Technical and Final Report: Application and Findings of the North Bay-Delta Transect Watershed Assessment Framework (WAF)

Application of the Watershed Assessment Framework (WAF) in the Napa River Watershed - County of Napa 460000793

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May 24, 2010

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Acknowledgements

The project team would like to thank the project's funders and contributors.

Most of the project's funding came from the Department of Water Resources, agreement number 4600007937. Thanks also to the Supervisors of the County of Napa, and to the Napa County Resource Conservation District, for providing matching funding.

The approach taken here owes a debt to the North Bay Watershed Association's work on indicators and performance measures, and to the Watershed Health Scorecard project led by the Sonoma Ecology Center and Napa County RCD.

Thanks for supporting this effort go to Hillary Gitelman, Director; Patrick Lowe, Deputy Director; and Lynsey Kelly, GIS/Planner, at Napa County's Conservation, Development, and Planning Department. Kathleen Wallis in Napa County Information Technology Services also provided volumes of necessary data.

A special thank you also to other WAF project teams throughout the state. Their willingness to share their understanding, their work products, and the challenges of the tasks at hand made this project go further along than it would have had we worked in isolation.

Executive Summary and Report Card

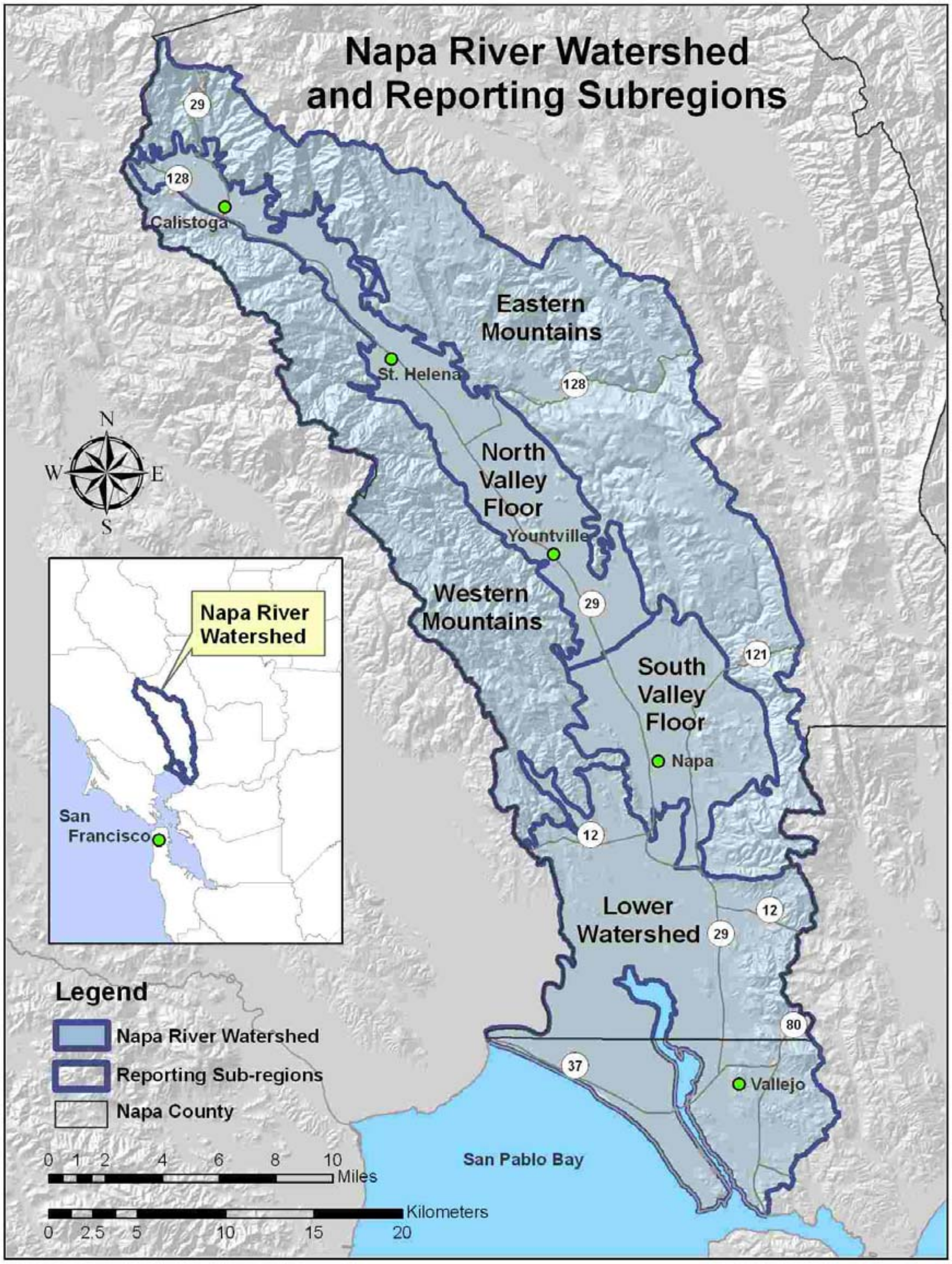
The Project

The Watershed Assessment Framework (WAF), as applied to the Napa River watershed, is a method of reporting on key indicators of watershed health over time, to guide watershed management actions. Watershed health is defined broadly, to include ecological, terrestrial, aquatic, water-related, social, and economic measures. The outcomes of this application are an easily understood Report Card on the health of the Napa River watershed, and more in-depth technical report detailing the process and analysis behind the WAF application and development of the Report Card.

The project was funded by the California Department of Water Resources, agreement number 4600007937. The County of Napa and the Napa County Resource Conservation District provided matching funds. The collaborative project team was headed by Jeff Sharp at the Napa County Conservation, Development and Planning Department, and Fraser Shilling at the University of California, Davis, Department of Environmental Science and Policy. Other partners were Napa County Resource Conservation District, Sonoma Ecology Center, and Oregon State University (Corvallis), Agricultural and Resource Economics Department.

The Setting

The Napa River is the largest river system that empties into the northern portion of San Francisco Bay. Relative to other watersheds in the North Bay, the Napa River watershed remains predominately rural, with about 34 mi^2 developed for urban uses. The watershed supports an abundance of wildlife and a nearly intact community of more than 29 native fish species, including steelhead and fall-run Chinook salmon. However, similar to the rest of the Bay-Delta region, the abundance and distribution of anadromous fish are substantially diminished since the 1940s. In response to this and other water quality issues, the State Water Board listed the Napa River and several other North Bay-Delta waterbodies as impaired by excess sediment, nutrients and pathogens. A Pathogens TMDL was approved the State Water Board in 2007 and a sediment TMDL was adopted by the Regional Water Board in 2009 and is pending State Board approval. Other regional and state policies affecting the Napa River watershed include a north coast Instream Flow Policy, adopted by the State Board in May 2010, a regional Stream and Wetlands Protection Policy under development, and a Wetlands and Riparian Area Policy being developed at the state level.


Napa River Watershed
and Reporting Subregions
29
128
Calistoga
Eastern
Mountains
St. Helena
128
N
W
E
S
North
Valley
Floor
Yountville
Western
Mountains
29
Napa River
Watershed
San
Francisco
South
Valley
Floor
121
Napa
12
Lower
Watershed
12
29
80
37
Vallejo
San Pablo Bay
Legend
Napa River Watershed
Reporting Sub-regions
Napa County
0 1 2 4 6 8 10
Miles
Kilometers
0 2.5 5 10 15 20

Stakeholder Involvement

Fortunately, the Napa River watershed has strong community stakeholder involvement. This project grew out of local initiatives to understand ecological and community conditions in Napa Valley, such as the Watershed Information Center and Conservancy of Napa County, and out of regional (Napa-Sonoma Water Quantity Scorecards) and state-level efforts to standardize ecological reporting from watersheds. Through various planning efforts the local stakeholder community has expressed a suite of goals related to ecosystem protection and quality of life in the Napa River watershed. The project team consolidated these community-derived goals and used them to select 14 meaningful indicators that had readily available and reliable data.

Report Card Development

A goal of the WAF project was to develop an easily understood report card ("scorecard") of watershed health relative to watershed goals. A report card using a scoring of 0 – 100 (very poor health to excellent health) was used to assess and track watershed health. A draft Napa River watershed report card was developed using community-derived goals and is provided below. An illustrative and more publically approachable version of the draft report card can be found in Appendix 8.2 of this report and is designed to be a brochure template.

Reading the Report Card

Each watershed subregion was evaluated for its condition relative to targets for each indicator. Scores close to 100 reflect excellent watershed health. The subregions are: **WM** – Western Mountains, **LW** – Lower Watershed, **EM** – Eastern Mountains, **SVF** – South Valley Floor, **NVF** – North Valley Floor. Trend was evaluated from a combination of trend assessments from each subregion. Confidence refers to quantitative and professional assessment of confidence in the result. **ND** indicates that the score or trend was not determined because data were not available or sufficient.

Goals	Indicators	Watershed Subregion Condition Score					Watershed Condition Score	Trend	Confidence for Subregion Scores
		WM	LW	EM	SVF	NVF			
Improve and protect geomorphic and hydrologic processes	Impervious area	ND	ND	ND	ND	ND	75	Declining	Moderate
Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making	Local media coverage of watershed topics	ND	ND	ND	ND	ND	46	No trend	High
	Access to public open space	2	22	1	74	58	38	ND	Low - High
Conserve, protect and improve native plant, wildlife and fish habitats and their communities	Fish community	ND	37	ND	78	ND	ND	ND	Moderate
	Habitat fragmentation and connectivity	77	34	100	29	51	67	ND	High
	Sensitive bird species	64	77	82	88	60	74	No trend	Low
	Aquatic insects	59	33	53	39	41	45	ND	Moderate - High
	Fire recurrence	84	80	42	99	48	65	ND	Moderate

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Goals	Indicators	Watershed Subregion Condition Score					Watershed Condition Score	Trend	Confidence for Subregion Scores
Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change	Carbon storage and net primary productivity	98	100	97	93	94	97	No trend	Moderate
Support community planning and management actions that further the goal of a healthy, happy, and economically just community	School lunch program enrollment	ND	45	55	70	61	58	Declining	Low – High
	Housing affordability	66	60	66	57	40	58	Declining	Moderate – High
Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity	Groundwater	Spring: Main Basin = 100, MST Basin = 29; Fall: Main = 67, MST = 7					ND	ND	Moderate
	Water conservation	ND	ND	ND	39	ND	ND	ND	High
	Stream temperature	100	81	ND	87	54	82	No trend	Moderate

NOTE: No watershed score was calculated for Fish Community, Groundwater and Water Conservation as data for these indicators were available for only for a few select subregions of the watershed.

Results and Recommendation

Are we reaching our goals? How healthy is the watershed?

The watershed condition scores across all 14 indicators are not extreme, in the positive or negative sense; all of them lie between 38 and 97. For some indicators no watershed score was calculated because the data for these indicators were available only for a few select subregions within the watershed.

In general, based on the objective measures used in the project, overall watershed health of the Napa River can be described as fair. For certain indicators and certain subregions, conditions are good (e.g., terrestrial and aquatic conditions tend to be better in the less disturbed eastern and western mountains). For other indicators and subregions, conditions tend to be poor. (e.g., aquatic and biological conditions in the developed valley floor tend to be worse than the mountains). This does not mean that conditions in the Napa River watershed are worse than other watersheds in California. Many of California's watersheds are in fair or worse condition. What should be of most concern to the Napa River watershed community is that conditions are only fair and that for many indicators where a trend could be determined, there is a measurable decline in condition over time.

It is important to keep in mind that the reliability of these findings varies dramatically among the 14 indicators scored and that variability in reliability of an indicator may be different for individual subregions. In some cases, a given indicator may have no score for a particular subregion; this may be because it does not apply there or because there are insufficient data to support a statistically significant scoring.

Setting targets and comparing indicators against them presents a unique set of challenges. This project defined a reference or target condition for each indicator, with which the value of the indicator metric could be compared and presented in a score on a scale of 0 to 100 (0 being very poor condition and 100 very good condition). In some cases, based upon established science, a non-linear scaling curve was used rather than a linear scale. In this manner, a score of 50, for example, can be interpreted as halfway between the two known extremes, be they environmental, social or economic conditions.

Ideally, all indicators would be independent of each other, and their scores would be affected only by external forces such as management actions, weather, fire, or economic conditions. In reality, however, none of the indicators analyzed is strictly independent of the others, but each is different enough from the each other to reflect a useful aspect of watershed health.

Although not perfect, use of these measures (i.e., indicators) of watershed vital signs can help guide community decisions to turn declining trends around and encourage a trajectory toward a healthy and more sustainable watershed.

In general, the community needs more and better data, and deeper analysis, to understand the health of its watershed and if the watershed is meeting established goals. Many basic conditions—such as the state of the streams during the driest time of year, the water use efficiency of residents and businesses, the state of the local fisheries—cannot be tracked clearly (i.e., with great confidence) until watershed monitoring efforts are increased and improved.

Unfortunately the project's budget and timeline was reduced halfway through the original scope of work. This reduction by the funders prevented a full peer review of the processes undertaken and stakeholder follow-up. It is recommended that the results of this assessment be further reviewed by technical experts and by watershed stakeholders to refine the approach and ensure the community's goals are accurately presented.

1. Introduction

Why do we need indicators?

Environmental, economic, and social indicators are used world-wide to report performance of human, natural, and combined human-natural systems. Indicator frameworks vary depending on what is being measured and on the audience targeted for reporting. The National Research Council (NRC, 2000) identified two types of frameworks: those that measure the status or condition of the system, and those that seek to identify cause-and-effect relationships. Many contemporary indicator frameworks incorporate both condition indicators and indicators of pressures or influences. This combination allows for a condition assessment and an evaluation of what may be driving condition. This reflects a common attribute of these frameworks: that they are practical and intended to support decision-making, usually in support of restoration, regulatory, or sustainability goals. This combination allows for evaluation and reporting on system attributes that are important for watershed and regional residents and stakeholders, as reflected in regional and local goals.

Ecological indicators are used by, for example, the Millenium Ecosystem Assessment (http://www.milleniumassessment.org), the Environmental Performance Index (http://epi.yale.edu), the World Health Organization (http://www.ncbi.nlm.gov/pubmed/8518769), and the Chesapeake Bay Report Card (http://www.eco-check.org).

In this project, selection of indicators, analyses, and interpretation was conducted in an open, transparent process, which provides an educational (and networking) opportunity for all involved. Choosing indicators that reflect conditions facilitates a better understanding of how actions in a specific region can affect watershed function and processes. Within the North Bay and Delta, the Napa River watershed was chosen for this first phase of condition and trend evaluation.

For the focus watershed, the Napa River watershed, we evaluated the whole system (social, economic, and environmental conditions) at the watershed scale, to help build relationships between these conditions and processes and watershed management actions. The value of protecting and restoring watershed functions is in direct proportion to the services well-functioning watersheds provide. Before this can be assessed, appropriate valuation tools must be developed, such as the indicator system described here. We developed these tools and describe the status and trend of the focus watershed's conditions. To the degree that data sources allowed, each of the indicators were assessed relative to social targets.

Why use the watershed unit?

Watersheds are regions that drain to a particular water course or body of water (Figure 1). Humans depend on a vast array of resources and services provided by rivers, tributaries, and surrounding lands. Historically, the prosperity of many societies has been tied to the watershed resources they controlled (O'Conner and Costa 2004). Yet many human activities can greatly modify natural watershed processes, altering the patterns and functions of riverine and adjacent terrestrial ecosystems (Fight et al. 2000). Effective management and conservation of resources and ecosystems relies on knowledge of watershed processes and how human activities modify them.

In traditional application, a watershed is a geographic area defined by the movement of water (precipitation) draining to a common point or waterbody. A more expansive definition of a watershed is one that applies to natural attributes (soil, water, rivers, erosion, vegetation, animal species) and human uses and conditions (land use, social structure, and organization) within the traditionally defined area. The subtle difference in the latter, more expansive concept of a watershed is that it explicitly includes the relationship between people and the environment they utilize and manage.

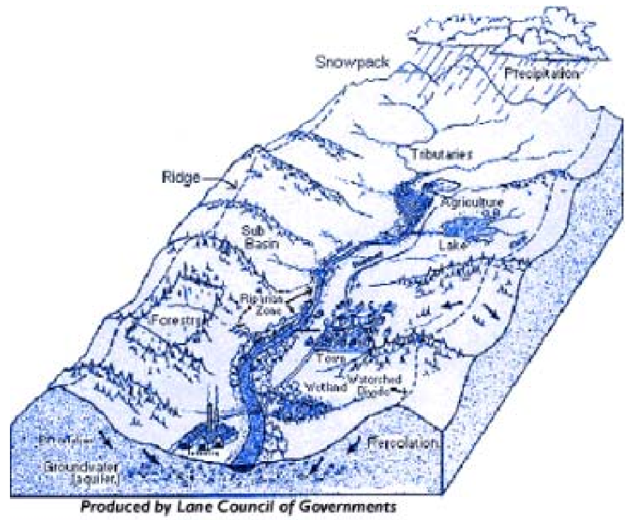


Figure 1. Depiction of a typical watershed (EPA

We used this more expansive definition of a watershed, one that includes human social and economic elements. Although still geographically based, the broader definition facilitates assessment of the degree to which natural process and condition goals are being achieved, knowing that these "watershed" goals are affected by (and perhaps correlated with) human social and economic systems and conditions. In using a broader application of the term "watershed," we gained the ability to assess indicators that measure how physical watershed condition(s) affect economic and social goals (e.g., fish-ability of streams, fire frequency, primary productivity), and conversely, how economic and social systems and patterns affect watershed condition goals (e.g., species biodiversity, habitat connectivity, water quality).

How can indicators be used?

Tracking a limited number of informative indicators allows watershed residents and managers to assess the condition of the watershed, to see trends or changes in those conditions over time, and to adapt their management actions to achieve desired conditions.

The system we used to develop and organize indicators is called the Watershed Assessment Framework (WAF) and is based on the US Environmental Protection Agency's Science Advisory Board's approach (SAB, Young and Sanzone, 2002). The SAB's recommendation to the USEPA was that environmental information be organized into categories corresponding to major environmental attributes and processes and that the indicators included be based upon the goals and objectives for the environmental system being evaluated. The "essential ecological attributes" (EEAs) recommended by the SAB are: landscape condition, biotic condition, physical/chemical condition, ecological processes, natural disturbance, and hydrology/geomorphology. The Watershed Assessment Framework builds on this basis and adds social and economic categories (quality of life) as important aspects of evaluating watershed condition.

The SAB approach does not provide guidance for comparing indicator values to a desired or reference condition, or guidance for aggregating normalized values into "scores" for the EEAs (and other possible aggregations). The SAB framework suggests that indicator information corresponding to measurable objectives can be extracted from the framework; however, how that can occur is not described in any detail. The WAF approach we propose here fills these gaps, describing the use of the framework to organize condition indicators, a normalization approach drawn from the statistical literature, an approach for measuring condition in system categories (e.g., EEAs), and an approach for measuring performance relative to desired goals and objectives.

The WAF approach is based on metrics and indicators (a glossary of terms is provided in Appendix 8.1) that are organized into a hierarchical structure corresponding to aspects of natural and human systems that are termed system "attributes". The use of WAF attributes is not the only way to organize these measures of environmental (both human and natural) condition. Another way to organize information describing ecological, economic and social conditions is according to the goals that society has for these conditions.

Central to the WAF is the description of goals for the watershed or region being evaluated. From these goals, measurable objectives are crafted. Indicators are chosen that allow evaluation of the objectives and thus the goals. Indicators may or may not be actual metrics for which there are data. For example, water temperature may be an indicator, which is also a metric. However, native fish populations may be an indicator, but fish population attributes such as adult population size, reproduction rate, and population demographics may be the actual metrics, or things measured about native fish populations.

There are several project goals for the indicator system application itself. One is to report on the condition of a single watershed (the Napa River watershed), another is to provide a proposed watershed-scale goals and indicators for the North Bay and Delta, and a third is to use this approach as an example for a statewide system. These project goals for eventual use of the WAF are separate from the goals for the watershed.

Other watershed health indicator projects

Five other WAF projects in California were funded simultaneously with this project (San Francisco Estuary Partnership, Sierra Nevada Alliance, Sacramento River Watershed Program, Los Angeles and San Gabriel Rivers Watershed Council, and Urban Releaf). Total initial funding for these projects was roughly $2,000,000. The projects were designed to coordinate with each other. Through December of 2008, each project participated in a statewide WAF coordination effort founded by the project team leaders, called the California Watershed Indicators Council (CWIC). CWIC was intended to assist in regional and statewide application of the WAF.

Coordinating and integrating among federal, state, and NGO indicator development efforts is critical to creating a stable system for reporting ecosystem condition and management effectiveness (GAO Report, 2004). The project team coordinated its work through CWIC with other local and regional applications of the WAF in the Bay-Delta region, Southern California, the Sierra Nevada foothills, the Sacramento River watershed, and the lower San Joaquin River basin. Specifically, the team shared information with other WAF practitioners about approaches we were considering, ways of linking goals (e.g., from Watershed Management Plans, General Plans, Strategic Plans, IRWMPs, and others) to attributes and metrics, possible statistical tools, and various reporting mechanisms. Since a large part of the project's focus was on the mechanics of developing robust and structured indicators, analysis, and reporting, the work and coordination of CWIC is key to future development of the WAF at the state level. The project relied on shared expertise among the regions and through our pool of academic members (e.g., UC Davis, Oregon State University) and state agency (e.g., OEHHA and SWRCB) collaborators and contacts. The collaboration leveraged our work with that in other regions and vice-versa, coordinating assessment of watershed conditions and coordinating reporting of conditions to decision-makers and the public.

More locally, a great deal of watershed assessment and indicator work is being done that affects the Delta/North Bay region and the Napa River watershed. Up to ten projects have developed, or are developing, various indicator systems for reporting on the health of watersheds in the region. These projects vary in geographic scope, conceptual scope, and audience. They include at least the following:

- Sacramento River Watershed Program WAF
- San Francisco Estuary Partnership WAF for San Francisco Bay
- Watershed health scorecard for Napa River and Sonoma Creek watersheds
- North Bay Watershed Association indicators and performance measures
- Marin County Department of Public Works Watershed Stewardship Plan
- CALFED Science Program performance measures and CALFED monitoring assessment framework report card
- Bay Delta Conservation Plan
- Delta Vision
- Interagency Ecological Program
- California Water Quality Monitoring Council

Napa County context

The North Bay watersheds are home to major cities, agriculture, fresh-water wetlands, salt and brackish water marshes, managed and natural waterways, and native upland habitats. Because of historic and contemporary interactions among these systems, as well as impacts from outside the region, many of the native systems in the region are in decline.

Watershed and ecosystem restoration has been a priority for local governments for much of the last decade, and the Napa experience is illustrative. In 2002, the Napa County Board of Supervisors responded to increasing concern over environmental issues by creating the Watershed Information Center and Conservancy (WICC) of Napa County. Since then, the WICC Board has taken the lead in hammering out community environmental goals and a watershed monitoring strategy for the watersheds of Napa County. The WICC monitoring strategy embeds the selection and use of indicators within a larger context of adaptive management. The steps are as follows:

1. Identify management goals and monitoring objectives
2. Formulate assessment questions

3. design a monitoring program

4. Select watershed indicators

5. Develop data quality objectives

6. Manage data

7. Assess and analyze data

8. Provide for continual reporting and communication

9. Evaluate the validity and effectiveness of the program

10. Plan for general support and infrastructure

Within Napa County, the bulk of the population is concentrated within the incorporated areas of the Napa River watershed, and that is where the primary focus of these efforts has been directed. Because of this background, the Napa River watershed was selected as the pilot of this first phase of condition and trend evaluation.

The Napa River watershed has strong community stakeholder involvement and the stakeholders have an interest in working with partners on developing indicators for assessing watershed condition. Using an assemblage of established watershed goals and objectives (see Indicator Selection section of this report) the Napa River watershed served as an appropriate pilot watershed to test the application of the WAF using existing social, economic and environmental data. The knowledge gained through the application process of the WAF can then be used by the local stakeholders and partners to grow their understanding and connection with the Napa River watershed and its management.

The Napa River drains a 426 mi^2 watershed that discharges to the San Pablo Bay through the Napa-Sonoma Marsh. Relative to other watersheds in the North Bay region, the watershed remains predominately rural, with roughly 34 mi^2 developed for urban uses. The watershed supports an abundance of wildlife and a diverse and almost entirely intact community of sixteen native fish species, including steelhead and fall-run Chinook salmon. However, similar to the rest of the Bay-Delta region, the abundance and distribution of anadromous fish are thought to be substantially diminished since the 1940s. In response to anadromous fish declines (and other beneficial uses), the Water Board listed the Napa River and several other Bay-Delta waterbodies as impaired by sedimentation and other pollutants.

Various basin planning efforts are underway for the Napa River by both the State and Regional Water Boards. A Pathogens TMDL was approved the State Water Board in 2007 and a sediment TMDL was adopted by the Regional Water Board in 2009 and is now pending State Board approval. Other regional and state policies affecting the Napa River watershed include a north coast Instream Flow Policy, which was recently adopted by the State Board in May of 2010, a regional level Stream and Wetlands Protection Policy, currently under development, and Wetlands and Riparian Area Policy, which is being developed at the state level.

Through these various basin planning efforts and the recent updating of the County's General Plan, along with current challenges in response to existing ecosystem and regulatory conditions, the stakeholder community has expressed a suite of goals related to ecosystem protection and quality of life in the Napa River watershed. This increased level of community awareness has motivated watershed stakeholders to embrace the concept of using watershed condition indicators as a means to determine if established goals are being met. In response, the Watershed Information Center & Conservancy (WICC) of Napa County, which represents elected officials from the County and every city and town in the watershed, and a cross-section of community environmental and industry interest groups, initiated work with its partners and technical advisors, to utilize the WAF as a basis to initiate development of a county-wide watershed monitoring program.

The goal of the monitoring program is to identify appropriate watershed indicators for evaluation and test them at the local (i.e., Napa River) watershed scale. In the end, the work conducted by this project will benefit community stakeholders and the WICC, along with its partners and technical advisory committee, by completing the foundation upon which to build a robust and adaptive watershed monitoring plan, by selecting appropriate indicators and tools for analysis, and where data is sufficient, conducting initial analyses of watershed condition. Implementation of the project (pilot) in the Napa River watershed will also identify data gaps and provide needed evidence and encouragement for funding to begin collecting essential data for future analyses and assessment under the WAF.

Project geography

Figure 2 (below) shows the location of the project and the subregions of the Napa River watershed we used for reporting watershed health condition.

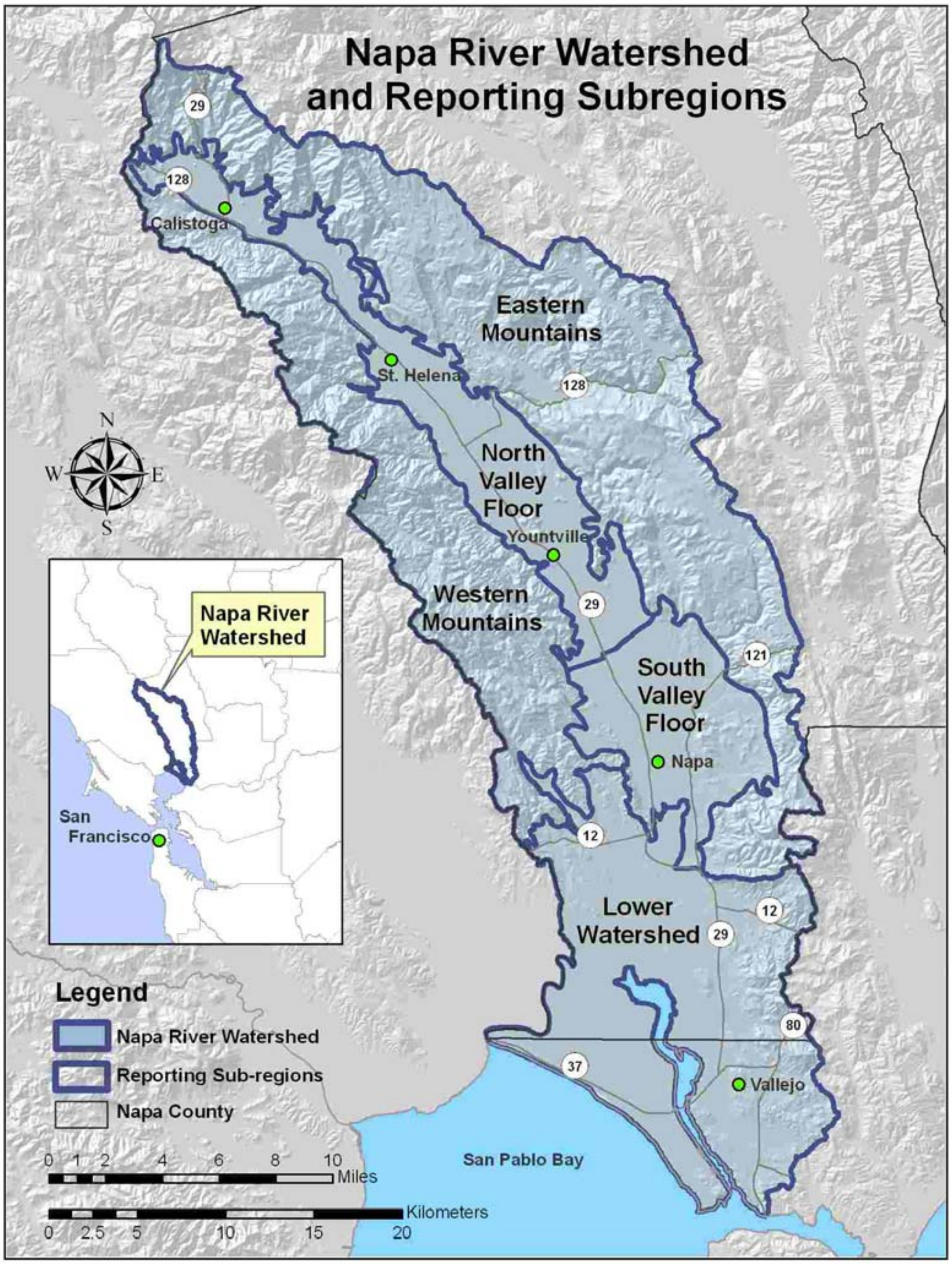


Figure 2. Project Area.

Because the project's timeline was truncated halfway through the grant period, the project study area was contained within the original pilot watershed, i.e. the Napa River watershed. As originally funded, the project area was to cover an east-west transect from the North Bay watersheds of Napa and Sonoma counties in the west to the Mokelumne and Cosumnes Rivers watersheds in the east. A focused pilot application of the WAF was to be implemented in the Napa River watershed and a discussion of scaling that effort along an east-west transect was to be included. The project was re-scoped after the 2008-2009 state bond/budget crisis, to focus solely on the Napa River watershed. The focus watershed for data analysis did not change. Candidate indicators corresponding to the goals and objectives were selected. These candidate indicators were refined to a shorter list for data analysis and report card development. The focus watershed is intended to be an example for the North Bay region, while recognizing that intra-regional differences in ecosystem properties will limit the direct application of indicators everywhere. The combination of the focus watershed and regional framework provides a foundation for region-wide application at the watershed scale, and serves as an example for possible statewide application. Documentation and presentation of the processes undertaken and results derived from implementing and testing the WAF in the pilot watershed are main focus of this report.

Project team and stakeholder involvement

This project was completed by a team of experts (project team) with input from a Technical Advisory Committee and many watershed stakeholders.

Primary project team members included:

Jeff Sharp (project manager) and Lynsey Kelly: Napa Co. Conservation, Development and Planning Dept., Napa

Fraser Shilling, Ph.D. (lead scientist), Jennifer Hemmert, Allan Hollander, Ph.D., Keir Keightley, David Waetjen, Emil Aalto, Lisa Komoroske: Univ. of California, Davis, Department of Environmental Science and Policy

Frances Knapczyk and Bob Zlomke: Napa County Resource Conservation District, Napa

Caitlin Cornwall, Deanne DiPietro, Zhahai Stewart, Arthur Dawson, Liz Lotz: Sonoma Ecology Center, Sonoma

Rich Adams, Ph.D.: Oregon St. Univ., Agricultural and Resource Economics Dept., Corvallis

Technical Advisory Committee members included:

Lisa Micheli: Pepperwood Preserve, Santa Rosa, formerly Sonoma Ecology Center

Jonathan Koehler: fisheries biologist, Napa County RCD

Felix Riesenberg: Napa County Public Works

Steven Lederer: Napa County Environmental Management

Jim King: If Given a Chance, Napa

Donna Feingold: Moving Forward Toward Independence, economic self-sufficiency committee of Napa Valley Coalition of Nonprofits, Napa

Jack Betourne: Napa County Flood Control and Water Conservation Dist.

Jim Lincoln: Napa County Farm Bureau

Ken Ramirez: Vineyard Worker Services, Napa

Mike Napolitano: Regional Water Quality Control Board, Region 2, Oakland

Sandra Guldman: Friends of Corte Madera Creek Watershed, Corte Madera

Chris Farrar: US Geological Survey

The Watershed Information Center and Conservancy (WICC) Board of Napa County was presented with periodic updates on the project and provided important input, particularly related to implementing it in the Napa River watershed. The role of the WICC Board is to assist the Napa County Board of Supervisors in their decision-making process and to serve as a conduit for citizen input by gathering, analyzing and recommending options related to the management of watershed resources countywide. The WICC Board has a responsibility to publicly evaluate and discuss matters relating to the development of long-term watershed resource management plans and programs, and serves to provide public outreach and education, monitoring and assessment coordination of Napa County's water and watershed resources.

In order to develop a comprehensive set of goals and objectives for the Napa River watershed, the project team surveyed 65 active watershed stakeholder groups throughout the North Bay by mail using a worksheet on which they were asked to write their goals and objectives for their watersheds. The Indicator Selection Process provided in Appendix 8.5 provides more detail on the use of stakeholder input.

Project products

Various work products were produced as a part of the project and were provided to the funder (DWR). The work deliverables demonstrate the processes that were developed and conducted in the course of completing the project. Those work products can be found in the appendix of this report (chapter 8). This report serves as the project's Technical Report and as the Final Report.

Final report

The final report (this document) serves three purposes. It 1) records the accomplishments of the project, 2) provides useful material for the continued development of watershed health indicator practice across California and in Napa River watershed particularly, and 3) transmits required work products (Tasks 4 and 5 in the reduced workplan) to the project's funder. The audience for the final report is assumed to have a modest understanding of scientific analysis and an interest in watershed science.

The final report describes the background and purpose of the project, the methods used to set goals and objectives, the methods used to select indicators, the mechanisms used to analyze data and interpret the results, expected uses of the project's products, and recommended next steps for this and other watershed assessment work. The appendices contain deliverables for the project's funder, many of which are the basis for sections contained in the main body of this report. Methods are provided in detail such that the projects results may be reproduced by other groups or organizations. At a later date, elected portions of the report, particularly the individual indicator reports in Chapter 4, will become the content of a proposed web-based report.

Report card

The Report Card is designed to quickly convey the results of the indicator analyses for the Napa River watershed as a whole, using graphics and text, and to present our best interpretation of the results in the context of living in and managing the Napa River watershed. The Report Card is a synopsis of this report's executive summary, presented in a brochure format. A copy of the Report Card can be found in Appendix 8.3. The Report Card is designed to be understandable by a broad audience of watershed stakeholders, including residents, landowners, elected officials, and resource managers. The Report Card provides the website address for the project, so that readers may access the more detailed final report.

Several important concepts are communicated in the Report Card for each indicator: the goal that the indicator was chosen to assess, target that was chosen to represent excellent condition of indicator, current condition of indicator with respect to target, trend, variability in condition across the watershed, statistical uncertainty of the condition, and the team's judgment of the quality of information with which each indicator was analyzed. The Report Card includes photos of the Napa River watershed, a table summarizing indicator analysis for Napa River watershed as a whole and Napa River subregions, and text describing the goals and history of the WAF project.

Online presentation

The materials described above, including goals, indicators, and analysis results, will be provided for download at a web address to encourage wide public access, paperless distribution, and in an updatable structure. Please see: http://sfcommons.org/scorecards/waf/napa as those resources become available.

A web-based system for storing, presenting, and sharing the elements of a watershed scorecard was also explored and prototyped by the project. This was done to address the need for a digital statewide framework for multiple watershed scorecards and multiple analyses over time for individual scorecards. The envisioned system allows for flexibility of presentation and scalability as new indicator analyses and additional watershed scorecards are completed in the future. For example, at the individual watershed level an online map links the subregions to the results of analysis at the subregion level, and at the regional level multiple scorecards could be presented by watershed and by WAF attribute and indicator. A wide variety of online views could be constructed as well as providing for outputs of the information in other media such as brochures, spreadsheets, and sections for reports. Outputs in XML (eXtensible Markup Language) would be used to share the data between systems, and RSS feeds could also potentially be employed for alerting users to new developments. Elements that are common across watersheds can be referenced from a shared source.

An open-source content management system was used to construct containers for the elements of a watershed scorecard as described by the Watershed Assessment Framework: goals, indicators, and indicator analysis results with supporting data and metadata. Such a system provides for entry of the information into forms, with the resulting structured content held in a database. The prototype demonstrates presentation of results from a single watershed point of view, and these results could be aggregated upward to become part of a multi-watershed comparison. Below is a schema for the data system.

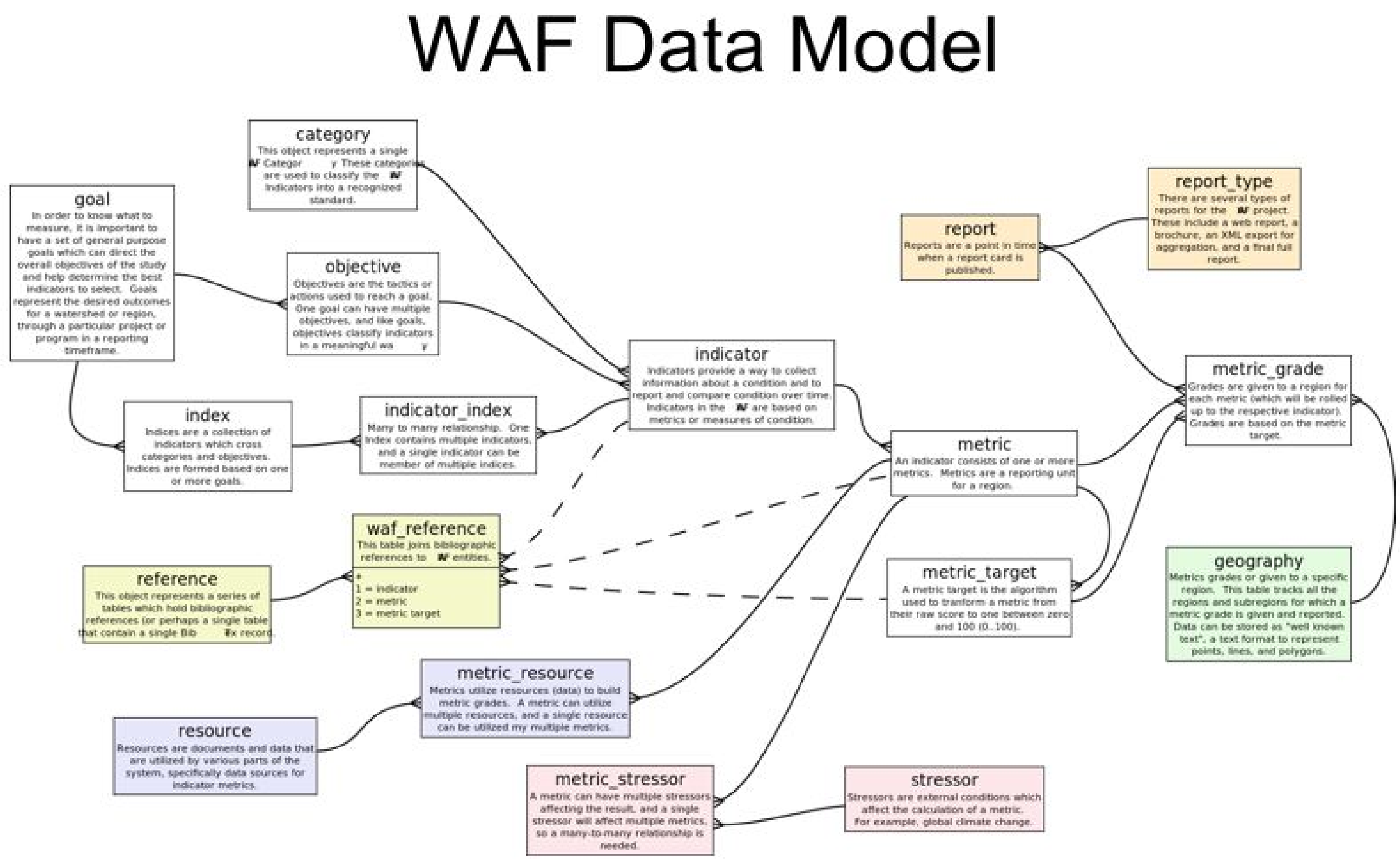


Figure 3. WAF Data Model, showing elements and relationships.

2. Indicator Selection

Goals and objectives

Central to the application of the WAF is the description of goals for the watershed or region being evaluated. From these goals, measurable objectives are crafted. Indicators are chosen that allow evaluation of the objectives and thus the goals. Indicators may or may not be actual metrics for which data are collected. For example, water temperature may be an indicator, for which water temperature could be a metric. However, native fish populations may be an indicator, but its metrics might be measurements such as adult population size, reproduction rate, and population demographics. A critical and sometimes missing component of indicator system development is an explicit or transparent link between the goals for the system and the indicators chosen to represent the system condition.

