, GreenInfo Network, http://www.calands.org/cced (last visited Dec. 12, 2015).

[31] *FRAP Data*, Cal. Dep't of Forestry & Fire Protection (Cal Fire), http://frap.fire.ca.gov/data/frapgisdata-ffrcc (last visited Dec. 12, 2015).

B. State Scale: California Examples

California state agencies are doing great work to develop indictors and metrics. While these may not be designed to measure resilience, many of them prove to be excellent proxy measures for the resilience of the state's forests and rangelands, public health, infrastructure, and water systems.

1. Safeguarding California Plan and Implementation Action Plan

The California Natural Resources Agency (CNRA) is currently assembling implementation plans for *Safeguarding California*, the state's climate change adaptation strategy.[32] In October, CNRA released draft implementation plans for public comment.[33] Both *Safeguarding* and the draft implementation plans address a broad range of conservation issues including ocean/coastal resources, biodiversity and habitats, energy, public health, community development and land use, water, and emergency management.[34] In the draft Implementation Action Plan, each sector has included a set of draft metrics.[35] These provide a good starting point, but will need significant expansion to provide a comprehensive picture of resilience and will also need to be updated and monitored over time.

2. Department of Water Resources— Evaluating Projects, Resource Management Strategies, and Integrated Regional Management Plan Benefits with Climate Change[36]

California's Integrated Regional Water Management Plan (IRWMP) standards demonstrate how climate change resiliency is included with other objectives and performance metrics so that the contributions of a project to adapt to and mitigate climate change are considered in project development and evaluation, alongside other planning objectives. Many of these could be scaled up to the regional and state level.
For example:
Objective: Develop a reliable water supply.

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[32] *Safeguarding California: Implementation Action Plans*, California Natural Resources Agency, http://resources.ca.gov/docs/climate/Safeguarding%20California_Implementation%20Action%20Plans%202015%20(CNRA).pdf.

[33] *Id*.

[34] *Id*.

[35] *Id*.

[36] Climate Change Handbook for Regional Water Planning, *Evaluating Projects, Resource Management Strategies, and IRWM Plan Benefits with Climate Change*, Water.Ca.gov, http://www.water.ca.gov/climatechange/docs/Section%206%20Evaluating%20Projects-Final.pdf (last visited Feb. 23, 2016).

Sub-Objective: Increase water supplied by sources that are not vulnerable to climate change.

Performance Metrics:

1. Number of sources not vulnerable.
2. Amount of annual supply with reduced vulnerability.[37]

By incorporating climate change into the IRWMP objectives and performance metrics, the resiliency benefits of projects will be quantified in the project's performance measures, thereby factoring into project prioritization. For example, with respect to the protection of coastal wetland habitat, one objective is set to "minimize habitat loss to sea level rise" and the performance measure is "land preserved to accommodate wetland migration". This is measured at the project level by acres of land preserved.[38] Projects that provide this benefit will be given priority as a result.[39]

Other examples of resource management strategies with measurable climate resilience benefits include:

Resource stewardship includes stewardship of land, wildlife, and water by way of conservation and preservation, ecosystem restoration and forest management, watershed management, flood attenuation, and water-dependent recreation.[40]

Riparian habitat restoration can be a key aspect of integrated flood management, as the natural storage provided by riparian wetlands can serve as buffers that absorb peak flows and provide slow releases after storm events.[41] Performance metrics examples include:

1. Presence/absence of key indicator species,
2. Acres of a certain habitat or floodplain function restored/protected, and
3. Volume of natural flood storage provided.[42]

Improved flood management involves emergency planning, general planning activities (e.g. infrastructure improvements), and policy changes (e.g. defining new hazard zones).[43] Flood management strategies can help a region adapt to many other climate change impacts, including ecosystem vulnerabilities and water quality.[44] Performance metrics that could quantify flood management project adaptations include:

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[37] *Id.* at 4.
[38] *Id* at 3.
[39] *Id* at 25.
[40] *Id* at 14.
[41] *Id.*
[42] Climate change Handbook for Regional Water Planning, *supra* note 36.
[43] *Id* at 15.
[44] *Id.*

1. Acres of a certain habitat or floodplain function restored/ protected,
2. Volume of natural flood storage provided,
3. Storm return period used for planning, and
4. Expected damage resulting from a certain return period storm.[45]

C. Regional/City Scale

Climate impacts affect humans and nature at the local/microclimate level (as seen with hazard mitigation planning) and so it is essential to downscale metrics to this level, whenever feasible.