The project team began by considering watershed goals to guide the indicator selection process. The project team used three approaches to develop the list of watershed goals. First, the team surveyed 65 active watershed stakeholder groups in the North Bay by mail using a worksheet on which they were asked to write their goals and objectives for their watersheds. Ten groups responded to the survey. Second, we extracted goals and objectives from planning documents and mission statements of 17 stakeholders that did not respond to the mailed survey. The team searched online documents of state and federal agencies that are active in the region, and goals pertaining to the watershed attributes identified in the WAF were included in the comprehensive list. Third, the team presented the list of compiled goals to the project's Technical Advisory Committee, which suggested more goals that were added to the list.

The list of goals and objectives was subsequently refined, on the basis of the project team's investigation of relevant indicators likely to have sufficient data for evaluation. A broad list of potential indicators was then assembled, keyed to specific goals and objectives, on the basis of joint consideration of the indicator selection criteria, recommendations from project team members, and comparison with comparable systems in the global indicator literature. See Appendix 8.3 for a discussion of criteria used to select indicators.

This rather lengthy list of indicators was then subjected to a series of winnowing steps to produce a final set of indicators. Local resource agency staff first carried out an informal review of the list, selecting 21 indicators (approximately half) for closer analysis. This first-cut selection included at least one indicator for each of the 9 goals identified and at least one for each of the 8 attributes in the California Watershed Assessment Framework (WAF attributes). The procedure for making the final cull may be summarized as follows:

1. The first list of 9 goals and corresponding objectives was consolidated. There were areas of overlap between different goals, so we combined related issues into single goals. The resulting list included 6 goals, and for two of them a limited number of objectives were retained.

2. Indicators previously identified were organized into a table according to the new consolidated goal and WAF attribute with which each was most closely related. Table column headings corresponded to WAF attributes and table rows corresponded to goals and objectives. This made it easier to ensure that "all bases were covered" as we considered the final selection. Note that many indicators could logically be related to several different objectives, goals, or attributes. Indicators promising to serve multiple purposes should be carefully considered, not only for their value, but also the challenges they present during the reporting of results and any aggregation across WAF attributes. For simplicity, the team chose to highlight only one of these relationships.

3. The indicators were evaluated using a set of 7 criteria developed and used by two other regional WAF projects: Sacramento River Watershed Program and the Los Angeles and San Gabriel Rivers Watershed Council. Making use of short indicator descriptions supplied by UC Davis and our indicator selection criteria, we determined the degree to which each criterion appeared to be satisfied for each of the 21 indicators. For each of the 7 criteria, we judged whether the degree of satisfaction was high, medium or low, and we used these judgments to guide our selection of preferred indicators. Our aim was to select one indicator for each goal or objective. In doing this, the project team relied on both local knowledge and experience and the resources of our academic partners.

4. After review of the results of the previous step by UC Davis project partners, the project team decided to retain all indicators on the final list, subject to review in light of the availability and suitability of data.

The indicators analyzed for this project are listed in Table 1 below, together with their corresponding goals, objectives (if any) and WAF attributes. Additional details on the indicator selection process can be found in Appendix 8.5.

Table 1. Napa River Watershed Assessment Framework: Correspondences between goals, objectives, indicators, and WAF attributes

Goal	*Objective*	***Indicator***	Landscape	Hydrology & Geomorphology	Physical & Chemical	Biotic	Social	Economic	Natural Disturbance	Ecological Processes
Improve and protect geomorphic and hydrologic processes										
	Restore natural variability of hydrologic systems, including stream geomorphology and benthic composition									
	Reduce artificially increased inputs of sediment to streams, particularly those due to increases in runoff from developed areas									
		Impervious area	X							
Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making										
		Local media coverage of watershed topics					X			
		Access to public open space					X			
Conserve, protect and improve native plant, wildlife and fish habitats and their communities										
		Fish community				X				
		Habitat fragmentation and connectivity	X							
		Sensitive bird species				X				
		Aquatic insects				X				
Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity										
		Fire recurrence							X	
	Improve and protect flows to benefit aquatic communities and ecosystem processes									
		Late-summer streamflow		X						
	Reduce reliance on imports by reducing demand, improving the efficiency of water use, and increasing the reliability of water quality and yields from groundwater basins									
		Groundwater		X						
		Water conservation						X		
	Protect and improve water quality for aquatic ecosystems									
		Stream temperature			X					

Goal	Objective	Landscape	Hydrology & Geomorphology	Physical & Chemical	Biotic	Social	Economic	Natural Disturbance	Ecological Processes
Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change									
	Carbon storage and net primary productivity								X
Support community planning and management actions that further the goal of a healthy, happy, and economically just community									
	School lunch program enrollment						X		
	Housing affordability						X		

Table 2 below lists high-priority indicators that the project team did not analyze, because suitable data was lacking.

Table 2. High-priority indicators not analyzed for this project.

WAF Category	Goal	Priority indicators not analyzed
Hydrology/ Geomorphology	Improve and protect geomorphic and hydrologic processes	1. Embeddedness, permeability; 2. Channel morphology, dynamicism
Physical/ Chemical	Improve and protect geomorphic and hydrologic processes	1. Pollutant reduction through tmdl; 2. Water quality: dissolved oxygen, etc.
Social Condition	Support community planning and management actions that further the goal of a healthy, happy, and economically just community	1. sustainability policies index; 2. annual change in average house price compared to state average; 3. % residents that have positive view toward environment
Economic Condition	Support community planning and management actions that further the goal of a healthy, happy, and economically just community	1. income difference between top and bottom 20%; 2. % new development in urban areas, housing density; 3. annual change in average house price compared to state average
Natural Disturbance	Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity	1. Natural flooding and connection with floodplain; 2. % of un-developed watershed burned per year

Indicator selection criteria

An established set of criteria was used to assess and select candidate indicators for the Napa River watershed. More detail on selection criteria is provided in Appendix 8.5. Selection criteria for the indicators, in general, included the following:

- Availability of high-quality data
- Data affordability
- System representation
- Ability to detect change over time (i.e. data will continue to be collected)
- Independence of indicators from one another
- Supports management decisions and actions
- Can be reported and understood in public arenas

Challenges with indicator selection

Initially, there were 40 potential indicators, more than could reasonably be handled in this project. Reducing this number in an even-handed manner was a challenge. To some extent, indicators were selected because they related to issues that have aroused local interest. This is justified, because issues that arouse public interest are more likely to be studied and to have available data. The project team implicitly relied on the stakeholders to know what they thought was important and was guided by that. However, there may be important issues (and indicators) which this process has overlooked.

The criteria that were established to evaluate potential indicators made possible objective consideration of the merits of each, but individual members of the project team frequently found themselves working outside their areas of personal expertise in judging the various indicators. The breadth spanned by the range of indicators considered offers a challenge to the most well-rounded environmental scientist. It was important to get feedback from a variety of people with different qualifications and backgrounds, and to seek the opinions of both local agency people and university researchers. The project team distinguished between a first tier and a second tier of indicators, on the basis of the indicator selection criteria.

It frequently happened that an indicator that seemed promising turned out not to have available data of the desirable quality, or there was some other unforeseen difficulty. A common problem is that the data needed to study a broad range of environmental indicators are held by a great variety of organizations, so that finding the data is a challenge. Even when located, the data are not always available in an easily portable format, and some promising data sources were not used because of various practical difficulties.

For reasons such as these, some of the indicators initially selected as most important – the first tier – were not used after all, and those in the second tier section became more important.

3. Methods

This chapter describes the general principles and methods used for individual indicators. The exact methods used are described in association with each indicator. The sections below discuss the management of data, subregion reporting unit strategy, scoring indicators, trends analysis, aggregating scores, and determining confidence in results. This chapter is based in part upon initial methods presented in the project's "Data Analysis Framework," found in Appendix 8.6.

Reporting and analysis units

The reporting and analysis units were based on subregions of the Napa River watershed (see Figure 2). The project team aimed to provide some indication of the variation among different sections of the watershed without going to the tributary watershed level; the latter course was not practical, since there are approximately 50 recognized tributaries to the Napa River. The subregions used in this project are based on broad differences in elevation, vegetation, land-use, and relationship to the tidally-influenced zone. There are five watershed subregions:

- Lower Watershed
- South Valley Floor
- North Valley Floor
- Western Mountains
- Eastern Mountains

The Lower Watershed includes the entire watershed from the mouth at Carquinez Strait to the southern outskirts of the City of Napa; this includes the marshes, the City of American Canyon and portions of Vallejo, and Carneros, and the greater part of the tidal exchange occurs here. The rest of the watershed is divided into valley floor and mountains. The southern and northern portions of the valley floor are divided at Oak Knoll Avenue, the location of the most important USGS gaging station on the Napa River. The water level in the river is somewhat tidally influenced up to this point, so that the South Valley Floor is technically part of the tidal reach. Approximately half the watershed drains to the river north of Oak Knoll Avenue. The City of Napa lies within the South Valley Floor subregion, while the remaining communities of Napa Valley lie in the northern valley subregion. The surrounding mountains are divided into two separate subregions (western and eastern) for reporting purposes, in recognition of their differing ecology; the Eastern Mountains are considerably drier.

Scoring

To facilitate the future application of the WAF across broader regional scales, the project team developed a scoring methodology in coordination with the Sacramento River WAF project. As such, this section parallels the Sacramento River Watershed Program WAF Technical Report section on scoring in many ways.

An important step in making indicators useful is describing the meaning of specific values or ranges of values from an educational or decision-making perspective. For example, surface water temperature is a parameter that can be reported daily or annually, but if reported on its own may not be overly meaningful. When water temperatures are compared with temperatures important for the salmonid life cycle, then water temperature can be reported as an indicator of condition relative to the needs of fish. This provides a more meaningful context in which to interpret indicator status and trends. A creek with a temperature of 20^{o}C may be fine for recreational use and may support certain fish and wildlife species; however, salmon eggs and fry will be stressed at this temperature, so the indicator score based on the physiological needs of salmonids may be low for this temperature.

Each indicator status value (or trend) was compared to a reference or standard value, and the comparison was used to generate a score. Although it is important to pick a reference value that is meaningful for decision-making, it is just as important to make the choice transparent so that the reference value can be changed in the future if warranted by changes in knowledge, goals, or assumptions.

The project team chose reference or target conditions specific to the indicator using best available science, goals expressed by stakeholder organizations, and professional opinion. These are all mutable choices and can be regarded as proposals for how indicators can be evaluated. A very important benefit of taking this step is that scores can be combined across very different indicators (e.g., water temperature and benthic macroinvertbrate communities), whereas otherwise this would not be possible. Because all indicator conditions were quantitatively compared to a target, it was possible to try to normalize them in terms of *distance to target* according to a common scale.

Because environmental and socio-economic processes and conditions rarely respond to influences in a linear fashion, evaluating indicators relative to reference conditions must take into account these non-linear responses. For example, there is a linear rate of increase in carbon sequestration with area of vegetative cover, but there are non-linear effects of temperature on salmonid species.

Indicator metrics were quantified in their raw or native units (e.g., ^{o}C or tons C sequestered), and evaluated on the basis of their separation from the target condition. This target or reference condition is sometimes called the "ideal point" (Malczewski, 1999). The ideal point method was first introduced in the late 1950s and expanded by Milan Zeleny in the 1970s (Pomerol and Barba- Romero 2000). Zeleny (1982) operationalized the measurement of closeness with

$$d_i = f_i^* - f_i\,(x_{ji})$$

Where d_i is the distance of attribute state x_{ji} from the ideal value f_i^*, i indicates the attribute and j indicates the objective. For the Report Card, indicator distances from target were calculated in their native units and converted to a common scale (0-100) to be compared among disparate indicators, or to be aggregated into composite indices. The common scale conversion was relative to a threshold or objective specific to each indicator and was based on the appropriate linear or non-linear rate of change relationship.

Trend/time series analysis

The project team developed a methodology for time series analysis in coordination with the Sacramento River WAF project. Therefore, this section's text parallels the Sacramento River Watershed Program WAF Technical Report section on time series analysis.

Time series or trend analysis was primarily conducted using the Mann-Kendall statistical test. Trends analyses using the Mann-Kendall tests were conducted using custom programming in R, an open source statistical package. Changes in ecosystem characteristics over time are an important type of analysis and one of the most valuable types of information conveyed with indicators. Somewhat counter-intuitively, they are also rarely conducted using appropriate statistical techniques. Analysis of trend in time series data is necessary to determine if conditions in a subregion are improving or deteriorating. One of the most common techniques for determining trend is linear regression. However, linear regression requires certain data characteristics, such as normal distribution of values, which are not easy to assess in small data sets. Distribution-free trend analysis is ideal due to the unknown nature of the data, so non-parametric tests are preferred. Of the various commonly used options, the Mann-Kendall rank correlation trend test is the strongest (Berryman et al. 1988). It is appropriate for data that are not normally-distributed, tolerates missing values, and is relatively unaffected by extreme values or skewed data. Although it is sensitive to autocorrelation, this is only an issue in very long datasets and was not considered for these indicators. The output of the Mann-Kendall analysis is an assessment of the trend slope and its statistical significance.

One weakness of the Mann-Kendall is an inability to adjust for seasonality or cycling in the time series. Almost all environmental data will have daily, seasonal, inter-annual, and/ or inter-decadal cycles. This means that one cannot detect change in these data without taking into account and controlling for these cyclic effects. Full decomposition of a time series into its component parts (trend, oscillations, seasonal factors, and disturbances) is not always possible or practical (Jassby & Powell 1990). For these data, the Seasonal-Kendall test can be used to determine whether or not significant changes have occurred over time, while taking into account variation due to seasonal effects (Hirsch *et al*., 1982; Hirsch and Slack 1984; Esterby 1996). It retains the non-parametric strengths of the Mann-Kendall, but performs separate trends analysis for each season and compares the results. For certain indicators, there may have been infrequent data collection (e.g., annual), or only a few years of data collection (i.e., <5 years), in which case a seasonal trends analysis was not conducted and instead the standard Mann-Kendall was used.

Hess et al. (2001) ran simulations for six linear trend analysis techniques, and determined that the strongest are the Seasonal-Kendall test and a *t*-test adjusted for seasonality. France et al. (1992) also found the Seasonal-Kendall to be the strongest option, and the best when seasonality is unknown as well. For non-seasonal data, such as annual data, the Mann-Kendall is probably superior (Hamed & Rao 1998). When assessing trend within a broad region with multiple sampling sites, the same principle applies as with seasonal data: it is better to compare trends across sites than to combine them into a single time series. The Regional Mann-Kendall is analogous to the Seasonal-Kendall, but compares individual locations rather than seasons (Helsel & Frans 2006). Because it is statistically identical, it has all the advantages of the Seasonal-Kendall. This approach was used frequently for subregion analysis.

Uncertainty/confidence

The project team developed an approach to uncertainty in coordination with the Sacramento River WAF project. Therefore, this section’s text is similar in nature to the Sacramento River WAF Technical Report section on uncertainty.

The degree of certainty in the project results depends on two conceptual questions: whether good indicators were chosen and how well the data presented for each indicator accurately reflect the real status or trend in the metric(s). The first of these questions pertains to the indicators themselves and how well they address the objectives or attributes they are meant to represent. Certainty about the indicators depends on four main factors:

Importance — the degree to which a linkage (functional relationship) controls the outcome relative to other drivers and linkages affecting that same outcome,

Understanding — the degree to which the performance indicator can be predicted from the defined linkage (functional relationship) and its driver(s),

Rigor — the degree to which the scientific evidence supporting our understanding of a cause-effect relationship (linkage) is contested or confounded by other information, and

Feasibility — the degree to which input data necessary to calculate the proposed performance measure can be delivered in a timely fashion (without external bottlenecks) and the amount of effort (relative to other possible indicators) needed to implement the cause-effect linkage in a computer model.

Where possible, confidence findings for each indicator are mentioned in the corresponding sections as they form an important component of overall confidence in the results of the project.

The second question pertains to statistical confidence in the data presented for each indicator. The available data may contain a variety of sources of uncertainty including:

Measurement error – random or systematic errors introduced during the measurement process, sample handling, recording, sample preparation, sample analysis, data reduction, transmission and storage (USEPA 2006; Thompson 2002).

Uncertain/inappropriate interpretation of sampling frame – errors in inference resulting from opportunistically mining the available data without knowledge of the sampling frame (the complete list of sampling units in the target population for a particular study). For example, bird population data may have been collected by several different studies with different objectives and target populations (e.g. they could have focused on varying transect areas). Without this knowledge, we must make assumptions about the probability of selecting each site and the appropriate weighting of the observation.

Sampling error – the error resulting from examining only a portion of the total population (Cochran 1977; Lohr 1999; Thompson 2002). If a census of the population is taken (e.g., school lunch enrollment) then there is no sampling error.

Process error – actual variability between spatial or temporal units in the population. This source of variability exists even if a census is taken with no measurement error. This is often referred to as natural variability.

All of the above sources of uncertainty affect confidence in the estimates of status and reduce the ability to detect trends over time. For some indicators quantification of different sources of uncertainty in the data may be possible, but in many cases there are limitations to providing a qualitative description of the likely sources of error and associated magnitude. For each indicator, the best available data were aggregated to produce an estimate for each subregion. The 95% confidence interval for the metric statistics is presented, along with the minimum, maximum, and number of observations or sites (n). Finally, when possible, the estimates and associated confidence intervals were transformed to a 0-100 scale (as described in section 3.2).

Spatial scale and aggregation

To facilitate the future application of the WAF across broader regional scales, the project team developed a spatial aggregation approach in coordination with the Sacramento River WAF project. As such, this section parallels the Sacramento River Watershed Program WAF Technical Report section on spatial aggregation.

A desired feature when selecting indicators is that they can be scalable; that is, they are valid across different spatial and temporal scales. For instance, indicators reviewed on a larger (national) scale can be also useful on the regional and local level. The Indicator Development for Estuaries Manual (USEPA, 2008) suggests that, whenever possible, it is always best to try to align local and regional programs with programs at a higher (i.e., national) spatial scale, because this allows for future comparisons with data collected over the larger area. For example, the "benthic index", which provides a quantification of the response of benthic communities to stress, is an example of a scalable indicator (Kurtz et al., 2001). Finding scalable indicators is a difficult task because many cost-effective methods to measure and summarize social, economic, and ecological data are scale dependent (Hagan and Whitman, 2006).

Scalability of indicators may be more feasible in nested systems than in non-nested ones. For nested systems the issues of sampling and data aggregation are more straightforward because of the direct spatial correlation from one scale to the next. Data can be sampled at one scale finer (e.g., monitoring site) than the question of interest and then "up-scaled" to a larger evaluation or reporting unit (e.g., subregion). Sampling and data aggregation in non-nested systems prove to be more difficult because the emergent properties of the systems are different and simply aggregating data will overlook the synergistic effects of systems (US Forest Service, http://www.fs.fed.us/institute/monitoring/Scale_Overview.htm). In nested natural systems, cross-scale aggregation of environmental indicators may be more realistic than social or economic indicators. In contrast, social and economic indicators may be easier to aggregate when using nested political boundaries (e.g. municipality-county-state).

In the particular case of the USEPA SAB reporting framework, the Essential Ecological Attributes (EEAs) were successfully mapped onto structural, functional, and compositional characteristics of ecological systems at a variety of scales in order to assure coverage of different aspects of natural systems (Young and Sanzone, 2002). Furthermore, the EEAs and their subcomponents were checked to determine whether they would be relevant at several geographic scales (ecoregion, 1000 km2; regional landscape, 100 km2; small watershed or ecosystem, 10 km2; reach or stand, <1 km2). Overall, it was found that all the components of the SAB reporting framework were relevant to each geographic scale (Young and Sanzone, 2002), which is important because the SAB approach is the basis for the Watershed Assessment Framework and the Report Card.

Several different nested geographic scales at which aggregated indices can be developed include: (a) whole ecosystem/watershed, (b) primary subsystem habitat types (e.g., uplands, wetlands, in-stream), (c) categories of parameters within habitat types (e.g., wetland water quality), and (d) parameters within habitat types (e.g., in-stream nitrogen concentration). For the Napa River Watershed we reported indicator values and aggregated values to goals and objectives at the subregion extent. The project provides a method for translating characteristics at the site, reach, or creek drainage scale to the river basin and state scale.

The technique for reporting to the subregion level depended on the geographic type of data collected. Many of the datasets such as the water sampling information were collected at point localities, for instance a monitoring station on a stream. In this case, these data were assigned to subregions by a GIS operation of overlaying the points on the polygon boundaries of the subregions, and averaging values within a subregion. Some of the datasets, such as the fire history information, were originally represented by vector polygon GIS coverages. These were intersected with a polygon layer based on CALVEG vegetation units that provide for refined analysis within each subregion. Values were then reported to the subregional level by averaging across all analysis units within each subregion. Finally, some datasets were developed from raster surface layers such as land cover data which exhaustively covered the entire watershed. In these cases, the derived data (e.g. carbon stock values) were reported to a subregion by averaging the values for all pixels within a subregion.

Temporal scale and aggregation

The project team developed a temporal aggregation approach in coordination with the Sacramento River WAF project. Therefore, this section's text is nearly identical to the Sacramento River WAF Technical Report section on temporal aggregation.

Estimates of status and trend for a given indicator must also consider temporal aggregation. The temporal scale includes both aggregation within a year and among years.

How the data are summarized within a year depends on the specific data type. Some data are collected frequently throughout the year (e.g., continuous temperature data). In such cases periodic behavior should be accounted for before aggregation takes place, and these methods are described in detail in the section on Trend Analysis. For many indicators there is only one record per site per year and there is no aggregation to consider within the year. The temporal scale or resolution of the data can affect its meaning. Higher resolution (i.e., more times at which data were collected) will tend to lead to a more accurate assessment of condition/status and change in condition than a single time-point measurement.

Status refers to the "current state," and most often this refers to the state for a specific year. However, if reporting occurs only every few years the status should reflect the average status since the last report, or the status for some recent time window (e.g., 5 years). In the case of this project, the best and most recent available data were used. In some cases, these data were several years old.

It is insufficient simply to assess the current status, without assessing whether or not a trend exists or vice versa. These two pieces of information together provide a far more useful tool for decision makers than either does alone. It is important to consider the time-frame (i.e., number of years) within which to evaluate trends. In most cases there are insufficient data to allow much choice, but as more data are collected it is possible to have scenarios where the recent trend is much different from the older trend; one could imagine a shift in the slope from negative before restoration to positive after restoration. It may be necessary to limit the analyses to the more recent years or to weight scores from recent years more heavily. Another strategy is to use piece-wise regression to allow different windows of time to have different slopes. The Trend Analysis section provides detailed information about how to complete a robust trend analyses.

Data storage and manipulation

Calculating environmental and social-economic indicators for the watershed required temporal and geospatial data from numerous sources. While some indicators utilized a single data source, others required a combination of multiple sources to provide a complete record. This section describes some of the general data management strategies used in this project. For specific details of the data sources and management strategies used for an indicator, please visit the appropriate section in this report.

The teams from UC Davis, Napa County, Napa County RCD, and Sonoma Ecology Center, along with other stakeholders who had knowledge and expertise of the Napa River watershed, all participated in identifying and acquiring data for use in the calculation of environmental indicators. For the purposes of management within the team, the data types were divided between point-source monitoring data and GIS based data.

Point-source monitoring data focused on temporal variation across the basin originating from numerous collection sites across the basin. The types of indicators that were point data referenced included fish, birds, benthic macroinvertebrates, temperature, and school lunch programs. Each had an assigned metric to a specific point in the watershed. The condition data were often averaged across the subregion reporting units to calculate an overall subregion score. The collection sites were mapped with a GIS to identify the subregion to which they belonged and to provide a mapped visualization for the corresponding indicator reports.

Spatial data analysis was performed across the basin using various GIS based data sources. The indicators which utilized GIS analysis included fire frequency, carbon budget, and fragmentation index. These data were analyzed using the same boundary base layer that identified each of the subregions.

The acquisition of temporal and spatial data came from the following organizations that had assembled data for the Napa River watershed.

National Organizations:

National Aeronautics and Space Administration

United States Geological Survey: National Water Information System

USDA Forest Service

State and Local Agencies:

California Department of Education

California Department Fish & Game

California Department of Water Resources

Friends of the Napa River

County of Napa

Napa County Flood Control and Water Conservation District

Napa County Open Space District

Napa County Resource Conservation District

Napa Sanitation District

State Water Resources Control Board Surface Water Ambient Monitoring Program

<u>NGO and Academic Centers:</u>

California Land Stewardship Institute

Information Center for the Environment (UC Davis)

Pt. Reyes Bird Observatory

University of California, Davis

Each environmental indicator included one or more data files and other relevant information. These files were shared among the indicator team, with careful consideration to version control as these data were analyzed and derivative products were created.

These data were stored in various formats, including text based delimited formats (.csv, .txt), spreadsheet packages (such as Microsoft Excel and OpenOffice Spreadsheet), GIS Raster Formats (geoTIFF), GIS Vector formats (such as Shapefiles or Google Earth KML files), and personal geodatabases (Microsoft Access). Temporal metadata were collected in various formats but were most often available as part of a document or report that one could download with the data. When available, source GIS based metadata were stored in a standard FGDC XML format and utilized by the various GIS packages.

An initial search was performed to identify available data for an indicator and to collect general data attributes, such as the data provider, temporal range, spatial extent, and data representation, including units of measure and data quality attributes. These general attributes were assembled in a shared spreadsheet, which identified all relevant sources of data for the various indicators in the study. These data and metadata were downloaded, organized, and assembled for each indicator. It was often necessary for the data to be manually manipulated to transfer them into a common format. Additional resources which documented the data were also collected, such as Standard Operating Procedures (SOP), lab/organization identification protocols, Quality Assurance Policy and Procedures (QAPP's), and other documents and reports that reported proper use of these data.

Data transformations were often required, because some indicators utilized data from multiple sources, which were frequently stored in different units of measure and temporal frequencies.

The common data elements were extracted and stored to produce a new dataset that combined all sources. Specific description of the data manipulations can be found with each indicator report provided in section 4.

The quality of the data was an important factor when considering what to include in the study. Various forms of quality assurance were performed on these data, especially as additional collection sites or new data sources were added to an indicator. For many data sources, the providers had already performed a rigorous QA on the data, and these data could be used in the state in which they were downloaded. In rare cases, the data were found to be corrupted or to have extreme outliers (spatially, temporally, and in terms of a valid data value), and these data were omitted from the study.

Cross-indicator score aggregation

The project team developed an approach for aggregating scores across indicators in coordination with the Sacramento River WAF project. Therefore, the approach detailed below is very similar to that described in the Sacramento River WAF Technical Report section on aggregating scores across indicators.

One value of this effort is that indicators were normalized to a common scoring scale, 0 (poor condition) to 100 (good condition), where good and poor conditions were defined for each indicator. For goals and objectives that have more than one indicator, it is then possible to combine the indicator scores into an overall score for that goal or objective. The steps for doing this include: 1) analyzing individual indicators, 2) transforming indicator values to a single scoring scale, 3) determining the relative importance of each indicator (by default we assume that each is equally important), and 4) averaging the scores for indicators within a goal or objective. In the case of (4), averaging is one way that the scores could be used. Another possibility would be to select the lowest score in order to point out the conditions that might need the most attention, or to weight the scores according to a social or management ranking of indicator importance.

Carrying out this type of score aggregation is appropriate for a decision-support device like the Report Card, which is intended to provide a quantitative estimate of how well conditions are performing relative to goals. The scores may seem less relevant to an ecological or economic model where the base parameter units (e.g., tons of nitrogen, $) may be more useful. However, there are few quantitative modeling approaches that can use multiple parameters in their native units to reflect conditions in complex systems like watersheds. It is possible that the normalization approach used for the Report Card can be used to quantitatively reflect conditions of and interactions among watershed components.

4. Analysis and Findings

The project team developed Indicator Reports for each final indicator. Each report provides the same information in a consistent format. Each report refers to the watershed goal, objective, and WAF attribute the indicator addresses, the methods of analysis and any post-processing of the data, the results derived in summary and in detail, the target to which the results are compared, and any challenges or recommendations for future use of the indicator. These Indicator Reports should be considered drafts, because they have not been peer reviewed. An online approach and partial summary of this Chapter's content will be developed and available at http://sfcommons.org/scorecards/waf/napa.

Taken jointly, the Indicator Reports provide detailed analysis and findings for the project's investigative assessment work. Section 4 – Analysis and Findings, along with section 3 – Methods, serves as the project's Technical Report. Overall findings, recommendations, and next steps related to the project are discussed in section 5 – Interpretation and section 6 – Recommended Next Steps.

Impervious Area

Goal:

Improve and protect geomorphic and hydrologic processes

Objective:

Reduce artificially increased inputs of sediment to streams, particularly those due to increases in runoff from developed areas.

WAF Attribute:

Landscape condition

Table 1. Score, trend, and reliability for Impervious Area

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	75	Declining	Moderate
Napa River watershed subregions:			
Western mountains	ND	ND	ND
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	ND	ND	ND
Eastern mountains	ND	ND	ND
South valley floor	ND	ND	ND
North Valley floor: north of Oak Knoll Avenue	ND	ND	ND

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

This indicator measures the fraction of a watershed's surface covered by roofs, asphalt, concrete, and other materials that prevent water from penetrating the ground. Impervious surface area is an important indicator of the extent of direct watershed hydromodification caused by human activity. Hydromodification is an umbrella term that covers many possible changes to the natural flow and storage pathways of the hydrologic cycle. In the widely-used universal soil loss equation (USLE), pasture and grassland areas are given runoff coefficients of 0.1, meaning that only 10% of rainfall is estimated to run off, while 90% infiltrates the soil. In contrast, impervious surfaces are assigned runoff coefficients of 1.0, with 100% of rainfall estimated to become runoff and none available for infiltration and ground water recharge. In this analysis we look at impervious surfaces at a single point in time as a measure of watershed condition.

Why is it Important?

Impervious surfaces cause direct impacts, including 1) reduced recharge (the amount of infiltrated water that passes through subsurface soils into the saturated groundwater zone) and 2) increased stream flows and flooding. As impervious surfaces accelerate the rate of flow concentration, peak flows tend to grow in magnitude. The result is greater shear stress on stream channels and, in turn, greater erosion of stream bed and banks. For the Napa watershed, impervious surfaces are expected to cause increased flooding, bed and bank erosion, and sediment in stream channels; more runoff and sediment delivery to the San Francisco Bay estuary; and a reduction of water retained for human and ecological uses.

Studies suggest that measurable effects can begin to occur when as little as 2% of a watershed is covered by impervious surfaces. No empirical studies of impervious area response are known for the Napa Valley. The studies most applicable to our region were based in Southern California and Maryland. Intermittent streams in arid areas tend to be more sensitive to impervious surfaces than perennial streams in humid areas. Streams in Napa Valley fall somewhere in the middle of this spectrum, with many streams ceasing to flow during the summer dry season.

Accurately capturing the effects of impervious area on a watershed hydrograph presents numerous challenges. These include: natural variability in the quantity of rainfall and stream flows; inability of monitoring networks to capture the spatial distribution of rainfall at fine resolution; and the limited number and locations of accurate streamflow gauges. Evidence suggests that, to be successful, such studies should focus on a smaller watershed to accurately capture change in the response variables.

Existing studies suggest that watershed scale and the distribution of impervious area influence hydrologic response. For example, Coleman et al (2005) examined the hydromodification response of southern California streams to increasing impervious area. They found two key aspects of a watershed affected this response: 1) the size of the watershed, and 2) the seasonality of a stream channel. They found that hydromodification from changes in impervious area is most recognizable in watersheds smaller than about 20 square miles, and management of impervious area is most critical in watersheds less than 2.5 square miles. These findings suggest the value of evaluating impervious area and hydrological response at the scale of a subwatershed within the larger Napa River watershed. Further, the effects of hydromodification are much more pronounced in small storms than in larger storms.

What is the target or desired condition?

Since the beginning of European-style settlement in the 19th century, the amount of impervious surfaces has steadily increased. When the area covered by impervious surfaces reaches 2-3% of a watershed, measurable changes begin to happen. At 10-15% impervious surfaces, watershed health begins to be seriously compromised.

We take the desired condition to be a landscape where impervious surfaces are minimized and mitigated with rain gardens, bioswales, green roofs, etc. Because the landscape ranges from urban to wildlands, the percent of impervious surfaces ranges from 0% in undeveloped areas to over 25% in some parts of the city of Napa. If rain gardens, bioswales, permeable paving, green roofs, etc. were installed on every reasonable site in the city, this could be significantly reduced. In comparison, large areas of Napa Valley have little or no impervious surfaces. These areas should be protected and preserved as much as possible.

What can influence or stress condition?

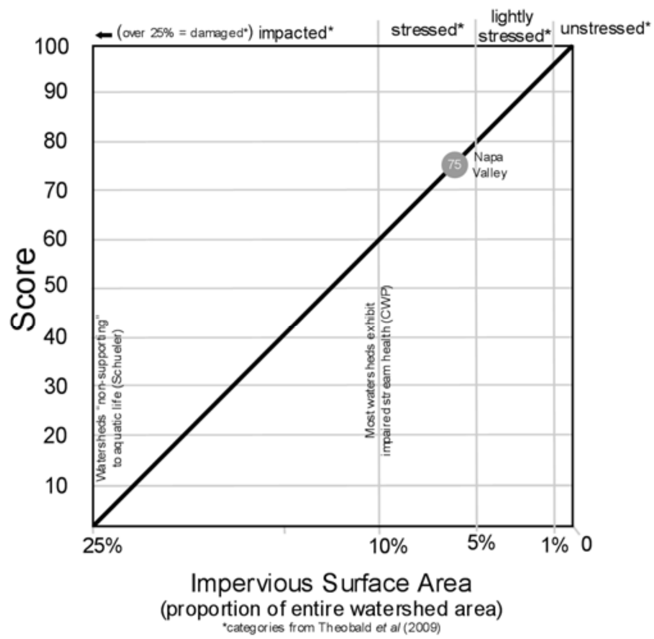
A number of things can influence the amount of impervious surface in an area. These include: the amount and rate of development; building codes and other policies; the existence (or lack) of incentives encouraging 'recharge friendly' landscaping and hardscaping; and public outreach and education.

What did we find out?

Coleman et al (2005) examined the response of southern California streams to increasing impervious area and the accompanying hydromodification. Besides the size of the watershed influenced response, they found vulnerability to change was also influenced by the seasonality of a stream channel. Most watersheds in the study had some channels with ephemeral or intermittent flow; these are very common in semi-arid climates, even in larger watersheds that have more contributing runoff. The researchers found that ephemeral channels are more sensitive to change in total impervious area, and exhibit signs of degradation at 2-3%, In contrast, according to other studies, perennial channels in humid regions start to degrade at 7-10% (Schueler 2000). Since ephemeral channels are plentiful in this watershed, these features may be considered highly vulnerable to changes in impervious area.

Our finding was that the Napa River watershed has 6.1% impervious area. Twenty-five percent total impervious area has been shown to create "poor" conditions in humid watersheds (Schueler 2000). Likewise, Theobald et al (2009) consider 25% to be the threshold at which a watershed deteriorates from "impacted" to "damaged". Accordingly, we assigned a score of zero to this threshold and a score of 100 to the hypothetical condition of no impervious area. Making the assumption that the proportion of impervious area over this range is linearly related to watershed health, we derived a score of 75 and a Theobold rating of "stressed" for the Napa River watershed. Figure 1 below illustrates this analysis.

<u>Figure 1</u>: Napa Valley Watershed Scoring Chart for Impervious Surfaces



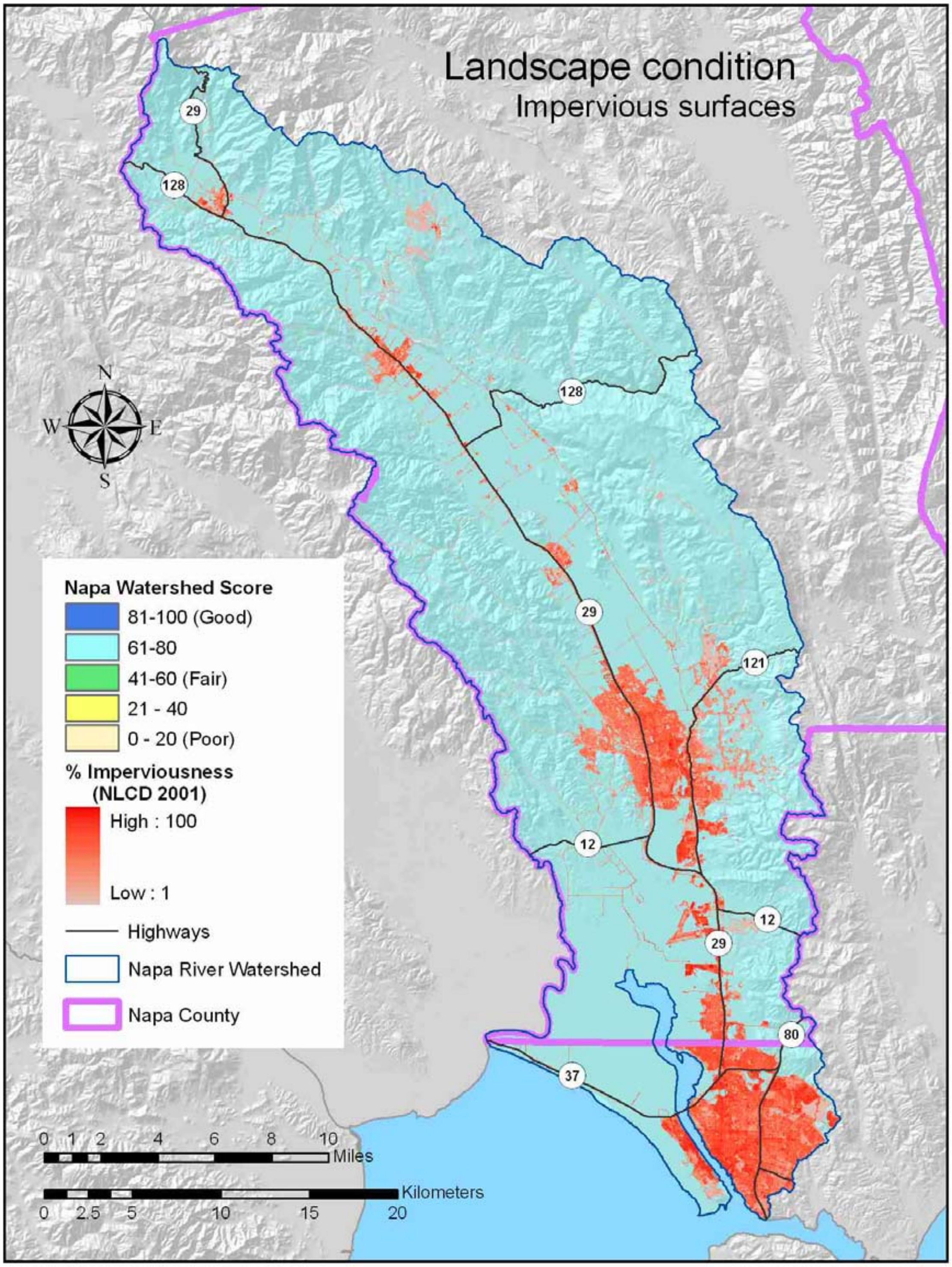


Figure 2. Napa Valley Watershed Impervious Area Score

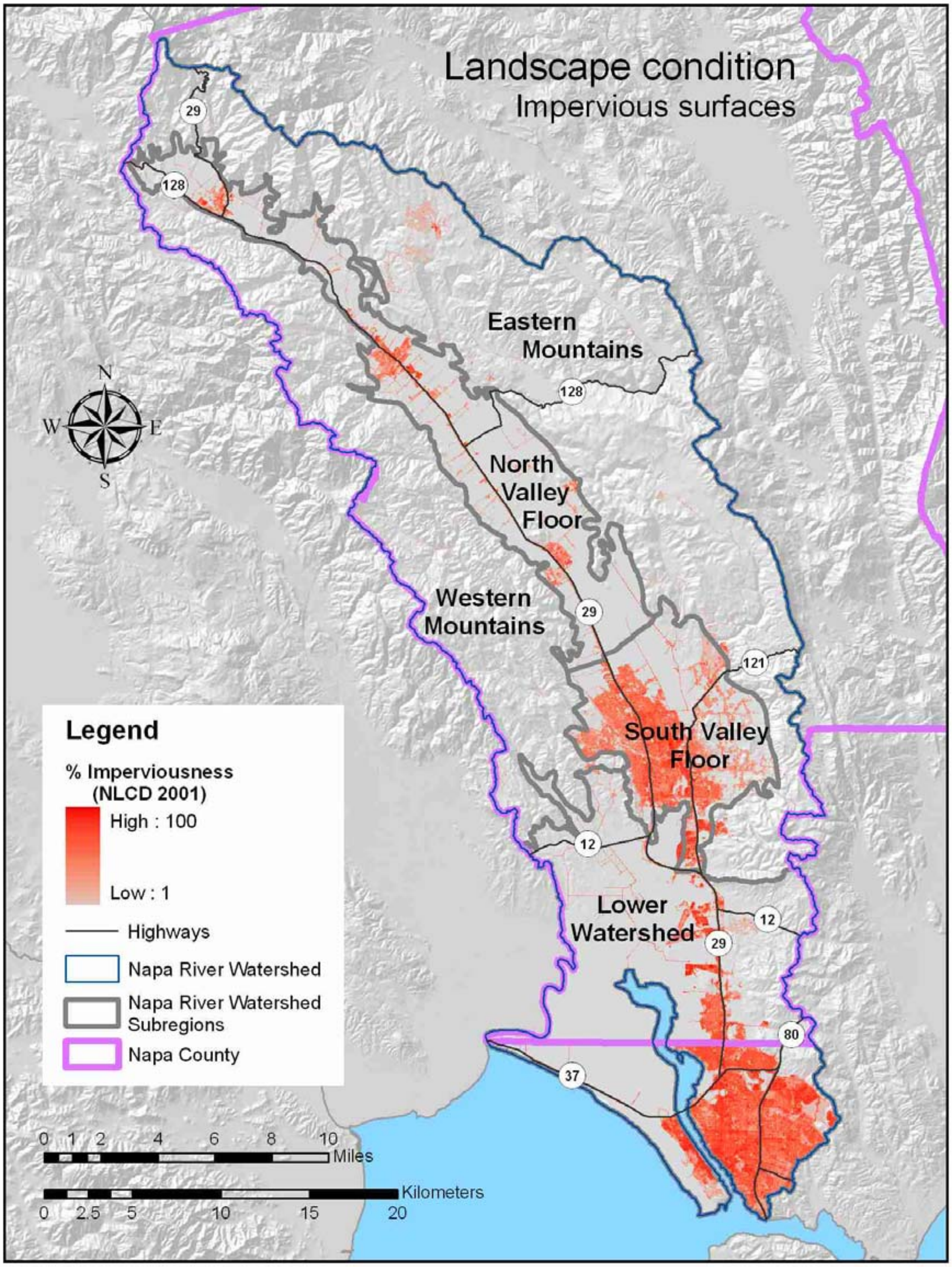


Figure 3. Impervious surfaces and the Napa Valley Watershed subregions

Figure 3 and Table 2 illustrate how the impervious surface total varies widely among the regions, from a fraction of one percent in the Mayacamas Mountains (WM)) to over 20% in the city of Napa (SVF). However, because all referenced studies analyzed total impervious area as a proportion of entire watersheds (not subregions), we decided not to score individual regions. For example, the city of Napa (SVF) has a very high total impervious area, but it would be misleading to use this figure to score its watershed health. Instead, the entire drainage above the city, which encompasses all of part of several other regions, would have to be included. Thus considering the entire watershed (all regions) was deemed to provide the most accurate assessment. In addition, scoring regions separately would have required setting vastly different targets (e.g. "remain under 1%" in the mountains" vs. "reduce hardscape by 40%" in the city of Napa).

Table 2. Impervious Area by Region

Region	Total Impervious Area, 2001 (percent)
LW: Carneros area, Napa River Marshes, Jamieson/American Canyon	14.67
SVF: Southern Napa Valley Floor, Napa	21.37
NVF: Northern Napa Valley Floor, Calistoga, St Helena, Yountville	4.40
WM: Western Mountains	0.19
EM: Eastern Mountains, Angwin Area	0.39

Trend Analysis

Missing from our analysis, for lack of time, is a quantitative statement of the uncertainty associated with the results, the score and the trend.

Over the long term it is inevitable that more development will occur in the Napa River watershed, potentially leading to an increase in impervious area. However, the amount of "effective" impervious area (EIA), the amount of impervious area directly connected to stream channels, may decrease over time. With the growing popularity of low impact development (LID) design, and stormwater control provisions showing up in building codes, more runoff may be treated onsite before flowing into stream channels. Pervious pavement, filter strips, and other design options allow for the more natural percolation of water into the ground, so that large flows do not inundate stream channels, erode banks, and exacerbate the problems caused by hydromodification.

This metric tells us that the Napa River is at increasing risk for the negative impacts hydromodification brings to river systems. Because this watershed assessment does not include analyses of biological indicators of ecological health, it is difficult to determine what scale the problem has reached and whether the system is at great risk for degradation. However other studies, such as those related to the sediment, nutrients, and pathogens TMDLs, indicate that there are major problems caused by increasing development (urban, suburban, and agricultural) which are affecting water quality.

Temporal and spatial resolution

Impervious surfaces were measured at 30 x 30 m resolution with data that was roughly a decade old.

How sure are we about our findings?

Impervious surface estimation is difficult for a number of reasons, and the results should be treated carefully. First, estimation methodology depends upon combining synoptic land cover data from remote sensing platforms with plot-level measurements of impervious surfaces.

This indicator used data from the National Land Cover Database (NLCD, see discussion under Technical Information below). Ideally, this indicator would use a dataset updated more frequently. This evaluation sets a baseline that may need to be re-evaluated, should funding become available for more localized and frequent assessments of impervious cover. Higher resolution photographs taken from aircraft could be analyzed and impervious areas delineated with more exact area calculations. Using this alternative method, statistics on impervious area could be obtained for individual subwatersheds or even smaller scales to allow for more site-specific planning of development and riparian area management.

It can be argued that effective impervious area (EIA) is the more accurate indicator of stream health (Brabec et al 2002). The argument against the use of TIA (total impervious area) comes from the fact that watersheds with a comparable percentage of TIA can have a wide range of biological conditions, due in part to the varying percentages of impervious areas that directly feed runoff into streams without some kind of pretreatment. This is particularly relevant in watersheds with little urban development (Walsh 2004; Booth et al 2002). Walsh conducted a study in 16 watersheds near Melbourne, Australia to test this theory (2004). His results showed that the amount of storm water connections, or degree of drainage connectivity, was a better predictor of macroinvertebrate taxa richness and composition than simply TIA. He also suggested that in order to restore stream health and improve degraded watersheds in an urban setting, local governments should focus first on reducing the number of direct connections between streams and the storm water system and then later address habitat restoration. Even if riparian buffers and other natural filters for runoff are implemented, their potential for filtration might not be fully utilized as long as storm water systems bypass these areas. Further, the offsite causes of habitat degradation would still be in place if drainage connectivity is not first reduced.

Recommendations

If possible, this assessment should use EIA as the metric instead of TIA. EIA may be considerably different because it includes only the impervious surfaces that are directly connected to streams and other water bodies. There are several possible means of connection, including a storm drain system, or agricultural areas with extensive engineered tile drainage or plastic covering for crops, which shunt runoff directly into ditches and streams. EIA excludes those areas that direct runoff into some sort of treatment area because it is less likely that those areas contribute a significant amount of pollution to receiving waters (Booth and Jackson 1997; Walsh 2004). A disadvantage is that EIA is much more difficult to quantify than TIA; it requires more complex input data. If direct surveys are not feasible, it may be possible to develop a proxy for EIA using greywater permits, landowner questionnaires, stream flow at first flush, and perhaps other sources. In addition, even though design features to disconnect new development projects from immediate runoff to streams are increasingly being required by local codes, exactly what is required for them to function effectively is not well understood.

However, given the variable distribution within a watershed, and varying recognition of impacts, precision may not always be important. Many applications do not require the use of IA as a precise indicator, but instead apply it as a screening device to make a rough estimate of where in a watershed pollutant loads or other impacts could be high, where effects of hydromodification might be more pronounced, or where to prioritize the implementation of management measures in order to identify current and predict future impacts so they can be mitigated or prevented. To make coarse calculations, it is not necessary to have a precise means of measurement. As part of its storm water permit from the state, Napa is taking steps to implement low-impact development and best management practices, both of which should reduce waterborne pollutants.

We recommend that this metric be complemented in future iterations of this assessment with an assessment of the runoff coefficient (a measure of what is termed the “flashiness” of the system) at a subwatershed scale, to track impacts of watershed development in terms of hydrologic response over time.

In the future, this indicator should be scored in terms of the “impervious area” per resident, with the target of reducing the existing level of impervious area by gradually reducing the impervious area per capita.

Technical Information

Data Sources

There are a range of methodologies for estimating or calculating impervious area, which include using satellites, ground surveys, global positioning system technology, aerial interpretation, land use designations, or a combination of methodologies. The data sources considered here are based on methodologies developed in a standardized manner for the entire United States, allowing for applications in other watersheds in California or across the country for comparison.

Two major datasets were considered for the percent impervious area (IA) indicator: the National Land Cover Database (NLCD) which covers the entire United States and a dataset based on General Plan land use data developed by the Information Center for the Environment at UC Davis. The reliability of NLCD (as a federally funded and widely-used dataset) and the shorter time needed to calculate impervious area made it the best choice for this project.

NLCD was developed through a partnership called Multi-Resolution Land Characteristics Consortium (MRLC), a group of several federal agencies (USGS, EPA, USFS, NOAA, NASA, BLM, NPS, NRCS and USFWS). The first version of NLCD was developed in 1992, and updated for 2001. Percent imperviousness was calculated using Landsat imagery and ortho photographs to calibrate an algorithm that produces % imperviousness per pixel. This particular dataset is ideal because it applies a consistent methodology to all 50 United States and Puerto Rico, so that data for imperviousness can be compared across many watersheds and regions. There are a few caveats about the NLCD that stem from it being a widely applied dataset across a large area. First, the dataset is over 9 years old. A large amount of development has occurred since then, and it is difficult to estimate the % change in total impervious area (TIA). Second, the data are based on an algorithm that was calibrated using a sample of photographs, and there may be errors due to how certain structures or landscapes appear in a photograph and how much impervious area is actually present. A detailed description of the methodology and dataset is explained in Homer et al 2004 and at http://www.mrlc.gov.

It is likely that this dataset will see a third version within the next 5 or so years. However, there is no information from MRLC at this time that indicates the future updating of this dataset

Data Transformations and Analysis

For this analysis we calculated total impervious area (TIA), to be distinguished later in our discussion from effective impervious area (EIA). TIA was calculated using the NLCD data layer in combination with the computer program ArcGIS. The method described here has been used to calculate TIA for 20 Bay Area watersheds by Circuit Rider Productions, Inc., and for the NOAA/NMFS steelhead recovery effort presently underway. We used these results to calculate values for TIA.

The NLCD was loaded into a map document, along with watershed boundary shapefiles. A mask for the watershed boundary was applied, with the analysis extent for the impervious layer set as the same for the watershed. Then the raster calculator was used to calculate the percent of watershed area categorized as impervious within the watershed boundary.

Other methods are more time consuming, although they may be slightly more up-to-date or detailed due to changes in resolution.

Evaluation and scoring

There are concerns about the utility of using simple rules of thumb regarding the relationship between TIA and watershed health in semi-arid regions such as the Napa Valley. While the Center for Watershed Protection (CWP) in Ellicot City, MD has popularized the idea that watersheds consisting of more than 10% impervious area tend to exhibit impaired stream health, and others argue that with IA over 25% the system may be "non-supporting" to aquatic life (Schueler 2000), we believe these thresholds are far too high to use as effective targets for local watersheds. While degradation occurring at these thresholds has been confirmed by numerous other studies, the literature also points to greater sensitivity in semi-arid regions. In studies based in southern California, streams have been more sensitive to IA than the CWP 10% threshold would suggest, with "physical degradation of stream channels… [detected] when basin impervious cover is between 3% and 5%." However, biological effects are probably occurring at even lower levels (Stein and Zaleski 2005). Some studies have concluded that any amount of IA, under existing management practices, will negatively affect aquatic systems (Booth et al 2002).

We did not attempt to calculate a trend in this indicator from the 1992 data, due to lack of time. However, we state that there is a downward trend in the indicator, based on the amount of development, and therefore increase in TIA, that has occurred since 2000. Low impact development, and other efforts to reduce the effective imperviousness of new development and redevelopment have not yet been implemented on a scale that has caused EIA to diverge substantially from TIA, although this divergence may be seen in the next 10 years or so.

Citations

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Local Media Coverage of Watershed Topics

Goal:

Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making

Objective:

No specific objective

WAF Attribute:

Social Condition

Table 1. Score, trend, and reliability for *Local media coverage of watershed topics*.

Region	**Score (0 to 100)[1] ± standard deviation**	**Trend**	**Reliability of findings[2]**
Napa River watershed	46 ± 14	No Trend	High
Napa River watershed subregions:			
Western mountains	ND	ND	ND
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	ND	ND	ND
Eastern mountains	ND	ND	ND
South valley floor	ND	ND	ND
North Valley floor: north of Oak Knoll Avenue	ND	ND	ND

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

For this indicator we examine how frequently watershed topics have been covered in the Napa Valley Register, the most well read and broadly distributed daily newspaper in the Napa River watershed. The subjects of articles and letters to the editor in local newspapers reflect the concerns of the readership. Therefore, we assume that the relative frequency of mention of watershed key words in newspaper articles reflects the interest that residents have in learning about local environmental issues, becoming better stewards of their watershed, and getting involved in making decisions about watershed management. In this analysis, we performed a key word search of ten watershed related words of the Napa Valley Register's online archives. The archives contain articles published in the newspaper from 2002 to the present. Using eight years of data, we examined how frequently key words were mentioned each year, and how the frequency has changed over time.

Why is it Important?

Local newspapers like the Napa Valley Register are both an important source of information about topics of concern and a reflection of local interests. The Napa Valley Register is often the sole source of coverage for topics that are specific to the Napa Valley, such as planning and development along Napa River tributaries, or the health of local fish populations. As a consequence, content is highly reflective of issues about which communities are wrestling, debating, and trying to understand. Content also reflects events, activities, and policy decisions that occur in a region. Therefore, change in community interest in watershed issues should be reflected in the newspaper as a change in frequency of articles about watershed-related topics.

As newspapers devote more space to environmental issues, including local restoration activities, management policies, and engagement opportunities, more people will have the opportunity to become educated about the topic. Raising awareness about the Napa River watershed should have at least two important effects. First, individuals that are aware of the local ecology will be more likely to take steps individually towards better stewardship of the watershed. Second, informed individuals will be more likely to support local funding for restoration projects, ecological monitoring, stewardship groups, clean-up events, and legislation to protect threatened species and habitats.

What is the target or desired condition?

The Napa Valley Register divides its web content into five main categories: News, Opinion, Obituaries, Sports, Arts and Life. Because watershed topics pervade all aspects of daily life, including politics, economics, food production, disasters, recreation, social networks and stories, and events, we expect to find articles related to the watershed in most sections of the paper. Furthermore, we expect that more than one of the keywords we chose to search would be mentioned in most articles about watershed topics. For example, many articles that mention "erosion" also mentioned "creek" and "water quality". Therefore, we decided that excellent coverage of watershed issues means that, on average, each topic is covered once per day in the newspaper. If watershed topics were represented throughout the paper so frequently, the community would have an opportunity to appreciate their watershed and the importance of their stewardship actions. In contrast, extremely poor coverage of watershed topics would mean that there is no coverage in the newspaper.

What can influence or stress the condition?

Several factors should influence local media coverage of watershed topics. Local coverage is closely dictated by local events, politics, debates, and weather. In years when these topics involve environmental issues, such as years of extreme flooding or drought, we expect that local media coverage should be greater. Coverage is also dictated by the economic status of the newspaper, in years when the newspaper has fewer reporters, we expect that coverage of watershed topics would decrease, at least as much as coverage of all topics would decrease. Coverage of watershed issues may decline more than other topics, as newspapers tend to prioritize coverage of topics related to human health, social services, and government actions over coverage of environmental topics (Pew Project for Excellence in Journalism 2009).

What did we find out?

In 2009, local media coverage of watershed topics in the Napa River watershed was moderate. The score for this watershed health indicator was 46, which means that, on average, a watershed topics occurs in the paper once every other day. This is half the rate that we considered reflective of excellent watershed awareness and knowledge in a community. The daily occurrence of watershed key words or phrases that we chose ranged from 0.07 to 1.42 (Table 2).

Table 2. Summary of watershed key word search of articles published in the Napa Valley Register in 2009.

Word or phrase	Number of articles in 2009	Daily occurrence rate
Watershed	58	0.16
Creek	518	1.42
Water Quality	125	0.34
Wildlife	123	0.34
Erosion	26	0.07
Salmon	162	0.44
Steelhead	43	0.12
Wetlands	41	0.11
Open Space	354	0.97
Flood	236	0.65
Average ± standard deviation	169 ± 51	0.46 ± 0.14

Trend Analysis

We found that the frequency of occurrence of watershed topics in the local media has not changed significantly over the past seven years (Figure 1; $F_{1,78} = 0.85$, $P = 0.36$).

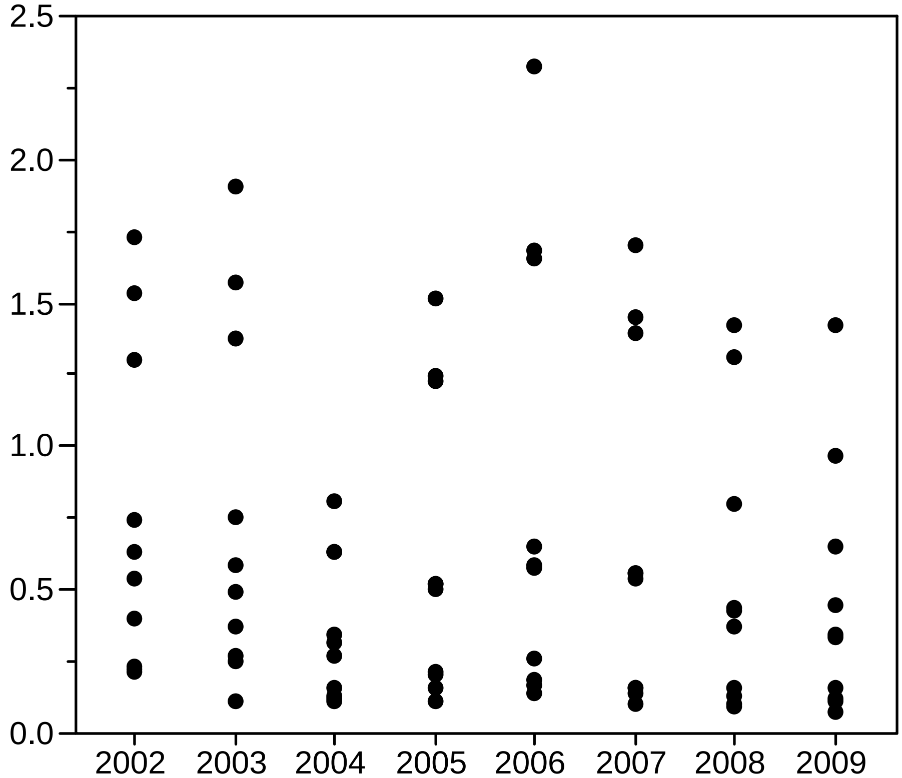

Figure 1. Daily occurrence rate of ten watershed key words in articles published in the Napa Valley Register over the period 2002 – 2009.

Temporal and spatial resolution

According to the Napa Valley Register's website (www.napavalleyregister.com), the newspaper is read regularly by 50,000 adults and is distributed to 20,000 households or businesses daily. The newspaper is distributed most heavily in Napa, American Canyon, St. Helena, Calistoga, and Yountville, and reaches members throughout Napa County. Therefore, we attributed the indicator results to the whole watershed.

How sure are we about our findings?

This indicator reliably reports on coverage of watershed related topics in the Napa Valley Register. All articles that have been published by the Napa Valley Register are part of their searchable web archive. Although the Napa Valley Register is just one media outlet in the valley, it is the most broadly distributed and frequently consulted source of news in the watershed.

Approximately 90% of the articles that we found through our key word search were articles with environmental themes, so the search results accurately reflected the occurrence of articles about watershed topics. There are numerous watershed key words that we did not search, so we predict that there are many articles about the environment that were not found in our search.

Recommendations

Due to time constraints, we did not review the microfiche collection of newspaper articles before 2002. Since the Napa Valley Register's 130 year archive is available, we recommend that it be searched for articles having to do with watershed topics to discern how coverage has changed over the past century.

We also recommend that future watershed health indicator projects examine how coverage varies across subregions. Some subregions are likely to get a lot more coverage because of different levels of activity and interest in the environment across subregions.

An analysis of how watershed topics are discussed in the press would also be worthwhile. Some articles may discuss environmental problems, or conflicts between community members and the environment, whereas other articles may have a celebratory tone. It would be interesting to know if coverage has become more positive or more negative over time.

Local media coverage of watershed topics is a fair indicator to measure progress toward broader watershed awareness and understanding. We would like to see this indicator complemented by other measures of watershed awareness, including public opinion surveys, and pervasiveness of school outreach programs.

Technical Information

Data Sources

The analysis was performed using the Napa Valley Register's website archive of articles (www.napavalleyregister.org), which contains articles from 2002 to present.

Analysis

We searched the Napa Valley Register's website archive of articles for ten words or phrases that we determined to represent broad watershed knowledge, including knowledge of recreational opportunities, environmental impacts of development, watershed health, and watershed challenges (pollution and flooding). We also selected words that would rarely be found in articles that were not related to watershed subjects. For example, we considered searching “Napa River”, but since many businesses and developments in the watershed have this phrase in their title, we excluded this phrase from our analysis. The following words or phrases were selected for the search: watershed, creek, water quality, erosion, wetlands, park, open space, flood, wildlife, steelhead, salmon. We searched the archive for occurrences of these words in articles in each year from 2002 to 2009. We recorded how many articles were found. Articles included standard news articles, events in the newspaper’s calendar feature, letters to the editor, and newspaper hosted discussion forums.

To determine the indicator’s score for 2009, we determined the average number of articles published in that year that contained each watershed key word. We then divided this number by 365 to determine the daily rate of occurrence of a watershed topic in the newspaper. We then multiplied this number by 100 to develop the indicator’s score, as we set one article per day to be the target rate of average coverage of one watershed topic.

To determine whether there has been a trend in coverage of watershed topics over time, we performed a linear regression, with number of articles per year per key word as the dependent variable, and year as the independent variable. A statistically significant relationship between year and number of articles per year would indicate a significant trend in the indicator. This analysis was performed in JMP 3.0.

Citations

Pew Project for Excellence in Journalism 2009. The State of the News Media: An Annual Report on American Journalism. Pew Research Center.
http://www.stateofthemedia.org/2009/index.htm.

Access to Public Open Space

Goal:

Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making

Objective:

Promote watershed awareness and stewardship through improved education, recreational access, and community involvement in decision-making

WAF Attribute:

Social Condition

Table 1. Score, trend, and reliability for: *Access to public open space*.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	38	ND	Medium-High
Napa River watershed subregions:			
Western mountains	2	ND	Low
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	22	ND	High
Eastern mountains	1	ND	Low
South valley floor	74	ND	High
North Valley floor: North of Oak Knoll Avenue	58	ND	High

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

Parks and publicly-accessible open space are sprinkled throughout the watershed. They occur at varying distances from where people live. This distance will affect the access and enjoyment of these public spaces. The indicator is a measure of how accessible public spaces are to watershed residents by foot/bike and by car. It is also a measure of the equity of access to parks based on income and ethnicity.

Why is it Important?

Recreational access to parks is important for a variety of health and economic benefits to watershed residents. Access to recreational facilities and opportunities is linked to children's health and obesity (Kerr et al., 2007; Pate et al., 2008; Roemmich et al., 2006). In some places access to parks, park congestion, and use of parks is related to race and economic status (Abercrombie et al., 2008; Giles-Corti and Donovan, 2002; Sister et al., 2009; Wolch et al., 2005). Discrepancy in park access has been identified as an important equity concern in California cities such as Los Angeles (Wolch et al., 2005). Park size and congestion are also important considerations as smaller and more congested parks tend to be in poor and non-white neighborhoods (Sister et al., 2009).

Access to parks and other open spaces is an important part of people's direct experience with the watershed. Providing this access equitably and in sufficient quantities to watershed residents is an important civic function. If people have access to outdoor park areas, especially areas that have natural attributes (e.g., adjacent to stream), they are more likely to support protection of these attributes. They will also realize a return of their social investment as watershed taxpayers.

What is the target or desired condition?

The target condition is for all watershed residents to have at least one public open space within 1 mile of their neighborhood. This distance is important for public health and for the continued enjoyment of open space, which is important in maintaining positive connections and impressions of open space. This 1 mile distance is greater than the ¼ mile and ½ mile distances that have been used before for studies of urban area park access (Boocock, 1981; Cunningham and Jones, 1999; Roemmich et al., 2006; Wolch et al., 2005), but may be more generally acceptable for less urban and rural settings.

What can influence or stress the condition?

Access to and use of public open space depends on the availability of that space to where people live. Children and adults will tend to only make regular use of parks and other open space near their homes. Although some people will periodically enjoy public open space several miles from where they live, most people will not on a regular basis. Thus, availability of these public open spaces near urban areas is important to maintaining people's connections to the outdoors and outdoor recreation. Investment in acquisition and maintenance of open space will expand opportunities for watershed residents.

What did we find out?

In general, watershed residents had access to open spaces within 5 miles of their neighborhood. Because of the spatial resolution of census blocks representing where people live, this is only a rough approximation of proximity to open spaces. Approximately 1/4 of watershed residents are within 0.5 miles of parks and other open space and 1/2 are within 2 miles.

The cities of the Napa Valley floor have many urban parks within their boundaries, contributing to their higher relative scores (Figure 1). The eastern and western mountains are both home to large parks, but not necessarily near where people live. The lower watershed city of Vallejo has virtually no parks of its own, though there are large public open spaces on the western side of the lower watershed.

For neighborhood settings, parks within ¼ mile of where people live is considered ideal. Only 10% of watershed residents lived in census blocks within ¼ mile of a park (Table 2). In contrast, 45% of watershed residents lived >2 miles from a park.

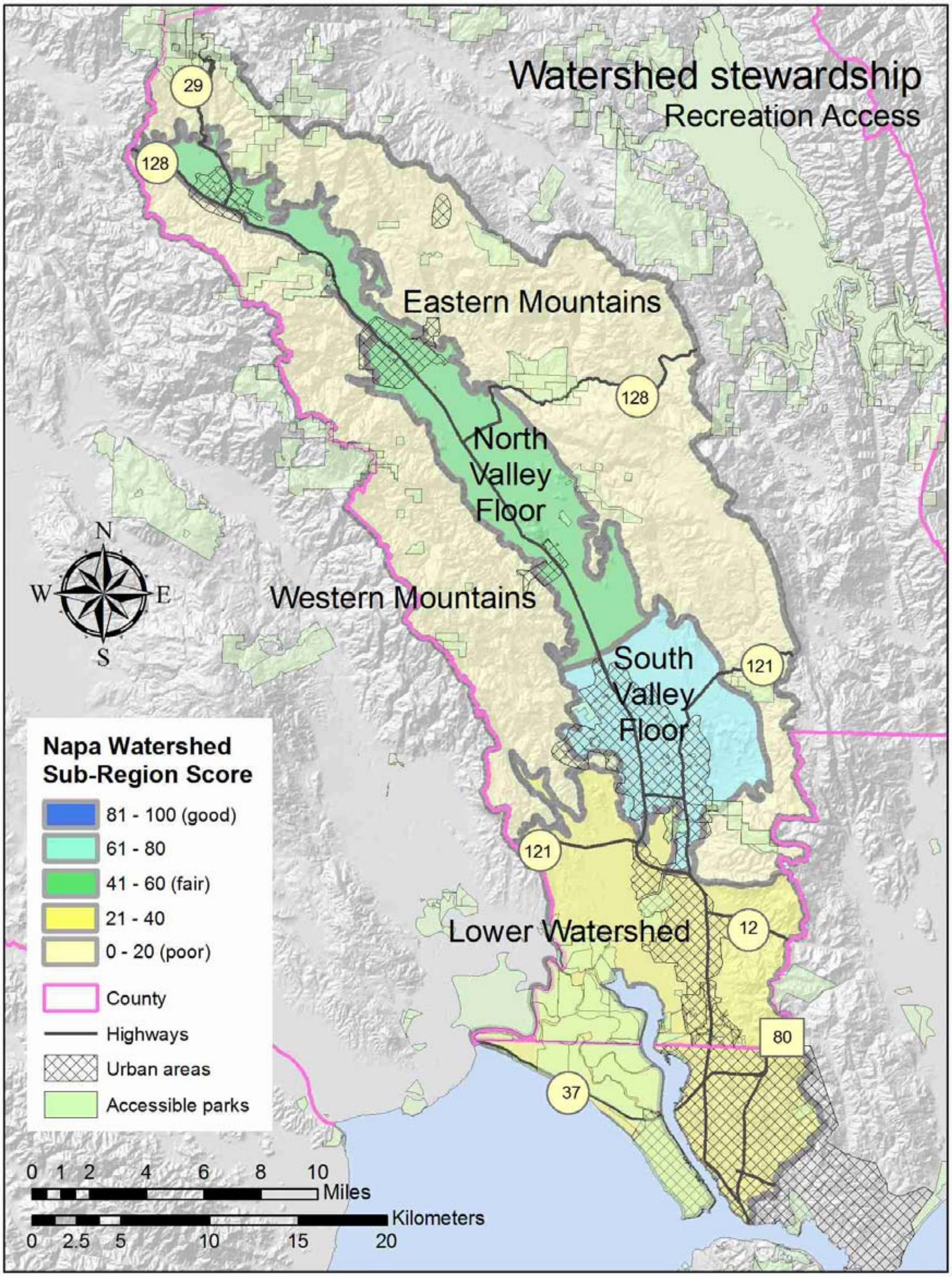

Figure 1. Distribution of parks and recreational access scores by subregion.

Table 2. Watershed resident access to recreational public open spaces.

Distance class	Number of people	% of population	Cumulative %
0 to 0.25 mi	37,565	10%	10%
0.25 to 0.50 mi	52,536	14%	24%
0.50 to 0.75 mi	28,184	7.5%	31.5%
0.75 to 1.0 mi	14,443	3.8%	35.3%
1.0 to 2.0 mi	74,086	19.7%	55%
2.0 to 5.0 mi	144,855	38.5%	93.5%
> 5.0 mi	24,457	6.5%	100%

Figure 2. Proportion of watershed residents within certain distance classes from parks. Cumulative percentage of population (red line and right-hand y-axis) shows how the population accrues as distance increases (x-axis).

An important consideration is who is near parks and who is not. Equitable access across race, income, and other ways of grouping people is important. The Census classes Whites and Hispanics fared best among ethnic groups in terms of park access, relative to African-American, Asian, and Native-American, the vast majority of whom live further than 1 mile from a park or open space (Figure 3).

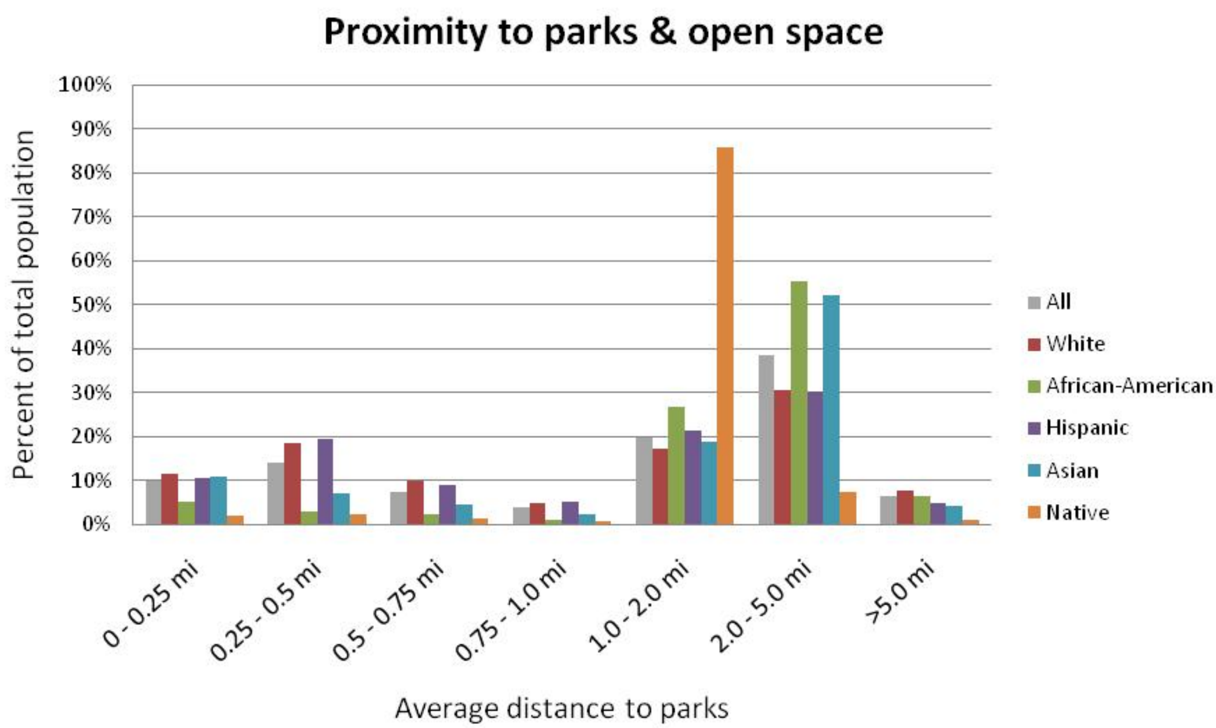

Figure 3. Distribution of recreational access distances by race.

Temporal and spatial resolution

The database used to locate parks and other open spaces did not have a temporal component, but in general, publicly-accessible open space has become more available over time. The open spaces database includes parks and open spaces that vary in size. Similarly, the census boundary map includes blocks that vary in size. The census blocks were used to represent where people live, thus the resolution for "peoples' neighborhoods" varied with census block size.

How sure are we about our findings?

The calculation of distance to open space was based on census blocks, which vary considerably in size (from <1 Ha To >500 Ha). Generally, the lower the population density, the larger the census block. This means that the accuracy of calculation of distance-to-open space for small urban blocks will be greater than for larger rural blocks. Since most people in the watershed live in smaller urban census blocks, the results are most accurate for most people.

Recommendations

This indicator relies on two long-term databases, with low rates of change – the Census data and the Protected Area Database. Both datasets are likely to undergo annual to biennial changes, which is about the maximum frequency reasonable for this indicator. Actual access of watershed residents to parks can be calculated using streets and transportation modes as access routes, which would be more accurate than Euclidean distance. Actual recreational use and type of use for individual open spaces combined with distance would be a useful modification of this indicator because it would get closer to watershed resident use of watershed open space. Finally, calculating the park and open space area available per person is an important attribute that would contribute to this evaluation.

Technical Information

Data Sources

Census 2000 block boundaries and population values were obtained from CalFire-FRAP (http://www.calfire.ca.gov/frap). Census 2000 data was obtained from the Census Bureau (http://www.census.gov). The Protected Areas Database was obtained from GreenInfo (http://www.greeninfo.org) and combined with a map from Napa County of county open spaces.

Data Transformations

All spatial data were projected using the Teale Albers projected coordinate system. All parks and open spaces within 10 km of the watershed boundary were selected using a buffered watershed boundary and combined into a single map of “nearby open spaces”. Census data from “SF3” files were joined to the census blocks using the unique block identifiers.

Analysis

Distance to nearby open spaces was determined using Euclidean distance calculation in ArcGIS 9.3, resulting in a raster map with 30 meter resolution. Distance to nearby open spaces for every census block was calculated using zonal statistics in ArcGIS 9.3. Census blocks were grouped according to their distance from any nearby open space and the total number of people and number of people in major ethnic groups in each distance group calculated.

Citations

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Sister, C., J. Wolch, and J. Wilson. 2009. Got green? Addressing environmental justice in park provision. Geo Journal. DOI 10.1007/s10708-009-9303-8.

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Fish Community

Goal:

Conserve, protect and improve native plant, wildlife and fish habitats and their communities

Objective:

No specific objective

WAF Attribute:

Biotic condition

Table 1. Score, trend, and reliability for Fish community.
No watershed score was calculated for this indicator because data was available for only two of the subregions.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	ND	ND	ND
Napa River watershed subregions:			
Western mountains	ND	ND	ND
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	37 (0)	ND	Medium
Eastern mountains	ND	ND	ND
South valley floor	78 (0)	ND	Medium
North Valley floor: North of Oak Knoll Avenue	ND	ND	ND

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

The abundance of individual fish and the diversity of fish species present can tell a lot about the conditions in waterways and watersheds. Two metrics of fish community condition were used, based on indicators used by the South East Queensland Ecosystem Health Monitoring Program (Australia, http://www.healthywaterways.org/ehmphome.aspx). These metrics are:

1. Percentage of native species expected (PONSE). This is a measure of observed number of fish species (species richness) compared to expected number of species based on expert knowledge and observations in other regions of the river. The primary source for expected species was the Sierra Nevada Ecosystem Project (SNEP), with adjustments based on survey effectiveness (see below under "Data manipulation").

2. Proportion native species (PNS). This is the percentage of native species of total fish caught or observed (not species number). This metric assesses what proportion of the community is composed of native species. Native/exotic identity was determined using information from the SNEP report.

3. In addition to these fish community composition measures, local Chinook salmon population assessment is used for the valley floor regions. Population is scaled from 0 to 100 by comparing recent carcass and redd counts to previous peaks.

Why is it Important?

Fish are a common and familiar component of freshwater environments, and fish communities reflect a range of natural and human-induced disturbances through changes in abundance and species composition. Ecological assessments based on fish community structure have the advantage over more traditional physical and chemical indices (e.g. conductivity, turbidity, nutrients) in that fish provide an integrated measure of stream condition due to the mobility, relatively long life, and high trophic level of the animals involved. Low native species presence can be an indicator of high disturbance levels, which disrupt natural community balance and exclude stress-intolerant species and/or non-generalists. Presence of exotic species is also a good indicator of poor ecological health (Meador et al. 2003). Many invasive species are highly competitive generalists, and can exclude local species. In addition, exotics may be able to establish due to altered habitat processes (i.e. higher water temperatures, changes in mean water level) or through direct human introduction (i.e. stocking, discard of aquarium fish).

Native salmonid species are of great ecological, economic, and cultural importance to local communities. They also serve as strong indicators of habitat quality and integrity in river systems, particularly with regard to water temperature, sediment load, and barriers to passage. Several runs of Chinook salmon passing through the San Francisco Bay are listed as threatened under the federal Endangered Species Act, giving them a high priority for restoration. The main threats to the remaining populations are loss and degradation of habitat. In particular, rising water temperature combined with loss of upstream spawning and rearing habitats blocked by dams has diminished available juvenile summer habitat greatly.

What is the target or desired condition?

Ideally, native fish communities will be fully intact and contain no invasive or introduced species. A PONSE and PNS of 100 indicate that every expected species was found in the area, and no exotic species were caught.

For Chinook populations, there are no numeric targets for total salmon populations in the Napa River. The maximum number of redds measured in recent history (103 in 2006) was used for a score of 100 and 0 redds was used for a score of 0.

What can influence or stress condition?

Primary stressors for native fish communities are spawning and rearing habitat degradation, excess fine-sediment deposition in benthic gravels, increasing maximum water temperatures, and introduced species. Salmon are negatively impacted by these stressors, as well as barriers to passage and predation by black bass and striped bass on their young.

What did we find out?

Fish community well-being was moderately good in the South valley floor reach (near city of Napa) and poor to fair in the lower watershed (Table 1 and Figure 1). Salmon have not returned to spawn the last 2 years, which may be part of a normal cycle, but if not, represents a very significant decline from several hundred fish in years past.

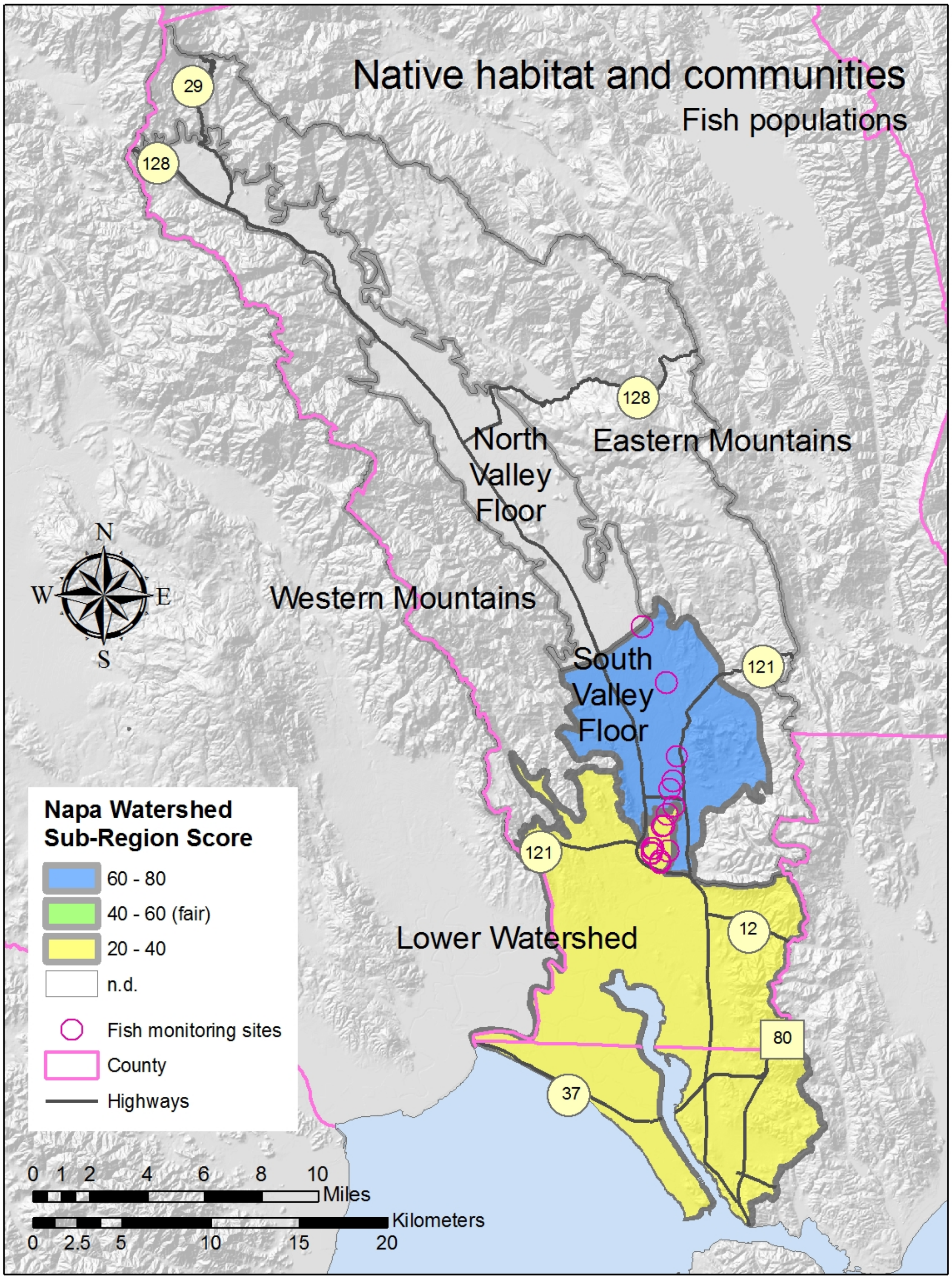

Figure 1. Fish community condition scores and community sampling sites on the Napa River across subregions.