Recently passed legislation reflects the importance of local climate risk analysis and strategies. Senate Bill 379[46] requires cities and counties to include a climate vulnerability assessment and adaptation strategies in the Safety Element of their County General Plan or upon the next revision of the Hazard Mitigation Plan. Furthermore, it requires the plan to include a set of adaptation and resilience goals, policies, and objectives based on the vulnerability assessment; as well as feasible implementation measures, including the identification of natural infrastructure actions that may be used in adaptation projects.[47] Planning this way will enhance the resiliency of California's communities to climate change and ensure that local governments are planning early. Importantly, the assessments can inform local resiliency indicators and process indicators can be used to track implementation of the adaptation implementation measures that are outlines in the General Plan.

Senate Bill 246[48] fosters climate adaptation planning at the local level by establishing the Climate Adaptation and Resiliency Program to be administered by the Office of Planning and Research (OPR). The program will coordinate state, regional, and local agency adaptation efforts. SB 246 also requires the Office of Emergency Services, in coordination with the Natural Recourses Agency and OPR, to update the state's Adaptation Planning Guide (APG)[49] every three years to provide tools and guidance to local governments in implementing climate adaptation and climate resiliency projects. Updates to the APG provide an opportunity to track progress on adaptation planning and should include local/regional resilience indicators.

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[45] *Id.*

[46] S.B. 379, Cal. 2015-2016 Reg. Sess. (Cal. 2015).

[47] *Id.*

[48] S.B. 246, Cal. 2015-2016 Reg. Sess. (Cal. 2015).

[49] *California Climate Adaptation Planning Guide*, Cal. Nat. Resources Agency, http://resources.ca.gov/climate/safeguarding/adaptation_policy_guide/ (last visited Dec. 12, 2015).

There are a number of examples of metrics being used at this scale, a select few are summarized below.

1. San Francisco Planning and Urban Renewal Association Bay Area Regional Collaborative[50]

The San Francisco Planning and Urban Renewal Association Bay Area Regional Collaborative report is an initial assessment of the efforts already underway in the Bay Area to measure and build climate resilience, including directional trends and quantitative or qualitative assessments.[51] Examples of ecosystem and public health metrics from this report are listed below.

Indicators for ecosystem health:

1. Coastal subsidence (or erosion): Rate of subsidence; existence of restoration plans to stop or ameliorate subsidence.[52]
2. Rarity: percentage Endemic or endangered species.[53]
3. Resilience to disturbances: percentage of important species that can move/shelter or have adaptive survival mechanisms in severe weather or fire.[54]
4. Protected migration corridors: Acres of protected land in ecologically rich areas; acres of protected land upland of existing wetlands for them to migrate.[55]
5. Flood Events: Measure trend (increasing or decreasing frequency and duration) (From the State of the Bay measure for ecological processes).[56]

Public health indicators and performance measures include:

1. Safe air: Air quality measurements for specific criteria pollutants: PM, ozone, NOx, etc.[57]
2. Safe water: Water quality standard attainment for surface waters (fishable, swimmable, etc.), drinking water quality meeting all federal goals (maximum contaminant levels).[58]

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[50] Laura Tam & Aleka Sevill, Sizing Up Climate Resilience in the Bay Area: A white paper by the Bay Area Joint Policy Committee and SPUR (2014), http://www.spur.org/sites/default/files/publications_pdfs/Sizing_Up_Climate_Resilience.pdf.