A Regional-Kendall trends analysis was performed on both PNS and PONSE data from each subregion. Results are shown in Table 2; no significant trends were found in these two metrics of fish community well-being.

Table 2. Regional-Kendall trend analysis of PONSE values for subregions. "Tau-b" is a Regional-Kendall test statistic.

	PONSE			PNS		
Subregion	tau-b	p-value	slope	tau-b	p-value	slope
SVF	-0.105	0.801	-0.009	0.000	0.807	-0.028
LW	-0.300	0.624	-0.004	-0.600	0.221	-0.178

Chinook Salmon Population

The Napa County RCD has been counting live and dead salmon and the redds (nests) they have built for the last 6 years. During the first 4 years, there were many redds and fish observed. In 2008 and 2009, the salmon didn't arrive. This may be related to off-shore conditions that have affected West Coast runs in general. It may also reflect a population on the edge, which can't withstand impacts in the ocean due to limited spawning and rearing conditions in coastal watersheds.

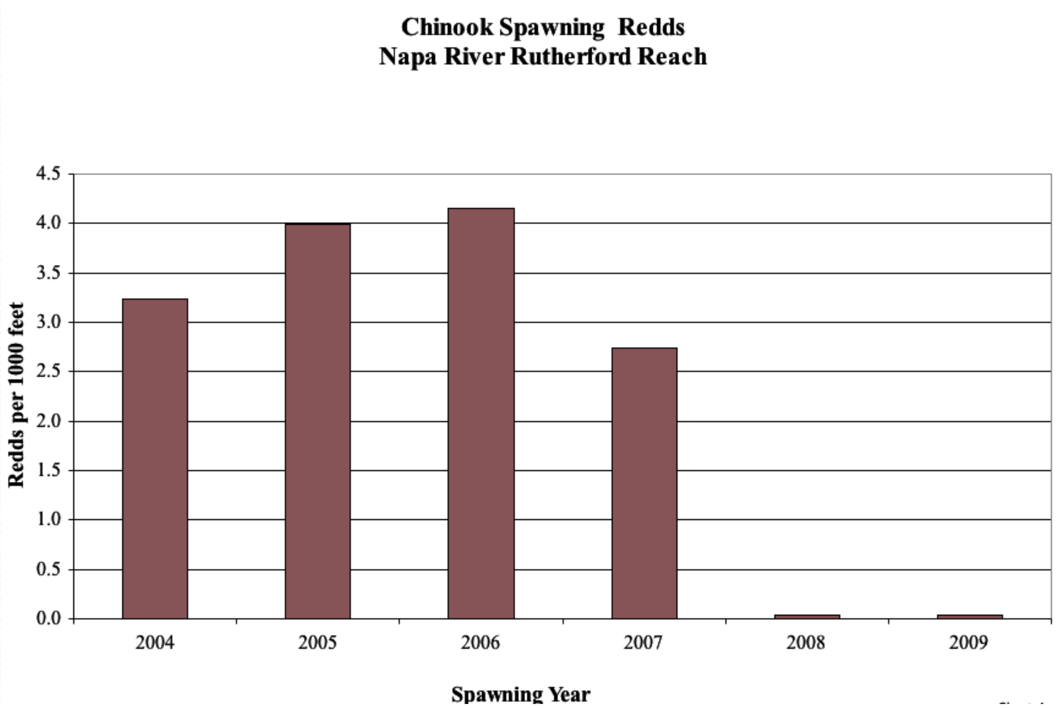

Figure 2. Linear density of redds by spawning year in the Napa River.

Table 3. Surveying details for salmon return counts – fish and redds, for 2004 to 2009.

	Rutherford Restoration Reach					
	2004	2005	2006	2007	2008	2009
Survey length (ft)	19129	24816	24834	24834	24834	24834
Redds	62	99	103	68	1	1
Carcasses	46	3			0	0
Live fish	216	218			2	0
Redds per km	10.6	13.1	13.6	9.0	0.1	0.1
Redds per 1000ft	3.2	4.0	4.1	2.7	0.0	0.0

Temporal and spatial resolution

There is very low spatial resolution, with essentially all monitoring for fish taking place on the mainstem Napa River. For salmon, the accuracy is likely high because of active surveying for live returning fish, carcasses, and redds. Temporal resolution is moderate, with monthly reporting for native and non-native fish species in the river.

How sure are we about our findings?

For both fish community and salmon population assessments assumptions were made about targets (species richness and abundance). Modifications of these targets because of habitat variation (fish community metrics) and new estimates of target populations (salmon) would change the corresponding condition scores.

Survey information was limited, with only a few surveys and years per subregion. Most surveys were performed during only a few months per year, so annual aggregation and trend analysis was most appropriate. Although not all surveys were conducted identically, with combinations of electrofishing, snorkeling, and passive monitoring, results could be compared once converted into PONSE and PNS values.

There were insufficient data to be very confident about the fish community findings and the spawning salmon abundances and for fish community metrics to be confident in the trends measured. Longer term monitoring will be needed to estimate trends in fish communities with greater confidence.

Recommendations

Finding trends in short term data can be unreliable and can lead to incorrect conclusions. The data from the Napa River is only present for a short time period, so any concluding statements need to be considered in light of the data deficiency. Running a Kendall analysis requires at least 10 years of data, and anything shorter should not be considered accurate. Long term monitoring data is critical in understanding overall trends in the environment.

The prospects for better data on fish populations in the Napa River have improved recently with the installation of a rotary screw trap on the Napa River, within the *South Valley Floor* reach of the river. This installation, maintained by technical staff of Napa County Resource Conservation District, is currently in its second year of sampling Napa River fish populations directly, and it is expected to result in a great increase of fish population data on the mainstem of the river. This effort should be supported by local governments and conservation organizations, so that it can be continued indefinitely.

Technical Information

Data sources:

California Department of Fish and Game fish community survey data on the Napa River (2001 -- 2005, 6 locations)

Napa County Resource Conservation District database for live fish, carcasses, and redds observed in the spawning segment of the river (Rutherford Reach, 2004 to 2009)

Data transformation and analysis:

Unidentified species: Unidentified species were not relevant to PONSE calculation, and were only included in PNS if the native/exotic status was well-defined.

Aggregation: Fish abundances from screw trap operation were considered one monthly sample. Subregion trends were then determined via a Regional-Kendall analysis for the single sampling reach within the subregion. Current state was determined by averaging PONSE and PNS scores for the most recent year within the subregion

Expected native species: Expected native species (n = 35) and potential non-native/exotic species (n = 25) were determined based upon a list provided by Jonathan Koehler (Napa County RCD)

Citations

Meador, M. R., L. R. Brown, and T. Short. 2003. "Relations between introduced fish and environmental conditions at large geographic scales." Ecological Indicators 3:81-92.

SE Queensland EHMP methods:
(http://www.ehmp.org/_uploads/ehmp/FileLibrary/freshw_methodsfishi.pdf)

Habitat Fragmentation and Connectivity

Goal:

Conserve, protect and improve native plant, wildlife and fish habitats and their communities

Objective:

No specific objective

WAF Attribute:

Landscape Condition

Table 1. Results for: Habitat fragmentation and connectivity.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	67 ± 24	ND	High
Western mountains	77 ± 29	ND	High
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	34 ± 20	ND	High
Eastern mountains	100 ± 22	ND	High
South valley floor	29 ± 24	ND	High
North Valley floor: North of Oak Knoll Avenue	51 ± 27	ND	High

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

This indicator is a measure of habitat fragmentation using a metric known as effective mesh size. Effective mesh size (EMS) is a method based on the probability that two points chosen randomly in a region will be connected, and that barriers like roads, railroads, or urban development do not separate the points (Jaeger 2000, Moser 2007, Girvetz et al., 2008). A high effective mesh size value indicates low fragmentation of the landscape. Fragmentation, or its corollary connectivity, was recently calculated for the whole of California (Girvetz et al., 2008).

Why is it Important?

Habitat fragmentation is a process by which larger areas become smaller, more numerous and isolated by physical or other barriers. Structural changes in ecosystems, such as fragmentation in vegetative cover, cause functional changes in hydrological, geochemical, and geomorphological processes. At the landscape scale, fragmentation (along with its corollary connectivity) for individual taxa may be the most important of physiographic properties, because it is a measure of intactness, which along with habitat type and forage availability describes what individual taxa and biodiversity need across daily to evolutionary timeframes. Landscape fragmentation results in further changes in other structures (e.g., aquatic habitat) and processes, leading to an unraveling of complex systems and loss of resiliency. Species existing in a fragmenting landscape will have different responses to the process. Some will be less able to adapt to the changes, leading to a reduction in the probability of survival over time. Ultimately, fragmentation can result in a reduction of biodiversity, a measure of the health of an ecosystem. All landscapes have some degree of natural fragmentation; however, a landscape with fewer anthropogenic sources of fragmentation is regarded as healthier and represents an objective for environmental protection.

Intactness and habitat quality, and the connectivity that they help to confer, are closely related to the ecological state of particular landscapes. A place that has undergone a large change in cover (e.g., from grazing or crop irrigation) may attain a different resilient state than the original, natural state. One commonly-proposed adaptation strategy is improving structural connectivity under different climate change scenarios to increase the likelihood that species ranges can change adaptively over time (Carroll et al., 2009). Providing for biodiversity conservation under climate change and land-use pressure includes protecting connectivity as a landscape attribute to facilitate individual species and community migration.

What is the target or desired condition?

Natural fragmentation of habitats is an expected characteristic of California landscapes and is desirable. Fragmentation by roads and other infrastructure and activities is not. Fragmentation affects different species and natural processes differently, meaning that there is no single value of fragmentation that has broad ecological meaning. A target condition (score of 100) was set at the largest measured effective mesh size in any Napa subregion (Western Mountains). All other subregions were compared to that value and scores expressed as proportions.

What can influence or stress the condition?

The most direct cause of habitat fragmentation is land-use actions by people. These include housing development, roads & highways, canals, logging, surface mining, agriculture, and recreation. The combination of infrastructure and use of the infrastructure causes the overall disturbance to habitats and landscapes. The decision-making that leads to fragmentation is spread among many private and public bodies and many social and economic benefits are derived from past and current fragmenting structures and activities.

What did we find out?

The largest average effective mesh size value for the subregions was 7,143, for the Western Mountains, which had a score of 100 (Table 1, Figure 1). The lowest score of 29 was for the South Valley Floor subregion, corresponding to an effective mesh size of 2,062. The average mesh size for all EMS delineated regions (referred to as planning watersheds, totaling ~108,000 ha) in the landscape was 6,010 indicating that the effective mesh size for most of the landscape is roughly centered between the high (11,471) and low (1,056) values.

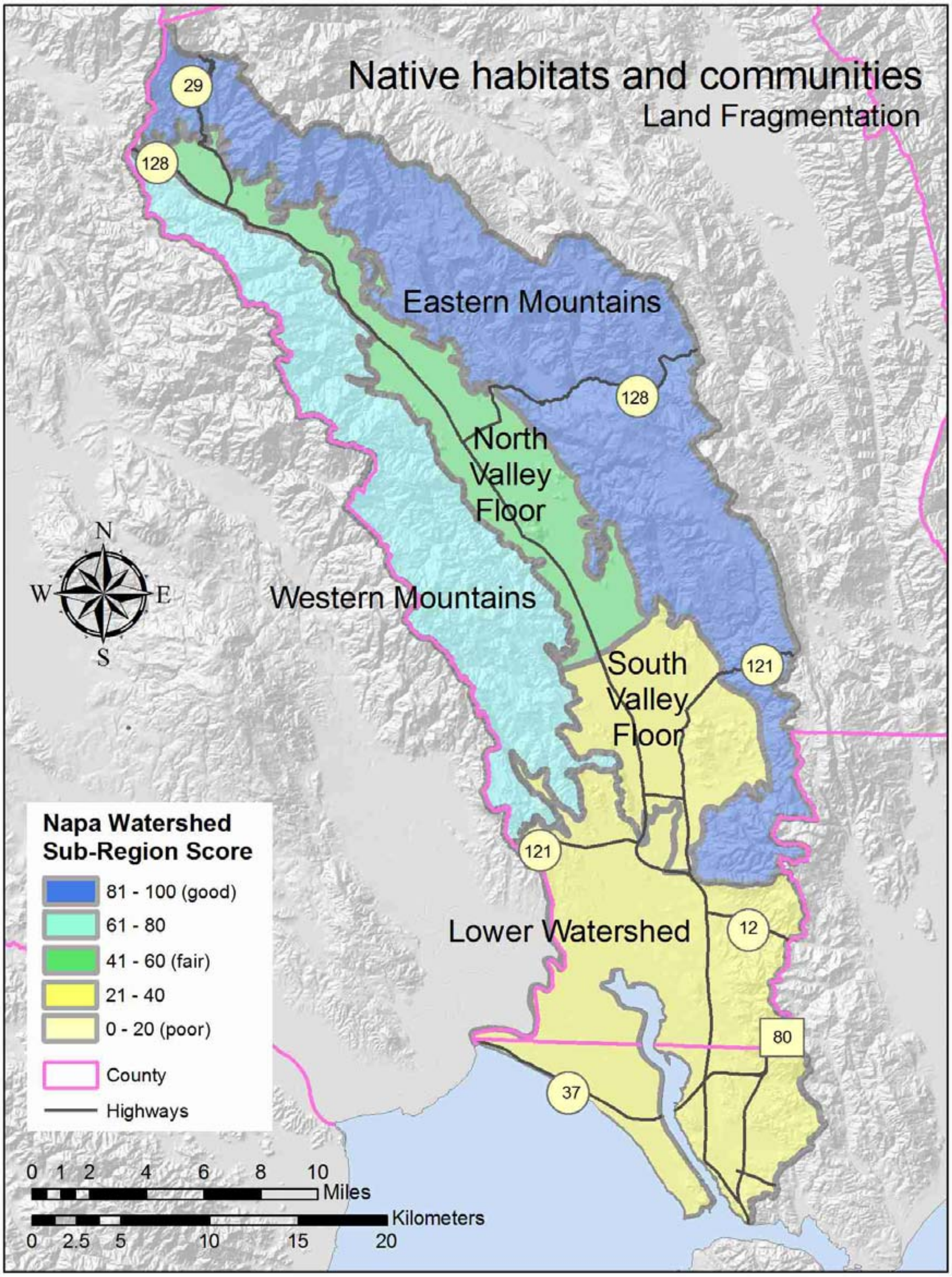

Figure 1. Distribution of subregion habitat fragmentation and connectivity scores.

Temporal and spatial resolution

Effective mesh size was previously calculated for the whole of California by Girvetz et al. (2008). The finest-resolution values were available for planning watersheds, which are creek drainages with sizes around 10,000 acres. This calculation has only been done once for the state for all fragmentation geometries, so temporal resolution is limited to this most recent calculation.

How sure are we about our findings?

The effective mesh size metric is one estimator of fragmentation. It treats all barriers as identical in their prevention of wildlife movement and inhibiting other ecological flows, though it is more likely that barriers are relatively permeable, rather than absolutely impermeable. There are other fragmentation metrics in the literature relating to the size, shape, and distribution of "patches", which are the pieces of habitat surrounded by roads or other habitats. The measurement itself is very accurate at the planning watershed and subregion scale, though there was considerable variation in effective mesh sizes among planning watersheds (Table 3). Due to the low sampling rate (see n in Table 2), the standard error of the EMS mean is provided in Table 2. This provides a measure of variability without making assumptions about distribution. Overall, this metric provides a good general indication of fragmentation condition, especially in a relative sense within a region or river basin.

Table 2. Standard error of the mean in effective mesh size in each subregion

Region	Confidence: Standard Error of EMS Estimate
WM	± 932
LW	± 1172
EM	± 600
SVF	± 1024
NVF	± 852

WM: Western mountains. LW: Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon. EM: Eastern mountains, including Angwin area. SVF: South valley floor, including Napa. NVF: North valley floor, including Calistoga, St Helena, and Yountville.

Recommendations

Changes in land use such as urbanization and vineyard establishment require road access. These activities influence the calculation of Effective Mesh Size and are best characterized by land use surveys (such as those conducted by CA Dept of Water Resources) and measures of population growth (U.S. Census). These data sources are published at intervals of 7 years or more. It would be preferable to identify a source for this information at the county level which could permit more frequent updates to the indicator.

Technical Information

Data Sources

Effective mesh size (EMS) data were those described in Girvetz et al. (2008) and were obtained directly from the authors.

Analysis

EMS has different values that are defined according to which fragmenting elements are considered. These categories of EMS are referred to as fragmentation geometries. For this analysis, 'fg3' was used as the indicator which considers all roads, railroads, urban and agricultural land use but does not consider natural fragmenting elements. Effective mesh size (expressed in sq. km) values for individual planning watersheds were aggregated to the subregions using area weighted averaging. The effective mesh size value for each subregion was compared to the maximum observed effective mesh size value among all subregions (Eastern Mountains). The following equation was used to generate a score for each subregion relative to the maximum observed EMS value: Score = EMSsr / max(EMSsr), where EMSsr is the area weighted EMS value calculated for the subregion and max(EMSsr) is the maximum EMS value observed in a subregion. The score ranges from 0 (low) to 100 (high).

Table 3. Basic statistics for effective mesh size (EMS) for subregions. "95% C.I. refers to 95% confidence intervals around the mean. "PW" refers to planning watersheds and "SR" refers to subregions.

Subregion Name	PW in SR (count)	Minimum EMS (sq)	Maximum EMS (sq)	Mean EMS (sq)	95% C.I. (sq)	Score
Western Mountains	13	1,056	11,471	5,486	1,827	**77**
Lower Watershed	4	1,056	6,160	2,398	2,297	**34**
Eastern Mountains	18	1,335	10,462	7,143	1,177	**100**
South Valley Floor	7	1,056	6,903	2,062	2,007	**29**
North Valley Floor	13	1,335	10,462	3,676	1,669	**51**

Citations

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Moser, B., J. Jaeger, et al. (2007). "Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem." Landscape Ecology 22(3): 447-459.

Sensitive Bird Species

Goal:

Conserve, protect and improve native plant, wildlife and fish habitats and their communities

Objective:

No specific objective

WAF Attribute:

Biotic condition

Table 1. Score, trend, and reliability for *Sensitive bird species*.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	74 (62-86)	Level	Low
Napa River watershed subregions:			
Western mountains	64 (36-64)	Level	Low
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	77 (64-86)	Level	Low
Eastern mountains	82 (82-100)	Level	Low
South valley floor	88 (75-100)	Level	Low
North Valley floor: north of Oak Knoll Avenue	60 (50-100)	Level	Low

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

There is an abundance of observational data about birds, thanks to surveys such as Christmas Bird Counts, the Breeding Bird Survey, and observational datasets such as eBird. The Napa River watershed is covered by a heterogeneous set of bird data. For instance, from 1988 to 1993, the Napa-Solano Audubon Society carried out a breeding bird atlasing project (Berner et al. 2003) that assessed the breeding status of bird species in Napa County in spatial units of 5 km by 5 km blocks. In terms of long-term datasets that can be used for trend analysis, there is one Breeding Bird Survey transect (the Glen Ellen route) crossing the Napa Valley and one Christmas Bird Count centered on Angwin in the Napa Valley region. Another important data source is the California Avian Data Center (CADC) archive (PRBO Conservation Science 2010) hosted by PRBO Conservation Science, which contains observations both from citizen science efforts such as eBird (Sullivan et al. 2009) and Project FeederWatch (Cornell Lab of Ornithology & Bird Studies Canada 2009) as well as more formal studies such as point counts carried out by PRBO.

A number of different metrics have been used to assess bird population data including change in species richness, change in diversity (e.g. Shannon index), or trends in abundance in selected bird species such as those from a particular guild or on a recognized watch list (Magurran 2004, Buckland et al. 2005). With limited amounts of long-term time series data — only one CBC count circle and one BBS transect are available for use in the Napa Valley watershed — we opted to devise a metric that takes advantage of a more heterogeneous dataset. In particular, we examine the persistence of sensitive bird species in each of the subregions in the watershed.

For this analysis we consider the set of species on several watch lists: the California Species of Special Concern list (Shuford et al. 2008) together with the state threatened and endangered lists (California Department of Fish & Game 2010), the National Audubon Society 2007 watch list (National Audubon Society 2007) and the Audubon Common Species in Decline list (National Audubon Society 2007a). From this set of species we created a list of which species were historically present in each subregion, historical observations being defined as from the time of the Napa County Breeding Bird Atlas or before. We then compared this list with current observations of these sensitive species within each subregion, current being defined from 2005 to the present. We rate each subregion by the percentage of sensitive bird species that are present currently as compared to being present historically.

Why is it Important?

This indicator helps assess the bird communities in the region, an important and highly visible component of the region's biodiversity. In this analysis we focus on sensitive bird species rather than overall species richness because we expect this will highlight regions that are being particularly disturbed, the idea being that environmental disturbance is more likely to cause rare than common species to disappear from the avifauna.

What is the target or desired condition?

The target condition is presence of the same set of sensitive species as were recorded in observations made during or before 1993. This date is chosen because it marks the completion of the Napa Breeding Bird Atlas (Berner et al. 2003), which is the most comprehensive survey of Napa County bird distributions to date. Bird occurrence records from other data sources such as the California Avian Data Center provided additional information about the presence of sensitive species in this time period. Table 2 lists this set of sensitive species by subregion together with the source of the observation.

Table 2. Napa Valley Sensitive Bird Species — Historic Condition

Species	**Western mountains (WM)**	**Lower watershed (LW)**	**Eastern mountains (EM)**	**South Valley Floor (SVF)**	**North Valley Floor(NVF)**
Northern pintail		SW 1	W 3		
Greater scaup		W 2			
Mountain quail	S 1		S 1	S 1	
Clark's grebe		W 2	S 1		
American bittern		W 1			
Northern harrier		SW 1			
Swainson's hawk					
Bald eagle			W 1		
Peregrine falcon	S 1		S 1		
Black rail		S 1			
Clapper rail		S 1			
Snowy plover		SW 1			
Long-billed curlew		W 2,4			
Western sandpiper		W 2			
Thayer's gull		W 2			
Least tern		S 3			
Burrowing owl		S 1			
Northern spotted owl	S 1		S 1		
Long-eared owl					
Rufous hummingbird		T 3			T 4
Allen's hummingbird	S 1	S 1	S 1	S 1	S 1
Nuttall's woodpecker	S 1	S 1	S 1	S 1	S 1
Olive-sided flycatcher	S 1		S 1	S 1	
Willow flycatcher					
Loggerhead shrike		S 1	S 1		S 4
Oak titmouse	S 1	S 1	S 1	S 1	S 1
Wrentit	S 1		S 1		
California	S 1		S 1		

thrasher					
Yellow warbler	S 1	S 1	S 1	S 1	S 1
Hermit warbler	S 2				
Yellow-breasted chat	S 1			S 1	S 1
Lark sparrow	S 1	S 1	S 1		W 3
Song sparrow	S 1	S 1	S 1	S 1	S 1
Tricolored blackbird		S 1			
Lawrence's goldfinch			S 1		W 1

Table 2 Key. S – Present as breeding species or in summer. W – Present in winter. T – Present as transitory species or in migration. Numeric codes are data sources: 1- Breeding Birds of Napa County (Berner et al 2003). 2 – Birds of Napa County (Heinzel 2006). 3 – CADC dataset (PRBO Conservation Science 2010). 4 — MVZ collection data (Museum of Vertebrate Zoology 2010).

What can influence or stress the condition?

Factors that can influence the persistence of sensitive species include broad-scale changes in the landscape such as deforestation, conversion to agriculture, and development. Degradation of habitat in the absence of broad-scale landscape changes can also lead to declining species richness, particularly through the extinction of rare species (Weber et al. 2004). Conversely, good management of reserves where rare species occur may promote their persistence over time. (Bohning-Gaese and Bauer 1996).

What did we find out?

Status by Subregion

Table 3 summarizes all observations of sensitive bird species in the period 2005 to the present, with the source of the observation and the number of distinct observations of the species indicated, the latter being binned into four discrete ranges for ease of tabulation. This table was compared with Table 2 to tabulate species in each subregion that were observed in both time periods. Table 4 gives this comparison. This table has rows for three different criteria for species persistence. In the first row, a species is considered to have persisted in a subregion if it had at least one observation in the current time period. This is the criterion that is used as the indicator score for each subregion, and is mapped above in Figure 1. The second row applies a stricter criterion, and only counts a species as having persisted if it has been seen at least twice in the current time period. The reasoning behind this criterion is that requiring at least two discrete observations increases the chance one is observing actual persistence of a population rather than the passage of a stray individual. The third row examines the case of species replacement; that is, it counts species that were seen in the current period but not seen historically. These latter two criteria are used as the lower and upper bounds in the overall indicator reporting.

Using the criterion of at least one species occurrence (the first row of Table 4), the fractions of persistent species by subregion range from 60% to 88%, with the highest value being observed in the South Valley Floor, and the lowest value (60%) being observed in the North Valley Floor. Qualitatively, this 60 to 88% range seems to go from barely adequate to good. Of note is the particularly low value for the Western Mountains (64%) and the quite high value for the South Valley Floor, which is dominated by the city of Napa.

When the stricter criterion of having at least two observations in current time period is applied, the Western Mountains region shows the greatest impact, with only 36% of the species observed in the 1993 and before period being recorded from 2005 to the present. The Eastern Mountains by contrast show the same number of persisting species with the stricter criterion as with the original criterion, 14 of 17 species.

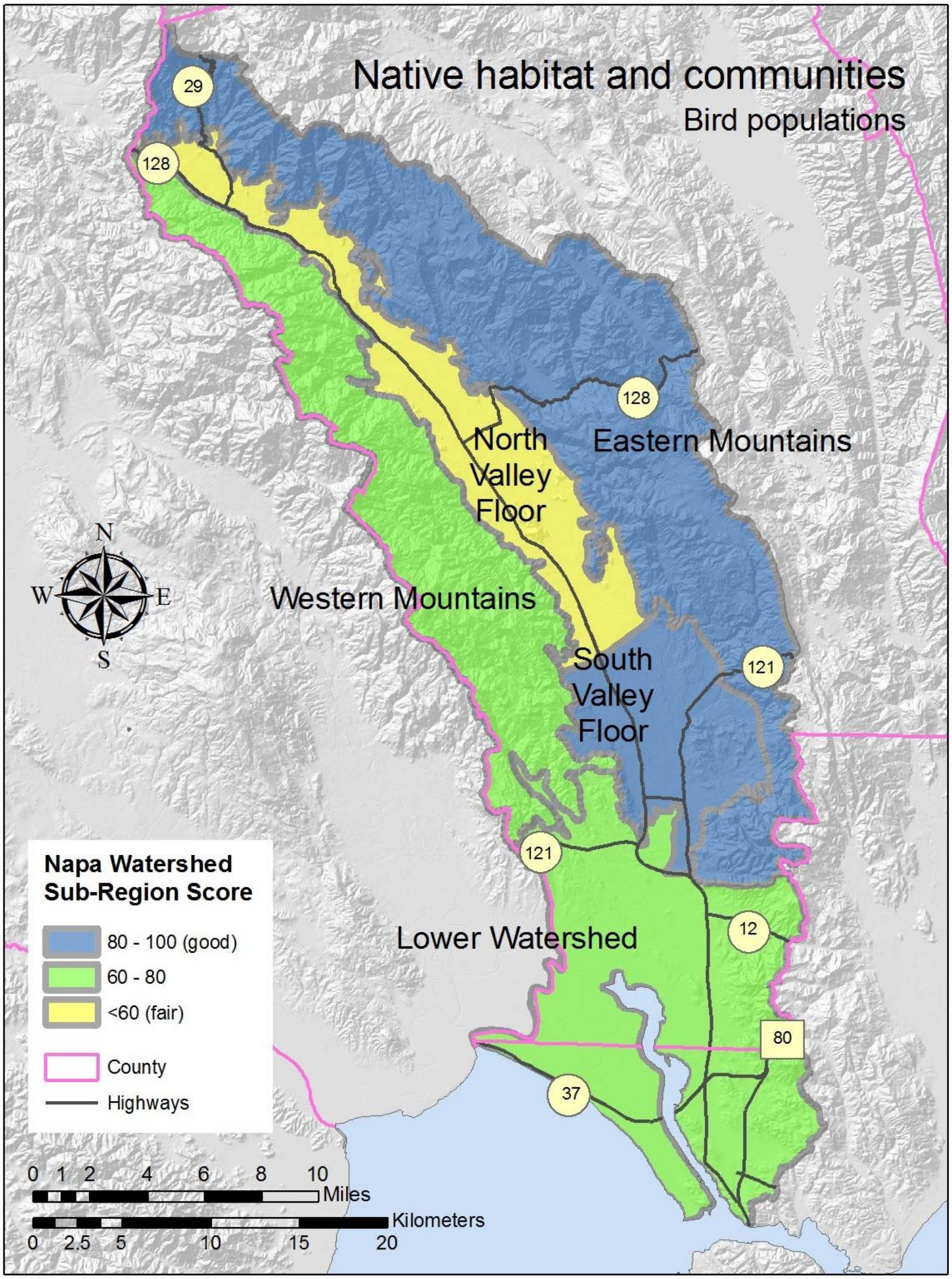

Figure 1. Sensitive bird species persistence scores across subregions.

If the species lists in Tables 2 and 3 are compared by just counting the number of sensitive species seen in each subregion in the two time periods, most of the subregions show an increase in the number of sensitive species. This is especially dramatic in the case of the South Valley Floor region, where 8 sensitive species were recorded in the period 1993 and before, and 22 sensitive species were recorded from 2005 on. It is not clear to what extent this increase is simply attributable to better data recording in the period from 2005 on. In the case of at least one species, the Swainson's Hawk, a note on an eBird observation states that the first Napa County record of the species was in April 2004, so it represents an example where a sensitive species clearly has become a new member of the avifauna, in this case in the Lower Watershed subregion.

Table 3. Current Observations of Sensitive Bird Species

	Western mountains (WM)	**Lower Watershed (LW)**	**Eastern mountains (EM)**	**South Valley Floor (SVF)**	**North Valley Floor (NVF)**
Northern pintail		10+a	2-5a	6-10a	
Greater scaup		6-10a		2-5a	2-5a
Mountain quail	NF		6-10a	6-10a	
Clark's grebe		10+a	10+a		1a
American bittern		NF			
Northern harrier		10+a	2-5a	2-5a	2-5a
Swainson's hawk		6-10a			
Bald eagle			6-10a	1a	1a
Peregrine falcon	NF	10+a	6-10a	2-5a	1a
Black rail		NF			
Clapper rail		2-5a			
Snowy plover		2-5a			
Long-billed curlew		10+a	2-5a	2-5a	
Western sandpiper		10+a		1a	
Thayer's gull		2-5a			
Least tern		NF		1a	
Burrowing owl		NF			
Northern spotted owl	1a		NF		
Long-eared owl					
Rufous hummingbird		1a		6-10a	6-10a
Allen's hummingbird	1b	2-5a		2-5a	1a
Nuttall's woodpecker	2-5a	6-10a	10+a	10+a	6-10a
Olive-sided flycatcher	NF		2-5a	6-10a	
Willow flycatcher			1a		

Loggerhead shrike		10+a	NF	2-5a	
Oak titmouse	10+a,b	NF	10+a	10+a	10+a
Wrentit	10+a		10+a	2-5+a	10+a
California thrasher	2-5a		10+a	2-5+a	2-5a
Yellow warbler	1b	2-5a	2-5a	1a	2-5a
Hermit warbler	NF		6-10a	2-5a	2-5a
Yellow-breasted chat	NF			NF	NF
Lark sparrow	1a	1a	NF	10+a	NF
Song sparrow	6-10a	10+a	10+a	10+a	6-10a
Tricolored blackbird		1a	1a		NF
Lawrence's goldfinch			6-10a		NF

Table 3 Key. Numeric ranges (i.e. 1, 2-5, 6-10, 10+) give the number of occurrence records in each subregion from 2005 to the present, for example 6-10 means the number of records fell between 6 and 10. The trailing letters "a" and "b" refer to sources; specificially "a" is the CADC dataset (PRBO Conservation Science 2010) and "b" is the Glen Ellen Breeding Bird Survey transect. "NF" means the species was observed in the reference 1993 and prior time period but not in the current time period.

Table 4. Persistence of Sensitive Bird Species by Subregion

Persistence criterion	**Western mountains (WM)**	**Lower Watershed (Napa marshes) (LW)**	**Eastern mountains (EM)**	**South Valley Floor (Napa city) (SVF)**	**North Valley Floor (NVF)**
At least one occurrence in current period	9 of 14 species (64%)	17 of 22 species (77%)	14 of 17 species (82%)	7 of 8 species (88%)	6 of 10 species (60%)
At least two occurrences in current period	5 of 14 species (36%)	14 of 22 species (64%)	14 of 17 species (82%)	6 of 8 species (75%)	5 of 10 species (50%)
At least one occurrence with species replacement allowed	9 of 14 species (64%)	19 of 22 species (86%)	18 of 17 species (106%)	22 of 8 species (275%)	13 of 10 species (130%)

Adequacy of Coverage

Figure 2 below displays a map summarizing all occurrence data used in this analysis, including the Glen Ellen Breeding Bird Survey transect, the count circle of the Angwin Christmas Bird Count, the 5 kilometer grid used by the Napa County Breeding Bird Atlas, and point observations from the California Avian Data Center. These latter point observations are subdivided by data source; in particular, the figure displays records from three citizen science efforts coordinated by the Cornell Lab of Ornithology, eBird, Project FeederWatch (PFW), and the Great Backyard Bird Count (GBBC). It is clear from this map that the subregions receive substantially different levels of coverage by observers. In particular, the Western Mountains region has very little observer coverage in the California Avian Data Center dataset, which probably explains its low indicator scores seen in Table 4. Additionally, the locations of the two datasets that give long-term observational time series, the Angwin Christmas Bird Count circle and the Glen Ellen Breeding Bird Survey transect do not cover the South Valley Floor subregion or the Lower Watershed subregion.

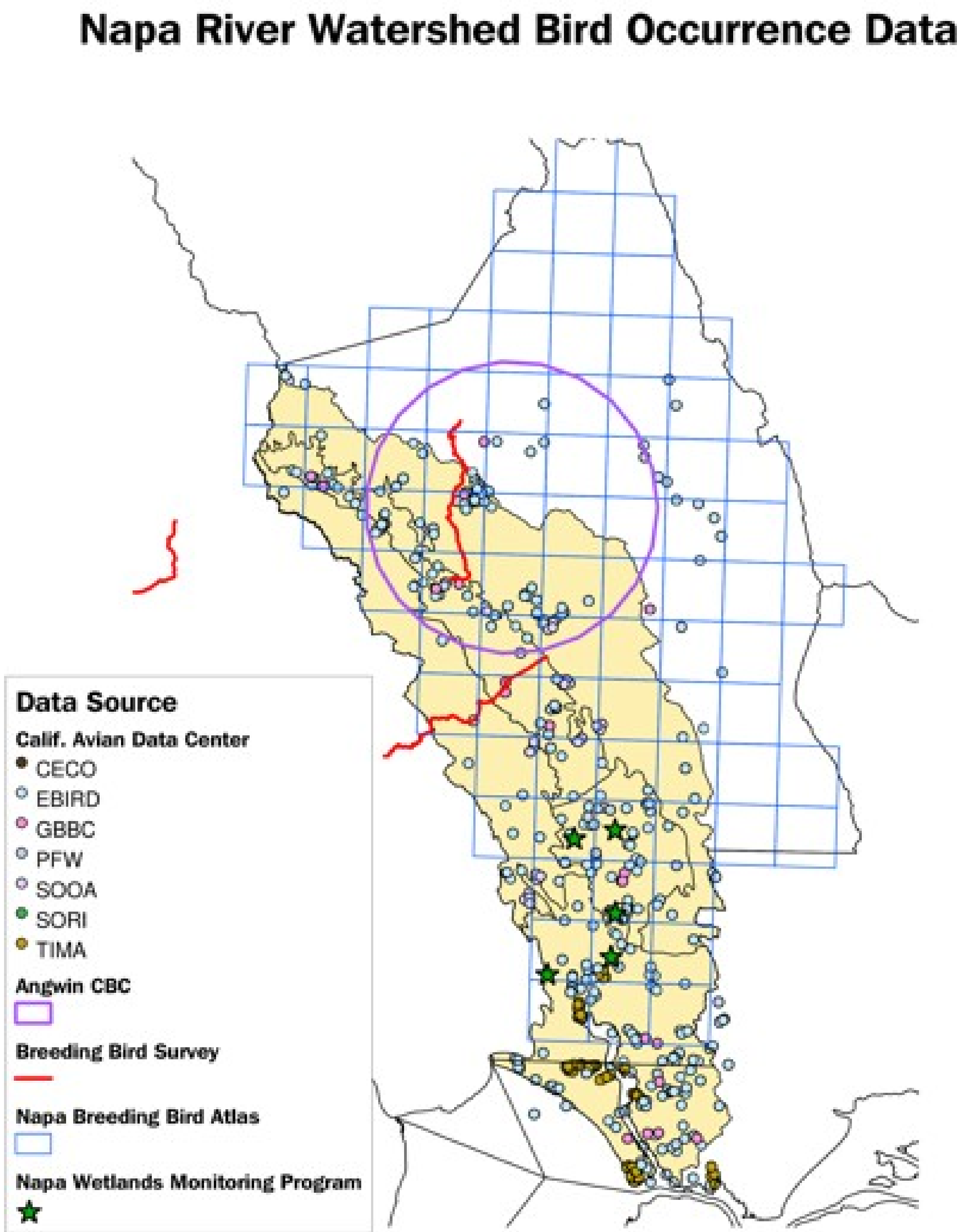

Figure 2. Summary of Bird Occurrence Data

Trend Analysis

Because the above analysis does not use long-term observational time series, it is important to try to check its conclusions against such time series data where available. As noted above, such data are limited in the Napa River watershed. For this trend analysis, we augmented the data from the Glen Ellen Breeding Bird Survey route and the Angwin Christmas Bird Count with data from the Benicia Christmas Bird Count. The Benicia CBC, centered at 38.1333 degrees north and 121.1 degrees west, is about 10 kilometers to the east of the Napa River watershed and provides a proxy for trends in species wintering in the Napa River marshlands.

To compute a trend for each subregion, we first assigned each species on the list of sensitive species for the Napa River watershed a time series of count data dating from 1994 to 2009 from either the Glen Ellen BBS, the Angwin CBC, or the Benicia CBC depending upon which survey best represented the location and seasonality of the species. We then amalgamated the time series for each species into sets for each subregion based upon the list of species in Table 2. Using Regional Kendall trend analysis (Helsel and Frans 2006) we then computed an overall trend for each subregion. These results are displayed in Table 5. As this table shows, the overall slope across the set of sensitive species is not significantly different from zero for all subregions. Nevertheless, more species showed a significant negative trend in survey counts than a positive trend in four of the five subregions.

Table 5. Trends in Survey Counts of Sensitive Species by Subregion

Subregion	No. of species with significant positive trend	No. of species with significant negative trend	Overall slope	Significance of overall slope
Western Mountains (WM)	2	3	0	Not significant
Lower Watershed (LM)	2	3	0	Not significant
Eastern Mountains (EM)	1	3	0	Not significant
South Valley Floor (SVF)	1	2	0	Not significant
North Valley Floor (NVF)	1	1	0	Not significant

Temporal and spatial resolution

Data sources varied widely in their spatial and temporal resolution. The Napa County Breeding Bird Atlas maps the occurrences of breeding bird species to 5 kilometer by 5 kilometer blocks over a five year time period from 1988 to 1993. Individual Breeding Bird Survey routes are run annually in late May or early June. In California, there are roughly four routes per latitude-longitude block. Each route is 24.5 miles in length, and consists of 50 stops at 0.5 mile intervals. The Christmas Bird Counts are held annually, from mid-December to early January. Each count is performed in a circle 15 miles in diameter, and species counts are reported spatially only to the whole circle.

How sure are we about our findings?

The results of the analysis present an inconsistent picture of how sensitive species are persisting in the Napa Valley watershed. This is an outcome of being forced to rely on such a heterogeneous set of data on bird occurrences. The bulk of the occurrence records come from either the Napa County Breeding Bird Atlas or the California Avian Data Center records, the latter mostly composed of eBird records. Unfortunately, only a few observers entering data into eBird have inputted old data from field records prior to the establishment of the eBird service in 2002. The data sources for the reference condition and the current condition are therefore rather incommensurate. And there is not enough long-term time series data to derive statistically significant conclusions about species population trends. (For the Breeding Bird Survey, one usually needs data from at least 14 survey routes to derive a trend for a single species (Pardieck and Sauer 2007)). Accordingly, we have fairly low confidence in the indicator values produced by this analysis. Anecdotal accounts though do corroborate a change towards increasing disturbance in the watershed. For example, Berner et al. (2003) report that the Northern Spotted Owl nested in the Angwin area in the Eastern Mountain subregion at the time of the Breeding Bird Atlas surveys, but was no longer present in 2002. Likewise, they also report that the Yellow-Breasted Chat used to occur regularly at the Napa River Ecological Reserve in the North Valley Floor subregion, but is no longer routinely found at that increasingly isolated reserve.