[51] *Id.*

[52] *Id.*

[53] *Id.*

[54] *Id.*

[55] *Id.*

[56] Tam, *supra* note 50.

[57] *Id.*

[58] *Id.*

3. Reliable mobility: percentage population with access to public transit within a quarter mile.[59]
4. Heat resilience: percentage of people in homes that have air conditioning; cooling centers per capita; percentage of people in homes that are retrofitted for energy efficiency and thermal comfort.[60]
5. Access to hospitals during an extreme weather event: percentage of people that can walk, bike, or drive to a health care facility within 20 minutes.[61]

While useful at the regional scale, much of this data may already be available to be employed at the state scale as well.

2. City Resilience Framework

The City Resilience Framework (CRF), from Rockefeller's 100 Resilient Cities report, provides a lens to understand the complexity of cities and the drivers that contribute to their resilience.[62] Looking at these drivers can help cities to assess the extent of their resilience, to identify critical areas of weakness, and to design actions and programs to improve the city's resilience. The CRF also provides a common language that enables cities to share knowledge and experiences.[63] Measures include:

1. *Leadership & Strategy:* Effective leadership and management; Multi-stakeholder alignment.[64]
2. *Health & Wellbeing:* Diverse livelihoods and employment; Access to financial assistance.
3. *Economy & Society:* Availability of Financial Resources and Contingency Funds; [Existence of] business continuity planning.[65]
4. *Urban Systems & Services:* Continuity of Critical Services; Flood Risk Management.[66]

These would need to be more clearly defined and data sources would need to be available across the state, but at a minimum, this provides

[59] *Id.*
[60] *Id.*
[61] *Id.*
[62] *The City Resilience Framework*, 100RESILIENTCITIES.ORG, http://www.100resilientcities.org/resilience (last visited Feb. 23, 2016).
[63] *Id.*
[64] *Id.*
[65] *Id.*
[66] *Id.*

high level guidance regarding how to approach measuring urban resilience at the city level.

3. City of Berkeley Climate Action Plan Progress[67]

The City of Berkeley provides a great model in measuring resilience at the city level. Strategies included in the City's Climate Action Plan include:

1. Prepare for the impacts of climate change on the region's water supply by encouraging rainwater recycling and graywater use through development of outreach materials and local guidelines;
2. In preparation for rising sea-levels and more severe storms, take steps to reduce property and ecosystem damage associated with flooding and coastal erosion; and
3. Mitigate increasing extreme heat events by protecting and increasing urban tree cover.[68]

Performance is measured with the following indicators:

1. Annual net tree gain (added 4,448 street and park trees since 2000);
2. Annual water consumption (17 percent less household water consumption since 2000); and
3. Graywater and rainwater harvesting (increase water conservation and reduce potable water use).[69]

Much of this data should be available throughout the state and thus easily scaled up to the state level.

D. Federal Efforts

There are a number of efforts to track ecosystem and community resiliency commencing in 2015-2016. This provides a great opportunity for California (and other states) to align their efforts and take advantage of the federal data and tracking tools and create comparable indexes.

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[67] *Climate Action Plan Progress*, City of Berkeley, http://www.ci.berkeley.ca.us/climateprogress (last visited Feb. 23, 2016).

[68] *Climate Action Plan Core Strategies Goals & Metrics for Climate Adaptation*, City of Berkeley, http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=70986 (last visited Feb. 23, 2016).

[69] *Berkeley Climate Action Plan: Tracking our Progress Adapting to a Changing Climate – Water Recycling and Graywater Use*, City of Berkeley, http://www.ci.berkeley.ca.us/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/Graywater%20Status%20CAP.pdf (last visited Feb. 23, 2016).

The White House set a goal to "evaluate and learn from ongoing resilience efforts to inform future actions."[70] Agencies to include DOI, USDA, NOAA, U.S. Army Corps of Engineers (USACE), Department of Defense (DOD), and EPA are to identify programs for resilience evaluation.[71] Such evaluations will include a) developing resilience metrics and b) evaluating whether investments produce resilience benefits for the resources and surrounding communities.[72] These efforts will be used to inform resilience indexes discussed below; one focusing on ecosystems, the other on communities.