Recommendations

The Western Mountains subregion and to some extent the Eastern Mountains subregion receive relatively little attention by casual field observers. We recommend that these subregions be surveyed more systematically, especially for rare species that do not usually get recorded in the Breeding Bird Survey. Example of such species in these subregions include Northern Spotted Owls, Hermit Warblers, and Peregrine Falcons. It is also important to encourage birders to record their observations in citizen science efforts, especially eBird. Such observations will become much more valuable as this data archive increases over time. Finally, we recommend that a long-term bird monitoring program be established for the Lower Watershed subregion. The Napa River marshlands contain a large proportion of the sensitive species list for the entire watershed, yet there are no long-term surveys in that subregion that are comparable to the time series provided by the BBS transects or the CBC counts.

Technical Information

Data Sources

Information on the 1993 and prior occurrences of birds in the Napa Valley watershed came from a number of sources including the Napa County Breeding Bird Atlas (Berner et al. 2003), records in the California Avian Data Center (PRBO Conservation Science 2010), descriptions in Heinzel (2006), collection records from the Museum of Vertebrate Zoology (MVZ 2010), the California Natural Diversity Database (California Dept. of Fish and Game 2010a) and range information in Grinnell & Miller (1944). Information on the occurrence of birds since 2005 comes from Breeding Bird Survey transects (Sauer et al. 2008), Christmas Bird Counts (National Audubon Society 2010), point counts undertaken as part of the Napa Wetland Monitoring Program (Koehler 2007), and observation points in the California Avian Data Center. The CADC records include many observations from the eBird (Sullivan et al. 2009) and Project FeederWatch (Cornell Lab of Ornithology & Bird Studies Canada 2009) citizen science initiatives.

Data Transformations

For the analysis of current condition, the numbers of observations of a single species in a subregion were binned into four classes: 1 observation, 2 to 5 observations, 6-10 observations, and greater than 10 observations. For the trend analysis using Christmas Bird Count data, counts of each species were normalized for effort by dividing the raw count by the total number of hours separate birding parties were in the field. This is the most common method for controlling for effort in analyses of Christmas Bird Count effort (Link & Sauer 1999).

Analysis

All statistical analyses were performed in the R statistical computing environment (R Development Core Team. 2009). To analyse trends across all sensitive species in each subregion, a Regional Kendall analysis was performed (Helsel and Frans 2006). This is to our knowledge a novel application of the Regional Kendall methodology, which was developed to combine trends in time series across different spatial locations. Since the Regional Kendall technique does not in fact make use of any spatial information, we perform a formally equivalent analysis by substituting time series for different regions (the normal practice with

Regional Kendall) with time series for different species. Slopes in the trends were derived using Sen's method (Sen 1968).

The indicator score for the entire watershed was computed by averaging the subregion score, and the confidence interval for the entire watershed is the standard deviation of the subregion scores. The confidence intervals for the subregions are reported using the criteria in rows 2 and 3 of Table 5 for the lower and upper bounds respectively. For the case of the upper bound in the reporting in Table 1, this value was set at a maximum of 100 if the score reported in row 3 of Table 4 was greater than 100.

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Aquatic Insects

Goal:

Conserve, protect and improve native plant, wildlife and fish habitats and their communities

Objectives:

No specific objective

WAF Attribute:

Biotic Condition

Table 1. Score, trend, and reliability for: *Aquatic insects.*

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	44.8 ± 10.5	ND	Moderate–High
Napa River watershed subregions:			
Western mountains	58.5 ± 5.5	ND	High
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	32.8 ± 9.0	ND	Moderate–High
Eastern mountains	53.0 ± 9.0	ND	High
South valley floor	39.0 ± 10.5	ND	Moderate–High
North valley floor: North of Oak Knoll Avenue	41.0 ± 11.0	ND	High

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

Freshwater aquatic insects, known as benthic macroinvertebrates or BMIs, are small animals without backbones that live on submerged rocks, logs, sediment, debris and aquatic plants during some period in their life. BMI include the immature forms of aquatic insects such as mayfly and stonefly nymphs, as well as crustaceans such as crayfish, molluscs such as clams and snails, and aquatic worms.

Many BMI are highly sensitive to changes in their aquatic environment and thus can act as continuous monitors of the condition of the water they live in. Human activities that interfere with or disrupt natural processes in a watershed can have significant impacts on the types and numbers of BMI that live there. We can assess the biological health of a watershed by looking at the types of BMI that either thrive or do not thrive in it. BMI represent an extremely diverse group of aquatic animals, with a wide range of responses to stressors such as organic pollutants, sediments, and toxicants. If only a few types of benthic macroinvertebrates live in a waterway, or if the macroinvertebrates present are primarily ones that are insensitive to disturbed systems, impairment of the system is indicated.

A variety of BMI metrics (e.g., diversity, sensitive taxa, functional feeding groups, rare species, etc.) can be used to assess watershed condition and the status of aquatic invertebrate populations. Two key, commonly-used metrics were used: Total Taxa Richness and EPT Taxa Richness.

1) Total Taxa Richness is the total number of macroinvertebrate taxa (Family/Genera), insect and non-insects at a sampling site. Total Taxa Richness provides an index of the general health of the BMI community and is expected to be higher in subregions with better habitat diversity, suitability, and water quality (Plafkin et al., 1989).

2) EPT Taxa Richness is the total number of EPT taxa (Family and Genera) found within the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). These are insect orders considered particularly sensitive to pollution and habitat disturbance so that the presence and abundance of EPT taxa provides an indication of overall water quality. Sites at which EPT taxa are more prevalent are considered to have cleaner water and provide better habitat conditions. EPT Richness is one of the most commonly used biometrics used to describe macroinvertebrate community structure and to assess possible stream degradation (Resh and Jackson 1993).

Why is it Important?

One of the best ways to assess a watershed is to identify the health of the aquatic organisms and their communities in the habitats of a system. Unlike chemical monitoring, which provides information about water quality at the time of measurement, monitoring of living organisms (biomonitoring) can provide information about past and/or episodic pollution and the cumulative effects of a suite of watershed impacts. BMI represent ideal biomonitors for assessing the overall health of watersheds for a number of reasons:

1. They are widespread

2. They are easy to collect and identify
3. They are relatively sedentary and long-lived, so reflect the longer-term effects of activities within their watershed
4. Some species of BMI are highly sensitive to pollution

BMI-related metrics (e.g., taxa richness and diversity, specific taxa pollution sensitivities/tolerances, etc.) have been used by various US agencies for many years as “bioindicators” of water quality, providing integrated information on toxic chemical concentrations, dissolved oxygen levels, nutrients, and habitat quality. Beyond their usefulness as bioindicators, BMI are themselves an important part of aquatic food chains, especially for fish. Many BMI feed on algae and bacteria, which are on the lower end of the food chain. Some shred and eat leaves and other organic matter that enters the water. Because of their abundance and position as “middlemen” in the aquatic food chain, BMI play a critical role in the natural flow of energy and aquatic nutrients in streams, lakes and wetlands.

What is the target or desired condition?

The desired condition is to have a rich and diverse community of BMI across the watershed, reflecting maintenance of natural river/stream processes and clean water that allows persistence of particularly sensitive species. Absent a defined California standard for desired BMI total taxa richness in aquatic systems, or alternatively readily available information from a pristine (reference) watershed for comparison, the highest Total Taxa Richness value (92) obtained at any of the historical sampling sites was used as a “good” target and given the highest score (100); a Total Taxa Richness value of zero was given the poorest score (0). A straight line function was used over this range of values to give equivalent scores to the average Total Taxa Richness found across the subregions. Although EPT Taxa Richness would be expected to vary regionally, Harrington et al. (1999) suggest a standard (based on Level 3 sampling) that could be used for California streams, where EPT Taxa Richness > 19 indicates good water quality, 12-19 indicates fair water quality, and < 12 indicates poor water quality. This standard was adopted as a target for desired BMI condition where subregions with an average EPT Taxa Richness of < 12 were scored as 0, those with > 19 were scored as 100 and those with EPT values between 12 and 19 were scored as an extrapolated straight line function between 12 and 19.

What can influence or stress condition?

Some BMI taxa require very good water quality, whereas others tolerate a wide range of environmental conditions. Although BMI can move about to some extent, drift downstream, and fly as adults, the aquatic forms generally cannot move quickly to avoid adverse conditions. Deteriorating water and/or habitat quality and pollutants can be expected to kill or at least stress less tolerant BMI taxa and encourage other more tolerant taxa to proliferate.

What did we find out?

The subregions are scored independently of one another and are aggregated to an overall watershed score (See Table 1). Western and Eastern Mountains score the highest at 58.5 and 53.0 scores while the other sites of the Southern valley floor and Lower watershed have the lowest scores of 39.0 and 32.8 (Figure 1). The Northern valley floor has a score of 41.0. The overall Napa watershed has a BMI score from the average all of the Total Taxa Richness subregional scores at 44.8. There are apparently impacts within the Napa watershed which are limiting the diversity of overall aquatic macroinvertebrate community whether it is from flows, land disturbances, land use practices, or physical parameters.

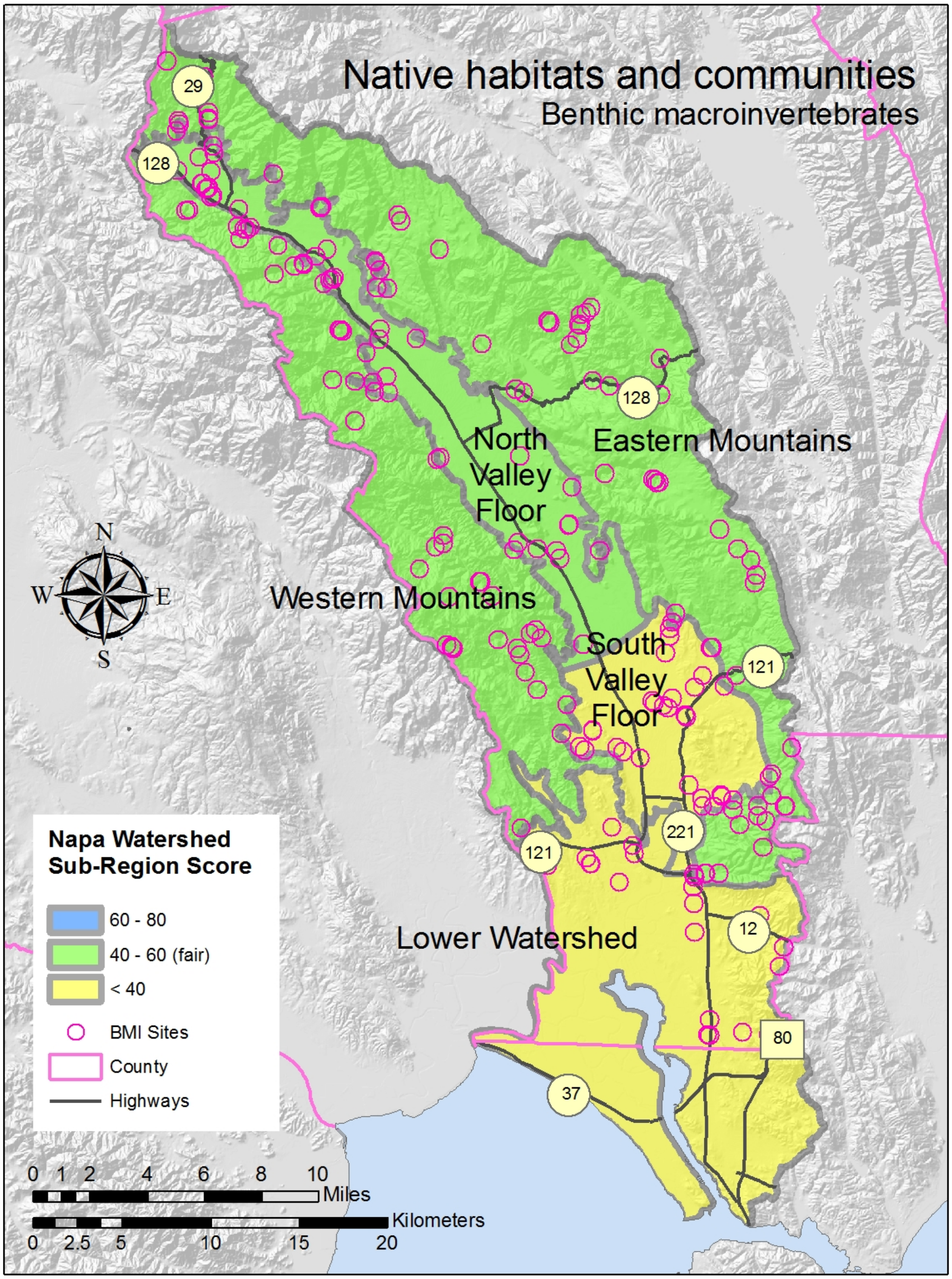

Figure 1. Distribution of aquatic insect (benthic macroinvertebrate) total taxa richness scores across subregions.

Condition

The results for the EPT taxa point at greater differences among subregions (Table 2). The Western and Eastern mountains had the highest richness of pollution sensitive species by California standards, with scores of 100 and 95. The high values mean that the sampled sites have on average >19 EPT taxa in these subregions (Table 4). The subregions in the valley have few of these intolerant species and have a greater mixture of insects that are pollution tolerant. The Lower watershed subregion scores the most poorly with an average EPT taxa richness of 7.4. Below is a summary of the Average Total Taxa Richness and Average EPT Taxa Richness for each subregion and the corresponding report scores for the EPT metric. The calculation of the EPT score based on 2 year's data, rather than just the last year (2006), is due to the lack of spatial comprehensiveness for just 2006 and to be more representative of all of the subregions.

Table 2. Total and EPT taxa richness among subregions.

Subregion	Average Taxa Richness	Average EPT Taxa Richness	Trend	Mean Condition for 2004 & 06 scores (EPT Richness only)
Western mountains	61.6	27.7	NA	100
Lower watershed	38.0	7.4	NA	0
Eastern mountains	55.9	21.7	NA	95.0
South valley floor	43.5	10.4	NA	0
North valley floor	50.4	17.6	NA	25.0

Summaries of the statistics for the BMI metrics and derived scores are presented for Total Taxa Richness and EPT Taxa Richness in Table 3 and 4. These results are discussed in previous sections but are provided to split apart the findings for better resolution of the 2 analyzed metrics and to show that they are interpreted differently while being kept independent of one another.

Table 3. Average Total Taxa Richness values and derived scores in each of five subregions. Mean Total Taxa Richness is calculated from the averages of the raw values for each site. The score is based on independently scoring each year per site and averaging these scores together.

Subregion	Mean (Total Taxa)	N (sites)	Min	Max	Score
Western Mountains	61.6	43	41	79	58.5
Lower Watershed	38.0	24	23	62	32.8
Eastern Mountains	55.9	58	30	86	53.0
South Valley Floor	43.5	29	20	72	39.0
North Valley Floor	50.4	47	18	92	41.0

Table 4. EPT Taxa Richness values and derived scores in each of five subregions. Mean Total EPT Richness is calculated from the averages of the raw values for each site. The score is based on independently scoring each year per site and averaging these scores together.

Subregion	Mean (Total Taxa)	N (sites)	Min	Max
Western Mountains	27.7	18	15	37
Lower Watershed	7.4	7	1	26
Eastern Mountains	21.7	26	4	37
South Valley Floor	10.4	9	1	33
North Valley Floor	17.6	5	2	41

Trend Analysis

No trends analysis was performed due to the lack of sufficient repeat-sampling at individual sites.

Temporal and spatial resolution

A total of 203 samples were collected over the 6-year period. There are specific details on site selection, sampling methods, time and space intervals of sampling, and specific goal objectives in the “Final Report Multi-metric Monitoring Project for Benthic Invertebrates in the Napa River Basin”, available from ICARE. All sites were sampled in the spring during the months of April or May between the years of 2000-2006, except for 2005 when no sampling occurred. Spatial resolution is summarized below in Table 5. Longitude and latitude were recorded for all sites and the bodies of water with repeat sampling were given new coordinates for each sampling occasion, so they are treated as new sites in this analysis. Closer analysis of the spatial distribution of sites could be used to group similar locations but more information might be needed. Also certain creeks had multiple sites occurring in more than one subregions, so grouping them would need to be carefully executed and interpreted.

Table 5. Number of samples collected each year for benthic macroinvertebrates (BMI) in Napa River subregions since 2000. Note that some of these are replicated sites, and are not necessarily truly independent sites.

Subregion	**2000**	**2001**	**2002**	**2003**	**2004**	**2006**
Western mountains	5	9	6	5	10	8
Lower watershed	4	3	4	6	4	3
Eastern mountains	7	8	12	5	12	14
South valley floor	4	5	7	4	6	3
North valley floor	11	36	11	14	3	2
Total per year	31	61	40	34	35	30

How sure are we about our findings?

The organisms for this indicator were identified by one lab, thus there is high confidence in terms of any "measurement errors" and uncertainties related to consistency of sampling protocols employed, processing thoroughness, and correct identification of BMI taxa (i.e., Level 3 analyses vs. Level 2 analyses – Richards and Rogers 2006). The samplers followed one collecting protocol of the California Stream Bioassessment Procedure (CSBP) for all data collected from 2000-2006. The level of organisms identified changes from 500 individuals per 3 replicates in the first three years of sampling (2000-2002) to 300 individuals identified per 3 replicates within 1 sample (2003, 04, and 06). In general, evaluating the status and trends of BMI can be very challenging and requires consistently sampled and analyzed data over time as macroinvertebrate populations are naturally highly variable both spatially and temporally (seasonally and annually) (EPA 2006). The confidence assigned to the values are High to Moderate (See table 1) with the greatest confidence in the locations with greater sampling within a subregion and also those which have greater frequency within a year (See table 5).

Recommendations

Recommendations are to sample a subset of all site locations every year to keep costs low and allow for trends analysis. A few sites in both of the Western and Eastern mountains would be maintained in these high EPT scoring areas but the focus would be to analyze the lowest to moderate scoring locations in the valley. Reference reaches could be established in the mountain regions but less sampling would be the primary focus of this monitoring with potentially a rotational site system in place to continue to get spatial coverage of the mountains. At least five locations per region in different habitat types could be monitored on a yearly basis to make sure that there is not a decline in the already healthy systems for Taxa Richness and EPT species in the mountains. The lower-scoring areas of the South and North valley floor and the Lower watershed subregions could have greater emphasis in order to assess if the fair condition is real and the potential causes of this condition. The site scores from 2000-06 should direct the selection process for which sites to continue to monitor after the baseline of 6 years of data. The recommendation for additional biomonitoring in the valley floor is because of the agricultural and urban development in the lower elevations of the Napa watershed.

An alternate approach is explained in the ICARE document, “Therefore, an effective way to monitor the overall health of the basin is to establish 3 sites along the mainstem of the Napa River in sites that are not likely to change. One site would be in the city of Napa above tidewater in an area that is unlikely to see change in the future. The second site would be in the Yountville Preserve, and a third site would be between Calistoga and St. Helena. These sites would serve as the primary sites tracking the long-term biological condition of the basin, while the long-profile samples in the tributaries or the mainstem would be used to identify the causal relationships in the basin.”

Technical Information

Data Sources

Data for our BMI community metrics were compiled from past sampling that has been undertaken within the partnership of the groups of the Friends of Napa and Napa RCD in one sampling project of ICARE. The ICARE program was made possible with grant funding of Friends of the Napa River in the Napa watershed. It is the first and only comprehensive dataset collected in the Napa watershed region. Friends of Napa River’s “Final Report Multi-metric Monitoring Project for Benthic Invertebrates in the Napa River Basin” (2000-2006) summarizes results from the same, collected samples as this report, but this project analysis focuses on just 2 widely accepted metrics: Total Taxa Richness and EPT Taxa Richness.

Data Transformations

Data were organized into a Microsoft Excel database for QA and divided by subregional location using corresponding GPS points. Sites that did not have coordinates were manually placed into a subregion using site descriptors; in this process 4 sites were eliminated. All sites from a pilot project in 1999 were removed from the data set due to sampling in this year occurring in the late fall season of October and November, which would result in different invertebrate communities from the communities sampled in April and May during the period 2000-2006, minus 2005. The same data were excluded also in the ICARE report except the one in 2000. All data had both metrics pre-calculated for the Total Taxa Richness (CA standard) and Total EPT Taxa, so no additional transformations or manipulations were made.

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Fire Recurrence

Goal:

Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity

Objective:

No specific objective

WAF Attribute:

Natural Disturbance

Table 1. Score, trend, and reliability for: *Fire recurrence*.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	65 ± 45	ND	Moderate
Napa River watershed subregions:			
Western mountains	84 ± 33	ND	Moderate
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	80 ± 58	ND	Moderate
Eastern mountains	42 ± 39	ND	Moderate
South valley floor	99 ± 58	ND	Moderate
North Valley floor: North of Oak Knoll Avenue	48 ± 36	ND	Moderate

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

This indicator is a comparison of observed fire frequency (for the last 80 years) to expected fire frequency as calculated by the LandFire (http://www.landfire.gov/) program using LANDSUM (Keane et al. 2002). The Napa County fire record maintained by the California Department of Forestry includes the years 1930 - 2007. These data are used to score the regions based on mean fire return interval from LandFire data and vegetation boundaries from CALVEG (http://frap.cdf.ca.gov/).

Why is it Important?

The size and number of fires that occur each year is an indicator of the state of the landscape regarding the health of plant communities. Specifically, disease pressure, drought, no-burn management practices and land development can directly impact the health of a natural landscape which can be observed in wildfire activity. Forests in a region damaged by increases in pest activity, dry from drought, laden with excessive fuel can burn more frequently and in greater extent. Other factors are also important such as fire intensity, which must be considered along with this information.

What is the target or desired condition?

Fire is a natural part of California's ecosystems. Historically, fires range from slow-burning under-story fires to raging stand-replacing fires (SNEP, 1996). The target condition for this indicator is for fire patterns and frequencies to oscillate around the central tendency of historical conditions. This is reflected in the vegetation based, zone-specific fire return intervals used for this indicator, where return intervals (and corresponding fire frequencies), vary with vegetation dynamics, topography, and spatial context. The undesired condition set for this indicator is both too few or too many fires (e.g. zero or several times the expected frequency). So a score of zero is attained under either of these conditions. A desired trend is for actual fire frequency to return to natural frequencies, depending on the vegetation present and danger to human communities.

What can influence or stress the condition?

Fire is affected by climatic variables such as preceding year's moisture, El Nino cycles, and the Pacific Decadal Oscillations (Swetnam and Betancourt 1998, Norman and Taylor 2003, Morgan et al. 2008). In fact, fire is so strongly determined by these climatic factors that land management seems to play only a minor role in regional fire patterns, except in changing vegetation patterns, locations of fire suppression, and soil moisture.

What did we find out?

Fire recurrence interval scores for the last 80 years were variable, reflecting departure of contemporary fire patterns from natural conditions (Figure 1). The fire return interval provided by LandFire is based on a landscape simulation spanning 10,000 years (Figure 2a). It is apparent that natural mean fire return intervals vary at large scales but are relatively consistent at smaller scales (i.e. averaged over larger areas). Contemporary fire behavior is influenced by substantial human activity in the Napa River watershed (Figure 2b). Factors influencing contemporary fire activity that have a large effect on scoring are the distribution of agriculture and fire suppression. The valley floor and lower watershed have no widespread fires because of lack of fuel and intensive land management. The western mountains have had both few fires, and small extents over the last 80 years. This is likely the result of fire suppression. The eastern mountains exhibit the highest fire frequency with some areas reporting 20 fires in 80 years. Each instance of fire in a defined area (defined by CALVEG vegetation designations) decreases the observed fire return interval. In the case of the eastern mountains, the high fire frequency negatively impacted the score (42).

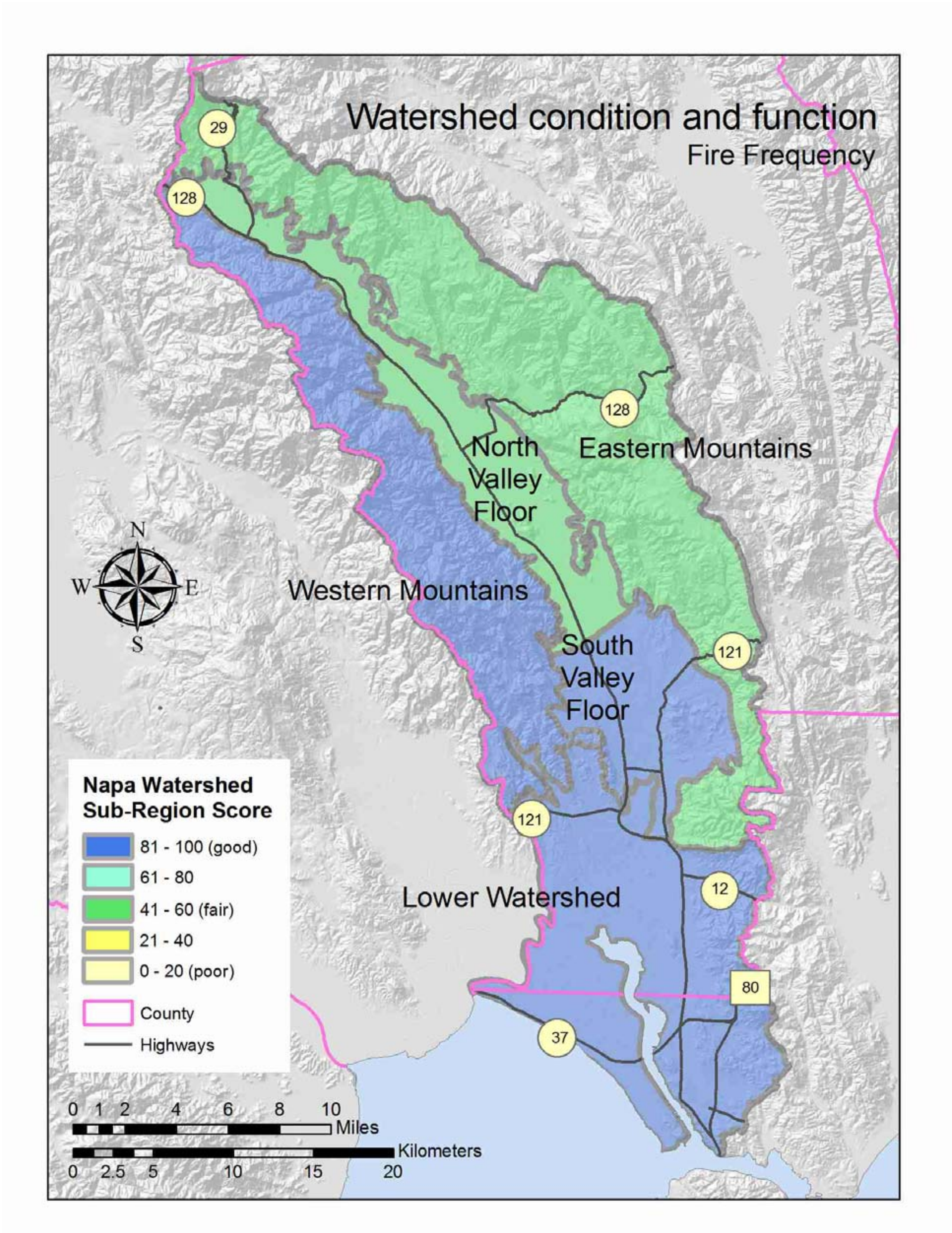

Figure 1. Fire recurrence scores across subregions.

The highest score was for the south valley floor (99). This score is the result of the fires in the eastern mountains encroaching on the south valley floor such that the number of fires observed in this subregion closely matched the natural fire frequency. For the north valley floor, the observed fire frequency was lower than the natural fire frequency, which is consistent with what is expected in a subregion dominated by agricultural land use (score = 48).

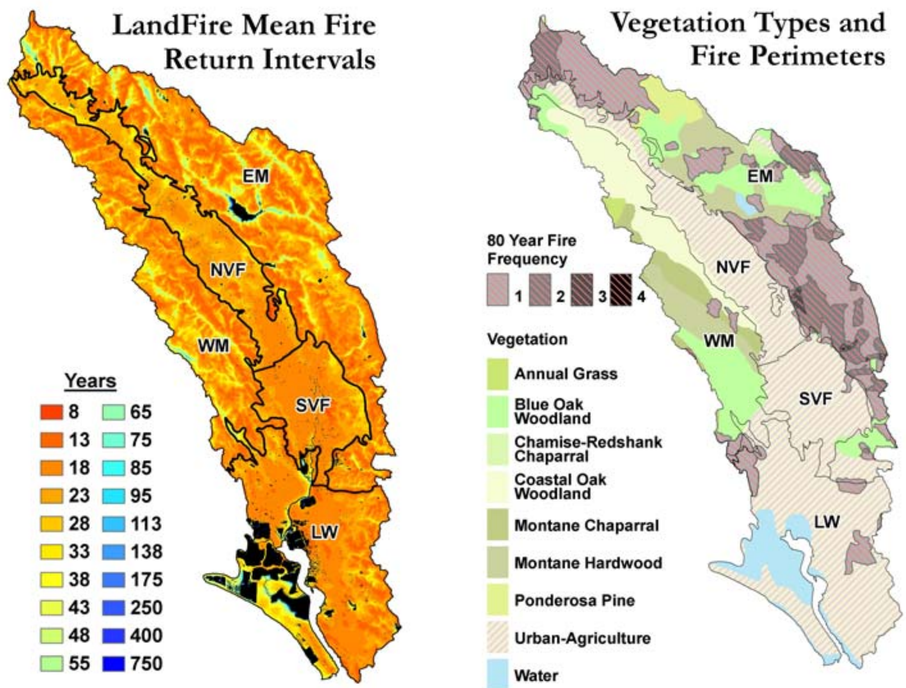

Figure 2. a) Mean fire return interval across the region as provided from LandFire. Black areas are surface water. b) Fire perimeters for the region showing areas of fire overlap, superimposed on the vegetation groups sourced from CALVEG. Each vegetation group was scored individually then aggregated to the subregion.

The fire recurrence interval score for the entire watershed is 65. This is an area weighted average of the scores calculated for the subregions. This score needs to be considered in the context of the subregions scores due to the heterogeneous distribution of fire activity in the Napa River watershed.

Trend Analysis

In order to obtain enough fire data to compare with natural fire recurrence data, the entire record of contemporary fires was used to establish observed fire return intervals. In order to determine contemporary trends in fire activity, the region of interest would have to be expanded to encompass larger areas and more fire instances/perimeters.

Temporal and spatial resolution

Fire data are updated on an annual basis and are available as an online GIS dataset. The fire perimeter resolution is high and fires less than one acre are recorded in the dataset. The CALVEG vegetation data were created in 1979, and were recently updated (2000). The spatial resolution is based on the LandSat MSS images with a resolution of 80 meters. The smallest CALVEG areas reported are less than one hectare. LandFire data were generated in 2006; however, the mean fire return interval (mFRI) data are simulation outputs that are only partly based on existing conditions. The spatial resolution of the mFRI data is 30 meters and is based on LandSat 30 meter imagery data.

How sure are we about our findings?

The method used here of evaluating the last 80 years for condition (1930 – 2007) is prone to several systematic errors. If fire frequencies are low or high for climatic reasons, the score will reflect that. Likewise, the boundaries of the subregions, CALVEG vegetation polygons and the fire perimeters interact in such a way that foothill fires that are primarily burning a mountainous subregion are reported in the valley subregions. This is observed for the valley floor subregions and is the cause of the high score for the south valley floor. Aside from these limitations, the limited extent of fires and their sporadic incidence can lead to large localized variation over short periods of time (less than 100 years). Analysis of fire data at these and shorter temporal resolutions can be difficult to interpret. This is exhibited by the high standard deviations and the standard error of the fire score mean (Table 2).

Table 2. Standard Deviation of the mean in fire scoring estimation in each subregion

Region	Confidence: Standard Error of Fire Score Mean
WM	± 12
LW	± 33
EM	± 10
SVF	± 29
NVF	± 12

WM: Western mountains. LW: Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon. EM: Eastern mountains, including Angwin area. SVF: South valley floor, including Napa. NVF: North valley floor, including Calistoga, St Helena, and Yountville.

Recommendations

Comparing current fire ecology with past records (or models) of natural fire ecology presents a challenge which is acknowledged in the literature. Fire behavior depends on many variables and has a number of descriptors (recurrence interval being one of many) that partially capture the nature of fire activity. The LandFire project addresses the complexity of this science and currently produces a fire regime departure dataset. Because of the intricacies of the fire record, this dataset does not include fire incidence data as part of its creation. It is for this reason that the FRCC Departure Index (FRCCDI) was not used in this report. Future products from LandFire will incorporate fire records in the calculation of FRCCDI and should be considered in future efforts for reporting on fire ecology. The California Dept. of Forestry produces statewide data that incorporate LandFire, CALVEG and other relevant themes. It should be the first source for relevant information in updates to this report.

Technical Information

Data Sources

Fire data were sourced from the CA Dept of Forestry (Fire and Resource Assessment Program) as a GIS layer that logs each known fire occurrence since 1930. The location and extent are stored as polygons with attributes such as date, cause and cost of fighting the fire (if available). Mean fire return intervals (mFRI) were obtained from LandFire (www.landfire.gov) and cross referenced using Nagel et al. (2005) and Stephens et al., (2007) and are presented in Table 3. Vegetation classes were acquired from the U.S. Forest Service CALVEG statewide natural vegetation database (http://www.atlas.ca.gov/).

Data Transformations

The fire data from the Department of Forestry were converted to observed FRI in the 80 years between 1930 and 2007. These values were assigned to the CALVEG vegetation polygons. LandFire mFRI was processed to provide average mFRI for each CALVEG vegetation polygon (Table 3).

Table 3. Mean fire return interval (LandFire) for select locations by CALVEG vegetation type

Vegetation Type	mFRI (years)
Annual Grass	26.0
Blue Oak Woodland	17.0
Chamise-Redshank Chaparral	29.1
Coastal Oak Woodland	19.9
Montane Chaparral	21.8
Montane Hardwood	22.6
Ponderosa Pine	23.3
Urban-Agriculture	18.9
Water	na

Analysis

Fire boundary data were located for the Napa River watershed. The number of fires was calculated for each of the analysis areas (referred to as observed fire frequency). These values were combined into an 80-year summary to compare contemporary fire activity with LandFire mFRI estimations (expected frequencies). Actual frequencies were compared to expected frequencies for each analysis area.

The comparison is standardized by generating a value (score) ranging from zero to 100 depending on how close the observed fire rate was to the expected fire frequency. A linear relationship between observed fire frequency and the score was established using a three-zone approach. From zero to two-thirds the expected fire return interval, the score increased from zero to 100 (Figure 3). A range of ± one-third the expected fire return interval above and below the expected fire return interval was assigned a score of 100. Above this range, the score decreased linearly reaching zero at 80 years. This relationship is based on the LandFire Fire Regime Condition Class (FRCC) which categorizes a 33% departure from the expected condition as "within the natural (historical) range of variability". The set of equations for the scoring follows:

a. when observed interval < 2/3 expected interval	Score = 100 x (observed interval / natural interval)
b. when 2/3 natural interval < observed < 4/3 natural interval	Score = 100
c. when observed interval > 4/3 expected interval	Score = 100 x [1-((observed interval – 4/3 expected interval)/(80 – 4/3 expected interval))]

The scores were calculated for all CALVEG polygons, then aggregated to the subregions using area weighted averaging.

Table 3. Basic statistics for fire interval scoring for subregions. "95% C.I. refers to 95% confidence intervals around the mean.

Subregion Name	CalVeg Areas (count)	Minimum Score	Maximum Score	95% C.I.	Score (area weighted mean)
Western Mountains	8	0	100	23	**84**
Lower Watershed	3	0	100	65	**80**
Eastern Mountains	14	0	100	21	**42**
South Valley Floor	4	0	100	57	**99**
North Valley Floor	9	0	100	24	**48**

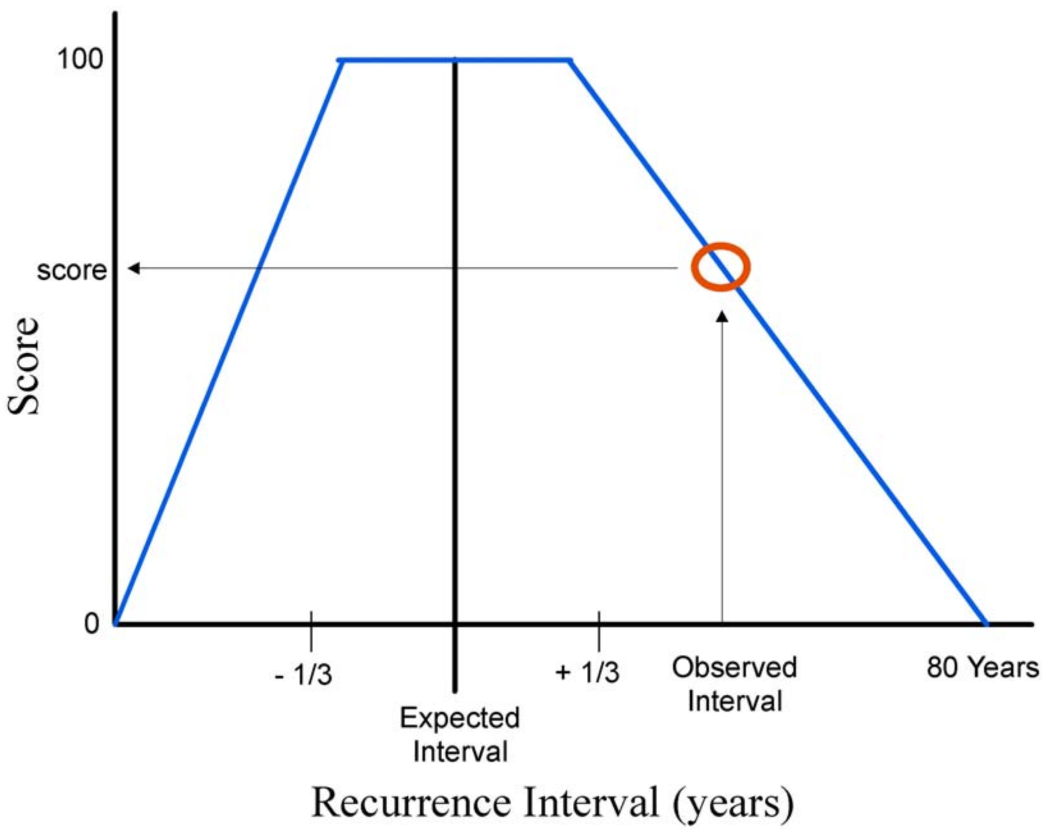

Figure 3. Relationship between score and fire recurrence interval. An example observed interval and corresponding score is shown.

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Late Summer Stream Flow

Goal:

Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity

Objective:

Improve and protect flows to benefit aquatic communities and ecosystem processes

WAF Attribute:

Hydrology & Geomorphology

Table 1. Score, trend, and reliability for: *Late summer stream flow*. NOTE: *This indicator was not scored.*

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	ND	ND	ND
Napa River watershed subregions:			
Western mountains	ND	ND	ND
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	ND	ND	ND
Eastern mountains	ND	ND	ND
South valley floor	ND	ND	ND
North Valley floor: north of Oak Knoll Avenue	ND	ND	ND

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

Late summer (or late-season, or dry-season) stream flow is the measure of the amount of surface water still flowing in the watershed's streams after the long summer drought. Under natural conditions this water comes from groundwater feeding the streams and is called base flow. In the Napa River watershed there is a natural amount of drying out of ephemeral streams and partial drying of reaches of the upper Napa River and tributaries fed by springs and other groundwater, and the native population of fish and other aquatic species is adapted to these summer conditions, finding refuge in the remaining flowing surface water.

Why is it Important?

Maximizing natural watershed stream flows during the dry season is fundamental to the health of the ecosystem and local communities. Adequate dry season streamflow helps maintain aquatic conditions and serves to connect habitat so that organisms may shift location as necessary to follow food and other resources. Steelhead/rainbow trout (Oncorhynchus mykiss) and Chinook salmon (O. tshawytscha) young over-summer in deep pools kept cool by overhanging vegetation and flowing water. Reduced flows in stream channels increase water temperatures, impede migration, increase predation and competition for scarce food and habitat, and affect territorial behavior and aggression among members of the same species. Absent sufficient flow, juvenile steelhead and other cold water species may experience low growth, weight loss, or mortality. Dry streambeds also indicate low groundwater table elevations and reduced rates of recharge via flow through streambeds into the aquifer during the dry season.

What is the target or desired condition?

The desired condition for this indicator is one in which Steelhead, and other aquatic species are supported through the summer months, and so a condition of zero increase in the length and number of naturally-occurring dry stream reaches and no significant reduction of the number of deep pools would be considered the ideal condition. The point at which aquatic species are negatively impacted is unknown, and more research would improve our ability to set appropriate thresholds by which to measure human impacts on this aspect of the environment.

What can influence or stress the condition?

The overall ability of the watershed to retain water and release it slowly over the dry season will affect the timing and degree of drying out of ephemeral streams and natural dry-reaches in year-round streams. It is generally considered that in a more natural, undisturbed watershed flow will persist longer: the response to rainfall input is slower and peaks are lower, whether one is considering individual storms or the rainy season as a whole. In the Napa climate, rainfall is concentrated in the winter and early spring, and the degree to which flow in the river persists into the summer months reflects the continuing capacity of the watershed to soak up rainfall and slowly release it to the river as subsurface flow.

Stream flows during the dry season are influenced by the status of supply from groundwater which is affected on a daily and even hourly basis by evapotranspiration rates and groundwater pumping.

What did we find out?

We explored methods of scoring the persistence of flow in the Napa River in the summer. In the daily streamflow record at Oak Knoll Avenue near Napa, we looked at annual series of the number of zero flow days and the total late-season flow, but we did not find a clear indication of a meaningful signal in the data. We have therefore not scored this indicator.

Temporal and spatial resolution

N/A.

How sure are we about our findings?

N/A.

Recommendations

The data sources explored for the current Napa Scorecard have not proved fruitful as a basis for scoring this particular indicator of the environmental health of the Napa River watershed. Future reporting on this topic will be improved if additional data sources can be found, and we recommend that other metrics reflecting summer stream conditions be explored, since the metric reported here is problematic.

Observations on summertime flow in tributaries of the Napa River, which typically go dry at some point, would provide a useful independent perspective on the phenomenon in question. These might take the form of observations of the date surface flow ends at various key points in the channel network, or the length of dry reaches on selected tributaries might be measured. Such observations can be carried out satisfactorily by volunteers, under appropriate supervision. Both sorts of observations are useful data in their own right, from the point of view of aquatic habitat, so they are well worth collecting. It is likely that a broadly dispersed dataset – with observations at a number of locations – would be more useful than a record for a single point, to allow for more insights into the factors affecting this phenomenon.

Technical Information

Data Sources and Analysis

One idea was to use measurements of the length of dry reaches of tributaries as the indicator. This idea seemed promising for Sonoma Creek, but it was rejected for Napa because no one has made systematic observations of this sort for Napa River tributaries. The program of dry stream reach observations established by Sonoma Ecology Center should be examined as a possible model for Napa.

Another idea was to measure the number of days of zero flow per year, either at a gauging station on the main stem of the river or at a tributary site where such observations are available. In the Napa River watershed, daily flow records going back at least 40 years are available at both the St Helena and Napa gauge sites on the Napa River, but no records of comparable length are available at tributary sites. Data for the Napa River gauge sites were analyzed and the number of days of zero flow per year compared with rainfall records; but the number of zero flow days did not correlate well with rainfall. In fact, through most of the eighties and early nineties virtually no zero flow days were recorded, so we became skeptical about the value of this method. The number of observed zero flow days per year is illustrated in Figure 1.

In fact, there is some uncertainty about the point of zero flow, despite the regular efforts of the United States Geological Survey (USGS) field personnel to identify it. On gravel-bedded streams like the Napa River at both gauge sites, the level at which actual surface flow ceases is a shifting target (Mike Webster, USGS, pers. comm. April 10, 2008). Accordingly, we shifted attention to the total amount of flow recorded during the summer months. Our hypothesis was that this metric would decline with increasing development in the watershed.

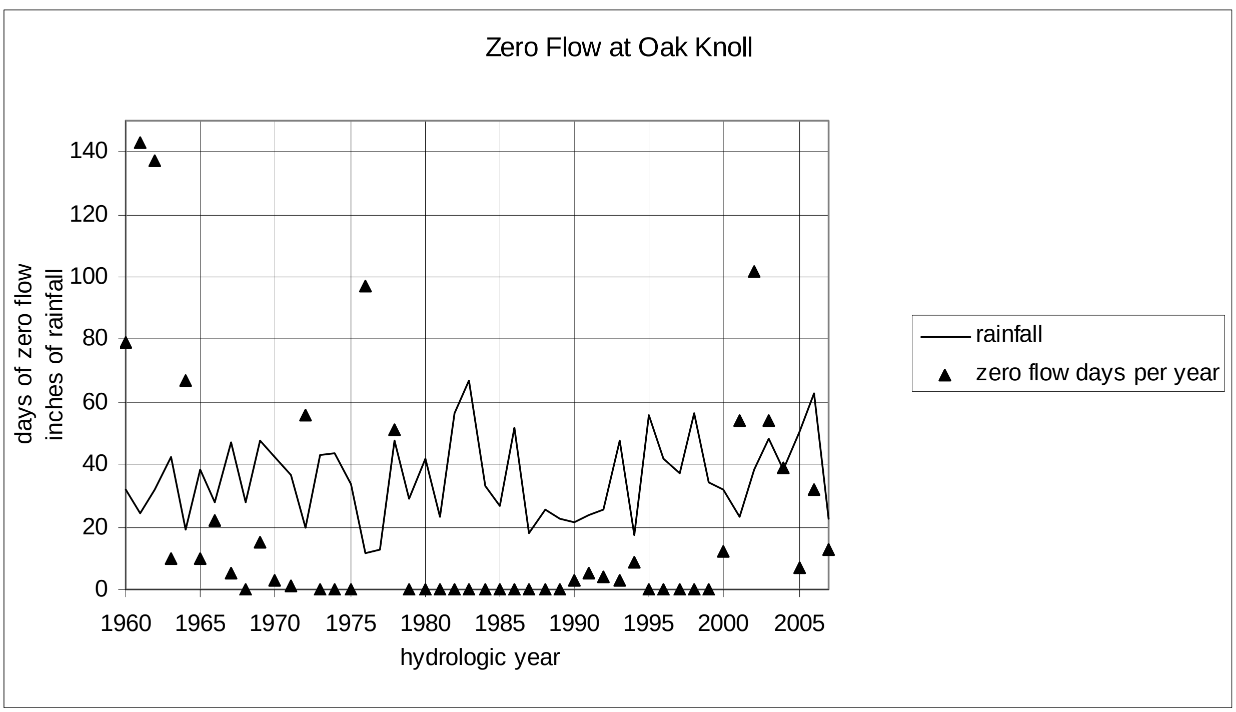


Figure 1. Recorded Days of Zero Flow, Napa River near Napa

For analysis of total amount of flow recorded during the summer months, Napa River flow records at both USGS gauge sites were considered, and the more downstream site near the City of Napa was chosen as most representative of the watershed as a whole. This dataset is collected by USGS and is continuous since 1959.

The approach used was based on the daily average flow record for USGS station 11458000 (Napa River near Napa) for the entire period of record 1959-2007. The flow for the months of June through September was summed for each year. Since the amount of this "dry season" flow is related to rainfall, we accounted for the influence of rainfall by dividing the volume of dry season flow by estimated total rainfall volume.

Total rainfall volume was estimated on the basis of annual rainfall totals for St Helena as published in the St Helena Star newspaper. This dataset is available for the period from 1908 to the present. In order to evaluate the appropriateness of this data record for the entire area above the USGS station, we compared annual totals from this record with data since 2002 for the rainfall stations in the locally-maintained ALERT network (http://napa.onerain.com/home.php). The St. Helena Star record was scaled down slightly, as described in Section 3.1 above, and used to estimate total annual rainfall over the entire drainage area. Finally, we calculated the ratio of dry season flow to total annual rainfall, both expressed as volumes, to use as our indicator. The resulting dataset is illustrated in Figure 2.

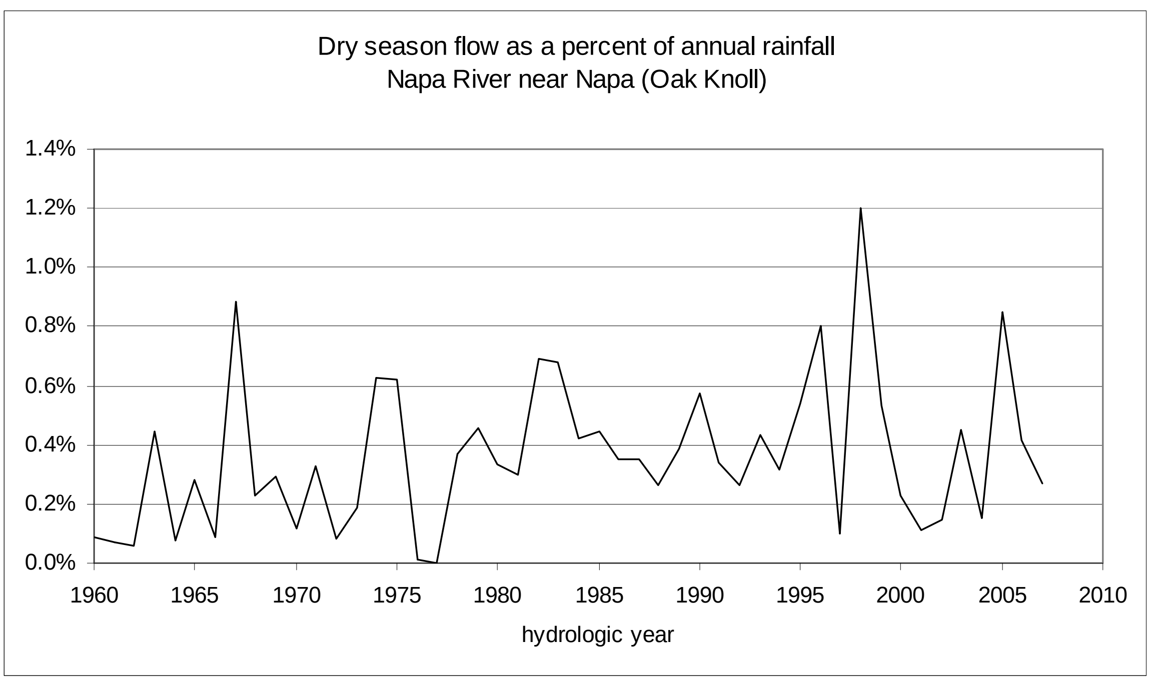


Figure 2. Dry season flow as a percent of annual rainfall, by year

Ideally it would be preferable to have physically distributed datasets for both dry season flow and rainfall. This would make it possible to observe and evaluate local variations in the overall picture, which would be most useful for land managers. Since such data are not available, the basin-wide methods described above were used.

To attempt to score the indicator, we experimented with a probability distribution for the period 1960-1999 and compared the current average dry season flow ratio with it. The annual values of dry season flow for the entire 40-year period were arranged in ascending order, and exceedance probabilities were assigned to each value. Our plan was to convert raw values to probabilities and establish scoring breakpoints defined by dividing the probability range (from 0 to 1) into 3 equal-sized sections. However, after further consideration we decided against scoring the indicator.

The data illustrated in Figure 2 show considerable variation from year to year. Even though we attempted to compensate for the effect of overall hydrologic condition by expressing the data as a percent of annual rainfall, there is a great deal of scatter in the figure. A trendline drawn by a computer spreadsheet program exhibited a value of R2 = 0.0818 for the data in the figure, so the slight upward trend observable in the figure (and shown by that trendline) cannot be considered statistically meaningful. In order to interpret this dataset as a useful indicator of environmental health, we would have to find a convincing explanation for the variation in the data. Until we do that, we do not have a basis for scoring this indicator. The most that can be said on the basis of this dataset is that there is no trend in the data that is perceptible above the level of apparent "noise."

Our hypothesis was that dry season flow would show a decline, in response to development activities in the watershed. There are several possible reasons why we did not find this. One is that the increase in development since 1960 has been too slight to stand out over the "noise" in the data, and that there has been no change in the pattern of dry season flow over the period of data. However, there is no basis for concluding that this is so.

The noise is likely due to a variety of confounding factors involved in the phenomenon of dry season flow. The accuracy of flow measurements at these low levels of flow is the most obvious issue; the considerations presented above on the subject of the measured point of zero flow apply to some extent to all low-flow measurements. It should also be borne in mind that we are comparing small flows in the application of this indicator. In all years except one (1998), the total summertime discharge is less than 1% of the total estimated rainfall volume, so it is a relatively small portion of the total annual discharge. Although USGS, the agency that collects the data, is committed to making the most accurate measurements possible at all flow levels, it may be that the upper part of the flow rating curve gets more attention, because of its importance in assessing flood risk.

Among other possible confounding factors, the varied timing of rainfall is a strong candidate. If rainfall is concentrated in the early part of the wet season, one would expect flow to tail off sooner than if it comes later.

Missing from our analysis, for lack of time, is a quantitative statement of the uncertainty associated with the data. However, we cannot escape the conclusion that the uncertainties associated with this indicator are too great to use it as an indicator in the Watershed Assessment Framework.

Citations

St. Helena Star, 1989. Rainfall chart: 82 years of record-keeping. Thursday, July 27, 1989.

USGS Surface-Water Data for the Nation: http://waterdata.usgs.gov/nwis/sw.

Faye, R.E., 1973, Ground-water hydrology of northern Napa Valley, California: U.S. Geological Survey Water Resources Investigations 73-0013, 64 p.

Groundwater

Goal:

Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity

Objective:

Reduce reliance on imports by reducing demand, improving the efficiency of water use, and increasing the reliability of water quality and yields from groundwater basins

WAF Attribute:

Hydrology and Geomorphology

Table 1. Score, trend, and reliability for *Groundwater NOTE:* No watershed score was calculated for this indicator because data was available for only two of the subregions.

Groundwater basin*	**Score (0 to 100)[1]** **(see text for significance of Spring and Autumn scores)**	**Trend**	**Reliability of findings[2]**
Napa River watershed basins:			
Main Basin	Spring 100 Autumn 67	Level Declining	Moderate
MST (Milliken/Sarco/Tulucay)	Spring 29 Autumn 7	Declining Declining	Moderate
Carneros	ND	ND	ND
Other portions of the Napa River watershed lack significant groundwater basins and were not scored			

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

The purpose of this indicator is to track groundwater storage. We do this by comparing groundwater level (the depth to the water table), over time. The intent is to get an idea of the extent to which the resource is being depleted or enhanced. Ideally, we would track groundwater in many wells over a long period of time and be able to identify rising or falling trends with some precision. We would also have a good idea of the storage in the aquifers underlying our watershed. Unfortunately, available groundwater data is sparse and we are forced to make do with rough averages of groundwater level.

What is the target or desired condition?

From a broad perspective, the desired condition is a sustainable ground water supply which supports human uses as well as a healthy riparian environment, and which has sufficient reserves to cover dry years and moderate droughts.

The historical record indicates that early settlers in Napa Valley found water available at shallow depths, and that some wells had water at surface level or above (artesian flow). It is unlikely that this level of recharge can be achieved while supporting current human needs, which include domestic, industrial, and agricultural uses. A more relevant goal is to stabilize the water table depth through balancing human and natural withdrawals with annual recharge from precipitation. We define the target as a stable or rising water table depth, as averaged over a period of years to account for weather variability.

What can influence or stress condition?

Water table levels in Napa Valley reflect the balance between annual recharge from precipitation and discharge to a mixture of natural (watercourse) and human (pumping) outflows. Napa Valley's groundwater tends to flow from recharge areas in the foothills and along portions of streambeds within porous geological formation, towards the center of the valley and then downstream. Wells extract water from this subterranean flow for human uses.

A significant variable which is changing the natural condition is the volume of groundwater used for agricultural, residential and recreational uses. Each well tends to create a local cone of depression in the water table. Collectively the many wells extract a large part of the groundwater flow below the valley floor. If more water is pumped than can be naturally recharged, the water table will drop over time.

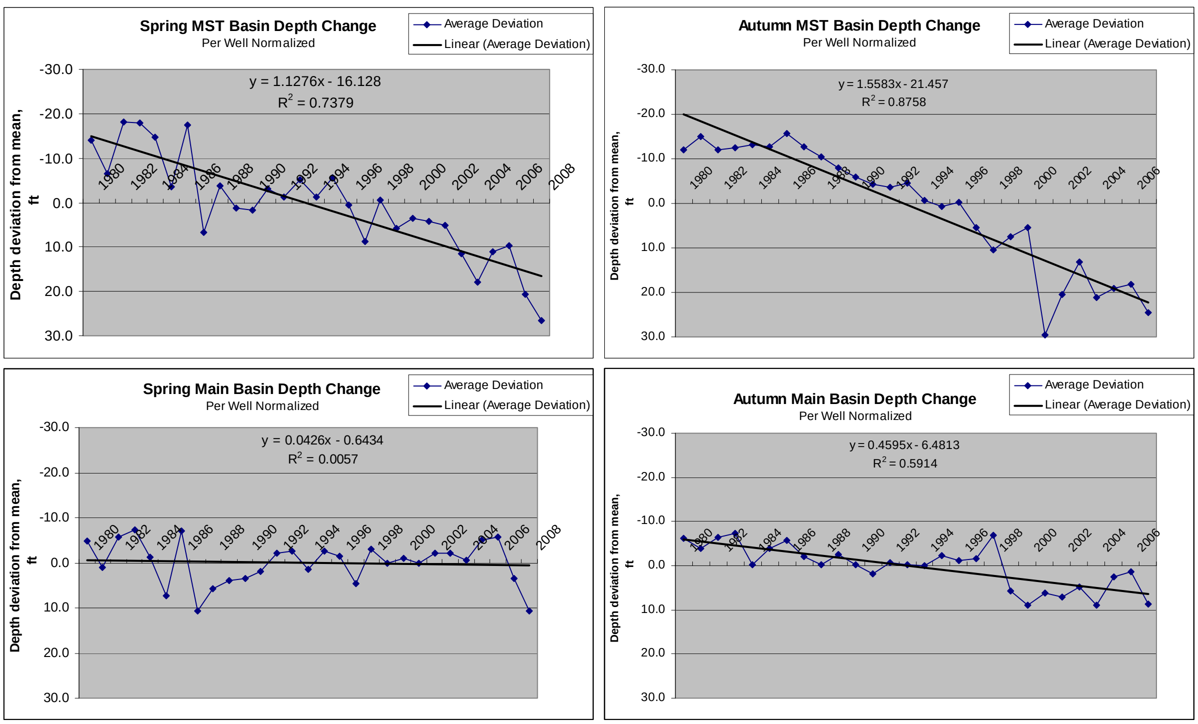
We are using well measurements to examine two metrics – the spring and autumn groundwater levels. Trends in the spring levels reflect the degree to which the aquifers are being recharged every year versus being successively depleted. If the spring groundwater levels are stable, groundwater is not being taken faster than precipitation can replenish it. If it is dropping, then the groundwater storage reservoir is being unsustainably depleted.

Autumn groundwater levels represent the availability of water during the driest part of the year. This can affect human uses, such as the depth of wells and cost of pumping, or even the drying of some wells at the season when water is scarcest. It can also affect base flows needed for aquatic and riparian ecosystems. Even if aquifers are being fully recharged in the spring, a trend towards increasing ground water depth in the autumn is of concern. Autumn scarcity may presage a future drop in spring groundwater levels. If dry season extraction and water table lowering continue to increase, eventually they are likely to exceed the wet season recharge potential and lead to unsustainable aquifer depletion.

What did we find out?

Each of the ground water basins studied has its own dynamics and requires its own evaluation.

Figure 1. Seasonal depth to groundwater, MST and Main Basins, Napa Valley watershed



The trend over the past three decades has been towards increasing depth to water for both spring and autumn measurements for the MST Basin, and for the autumn measurement of the Main Basin. There is no significant trend for the spring measurements of the Main Basin.

The indicator shows that, as measured by the fall data series, annual use of groundwater is increasing in both basins. Since the groundwater resource is limited, increasing demands on it will become unsustainable at some point, so this condition should sound a note of caution for water users. In the Main basin, spring levels appear to be rebounding to previous levels, a fact which gives some comfort: so far, the recharge capacity of the basin is adequate to the challenge. On the other hand, the MST basin is not rebounding well in the spring, suggesting that the current pattern is not sustainable. The state of the groundwater resource in the MST basin has received considerable attention from Napa County and other public agencies in recent years, and a recent detailed study by USGS has focused on that issue as well. Our indicator appears to support the concerns which have been expressed in that study (Farrar and Metzger, 2003).

While the long period trend provides a useful context, we desired to have a measurement which could be measured and recalculated over time to reflect the changing status of the resource. Large year to year variations makes short-term calculations mostly meaningless. The signal is so noisy that adjacent years yield very different values even though the watershed's true health has changed little. To avoid this problem, we used a 10-year window for slope fitting, striking a balance between reducing the annual noise and partially bridging weather-related influences (long-term drought influences may still remain). We also needed a metric with enough temporal resolution to expose possible effects of changes in pumping practices. For purposes of assigning a WAF score, the decade 1998-2007 was used to take advantage of the most complete recent data.

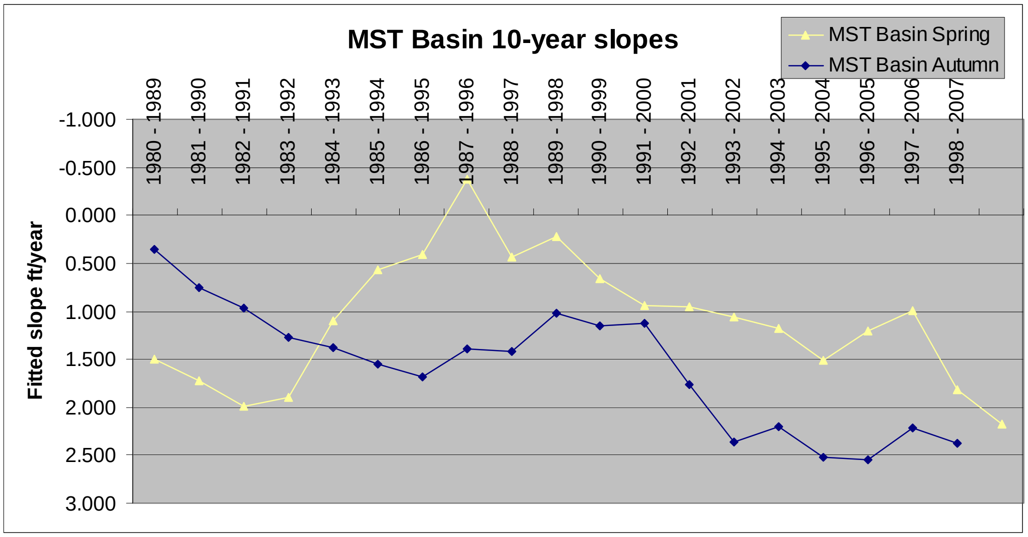
Table 2. Trends in depth to groundwater, 1998 - 2007

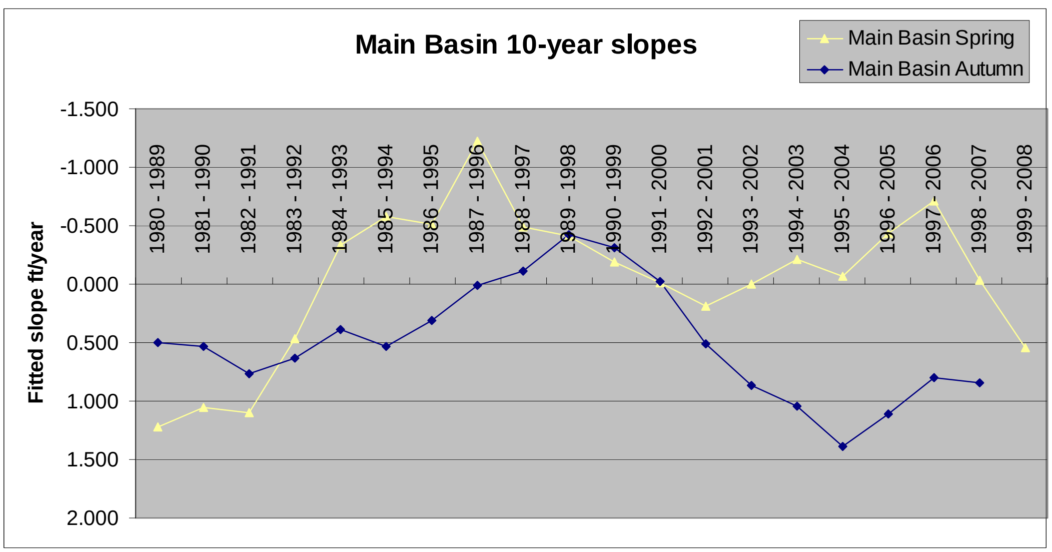
Metric	**Basin**	**Change in depth**	**R squared**
Spring 10-Year Trend	MST Basin	1.9 ft/year	0.706
	Main Basin	0.0 ft/year	0.001
Autumn 10-Year Trend	MST Basin	1.4 ft/year	0.316
	Main Basin	0.5 ft/year	0.100

In the MST Basin, the depth to water table is increasing (i.e., the level of the water table is falling) in both the Spring and the Autumn, at rates of 1.9 ft/year and 1.4 ft/year respectively. In the Main Basin, there is no significant trend for the Spring depth, and a weakly fit trend of 0.5 ft/year for the Autumn depth.

A sense of the sensitivity of these slopes over time can be found by computing the fitted slopes for a sliding 10-year window.

Figure 3. Fitted 10-year slopes for Napa Valley groundwater basins





Temporal and spatial resolution

There are three major groundwater basins in the Napa watershed: the Main Basin, the MST (Millilken/Sarco/Tulocay) Basin, and the Carneros Basin. Mountainous areas of the Napa Valley watershed lie outside of these Basins; they are important to recharge, but do not contain substantial aquifers for water storage. Because these Basins do not align with the Reporting Regions used for other indicators, and because the Main Basin and the MST Basin are hydrologically connected, it was decided not to use the Reporting Regions for this indicator. We have well data for only the Main Basin and the MST Basin, so numeric results can be provided only for these.

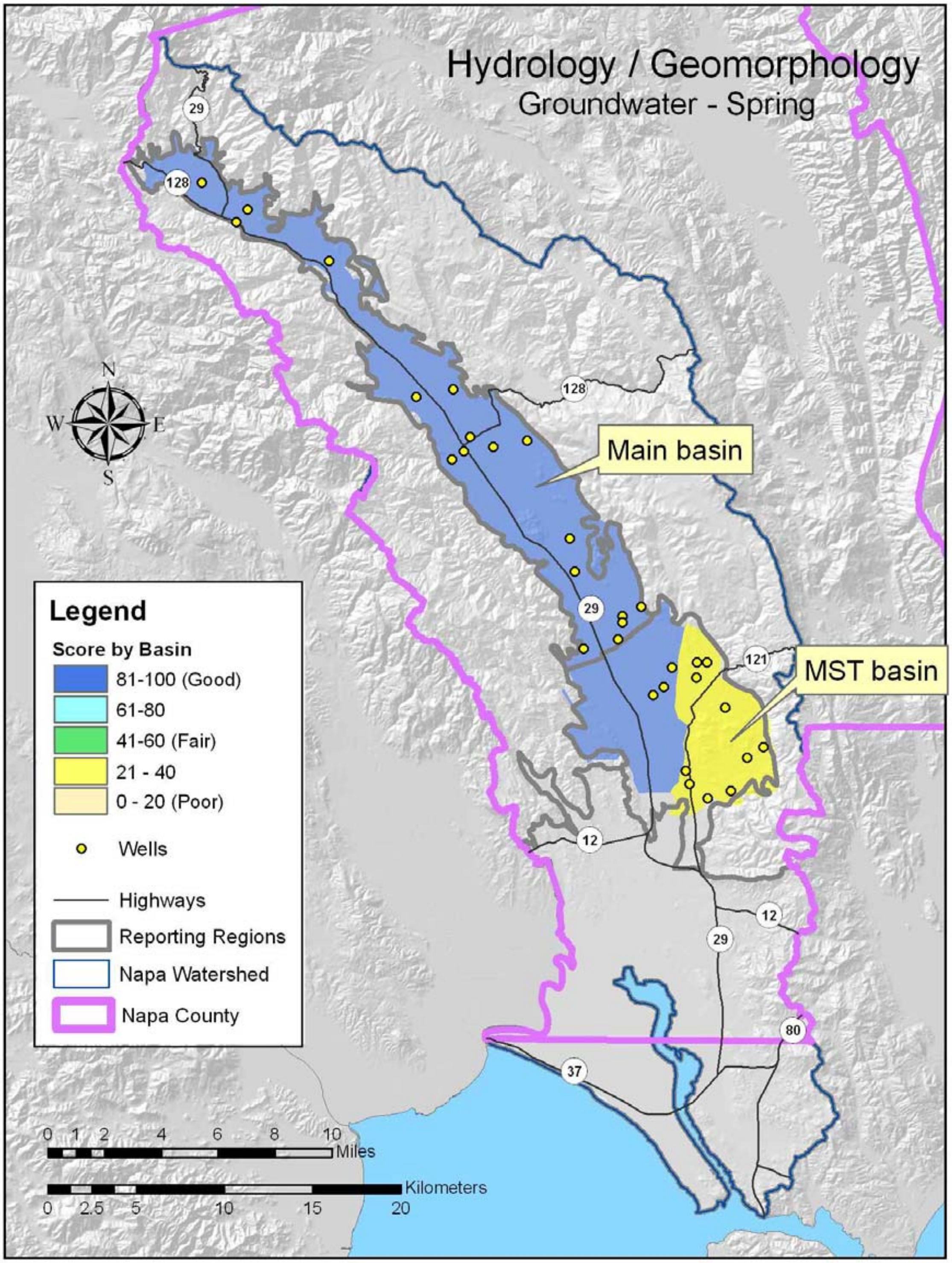


Figure 1. Scores for Main and MST Basins, spring groundwater levels.

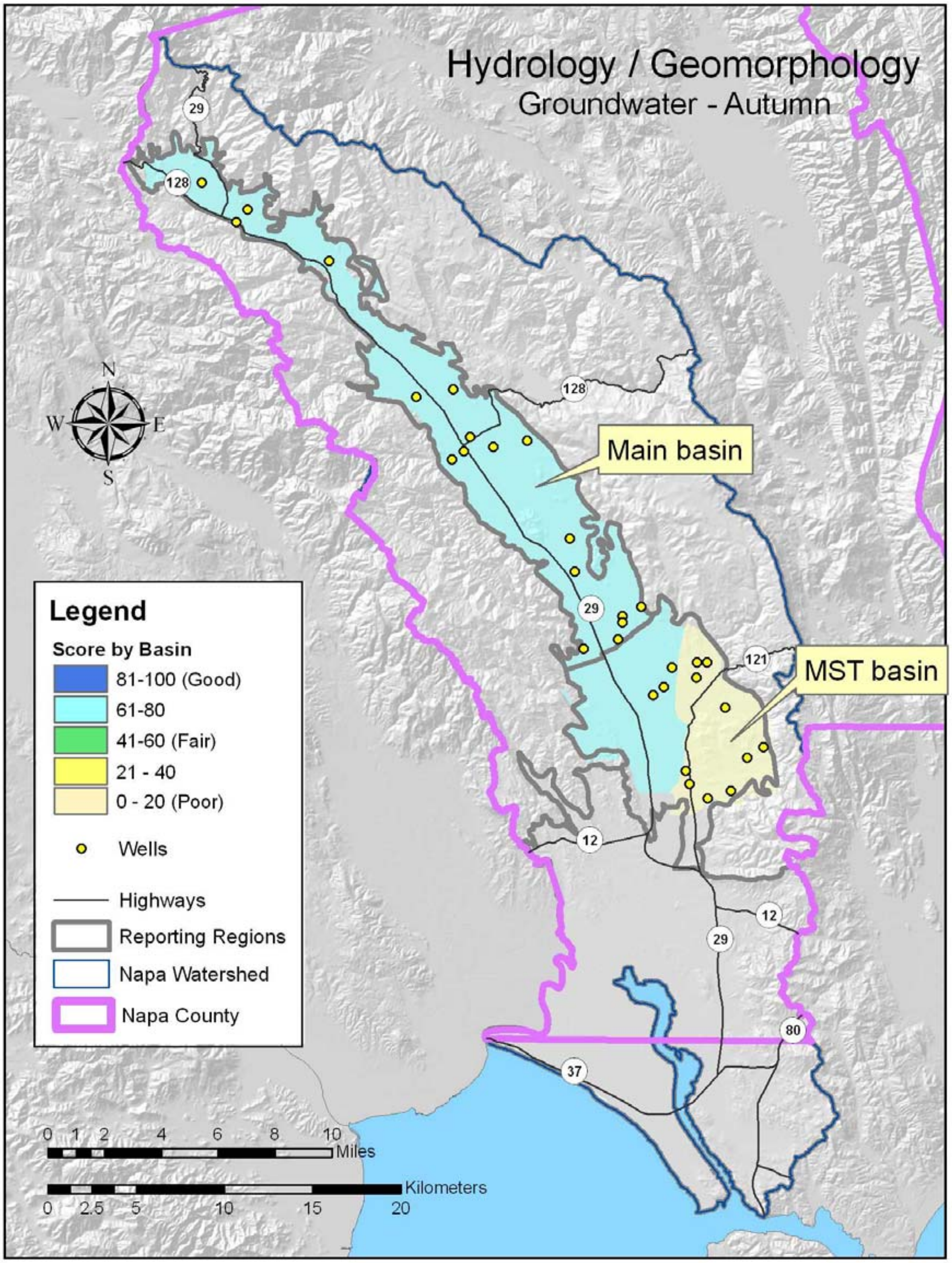


Figure 2. Scores for Main and MST basins, autumn groundwater levels.

We are using well data from the Department of Water Resources, covering the period of 1980 to 2008. Readings were taken twice per year – a spring high reading (most typically March or April) and an autumn low reading (usually September or October). In the local Mediterranean climate, the highest levels are most often seen at the end of the rainy season in the spring, and the lowest levels are typically seen at the end of the dry season before the first substantial rains. More frequent readings are available for a very few wells, but individual well data tends to be very "noisy" and to reflect local influences – in particular the pumping history of nearby wells To get a picture of the basin's groundwater, it is necessary to aggregate a number of wells over a larger geographic area. Only semiannual data is relatively widely available for these wells.

We set a criterion of at least 15 years of semiannual data within the study period. This produced 22 wells within the Main Basin and 11 wells within the MST Basin. These wells were generally distributed through each basin. An earlier study found little benefit in assigning area based weightings to each well over a simple mean, so we opted for the latter approach.

How sure are we about our findings?

The trends towards a receding spring water table for the MST Basin, and the fall water table for both basins was well established.

It is important to note that this indicator, particularly with regard to the MST basin, is based on a relatively small number of wells (11), which cannot be regarded a truly representative. For the same reason, it would be inappropriate to draw conclusions about specific localities in the MST basin from the locations of the 11 wells. These caveats apply to the Main basin as well, which has 22 wells but is considerably larger than MST.

While we chose the rate of change of the water table as our metric and water table stability as our goal, absolute depths are also relevant. If stability were achieved at current water table depths, the watershed would likely avoid serious consequences. However, it is very difficult to assign targets, or to set a zero point for WAF scales, to absolute depth and this makes it a poor indicator for the WAF approach. Nevertheless some measure of absolute depth might be useful as an important secondary indicator in future efforts.

We considered the possibility of measuring groundwater use more directly, instead of relying on the condition of the water table. Detailed pumping records are not generally available for private wells. It would be possible to collect statistics on the number of wells, their depth, etc., and one might estimate from them the amounts withdrawn. However, this method of defining the indicator was not used because of the increased effort required and the uncertainty that the results would justify it. Ideally of course, tracking withdrawal trends would be desirable, because of its clear focus on human management.

Recommendations

Because the data for this indicator are sparse, the strength of the indicator would be greatly improved by increasing the number of monitoring wells. However, it would take a long time to reap the benefit of such an increase, because the nature of the indicator requires a record of at least a decade. In any case, we strongly recommend that as many as possible of the existing monitoring wells be retained in the state database. Their value will only increase as the records continue into the future. It is particularly unfortunate that no monitoring wells in the Carneros basin have records going back far enough to be useful for this investigation, since groundwater levels are a major concern of landowners there. The Carneros Creek Stewardship group has instituted a private well monitoring program out of concern that water levels may be dropping, at least in some locations. Missing from our analysis, for lack of time, is a quantitative statement of the uncertainty associated with the results, the score and the trend.

Technical Information

Data Sources

The California State Department of Water Resources (DWR) maintains a database of groundwater information (http://www.water.ca.gov/iwris/). The database was searched for well sites in the Napa River watershed with at least 15 years of semiannual data since 1980. Groundwater levels are generally at their highest in the spring and at their lowest in the fall. Typically, measurements were made in April and October, but there is some variability in timing. For this study, measurements made at other times in the spring or fall were treated as if made in April or October respectively.

Well locations were used to geographically assign wells to groundwater basins. Water basin boundaries are somewhat speculative and vary between sources, so there is some degree of uncertainty of the boundaries between the Main and MST basins; to resolve this we used the Napa River as the dividing line, in accord with the hydrological studies by Johnson (1977) and Farrar and Metzger (2003).

Data Transformations

Well monitoring data generally contains numerous gaps when well measurements were not available for various reasons. The population of monitored wells also changes over time as some wells become unavailable due to physical factors or changes in the cooperation of owners, and new wells become available for monitoring. The typical range of water depths varies considerably between wells, depending on the altitude of the wellhead and of the local water table. And thus a simple semiannual mean of the water depths for the available wells each year suffers from additional "noise" due to deeper and shallower wells dropping in and out of the mean. To reduce this effect, water depths for each well were normalized by subtracting the well's mean depth. The normalized data for shallow and deep wells can then be better compared and aggregated.

Analysis

We essentially had two datasets for the wells reflecting high water in the spring and low water in the fall. Both measures are relevant. Increasing spring water depth reflects a lack of full recharge and thus a water deficit that depletes the aquifer over time, while changes in the autumn depth reflect the degree to which water from the aquifer becomes more difficult to obtain or even unavailable during the dry season. This lowering of the autumn water table reduces water available to be pumped (or requires deeper wells and more electric power), as well as reducing the base flow of streams and rivers supporting riparian ecosystems as well as human uses.

As our target is a stable water table, we chose to use the slope or rate of change of the water table depth as our metric for both spring and autumn metrics, rather than absolute depth. Well data is very "noisy" on a year to year basis, reflecting differences in recharge due to varying patterns of precipitation and evapotranspiration as well as local pumping practices. We chose to compute slopes based on a rolling ten-year sample period, which reduces some of the effects of individual year variation and better describes the meaningful changes to the water table over time.

We considered a third analytical measure used in the Napa Watershed Health Scorecard (Sonoma Ecology Center and Napa Resource Conservation District, 2010) namely the degree of recharge by winter rains as measured by the comparing the autumn low with the high the following spring. However this measure was found to be highly related to the depth of discharge in the previous dry period. The more the water table drops in the summer, the more likely it is to show a larger recharge in the winter; and the higher the water table at the end of summer, the less room for recharge in the winter. So larger rises in the water table are probably indicative of increased stress on the system rather than more health. In addition, that stress of increasingly lowered water tables in the fall is already reflected in the autumn trend analysis. So ultimately we decided that a third indicator based on spring and fall comparisons did not add sufficiently to understanding the status of the groundwater to be utilized.

Assigning WAF scores to the calculated values

The "problem" condition is a falling water table (increasing depth to water). A rising water table (decreasing depth) or lack of downward trend is considered sustainable and given a WAF score of 100. Choosing a rate of fall of the water table (or rate of increase in depth to water) for the WAF score of 0 is more difficult. While higher rates of fall are more problematic than slower rates, any sustained decline in the water table will eventually have adverse consequences. These include dry wells for all or part of the year, the need to drill deeper wells as a temporary expedient, and increased pumping costs. A lowered water table also decreases base flow in streams, drying up aquatic and riparian habitats. Even before effects become critical in "normal" or "wet" periods, a lower water table provides less reserve capacity to help bridge dry years and droughts.

After much deliberation, we decided to use a linear fit slope for a sliding 10-year window (because year-to-year measurements vary so widely, data for a shorter window is too "noisy") as the basis for the WAF score. The more quickly the water table declines over a 10-year period, the higher the slope value will be, corresponding to a lower WAF score. It was decided to set the worst recorded rate of decline for either basin (-2.55 ft/year for MST Autumn readings between 1996 and 2005) as the zero point.

Citations

California State Department of Water Resources database of groundwater information: http://www.water.ca.gov/iwris/

Farrar, Christopher D. and Loren F. Metzger. Ground-Water Resources in the Lower Milliken-Sarco-Tulucay Creeks Area, Southeastern Napa County, California, 2000-2002. U.S. Geological Survey Water-Resources Investigations Report 03-4229. Sacramento, California, 2003.

West Yost & Associates. 2050 Napa Valley Water Resources Study. Prepared for Napa County Flood Control & Water Conservation District, City of Napa, City of American Canyon, Town of Yountville, City of St Helena, City of Calistoga, and NapaSanitation District, 2005.

Johnson, M.J., 1977, Ground-water hydrology of the lower Milliken–Sarco–Tulucay Creeks area, Napa County, California: U.S. Geological Survey Water-Resources Investigations 77-82, 40 p.

Napa County Crop Reports: http://www.co.napa.ca.us/BUSINESS/Apps/CropReports/

Sonoma Ecology Center, Napa County Resource Conservation District, et. al.. Napa River Watershed Health Scorecard. http://sfcommons.org/scorecards/napa. 2010.

Water Conservation

Goal:

Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity

Objective:

No specific objective

WAF Attribute:

Economic condition

Table 1. Score, trend, and reliability for: *Water conservation. NOTE:* No watershed score was calculated for this indicator because data was available for only one of the subregions.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	ND	ND	ND
Napa River watershed subregions:			
Western mountains	ND	ND	ND
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	ND	ND	ND
Eastern mountains	ND	ND	ND
South valley floor*	39	Improving/Level**	High
North Valley floor: North of Oak Knoll Avenue	ND	ND	ND

ND indicates that the score or trend was not determined because data were not available or sufficient.
[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.
*Score was calculated from figures for the City of Napa, which covers 48% of this region.
**Trend has shown improvement over the last 20 years, level trend over the last decade.