1. Ecosystem Resilience Index

The Priority Agenda Enhancing the Climate Resilience of America's Natural Resources directs Federal agencies, to include DOI, NOAA, the Federal Emergency Management Agency (FEMA), the Army Corps of Engineers (USACE), and the Department of Transportation (DOT), to develop a federal Ecosystem Resilience Index, which will include a framework for a decision-support tool that will provide baseline resilience data and measure the progress of restoration, conservation, and other resilience-enhancing management approaches.[73] Experts will work toward developing common metrics, monitoring protocols, modeling approaches, and valuation methodologies to establish baseline conditions and provide measures of increased ecosystem resilience from cost-effective restoration.[74] This work will be coordinated with other Federal projects, including the Community Resilience Index (see below), the Disaster Resilience, the Climate Resilience Toolkit, and emerging efforts to develop indicators through the National Climate Assessment.[75]

2. Community Resilience Index

The Priority Agenda Enhancing the Climate Resilience of America's Natural Resources also directs FEMA to work in coordination with NOAA, National Institute of Standards and Technology, and insurers to identify or develop a community resilience index that considers

[70] Counsel on Climate Preparedness and Resilience, *Priority Agenda Enhancing the Climate Resilience of America's Natural Resources*, WHITEHOUSE.GOV, 20, http://www.water.ca.gov/climatechange/docs/Section%206%20Evaluating%20Projects-Final.pdf (last visited Feb. 23, 2016).

[71] *Id.*

[72] *Id.*

[73] *Id.*

[74] *Id.*

[75] *Id.*

environmental, economic, and social resilience.[76] This work will focus on economic and social components, in particular infrastructure, and will incorporate data and ecosystem information developed through DOI and NOAA efforts to measure progress on resilience through restoration. This work will produce a set of key indicators and an initial index methodology for implementation. Products of this effort will be incorporated into the Climate Resilience Toolkit as appropriate in the future.[77]

Additionally, the Third National Climate Assessment,[78] released in May 2014, which details climate change impacts across sectors and regions of the United States, provides a framework for more comprehensive assessments (including the development of indicators of change within regions and sectors) in the future.

Although these initiatives assess resilience at very different scales, they provide relevant and valuable context for state, local, and regional agencies, keeping in mind the effectiveness of indicators can be sensitive to scale. What is useful at the state or federal level may not be directly applicable when measuring and developing policy and programs to build resilience in the region.

III. Metrics in Action: Resilience Landscape Case Study

The Nature Conservancy's (TNC) Mount Hamilton project is a 1.5-million-acre conservation project and safeguards wildlife habitats that are threatened by urban development. Mount Hamilton contains some of the most scenic and also the most vulnerable natural settings in California. It supports majestic oaks, rare native grasses, and fields teeming with wildflowers.[79] In 1998, The Nature Conservancy began acquiring parcels of land that collectively would maintain the integrity of the ecosystem of Mount Hamilton.[80]

A detailed study of the Mount Hamilton region in 2010 identified several species that are the most vulnerable to climate change, and are in need of restored habitat.[81] Through the landscape scale assessment (see discussion on resilience ecosystem analysis above), TNC identified lack of connectivity and habitat that needed to be restored to enhance adaptive

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[76] Council on Climate Preparedness and Resilence, *supra* note 70.

[77] *Id.*

[78] *See* John Walsh, et al., *National Climate Assessment*, U.S. Global Change Research Program, (2014), http://nca2014.globalchange.gov/.

[79] *California Mount Hamilton*, The Nature Conservancy, http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/california/placesweprotect/mount-hamilton-1.xml.