What is it?

This indicator evaluates residential use of water, which consists of indoor use in single and multi-family residences (waste elimination, washing clothes and dishes, bathing, drinking) and outdoor uses (irrigation and cleaning). It measures the amount of water supplied to residences by surface water and groundwater from within Napa Valley or imported from the Sacramento-San Joaquin River watersheds. It does not measure our total water “footprint”, which is the volume of water required to produce all the goods and services that we consume. This indicator compares the gallons of water an individual uses each day (gallons per capita per day, or gpcd) to a target value of what could be achieved if currently available water saving devices and conservation measures were adopted by all residents.

This indicator examines two broad types of conservation measures: improving water-use efficiency and, to a lesser degree, substituting recycled water for some uses. Improving efficiency includes behavioral and managerial improvements, such as adjusting a watering schedule, and technological improvements. Technological improvements usually involve replacing equipment with alternatives that serve the same purpose with less water.

The five incorporated municipalities in the Napa River watershed – Calistoga, St Helena, Napa, Yountville, and American Canyon - are each supplied by their own municipal water agency. Approximately 85% of the 134,000 people living in the Napa River watershed live in these communities. These municipalities deliver water for residential, commercial, institutional, public landscaping, and agricultural uses and derive their supply from a combination of local ground and surface water sources, and water imported from the Sacramento-San Joaquin Delta through the North Bay Aqueduct. The rest of the residents in the watershed live in the unincorporated areas and are served almost exclusively by groundwater.

Because the reporting of water use varies widely among the watershed's municipalities, and because it was sometimes difficult to obtain recent data for scoring, it was decided to limit our analysis to the City of Napa. The City of Napa's population and water use dwarfs the other cities; it represents over 62% of the watershed's population of 134,000, and includes nearly 75% of the population served by public water purveyors.

Why is it important?

Residential use is the factor most directly controlled by individuals and families, whose decisions to conserve water in and around the home can collectively create large-scale benefits. More efficient use can reduce the financial and energy costs of water and wastewater treatment, transporting and storing water supplies, and developing new sources; replace ecologically harmful water diversions from rivers and streams; relieve competition for limited supplies; and reduce pollutant loads from irrigating lawns, gardens and crops. In short, more efficient water use can reduce the human "footprint" on the natural water balance.

What is the target or desired condition?

Our target value of 73 gdpc (gallons per day per capita) represents what could be achieved if currently available water saving devices and conservation measures were adopted by all residents. The analysis excludes any options that limit water use through deprivation or cutbacks in production.

What can influence or stress condition?

Annual water use is affected by the weather—dry springs and warmer summers increase outdoor water use. However, adoption of water efficient water using devices, water-use awareness and landscaping changes will result in significant reductions in residential water use over the long term.

What did we find out?

The long-term trend suggested by our data is an improving one, i.e. there has been a general reduction in water use since the drought of 1987-92. However, the more recent data for the City of Napa show no obvious trend in either direction. Missing from our analysis, for lack of time, is a quantitative statement of the uncertainty associated with the results, the score and the trend.

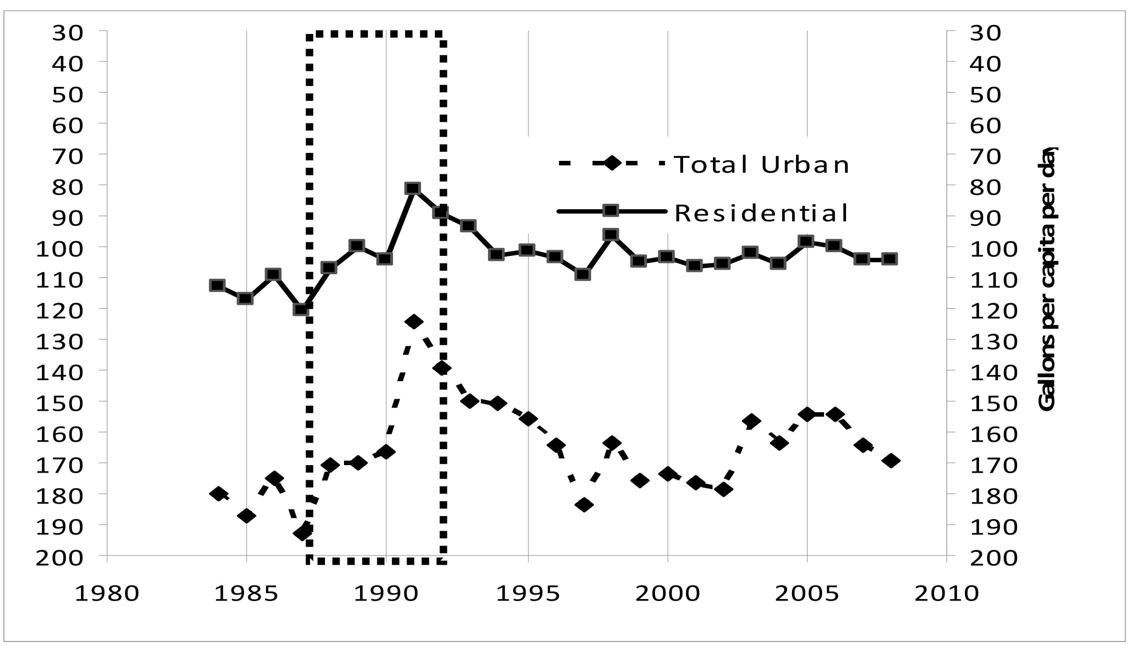


Figure 1. City of Napa Water Use, 1984 - 2008

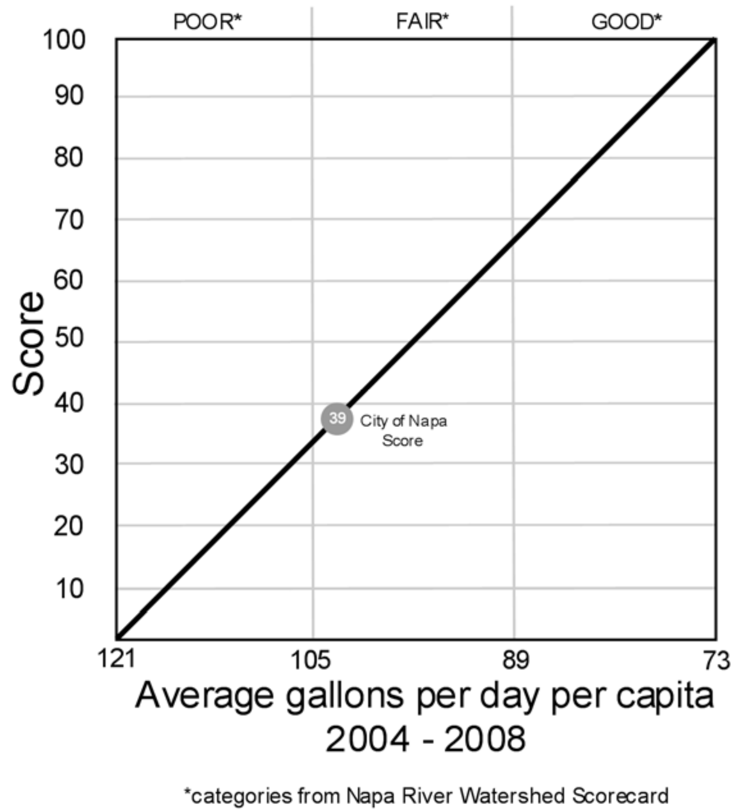


Figure 2. Scoring Chart for Water Conservation

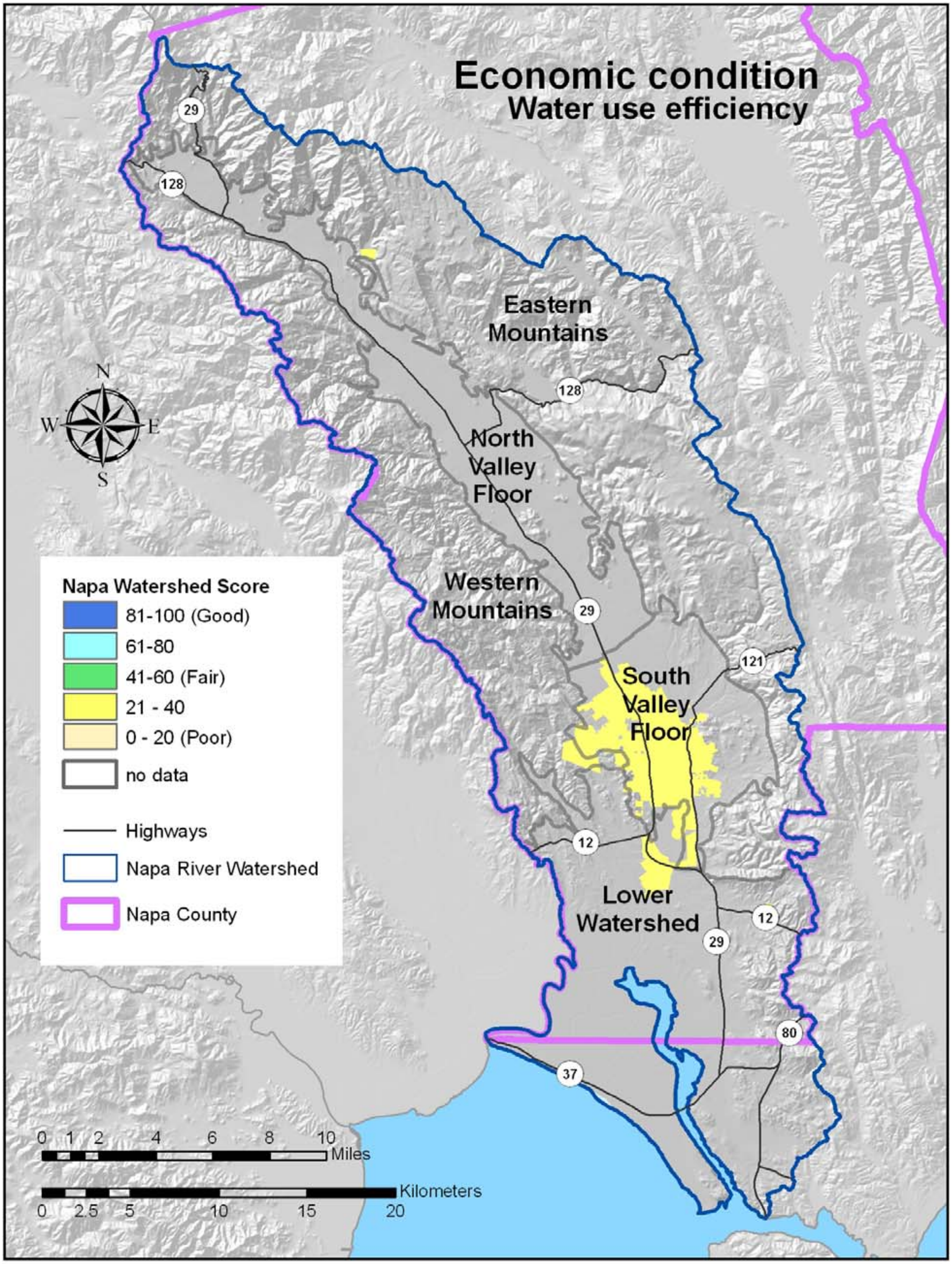


Figure 3: Napa Valley Watershed Water Conservation Score

The estimated municipal water use in the Napa River watershed in 2007 was about 23,000 acre-feet out of a watershed total of 64,000 acre-feet Single and multi-family residences are the largest sector of the municipal use, accounting for over 60% of the total. This represents about 22% of the total water use in the Napa River watershed. About 81% of the non-municipal water use is for agricultural water needs, with about 6% for rural residential use, 4% for winery operations, and most of the remaining 9% for golf course irrigation.

Temporal and spatial resolution

The period 2004 through 2008 includes an average year, two wetter years, and a dry year. The total municipal water production for the City of Napa is available back to 1984, and total residential water use is available back to 1989. Residential use was extended back to 1984 by correlating the total production with the total residential use. A long record of water use is helpful for putting recent water consumption into perspective and allows us to evaluate how both the drought of 1987-1992 and plumbing code changes affected water use. Higher per-capita water use prior to the 1987-92 drought serves as the lower reference condition for scoring. The City of Napa's population and water use dwarfs the other cities, representing nearly 75% of the population in the watershed served by public water purveyors.

How sure are we about our findings?

The City of Napa reports its monthly water use by the different customer classes to the California Department of Water Resources (DWR) annual Public Water System Survey (PWSS). It also reports annual water use by the different sectors to the California Urban Water Conservation Council (CUWCC), which makes the data available on-line at http://bmp.cuwcc.org/bmp/read _only/list.lasso. DWR and CUWCC do minimal checking of the agency reports; data obtained from them generally do not correct any gaps, errors or inconsistencies in the reports. The City of Napa has compiled water use for a longer time period than has been reported to DWR and CUWCC, so data were also obtained directly from the City. The public water agency reports to DWR and CUWCC also provide an estimate of the population served within their water service areas, which may include small areas outside of the city limits. The reports do not explain the derivation of the population estimates, and the data for the same year in the PWSS and CUWCCreports may differ a small amount because of rounding or not being updated in one of the reports. Data on population served are estimated from either census projections or from the number of water connections; but since the number of people served by these connections is difficult to determine, an average number of persons per connection is used.

Recommendations

The biggest data challenge in determining per-capita water use is obtaining accurate data, especially in areas that have high tourist use like the Napa Valley. All the water suppliers have good data for the number of water connections they have, but the number of people served by these connections can be difficult to determine. Data on the population served may not be accurate, resulting in poor per-capita calculations. Another challenge is to find accurate ways to determine outdoor water use when this not directly metered, which is currently the case with most residential accounts. The 'minimum method' used in this report and by DWR needs further refinement and validation. Other methods which should be considered include: remote sensing of landscape area, evapotranspiration calculations and on-the-ground mapping.

All five cities and towns in the Napa River watershed measure their water use by the different water-using sectors, but only the City of Napa and Calistoga regularly report their water use to DWR's annual Public Water System Survey (PWSS). Napa, Calistoga, and American Canyon are members of the CUWCC, a voluntary partnership of water suppliers that promotes efficient water use, including the reporting of water use and the implementation of best management practices. Yountville and St. Helena should be encouraged to submit water use data to DWR and join the CUWCC, as it provides many good resources to help small water suppliers improve their water use efficiency. American Canyon needs to keep current on their data reporting to DWR and the CUWCC as they are many years in arrears.

Any data on water use and population provided by a water supplier should include metadata, so that the accuracy of the data may be assessed and a judgment made whether per-capita calculations are feasible, and whether valid comparisons can be made over time and with other cities. This indicator shows that Napa residents can intensify their efforts to reduce their per-capita use of water to be good stewards of their water supply. Current use has stabilized at a level that barely puts it into the "fair" category. Residents can further reduce water use by adopting more water-saving appliances and technology and being more water-wise. Resource managers can help residents take advantage of available water-saving technology through financial incentives, mandated efficiency standards for new construction, mandated retrofits on resale and remodeling, and education. There is great potential for outdoor water use reductions; achieving them will require choices about landscaping as well as technological improvements. It remains to be seen whether new regulations that could potentially make it easier for residents to install greywater systems will make a significant difference in outdoor use, or whether financial incentives will be needed for greater adoption.

Technical Information

Data Sources

This indicator is based upon calculating water use in gallons per capita. Ideally this would include measurements of current water use and population in the five municipalities in the Napa River watershed, and comparing that to an estimated target efficient water use per person for those communities. Monthly or bi-monthly water use data are needed to calculate a per-capita indoor and outdoor use, the calculation of which is explained in the next section. All of the Napa Valley municipalities measure the water use of their different customers in order to bill them based upon the volume of use. Municipal water use is separated into different sectors or types of use, often distinguished by the size and type of water meter. Residential water use is accounted for separately from commercial, industrial, institutional and dedicated landscaping use. Different types of residential customers – such as single family and multi-family dwellings – are normally also accounted for separately. Water use is often measured and billed on a bi-monthly basis so data from an individual month may not reflect the use by all the customers.

The City of Napa and City of Calistoga report their monthly water use by the different customer classes to the California Department of Water Resources' annual Public Water System Survey (PWSS). These two cities, along with the City of American Canyon, also report their annual water use by the different sectors to the California Urban Water Conservation Council, which makes the data available on-line at http://bmp.cuwcc.org/bmp/read _only/list.lasso. DWR and CUWCC do minimal checking of the agency reports; data obtained from them generally do not correct any gaps, errors or inconsistencies in the reports. The Cities of Yountville and St. Helena do not report their water use to either DWR or CUWCC and multiple attempts to obtain water-use data from them for use in this analysis were unsuccessful. The City of Napa has compiled water use for a longer time period than has been reported to DWR and CUWCC, so data were also obtained directly from the City. The 2050 Napa Valley Water Resources Study Technical Memorandum 2 (Napa County Municipal and Industrial Demands) compiled water use data for the five cities through 2002, which is helpful for comparing water use between the various cities, but is not recent enough for scoring. The public water agency reports to DWR and CUWCC also provide an estimate of the population served within their water service areas, which may include small areas outside of the city limits. The reports do not explain the derivation of the population estimates, and the data for the same year in the PWSS and CUWCC reports may differ a small amount because of rounding or not being updated in one of the reports. Data on population served are estimated from either census projections or from the number of water connections; but since the number of people served by these connections is difficult to determine, an average number of persons per connection is used.

The derivation of a target or reference indoor water use relies on the data collected by different end-use studies of indoor water use, which measure the water use of the individual water-using devices in a household, including toilets, showers, dishwashers, washing machines, and faucets. The target outdoor use is based upon data collected in studies that examined a range of outdoor water efficiency options including landscape management practices (such as irrigation scheduling, mulching) hardware (such as ET controllers), and landscape design (such as drought tolerant gardens, reduction or elimination of turf), as well as the experience of water agencies and residential users when dry conditions require mandated and voluntary reductions in water use.

Analysis

The average daily water use per person – gallons per capita per day (gpcd) – is calculated by converting the reported monthly, bi-monthly or annual residential water use data into gallons, dividing by the appropriate number of days to get a daily use and then dividing that result by the population using that water to get the gpcd. It is assumed for purposes of this calculation that only the population reported to reside within the service area of the district consumes the residential water and that visitors to the area are consuming water from non-residential accounts (i.e. commercial or institutional accounts). The 2008 calendar year water use for the City of Napa was reported to PWSS and CUWCC in acre-feet. The single-family and multi-family sectors are combined to calculate the residential gpcd for 2008 for the city. Residential use is also compared to the total municipal use in order to determine the percentage of the total use that the residential sectors represent (per-capita use based on the total municipal use would measure, along with the residential use, different commercial, industrial, and institutional (CII) mixes by the different municipalities and thus make comparisons of what we as individuals use less meaningful).

The efficient water use target that the current water use is compared to is derived for indoor and outdoor use separately, so it requires separating total residential water use into indoor and outdoor use. Indoor use is calculated by the commonly-used "minimum month" method. This assumes that the residential water use in the lowest water-using months is used entirely indoors and assumes that indoor use is relatively constant throughout the year.

Analysis of the monthly water-use data reported to the PWSS shows that January and February and sometimes March are the lowest water using months. Since the billing is often bi-monthly the calculation sums the two lowest consecutive months, converts it to gallons and divides by the number of days in the two months to determine the indoor gpcd. The average outdoor gpcd is the difference between the annual total residential gpcd and the calculated indoor gpcd. The gpcd water use in the consecutive highest consumption months of July/August or

August/September is also calculated to be able to evaluate the relative magnitude of the peak outdoor use compared to the indoor use. The target residential water use is the sum of a target indoor quantity and a target outdoor quantity. Separate indoor and outdoor use targets are derived, because an indoor target can be established as an allotment of water in gallons per person, while the outdoor target uses a percentage reduction from the current use.

The indoor use target of 40 gpcd is the average of several studies that measure the water use of currently available, efficient water-using appliances (toilets, showerheads, washing machines, dishwashers) and assumes that household leaks are reduced or eliminated. Water use by these devices is relatively constrained by current technology and plumbing codes. The main variable affecting household water use is how often the devices are used in the typical household, which is what the different studies measure. Per-capita indoor use is thus relatively similar across a range of single-family and multi-family residences and lends itself to an allotment-based target. Greater indoor savings are possible with newer, more efficient devices (such as dual flush or high efficiency toilets) and through behavioral choices such as taking shorter showers and not leaving the water running. Thus the indoor target of 40 gpcd for an individual household is very achievable, while the target for a water agency assumes nearly all residential customers have installed the devices and taken care of their leaks.

Over time most residential customers will install water efficient devices indoors, but the target can be achieved sooner with the proper financial incentives and regulatory mandates. In contrast to indoor water use, outdoor water use is much more variable depending on customer behavior, weather, and the size and type of the landscaping, which might range from none (for an apartment dweller) to large expanses of turf. Because information on the size and the type of landscaping of residential customers is not readily available, it would be very difficult to establish an allotment-based target of outdoor use and it is more appropriate to express the target as percentage savings from the current outdoor use. There is a wide range of options to achieve outdoor water use savings. As previously mentioned, different studies have evaluated savings from landscape management practices (such as irrigation scheduling, mulching), hardware (such as ET controllers), landscape design (such as drought tolerant gardens, reduction or elimination of turf), and policies such as rate structures and requirements for zero footprint new development.

Using recycled water from wastewater treatment plants or from onsite greywater systems for landscape irrigation can also reduce the use of potable water for outdoor water use. The percentage savings that have been achieved from these measures are highly variable. A Pacific Institute paper (2003) evaluated many studies and estimated that outdoor water use reductions of 25% to 40% could be achieved in California. The urban water management plans for the City of Sonoma and Valley of the Moon Water District examined different measures and programs for reducing residential irrigation and estimated end-use savings ranging from 9% (for rain sensor retrofits) to 33% (for "cash for grass" programs). The actual savings depend on the level of participation or "penetration" of the programs and measures, which in turn depends primarily on the economic benefits and costs to the water agency and customer, although the social and environmental benefits of saving water (i.e. stewardship) may also motivate action. Another indication of the outdoor water use savings potential is the 10% to 15% summer and fall residential water savings that were achieved in 2007 by the Valley of the Moon Water District, stimulated in part by the reductions requested by the Sonoma County Water Agency and the State Water Resources Control Board to meet Russian River flow requirements. Some of this reduction was likely achieved by short-term changes in irrigation management and some may have been weather related. Many water agencies have drought management plans that specify percentages of total and outdoor water use reductions to be achieved through voluntary and mandated measures (such as no-water days).

Because outdoor water use savings depend on so many variables and requires information beyond the scope of this effort, a simple but achievable outdoor water use reduction target of 20% from current outdoor use is specified for the Napa River watershed. A 20% reduction in outdoor use can be met through a wide variety of measures depending on the individual circumstances ranging from behavioral changes (such as more careful water scheduling) to investments in hardware or changes in landscape design. A 20% reduction target is consistent with policy and legal requirements to achieve 20% per-capita reductions for overall water use and has been achieved in response to short-term requirements to reduce water use during dry periods. Those users who are currently using water efficiently may not be able to achieve a 20% reduction, but they are outnumbered by users who can achieve a greater than 20% reduction. Water agency planners that were consulted for this report (such as Carrie Pollard of the Sonoma County Water Agency) felt that a 20% outdoor water use reduction target is achievable.

Evaluation and scoring

Scoring this indicator requires the following steps:

1. Calculate the indoor and outdoor water gpcd for the municipalities that report their monthly water use over the 2004 to 2008 period. At the present time, monthly water use data are available only from the cities of Napa and Calistoga (only Napa was scored for this assessment).

2. Calculate the average annual indoor and outdoor use for the 2004 to 2008 period. Reduce the average outdoor use by 20% and add that target use to the indoor target per-capita use of 40 gallons per day to get the total target residential which is the upper reference value of 73

gpcd (score = 100) for scoring. Here and in the following discussion, we use the convention that “upper” refers to a more desirable environmental condition—for this indicator, a reduction in water use—while “lower” has the opposite meaning. Because the City of Napa has so much more population than Calistoga (84,000 to 5300) and a correspondingly greater water use, and because Napa has a water use record going back to 1984, only the Napa data was used to calculate the upper reference condition (target efficient use) and lower reference condition (water use with minimal conservation). Incorporating Calistoga data in the calculation of the upper reference condition would lower the target gpcd by one gallon.

3. Use the highest historical residential value from the longterm residential water use record for the City of Napa as the lower reference condition, 121 gdpc (score = 0) for the water use with relatively low conservation prior to the 1987-92 drought.

4. Score recent water use on a linear, 100 point from 121 gdpc to 73 gdpc. Evaluate the long term Napa valley water use to determine the long and short term trends.

Note on regions outside the city of Napa

The City of Calistoga per-capita residential water use in 2007 was 84 gallons per day, mainly due to lower outdoor use, which likely reflects smaller average lot sizes in Calistoga. In both of these cities the residential water use represents 60% to 65% of the total demand for water, which includes commercial, institutional, and industrial uses as well as the unaccounted water from leaks and billing errors.

Although recent water use data was not available for Yountville and St. Helena, data from 2002 and earlier years compiled for the 2050 Napa Valley Water Resources Study indicate that the per-capita residential use for those towns was 30% to 50% higher than Napa for comparable years. It is possible that the higher residential water use in Yountville and St. Helena is due to differences in what is included in the residential water use figures. Greater tourist use in residential bed and breakfasts establishments tends to be considerably higher than the target per-capita indoor use of 40 gpcd, but is very similar to the indoor use in other cities of the San Francisco Bay Area.

American Canyon water use reported to the California Urban Water Conservation Council for the 2002-2006 period indicates that its per-capita residential use is fairly similar to that in the City of Napa.

Like other cities in the Bay Area, the residential water use in the City of Napa has declined by 10% to 15% in the last two decades, spurred by plumbing code changes and conservation programs. These efficiency gains helped the city keep its water needs in 2008 only 12% higher than in 1987, while the population increased 27%. In contrast, the available data from

Yountville and St. Helena did not show the same declines in per-capita residential water use through 2002.

Citations

California Department of Water Resources. 1993 – 2008. Annual Public Water System Survey (PWSS), City of Napa. Available at the California Urban Water Conservation Council website: http://bmp.cuwcc .org/bmp/read_only/list.lasso.

Pacific Institute. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California.

Sonoma Ecology Center, Napa Resource Conservation District et al. 2010. "Watershed Health Scorecard: Napa River Watershed Interim Technical Report on Indices for Water Quantity and Quality." Available at: http://sfcommons.org/scorecards/napa

West Yost & Associates. 2005. 2050 Napa Valley Water Resources Study.

Stream Temperature

Goal:

Improve and sustain watershed conditions and functions that advance human and environmental economies, in particular water quality and quantity

Objective:

Protect and improve water quality for aquatic ecosystems.

WAF Attribute:

Physical and Chemical

Table 1. Score, trend, and reliability for *Stream temperature*.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings
Napa River watershed	54.0	Improving	Low
Napa River watershed subregions:			
Western mountains	99.72	Level	Low
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	80.69	Level	Moderate
Eastern mountains	ND	ND	Low
South valley floor	87.10	Declining	High
North valley floor: North of Oak Knoll Avenue	53.94	Improving	High

[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] ND indicates that the score or trend was not determined because data were not available or sufficient.
[3] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

Water temperature greatly affects aquatic ecosystems. In riverine environments, colder water temperatures generally contain more dissolved oxygen, and this is often favorable to certain aquatic species such as fish and benthic invertebrates. As sunlight hits the water surface, the temperature will rise. Aquatic species sensitive to high water temperature might not survive if temperatures exceed a certain threshold for long periods of time. This analysis calculates the maximum seven day average daily maximum (7DADM) for each year and for each subregion. Each year is represented by the highest seven-day average maximum water temperature within the year.

Why is it Important?

One of the consequences of increased withdrawal of river water for human uses is an increase in water temperature due to lowered volume. Increase of river temperatures from their natural levels has far-reaching effects on local ecology, including alteration of community processes and facilitating invasion by exotic species (Poole & Berman 2001). Restoring natural flow regimes and thus natural temperatures is critical to restoring a healthy natural system.

Native salmonid species are of great ecological, economic, and cultural importance to local communities. They also serve as strong indicators of habitat quality and integrity in river systems, particularly with regard to water temperature, sediment load, and barriers to passage. They are well-studied, including behavioral and physiological responses to temperature extremes.

Maximum water temperature is a critical part of habitat quality for salmonids. Temperature affects every aspect of salmonid biology, from feeding and growth rates to migration and spawning, and stress levels and survival (Carter 2005). Rainbow trout, for example, are more severely impacted by temperatures in excess of 20ºC than by fishing pressure (Runge & Peterson 2008). Upstream diversion of water for human usage increases downstream temperatures, as the lower remaining volume warms more quickly. Due to upstream barriers such as dams, only less-suitable, high-temperature regions are available for spawning and summer feeding. Anthropogenic temperature increases have been identified as key contributors to salmon decline (US EPA 2003).

What is the target or desired condition?

US EPA suggests as a guideline that a river sustaining salmonid populations should not have 7DADM temperatures over 18ºC to avoid impairment of salmon health. Similarly, migratory portions of the river should not exceed Maximum Weekly Maximum Temperatures of 20ºC and temperatures greater than 22ºC will cause broad mortality (US EPA 2003). For core rearing areas in mid-to-upper parts of the river basin, a maximum of 16ºC may be appropriate. Experimental studies indicate that spawning temperatures up to 16.5ºC do not have deleterious effects on juvenile salmon, but mortality increases markedly after that point (Geist et al. 2006). These temperature guidelines, along with additional information from Brett et al. (1982), were used to convert monthly maximum 7DADM into a 0-100 scale.

A score of 100 is equivalent to the EPA's stated protective criteria of 18ºC 7DADM for secondary foraging/rearing areas. A score of 0 will be equivalent to 25ºC 7DADM, the lethal point for juvenile Chinook salmon. Intermediate scores were scaled using an adaptation of the Brett et al. (1982) growth curve (Figure 1). Only the right side of the curve was used; temperatures below the EPA protective criterion were still scored as 100. Brett et al. (1982) estimate that natural populations of Chinook feed at roughly 60% of saturation (or R=0.6, the lowest growth curve). Because of daily temperature fluctuation, 7DADM temperatures are equivalent to constant laboratory temperatures roughly 1-2ºC colder (US EPA 2003).

The scaling curve is shown in Figure 2. The scaling curve does not exactly match the growth curve, due to the temperature thresholds for 0 (25ºC) and 100 (18ºC). Temperatures for the growth curve were adjusted upward by 1.5ºC to adjust for the use of 7DADM measurements. These scores apply only to summer maximum temperatures.

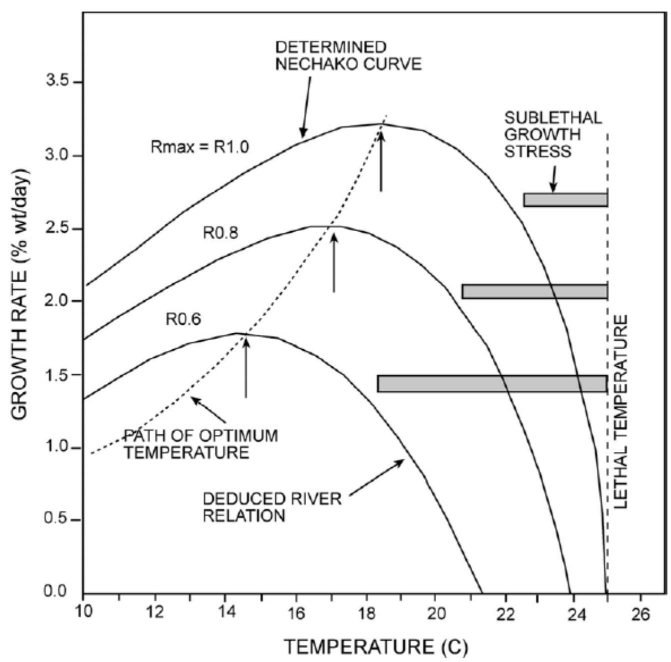


Figure 1. Chinook salmon growth curve (Brett et al. 1982). Growth rates at different temperatures for three feeding levels (R=0.6, 0.8, and 1.0). Rmax (R=1.0) represents satiation feeding, with R=0.6 closer to natural feeding levels.

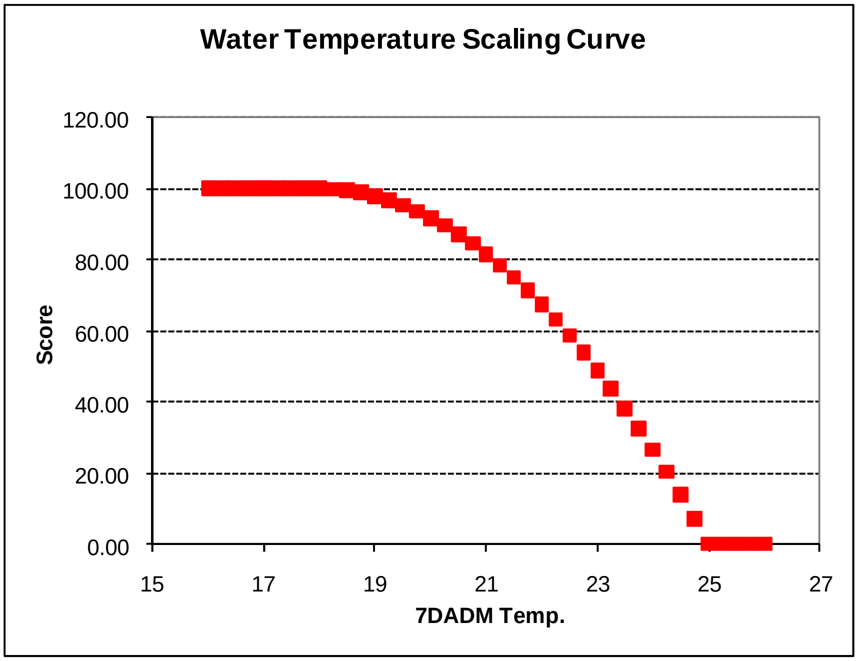


Figure 2. Stream temperature scaling curve. This curve is approximated from salmonid growth/survival data in Brett et al. 1982. It converts 7-day average daily maximum temperature to a 0-to-100 score. The formula for temperature (x) conversion to score is 100 – r(x-K)2, where r = 2.041 and K = 18ºC.

What can influence or stress condition?

The major factor which raises water temperature is decreased flow within the river. Low water volume allows the sun to warm the river much faster, and temperatures increase rapidly as the water moves downstream. Prolonged decreased flow (as opposed to seasonal variations) is most often due to human water use; water is retained in reservoirs and diverted to urban centers or for agricultural use, and only a small fraction is released into the original channel. Increasing temperature due to climate change is another possible factor.

What did we find out?

Many of the sampling sites were excluded from analysis due to data limitations. Many sites had only one year of data, sometimes represented by a single point. Most problematic was the prevalence of monthly samples at irregular times, which clearly do not represent temperature maxima. However, there were sufficient daily datasets from four of the five subregions to perform trend analyses. Due to the aforementioned data limitations, only current state assessments and annual Mann-Kendall analyses were performed. The current states of the subregions are shown in Table 1 and Figure 3.

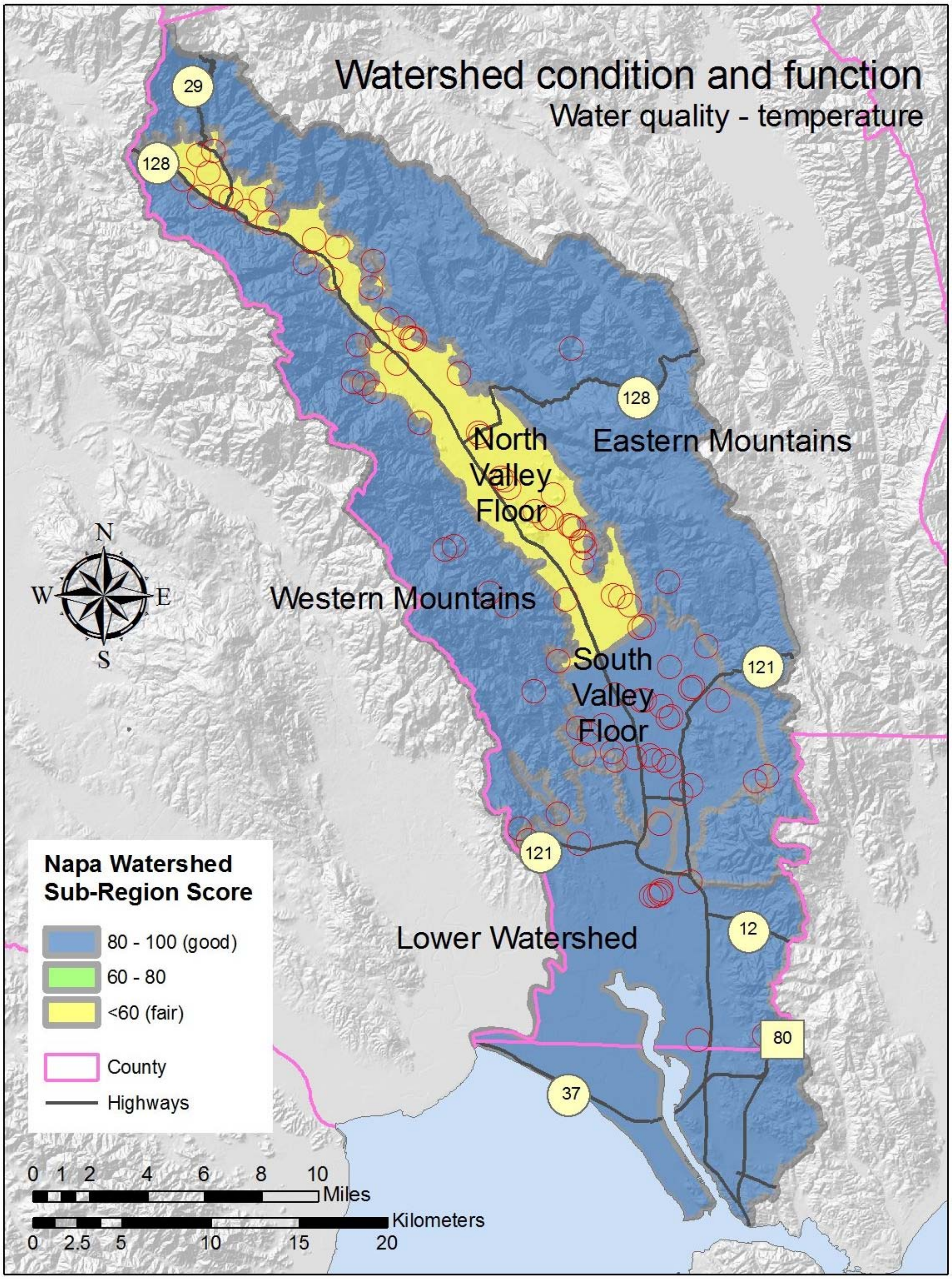


Figure 3. Stream temperature condition scores for subregions and distribution of sampling stations.

Trends Analysis

Regional Mann-Kendall analysis (section X.X) was conducted on each subregion, using the individual sites as separate regions. The North Valley floor had a statistically significant negative (decreasing) temperature trend while the South Valley Floor had a statistically significant positive (increasing) temperature trend. The other two subregions had positive temperature trends, but were not statistically significant (Table 2). While a negative trend is a good sign that the overall river temperature is cooling in this region, it is important to note the short analysis time period of eight years. When performing a Regional Mann-Kendall analysis, a ten year period is preferred. Therefore, the 11 year period for the South Valley Floor is a bit more sobering, and remedial actions should be considered for this region. As suggested by the results from the individual regions, the overall trend for the entire watershed was positive but not significant (tau-b = 0.0880, p = 0.2884). There was not enough data available to perform a trends analysis on the Eastern Mountains.

Table 2: Regional Mann-Kendall trend analysis. "Tau-b" is a Mann-Kendall test statistic.

Subregion	**Tau-b**	**Significant**	**p-value**	**Slope Magnitude**	**Years**	**N**	**Confidence**	**Remarks**
EM	NA	NA	NA	NA	NA	1	NA	Insufficient data
LW	0.1619	False	0.05285	0.03077	1967-2007	13	Medium	Long series, but false maxima
NVF	-0.447	True	0.002754	-0.62	1996-2004	10	Medium	Long series, but false maxima
SVF	0.4943	True	0.000888	0.6	1997-2008	13	Medium	Long series, but false maxima
WM	0.1429	False	0.8259	1.143	1996-2007	5	Low	Mostly short series

WM: Western mountains. LW: Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon. EM: Eastern mountains, including Angwin area. SVF: South valley floor, including Napa. NVF: North valley floor, including Calistoga, St Helena, and Yountville.

Temporal and spatial resolution

Water temperature is monitored more intensely in the valley floor of the Napa River watershed, both in terms of quantity of sites and frequency of sampling. The Eastern and Western Mountains collect data but the sites are spread out and the collection hasn't been as consistent over time. Temperatures are collected using a combination of monthly grab samples and continuously monitoring Hobo-temps (thermometers left in the waterways to collect data). Continuous monitoring provides the most consistent source of temperature data and indicator calculation, but it is conducted on fewer sites. A critical feature of watershed-wide monitoring would be the establishment of a network of continuous temperature measuring devices that covers all important waterways and times of the year.

How sure are we about our findings?

The overall condition assessment based on maximum seven day average daily maximum (7DADM) tells part of the story, but is best calculated based on complete data-sets. Water temperature is a straightforward parameter to measure, but is complicated to interpret. Choosing the highest temperature measured to assess condition would have resulted in most subregions receiving a score close to or at 0 (Table 3), meaning that the scores here may under-represent temperature problems in the watershed.