[80] *Id.*

[81] *Id.*

capacity and prioritized these areas.[82] As a result, the Upper Pajaro River Floodplain now preserves the wildlife corridor between the Diablo Range and the Santa Cruz Mountains, connecting warmer arid interior lands (Mt Hamilton/Diablo Range) to the cooler Santa Cruz Mountains along the coast, thereby enhancing adaptation options for species.[83]

These corridors are increasingly vital to many species as they are forced to adapt to climate change and help perpetuate the genetic diversity of large mammals and other wildlife.[84] Conservation efforts here are providing a refuge and habitat for endangered species such as the San Joaquin kit fox and the bay checkerspot butterfly, bobcats, mountain lions, tule elk, red-legged frogs as well as a various bird species.[85]

The Conservancy has also urged this analysis by used by the Department of Fish and Wildlife in the Implementation Action Plan of the Safeguarding California Plan.[86]

IV. Conclusions and Recommendations

The role of indicators to track the effectiveness of climate adaptation actions is an important and rapidly evolving issue but resilience is inherently difficult to assess as we cannot foresee the future. A vast amount of work is underway among governments and planners at all scales however no standardized approach is emerging and much of discourse is predominantly theoretical.

While governments and planners at all scales are actively involved in creating indicators to measure resilience, a standardized approach has yet to emerge. Cities and communities can provide a number of good examples, although not all are scalable at the state level and the data may not yet exist. This paper focuses on ecosystems, landscapes, and public health, primarily at the state level in California. Less attention was given to governance, economies, or the private sector, but these systems are important to a resilient state and warrant further research.

The following recommendations are provided:

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[82] *Id.*

[83] *Id.*

[84] *Id.*

[85] *California Mount Hamilton*, *supra* note 79.

[86] Final Safeguarding California Implementation Action Plan has not been released as of January 13, 2015.

A. Utilize Process and Proxy Indicators

Since climate resiliency is a moving target with an unclear time horizon, process and proxy indicators are more useful (than output or outcome indicators) to measure progress towards making the state more resilient. A single performance metric for resiliency is often not appropriate or adequate to capture an entire system. Instead, the extent to which a project, strategy, or plan, helps the region or state adapt to climate change is better described by a suite of performance metrics related to more general objectives.

Both are recommended. Process indicators are useful to track progress on the strategies or plans, such as those outlined in the Safeguarding California Plan and Climate Action Plans across the state.[87] Tracking progress on implementing these plans is important to hold agencies accountable in implementation and demonstrating the state is taking action. However, goals and strategies in guidance documents are often too vague and high level to capture the resiliency of individual systems and communities.

This is where proxy measures come into play—capturing the resilience at a more detailed level. Since a resilient state is a composite of so many factors (public health, water supply, fire risk, sea level rise, etc.), proxy indicators are able to capture all of these various sectors and their component parts. As the examples in this paper highlight, a number of indicators are already being tracked by the state or groups like TNC, and provide a good starting point for measuring resiliency.[88] Additionally, proxy measures lend themselves to numerical quantification and thus could more easily be used in ranking and comparing the resiliency of projects or development (as with the IRWMP). This, in turn, can be used to prioritize funding and investments in a climate-smart manner. The challenge in using these rankings across systems is to create a quantification system that reconciles numerical valuations of resilience across multiple sectors.

By utilizing both progress and proxy measure the results are a comprehensive view of resiliency—progress in implementing its strategies as well as the resilience of the ecosystems and communities across the state at all levels.

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[87] *See Safeguarding California*, California Natural Resources Agency, http://resources.ca.gov/climate/safeguarding/.

[88] *See* Klausmeyer, K.R., et al., *Laying the Foundation: How Existing Conservation Areas Have Helped Prepare California for Climate Change*, The Nature Conservancy, July 2013, at 1.

B. Use Local/Regional Scale Indicators

While it is important to capture the resiliency of the state as a whole, climate impacts are felt at the local/microclimate level and it is therefore important to track resilience at this finer scale, where feasible. SB 379 and SB 246 (discussed above) provide opportunities to connect local indicators and planning.[89] The required vulnerability assessments should be used to inform local resilience indicators and process indicators should be employed to track progress on the resulting adaptation implementation measures in general plans/local hazard mitigation plans and the Adaptation Planning Guide. To this end, updates to the APG should track local/regional resilience metrics.

Data and resources (such as funding and staff) should be provided to local governments to measure and track resilience and they should be mandated to track indicators consistent with those adopted by the State that can then feed into the State's efforts.

C. Determine Proper Baselines

California is already seeing the impacts of climate change, so the question arises: when do we start measuring the baseline? In the examples of proxy measures presented in this paper, baselines were not explicitly addressed but rather, by default, began when the data began to be collected. To address this, one option would be to align with the baseline used to measure GHG mitigation targets: from the year 1990 (where data is available). If data is not already available for newly developed metrics, estimates could be made by using a reverse trend line, or as a last resort, the current-day status can be used.

D. Adaptive Management and Continued Monitoring

Once the baseline is established, the indicators must be consistently tracked over time to measure resiliency. It is encouraged that indictors are measured and reevaluated every five years (or more frequently) and modified as needed. Results should be posted online for easy public access to foster transparency and create accountability.

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[89] S. 246, 2015, 2015-2016 Reg. Sess. (Cal. 2015), http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB246; S. 379, 2015, 2015-2016 Reg. Sess. (Cal. 2015), http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB379.

E. Create a Platform to Integrate Metrics

The State should develop a platform to integrate various state climate-related indicators discussed in this paper (IRWMP, etc.). Combining the proxy measures provided by the existing indicators as well as the conservation metrics proposed by TNC (drawing from existing data sources), would provide a holistic view of the resiliency of California ecosystems, water supply and quality, forest health and resilience to increased fire risk.

F. Address Research Gaps

While there are a number of indicators to draw from, there are still gaps to be filled. Areas that would benefit from more research in order to create comprehensive metrics include:

Vulnerable Populations

About 12.4 million Californians live in census tracts with high social vulnerability to climate impacts.[90] It is critical that the policies aim to help these vulnerable populations build resilient communities, as climate change results in a disproportionate impact on vulnerable populations, metrics and indicators can be used to tract resilience.

Effectiveness of natural infrastructure options

Natural infrastructure such as wetlands to buffer sea level rise, floodplains to reduce flood threats to farms and communities, and protecting and restoring California's forests, safeguards our water supply and reduces the risk of catastrophic wildfire. The Safeguarding California Plan highlights a number of natural infrastructure strategies and it is important to implement and track these strategies.[91]

Economy and Employment

Tracking the state's economy and job market in a changing climate (similar to efforts made in the Risky Business Report) is an important

[90] Pacific Institute, Social Vulnerability to Climate Change in California A White Paper from the California Energy Commission's California Climate Change Center 22 (July 2012), http://www.energy.ca.gov/2012publications/CEC-500-2012-013/CEC-500-2012-013.pdf.

[91] *See Safeguarding California*, California Natural Resources Agency, http://resources.ca.gov/climate/safeguarding/

component of resiliency and also a useful message to the private sector.[92] This can incorporate agriculture and food markets and ability to continue to provide products despite changing temperatures and water supply. Also, assessing job growth and decline due to climate change (similar to the green jobs created as a result of GHG reductions mandated by AB 32) should be tracked.

Align with Federal Efforts

If, and when, the federal government moves forward in creating the Community and Ecosystem Resilience Indexes, California should align its indicators, where feasible. Ideally, the federal indexes will be a source of data (although at a higher resolution) for California and vice versa.

In sum, there is significant work being done in this field that can be utilized in establishing state resilience metrics. Experts should convene to address the research gaps and other issues such as scale and baseline, and funding will be critical. The State should work to align with local and federal efforts, where feasible. Importantly, the time to act is now. The state is already experiencing impacts from a changing climate and tracking progress on resiliency is essential to ensuring success in safeguarding its ecosystems and communities.

[92] City Resilience Framework, 100 Resilient Cities, http://www.100resilientcities.org/resilience#/-_/.