Recommendations

The Eastern and Western Mountains are underrepresented in this study. Adding additional daily temperature data loggers across this region in each of the major tributaries is recommended. Any additional data, particularly for these two regions, would provide more assurance about the findings in this study.

Technical Information

Data sources:

United States Geological Survey (USGS), National Water Information System (NWIS)
Napa Valley Floor-Napa-MST, Daily Temperatures, 1978-1981, 1982-1989
Napa Valley Floor-Calistoga-StHelena-Yountville, Daily Temperatures, 1961-1979

California Department of Fish and Game, Bay Delta and Tributaries Database (BDAT)
Carneros Area_Napa River Marshes_Jamieson/American Canyon, Unpatterned, 1978-2004
Carneros Area_Napa River Marshes_Jamieson/American Canyon, Unpatterned, 1967-2004

California Land Stewardship Institute (CLSI)
Napa Valley Floor-Calistoga-StHelena-Yountville, Daily Temperature, 6/2007-10/2007

Napa County Resource Conservation District (RCD)
Carneros Area_Napa River Marshes_Jamieson/American Canyon, Napa Valley Floor-Calistoga-StHelena-Yountville, Napa Valley Floor-Napa-MST, Unpatterned,
1996-2004

Stillwater Sciences
Carneros Area_Napa River Marshes_Jamieson/American Canyon, Napa Valley Floor-Napa-MST, Intermittent, 2001-2005

Type of data

Analysis is on temperature maxima only. Non-maximum data, such as daily averages or single measurements, were treated in one of two ways:

1. if data set was inferior or redundant, data were excluded from analysis. Generally excluded were: data sets with only one year of data; data sets with no data within the last 10 years; and false maxima data in regions with 5+ sites with true maxima.
2. if data set was desirable (i.e. the particular region or time period had little alternative data), then data were be treated as if they represented daily maxima, but this was noted in the analysis and the data confidence evaluation.

Temporal aggregation:

Data were aggregated temporally as follows:

- Sub-daily data (i.e. hourly, 15min, etc.): included only daily maximum.
- Daily data: Daily maxima were averaged over 7-day periods to form a rolling 7-Day Average Daily Maximum (7DADM). Standard deviations calculated for each average. Averages started with the 7th day in a series, and then moved forward until the final day. Some averages extended into two months, but the 7DADM was associated with the final day in the average. For months with fewer than 7 days of reporting, a shorter average was used, though this was reflected in the standard deviation. Missing days were accommodated in a similar manner.
- Weekly data: Whether this was a single measure of weekly temperature, or a 7DADM point, only the maximum value was used to represent the month. Standard deviation for the maximum point was preserved.
- Monthly data: Seasonal Kendall and month-by-month trend analysis were carried out on monthly maxima data, when data permitted. Trends were reported for each season or month, as well as the overall yearly trend.
- Annual data: For annual analysis, the Mann-Kendall trend analysis was used on yearly maximum data. Standard deviations were maintained from the 7DADM averages when possible.

Subregion aggregation:

Data within a subregion was assumed to represent independent sampling events, and was used to calculate aggregate scores for that subregion. The number of sites was considered when assessing confidence measures.

Table 3. Basic statistics for subregion condition assessments. "SD" refers to standard deviation; "N" refers to the number of data points; "95% C.I." refers to 95% confidence intervals.

Subregion	Average Temp (ºC)	Min Temp	Max Temp	SD	N	95% C.I.	Score	Confidence	Remarks
EM	17.11	17.11	17.11	NA	1	NA	NA	Low	Only one data point
LW	21.08	13.10	25.50	3.99	21	1.71	80.69	Medium	Few true maxima
NVF	22.75	17.73	26.09	2.10	22	0.88	53.94	High	Good maxima data
SVF	20.51	15.58	24.18	2.35	11	1.39	87.10	High	Good maxima data
WM	18.37	15.00	20.59	2.30	6	1.84	99.92	Low	Not much data

WM: Western mountains. LW: Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon. EM: Eastern mountains, including Angwin area. SVF: South valley floor, including Napa. NVF: North valley floor, including Calistoga, St Helena, and Yountville.

Trends Analysis Reporting:

The primary values reported were Mann-Kendall trends and Kendall B estimated trend slope, with confidence intervals. When performing regional analysis, trends for sub-units were reported along with overall trend.

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Carbon Storage and Primary Productivity

Goal:

Reduce greenhouse gas emissions and adaptively manage watershed resources to address climate change

Objective:

No specific objective

WAF Attribute: WAF Attribute:

Ecological processes

Table 1. Score, trend, and reliability for: *Carbon storage and net primary productivity*.

Region	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	97.1	No Trend	Moderate
Napa River watershed subregions:			
Western mountains	97.7 ± 7.3	Declining	High
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	99.7 ± 2.6	Improving	High
Eastern mountains	97.3 ± 7.4	Level	High
South valley floor	92.7 ± 11.8	Declining	Moderate
North valley floor: North of Oak Knoll Avenue	94.3 ± 9.6	Level	Moderate

[1] Scores close to zero indicate extremely poor watershed health whereas scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.

[2] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan for the North Bay-Delta Transect Watershed Assessment Framework. The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

For this indicator we examine two elements of the carbon budget of the Napa River watershed, carbon sequestration amounts and net primary productivity. Both are of interest in terms of global change issues, in particular because of the potential for offsetting increases in atmospheric carbon dioxide by storage of carbon in terrestrial carbon pools (Dixon et al. 1994). In this analysis we look at carbon standing stock at a single point in time as a measure of watershed condition, and assess trends in carbon storage by examining changes in net primary productivity detected by satellite remote sensing.

Carbon Sequestration

Research on carbon sequestration has focused on measurements of carbon stocks and carbon flux. Measuring carbon flux requires sophisticated instrumentation making fine-scale studies difficult, but measurement of carbon stock is more amenable to landscape-scale studies. The general approach for carbon stock evaluation is to amalgamate remote sensing-based landscape classifications with vegetation plot data that includes above-ground biomass, litter accumulation on the soil floor, and below-ground carbon to estimate total carbon storage across the landscape. Typical units for the metric are in megagrams (Mg) of carbon per hectare for the stock and Mg C per hectare per year for the flux. In this analysis we use the results from a landscape-scale assessment of carbon stocks in California and compare that to a reference condition that assumes all trees are fully mature.

Net Primary Productivity

According to NASA, terrestrial biological productivity (or primary productivity) is the single most fundamental measure of "global change" of practical interest for humankind. Primary productivity is the measure of carbon intake by plants during photosynthesis, and this measure is an important indicator for studying the health for plant communities.

Net Primary Productivity (NPP) is the amount of carbon uptake after subtracting Plant Respiration (RES) from Gross Primary Productivity (GPP). GPP is the total rate at which the ecosystem captures and stores carbon as plant biomass, for a given length of time.

$$NPP = GPP - RES$$

Photosynthesis is the process in which the energy from the sun converts carbon dioxide (CO_2) from the atmosphere and water (or water vapor) to organic sugar molecules (carbohydrates), which are stored in the plants, and oxygen, which we, and other life on earth, consume. The extra water molecules which are derived in photosynthesis are reused by the plant or transpired into the atmosphere. Below is the chemical formula for photosynthesis:

$$6CO_2 + 12H_2O(+sunlight) \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

NPP measures the mass of the new plant growth (chemically-fixed carbon) produced during a given interval. Change in NPP may change with vegetation health, so NPP rates were used to analyze the overall trend of carbon uptake in this region over the past ten years. To analyze trend, we downloaded ten years of monthly satellite data from NASA, which are are reported as grams of carbon uptake per meter square per day ($gC/m^2/day$). With monthly data, we ran a Seasonal-Kendall trend analysis, and with annual data, we ran a Mann-Kendall and Regional-Kendall trend analysis.

Why is it Important?

Humans continue to release CO2 and other greenhouse gases into the atmosphere from the burning of fossil fuels and agricultural practices. Plants cannot convert CO2 into biomass as fast as it is entering the atmosphere, causing a global buildup. These greenhouse gases trap heat from the sun and cause the surface temperature to rise, which has started a chain of events that will have enormous impacts on the globe in the years to come. These changes include glacial melting, sea level rising, and climatic shifting, which in turn can affect the welfare and health of all living things on this planet.

Carbon sequestration is considered an important means to mitigate the impacts of greenhouse gases on climate change (Sedjo & Solomon 1989). Increasing the amount of carbon stored on a watershed may become an important policy goal with economic benefits accruing from the establishment of a carbon offset market (Richards & Stokes 2004).

Forest ecosystems sequester the most carbon of any terrestrial ecosystem, and most United States surveys of carbon storage to date have emphasized storage in forests, usually working with the USFS Forest Inventory and Assessment plots as a base (Woodbury et al. 2007, Blackard et al. 2008). The forests of the Pacific Northwest may have some of the highest potential to store additional carbon of any forests in the world (Hudiburg et al. 2009).

What is the target or desired condition?

Prior to the industrial revolution, the planet's carbon cycle was closer to a state of equilibrium. While an increase in solar radiation or an increase in planetary volcanism can drastically change the carbon cycle for a relatively short period of time, it has been shown that human activity has adjusted this cycle by adding more carbon and methane into the atmosphere at higher concentrations than any natural occurrence over the last 650,000 years (Siegenthaler et al., 2005). The carbon cycle is a global phenomenon, so to return to a desired condition at equilibrium will be a global, population-wide, effort. To select a desired condition at a regional scale, we look at the carbon *holding capacity* for each region and compare it with current conditions.

We take the desired condition to be a landscape where all trees are fully mature; that is, they have grown to the point where additional carbon storage on the landscape in aboveground biomass is limited to the rate of trees dying and new ones growing. Such a landscape is at its maximum potential for mitigating climate change through storage of atmospheric carbon dioxide.

We also selected a target for new carbon sequestration, as indicated by NPP, as an increasing trend, or at least not a declining trend. This means that a significant upward trend is a good condition from a climate mitigation point of view, and a declining trend is a poor condition.

What can influence or stress the condition?

Any changes in plant cover in the landscape will affect the amount of aboveground carbon storage. Most important are changes in forest cover, given that forests have the greatest amount of biomass of any habitat type. Processes that influence forest cover and hence carbon storage include fire, timber harvest, land development, and disturbances such as pest outbreaks as well as forest regrowth (Brown et al. 2004). In a recent study, scientists found that logging was the greatest impact on reduced carbon storage in forests and “no management” of forests resulted in the greatest sequestration of carbon (Nunery and Keeton, 2010). Fire can also reduce NPP, with reduction depending on fire intensity (Meigs et al., 2009). Remaining and newly-growing plants will tend to grow vigorously, so at the landscape scale, fire temporarily reduces NPP rates.

Regional climate will greatly affect the natural growth of shrubs and trees. Between 2006 and 2009, California experienced three consecutive dry water years. NPP will tend to decline in response to seasonal and drought-related drying. Plants take up CO2 through holes in their leaves called stomata. These will close under very dry conditions in order to reduce water loss by the plant. This means that as conditions dry, rates of carbon sequestration will decline. Because climate change may lead to drier and hotter conditions in many places in California, NPP may decline.

What did we find out?

There were relatively high scores for carbon standing stock, ranging from 92.8 for the Napa Valley near the city of Napa to 99.7 in the Napa River Marsh region (Table 1 and Figure 1). There were significant downward trends in monthly NPP for Western Mountains and Napa Valley Floor near the city of Napa, and a significant upward trend in the Napa River Marsh. It is important to note that these standing stock values are just for wildlands in the Napa Valley watershed, and they exclude agricultural or urban areas. Despite the high absolute values of the indicator scores, scores should be as close to 100% as possible, because of the need to reach global greenhouse gas mitigation goals.

Carbon Standing Stock

The indicator value is a comparison of current standing stock to a potential maximum, which is based on a combination of underlying vegetation types and canopy closure values. Figure 2 is an intermediate layer which shows carbon storage at a 100 meter pixel and provides additional detail about the patterns in each region.

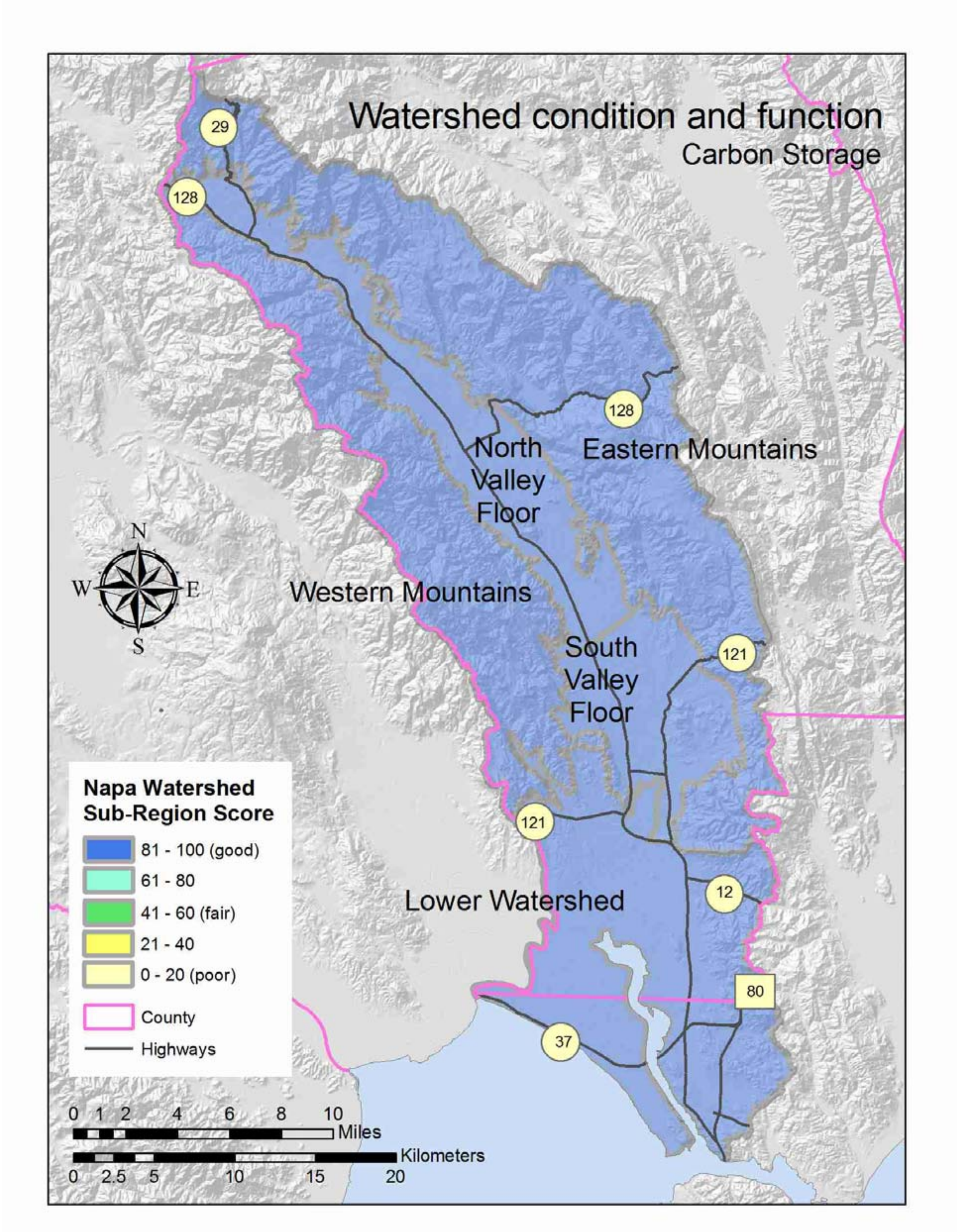

Figure 1. Carbon stock scores across sub-regions.

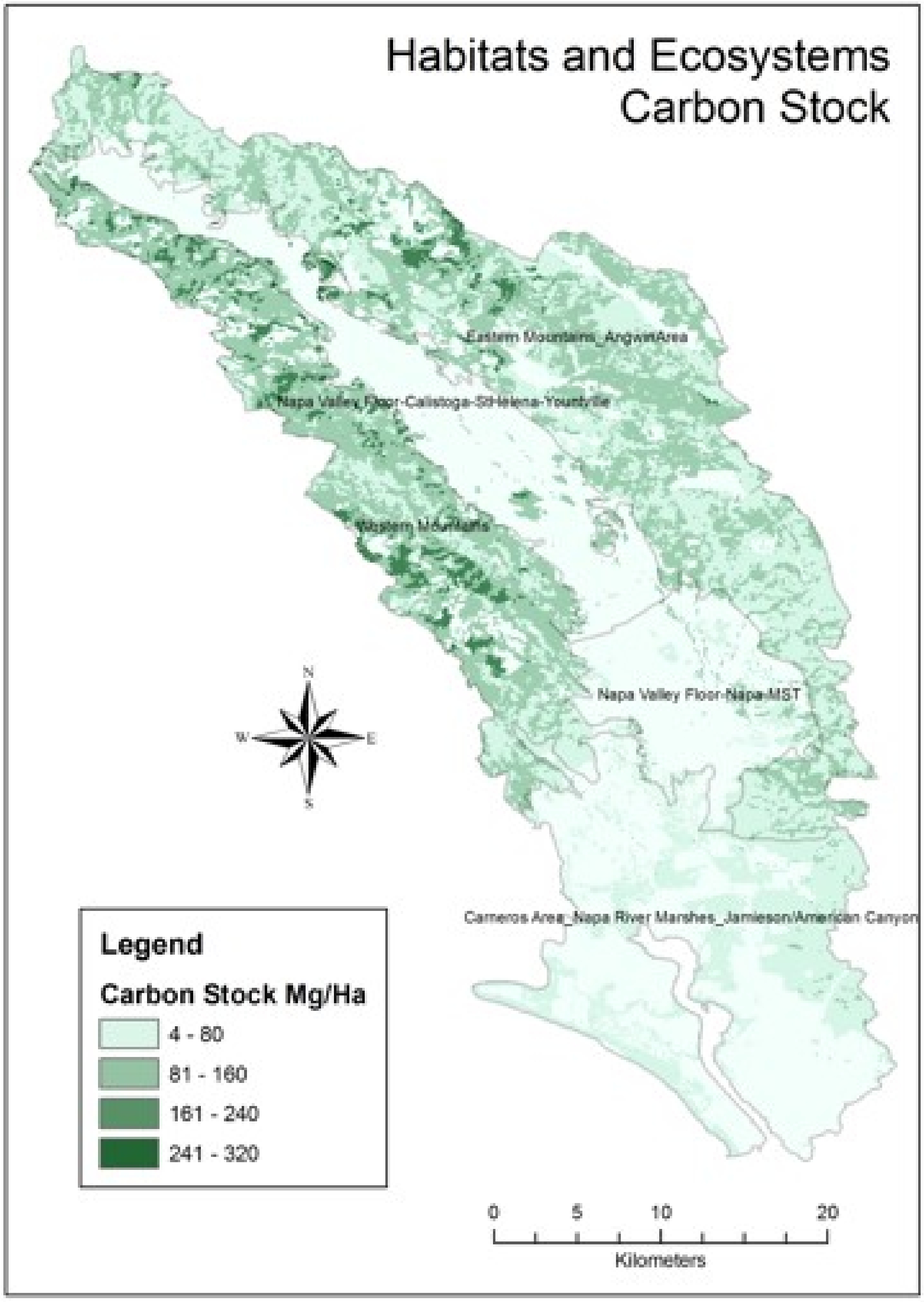

Figure 2. Actual carbon standing stocks based on vegetation present.

Trend Analysis

To study trends in the carbon budget, NPP was analyzed for each region. NPP provides a rate of carbon fixation or sequestration into plant material. Ten years of monthly NPP rates were available, allowing for an estimate of change in rate over time. We used the R statistical program to analyze these data, and used custom-made variations of the Kendall package depending on whether the analysis was for monthly or annual data. Kendall's rank correlation measures the strength of monotonic association between two vectors, such as year and data value (see section 3.3 for more information on trends analysis).

Monthly Trend

Monthly-seasonal variation over 10 years (2000 – 2009), was analyzed using a Seasonal Kendall statistical model. Monthly NPP raster data for each sub-region were aggregated as sum, mean, maximum, minimum, and standard deviation for each sub-region, and trends across each parameter were calculated (Table 2).

Table 2. Monthly Net Primary Productivity in each sub-region: trend and value showing the magnitude of the slope in the sum, mean, maximum, minimum, and standard deviation (StdDev) of NPP.

Region	**Monthly Trend**				
	Sum	**Mean**	**Max**	**Min**	**StdDev**
WM	Negative -0.2333	Negative -0.02592	Negative -0.01907	Negative -0.02592	
LW	Positive 0.04429	Positive 0.01476	Positive 0.01476	Positive 0.01476	
EM					
SVF	Negative -0.02789	Negative -0.02789	Negative -0.02789	Negative -0.02789	
NVF					Negative -0.01044

WM: Western mountains. LW: Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon. EM: Eastern mountains, including Angwin area. SVF: South valley floor, including Napa. NVF: North valley floor, including Calistoga, St Helena, and Yountville.

There was strong agreement between the sum, mean, maximum, and minimum analyses for trend. We found a negative trend (decline in NPP) in the Western Mountains and Napa Valley

Floor near the city of Napa (Figure 3 and 5, respectively). Declines in NPP are associated with changes in vegetation type (e.g., replacement of tree canopy by row-crops), increases in temperature, and/or decreases in available water (from irrigation or precipitation. In these regions, all of these could be occurring. In the Napa River Marshes, we found a significant positive trend across analyses (Figure 4). A negative trend in the standard deviation for the upper Napa Valley Floor tells us that the variability between years is decreasing for this region. We did not find any negative NPP rates, which are present in other parts of California, that would indicate a net export of carbon dioxide in the atmosphere during these times.

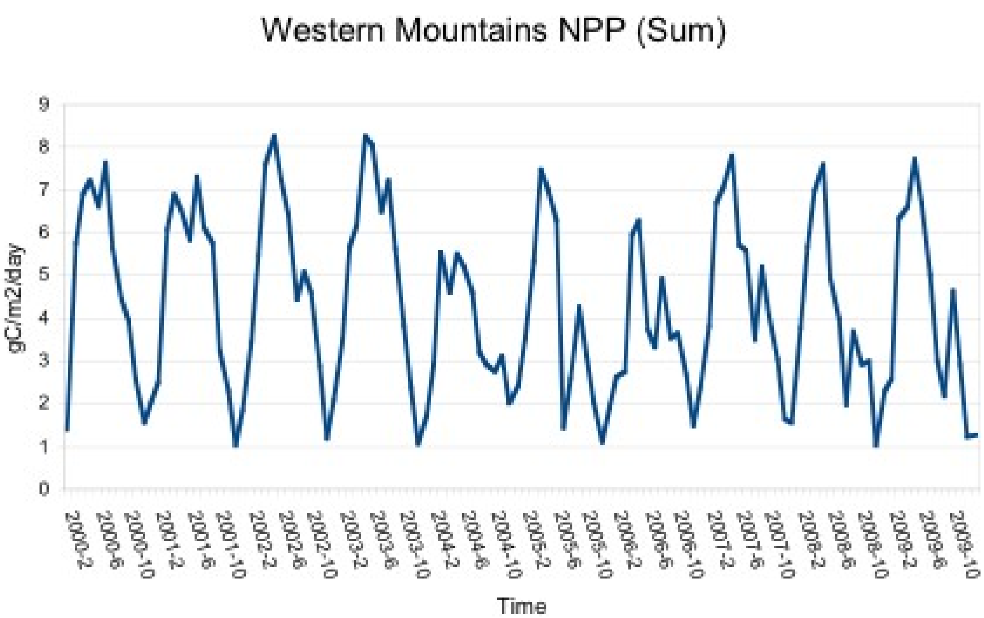

Figure 3: Monthly sums of NPP for the Western Mountains region, showing a statistically-significant downward trend.

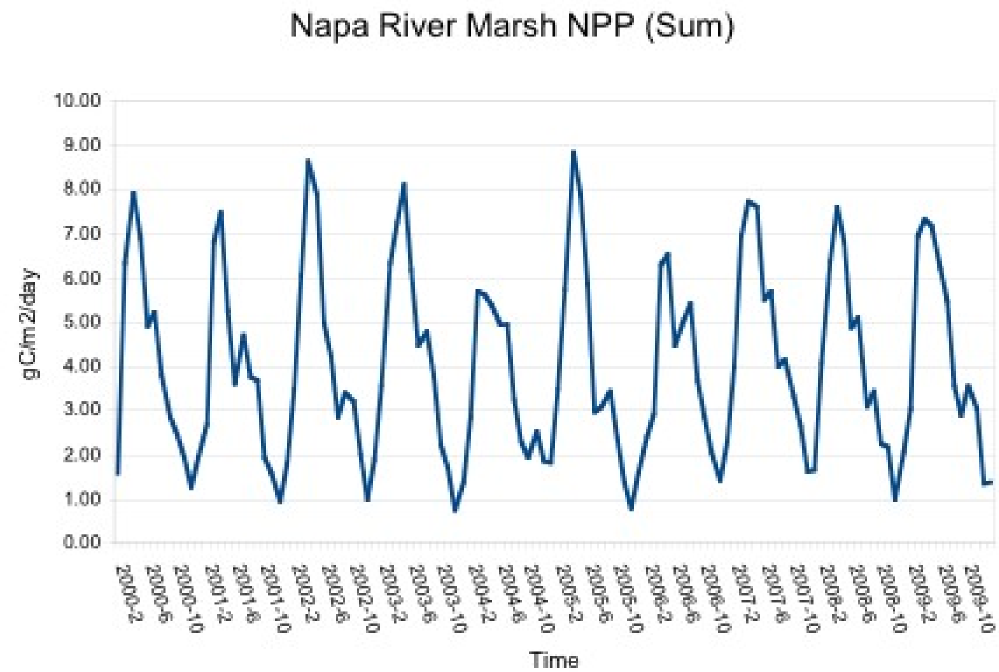

Figure 4: Monthly sums of NPP for the Napa River Marsh, showing a statistically-significant positive trend.

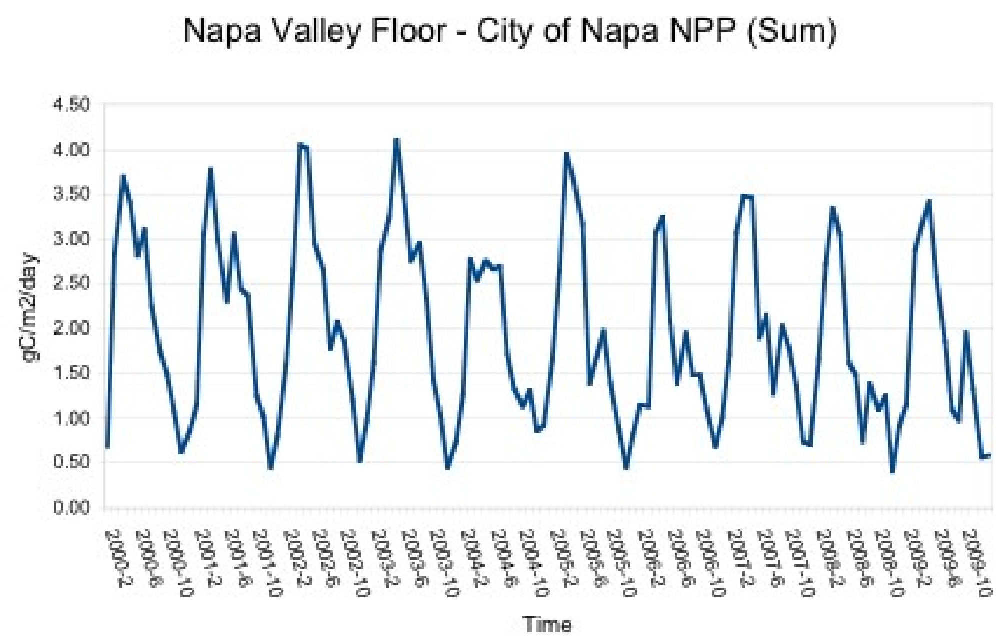

Figure 5: Monthly sums of NPP for the Napa Valley Floor near the City of Napa, showing a statistically-significant downward trend.

Annual Trend

NPP values were combined to create an annual average for each study region and then analyzed for trend using the Mann-Kendall and Regional-Kendall statistical tests. The data were aggregated from the monthly NPP values, where the annual sum is the sum across all months, annual mean is the mean across all months, annual maximum, annual minimum, and the mean standard deviation for all months in the year. Somewhat surprisingly, we found no trend in these data for any of the five aggregations.

Temporal and spatial resolution

Carbon standing stock was measured at 100 m resolution with vegetation data that was roughly a decade old. The NPP data were at a 0.1 degree resolution, which is equivalent to roughly 10 kilometers squared, using data that are recent and updated. The standing stock is unlikely to change rapidly over areas the size of the sub-regions, but for planning watersheds or similar units it may. NPP changes rapidly (daily to monthly) and high time-resolution is required for accurate estimations.

How sure are we about our findings?

Carbon Stock

Carbon stock estimation is difficult for a number of reasons, and the results above should be treated carefully. First, because estimation methodology depends upon combining synoptic land cover data from remote sensing platforms with plot-level measurements of carbon in living and dead plant material, it is important that the remote sensing-derived map has accurate information about vegetation height and cover. This is challenging because remotely sensed imagery usually only gives spectral information about the top level of the canopy and not the canopy depth, the latter corresponding more closely to volume of aboveground biomass. Also, plot-level data tends to be focused on forest stands (e.g. the Forest Inventory and Assessment plots (Woodbury et al. 2007)), with shrublands and grasslands being sampled more poorly. Carbon estimation is even difficult at the plot level, since the usual technique for estimating carbon stored in a tree is to measure diameter and height and then refer to a set of allometric equations (e.g. Jenkins et al. 2004) relating tree biomass to those parameters, and these equations may have been developed from measurements of trees located in a very different landscape than one's study plot.

For this particular analysis of carbon stocks, a couple things to note are the following. First, using the estimator equations in Brown et al. (2004) involves reducing the land cover data to types that are not very specific to California vegetation. It would be best if this assessment was made using equations based on California vegetation types, if these were available. Second, the reference condition assumes that carbon storage will be maximized if all vegetation types are at dense cover. This introduces error because some localities will not support dense forest (e.g. sparsely forested upper elevation rocky areas).

The standard deviation measure, which was calculated from the values of all pixels within each sub-region, is relatively high, with values ranging from 2.7 to 11.9 (Table 4). This reflects the fact that only four discrete canopy cover classes were used to calculate the carbon values in each pixel, leading to discrete and well spread apart bins in the output values.

Table 4. Standard Deviation of the mean in carbon stock estimation per sub-regions.

Region	Confidence: Standard Deviation of Carbon Stock Estimate
WM	± 7.3
LW	± 2.7
EM	± 7.4
SVF	± 11.9
NVF	± 9.6

WM: Western mountains. LW: Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon. EM: Eastern mountains, including Angwin area. SVF: South valley floor, including Napa. NVF: North valley floor, including Calistoga, St Helena, and Yountville.

NPP

With regard to NPP, these data were not readily available at the highest resolution provided by NASA. While the GIS processing of the raster data should provide an accurate estimate for calculated parameters, the smallest regions, for example Napa Valley Floor – City of Napa, contain only a few of the low-resolution data cells that NASA currently provides through their website.

Recommendations

Because of the degree of interest in carbon sequestration and carbon stocks, data sources for making such assessments are continually improving. For instance, the 2010 Forest and Range Assessment of the California Department of Forestry and Fire Protection (http://frap.cdf.ca.gov/assessment2010.html) includes analyses of threats to forest carbon. When data from this study becomes available, it will allow more accurate and up-to-date analyses to be made of regional carbon stocks. We recommend that future assessments review new data sources for deriving carbon stock.

In terms of trend analysis, higher NPP resolution would provide a more accurate indication of trend in each of these sub-regions. The data which are freely available to download are provided at 0.1 degrees, and at the latitude of Napa County, this is approximately eight kilometers (8 km). Higher resolution data might reveal more variability between the sub-regions.

Technical Information

Data Sources

The primary GIS data source for the carbon stock calculations was the CalFire Multi-Source Land Cover layer (Fire and Resource Protection Program 2003) which provides 100 meter resolution habitat data for all of California. This dataset was compiled in 2002 by amalgamating the best available local sources for land cover information in California present at that time. Most of these local data sources were made available in the period from 1993 to 1998. Equations for calculating carbon stock were from Brown et al. (2004), using equations originally published in Smith et al. (2003).

In February 2000, the Moderate Resolution Imaging Spectroradiometer (MODIS), aboard NASA's Terra and Aqua satellites, began producing regular global estimates for GPP and NPP at a spatial resolution of one square-km. When analyzing data from satellites, the scale, or resolution, which the data is collected can greatly influence the analysis. We downloaded these data from NASA Earth Observations, which provides global NPP data at a 0.1 degree scale (equivalent to approximately 8.5 km east/west and 11 km north/south at the study site). While this analysis could be improved with a finer-scaled dataset, with an average of 16.5 pixels for each sub-regions, this provided enough data to make estimates of general trends. The full dataset available was downloaded, with a temporal scale from February 2000 to January 2010 (120 GIS layers). These data were downloaded as georeferenced .tif files at the highest resolution (0.1 degrees) and as floating point pixel values. Each pixel represents the rate of NPP as grams of carbon uptake per meter squared per day ($gC/m^2/day$), averaged over the 0.1 degree box and for that month.

The downloaded MOD 17 data is a product consisting of 8-day Net Photosynthesis (PSN) and Net Primary Production (NPP). Annual NPP is the time integral of the PSN product over a year.

These NPP data were used to provide an estimate of NPP for this study region. It has been previously found that areas recently affected by fire can cause the MODIS algorithm which is used to estimate NPP (MODIS 4.1 fPar) to overestimate NPP for many terrestrial ecosystems (Cheng, et al. 2006), and therefore, if the specific values were important, another data source should be used to validate MODIS data. Since this study has a coarse spatial resolution with a fairly stable ecosystem, we use these data to analyze the overall trend and assume a consistent variation of NPP estimates.

Data Transformations

We calculated the indicator value for each sub-region in two steps. First, in a raster calculation we divided the estimated carbon stock layer by the target condition stock layer to produce a fraction giving the percent of maximum carbon storage for each pixel. Second, we averaged the carbon stock values for all pixels within each sub-region to produce a value for each sub-region. We calculated a measure of variation for each sub-region in a similar way by computing the standard deviation of the values of all pixels in each sub-region.

Analysis

Carbon Stock

Brown et al. (2004) provided the first comprehensive evaluation of carbon storage and greenhouse gas emissions across agricultural lands, forests, and rangelands in California. We followed their methodology at a watershed scale in this analysis. They used the CalFire, Fire and Resource Assessment Program Multi-Source Land Cover (MSLC) layer as well as Land Cover Mapping and Monitoring Program (LCMMP) change maps to assess changes in carbon stock in the 1990s, referring to Smith et al. (2003) for measures of carbon content by forest cover type.

In particular, the CDF MSLC layer provides habitat mapping for the state to 100 meter resolution using the vegetation classification from the California Wildlife Habitat Relationships mapping system (Mayer and Laudenslayer 1988). In addition to the vegetation type, this dataset gives information on vegetation canopy cover and canopy size where source data was available. The methodology in Brown 2004 calls for crosswalking the CWHR vegetation types to

5 forest types given in Smith (2003), namely Douglas fir, hardwoods, redwoods, fir-spruce, and other conifers. Taken together with canopy cover information, the equations in Brown (2004) allow for estimation of the carbon content (Table 5).

Table 5. Summary of equations available to estimate carbon standing stock in forest from Brown et al. (2004). In these equations, x is the canopy cover in percent, and y is the amount of carbon in Mg C/ha.

Habitat type	**Carbon estimation equation**
Douglas fir	y = -101 + 96 ln x
Fir-spruce	y = -125 + 83 ln x
Hardwoods	y = -70 + 52 ln x
Other conifer	y = 59 + 2 x
Redwood/sequoia	No equation provided, instead use carbon values of ~90 Mg C/ha for canopy densities < 40 %, and carbon values of ~300 Mg C/ha for canopy densities > 40% (the graph provides only 4 points because of scarcity of input data)

For shrublands and grasslands, Brown et al. (2004) use estimates for carbon content derived from other literature. In their report, Brown et al. (2004) do not provide carbon content values for woodlands, so we used the USDA Forest Service Carbon Online Estimator (NCASI 2010) to give carbon estimates for different age classes of blue oak, blue oak woodland being the dominant woodland habitat in the Napa River watershed.

In a raster GIS, we selected the portion of the MSLC layer that covered the Napa River watershed and restricted the analysis to the boundaries of the watershed using a raster mask. Using the CWHR habitat types in the MSLC layer and the crosswalk described above, we reclassified vegetation pixels within the watershed to one of eight vegetation types: either the five forest types listed above, shrublands, grasslands, or oak woodlands. We did not treat agricultural lands or developed lands in our analysis, and also masked these out. The MSLC layer provides canopy cover information using the four canopy cover classes described in CWHR, namely sparse (10-24% cover), open (25-39%), moderate (40-59%) or dense cover (60% or greater). In pixels where the MSLC layer did not identify a canopy cover value, we assumed this value was moderate cover.Using the mean values of the canopy cover class intervals, we took the carbon estimation relationships described above for the eight vegetation types to create a lookup table from which we assigned each pixel a carbon content value. All carbon stock GIS calculations were performed in the GIS GRASS (Neteler & Mitasova 2008).

We calculated a target condition layer using the same method, except that instead of taking the canopy cover value to be the actual value from the MSLC layer, we assigned it to dense cover. Because the carbon estimation relationships all reach their maximum value in the dense cover condition, this forces the output layer to have the maximum stock possible while keeping vegetation types the same for each pixel.

We intersected these raster data for carbon standing stock and the sub-region boundaries to generate a mean value per sub-region.

NPP

NPP spatial analysis was done with ArcMap 9.3 and a series of Python scripts using the arcgisscripting engine. The Napa River watershed was detailed by a vector polygon, and the zonal statistics aggregated the raster (pixel-based) dataset and summarized the results. A third party product, Hawth's Tools version 3.27, was used to perform raster analysis, specifically the Zonal Statistics, on the set of NPP raster layers. Zonal Statistics produces a data table which includes the summation, minimum, maximum, mean, and standard deviation of the raster NPP values for each sub-region. These data were then transformed from a column format (where each column represents a montly results) to a "long format", where month is its own column and has subsequent columns for the corresponding data value.

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School Lunch Program Enrollment

Goal:

Support community planning and management actions that protect and improve adequate public facilities and infrastructure, including affordable housing, in order to further the goal of a healthy, happy, and economically just community

Objective:

No specific objective

WAF Attribute:

Economic condition

Table 1. Score, trend, and reliability for: *School lunch program enrollment*.

Subregion	Score (0 to 100)[1] ± standard deviation	Trend (Slope %/year)	Reliability of findings[2]
Napa River watershed	57.6	Declining (1%)	High
Napa River watershed subregions:			
Western mountains	ND	ND	ND
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	44.7	Declining (1.5%)	High
Eastern mountains	54.8	Level	Low
South valley floor	69.8	Declining (0.5%)	High
North valley floor: North of Oak Knoll Avenue	61.0	Declining (0.7%)	High

[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] ND indicates that the score or trend was not determined because data were not available or sufficient.
[3] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

What is it?

Enrollment of children in school lunch programs is considered to be a sensitive measure of poverty at the sub-municipal scale. Children between 6 and 17-years-old are eligible if family income is less than the federal poverty level. This means that the metric is not particularly sensitive to geography-specific cost of living variation (Curran et al., 2006; Heflin et al., 2009), a limitation in its use. Data are available for every school that is participating in the federal program, including schools in the study area, for the last 20 years.

Why is it Important?

Poverty and income inequities are correlated with reduced life expectancy (Singh and Siahpush, 2006), child well-being (Pickett and Wilkinson, 2007), and academic performance (Caldas and Bankston, 1997).

Enrollment in school lunch programs is an extensive (data available for every school) but fairly general indicator of poverty. Because there are data for every school and every year, spatial and temporal resolution for this indicator is moderate. We can answer questions related to rate of poverty for individual schools (K-12) and change in this rate over at least the last 20 years.

Because rates of enrollment are available for each school, correlations can be drawn between this poverty indicator and other municipal or subregion condition and trends in condition.

What is the target or desired condition?

Community economic conditions can affect opportunities and sense of welfare for children and adults. Absent a state or local policy that states an acceptable level of poverty, we defined 0% school lunch program enrollment, as a good target score (100) and 100% school lunch program enrollment as a poor score (0). We used a linear function to calculate score, where Score = 100% - % children enrolled.

What can influence or stress condition?

Poverty is caused by a variety of factors, including employment availability, legacy of poverty, regional economy, and skills for employment. In this region, agriculture and wine-making provides much of the land-based income. Over the last few decades, influx of wine-related employment, retirees and ex-urban migration from San Francisco and the East Bay has led to changing demographics, including income. Global and statewide economic trends are likely to influence community economic condition. Communities that derive their economic well-being from productivity that tends to do well in or is independent from global markets may be less negatively impacted by economic declines.

What did we find out?

Condition

The valley floor communities and rural areas tended to have lower enrollments of children in school lunch programs, reflected in their higher scores. In contrast, certain valley floor community schools and the Vallejo area (lower watershed) had high enrollment rates and thus lower scores for community economic condition. In the lower watershed, Napa County schools had higher scores than nearby Solano County schools.

There was considerable year-to-year variation in enrollment rates (Figure 2), though it is unclear what drives this variation. It appears the school enrollment rates vary together, suggesting that large-scale economic conditions are responsible.

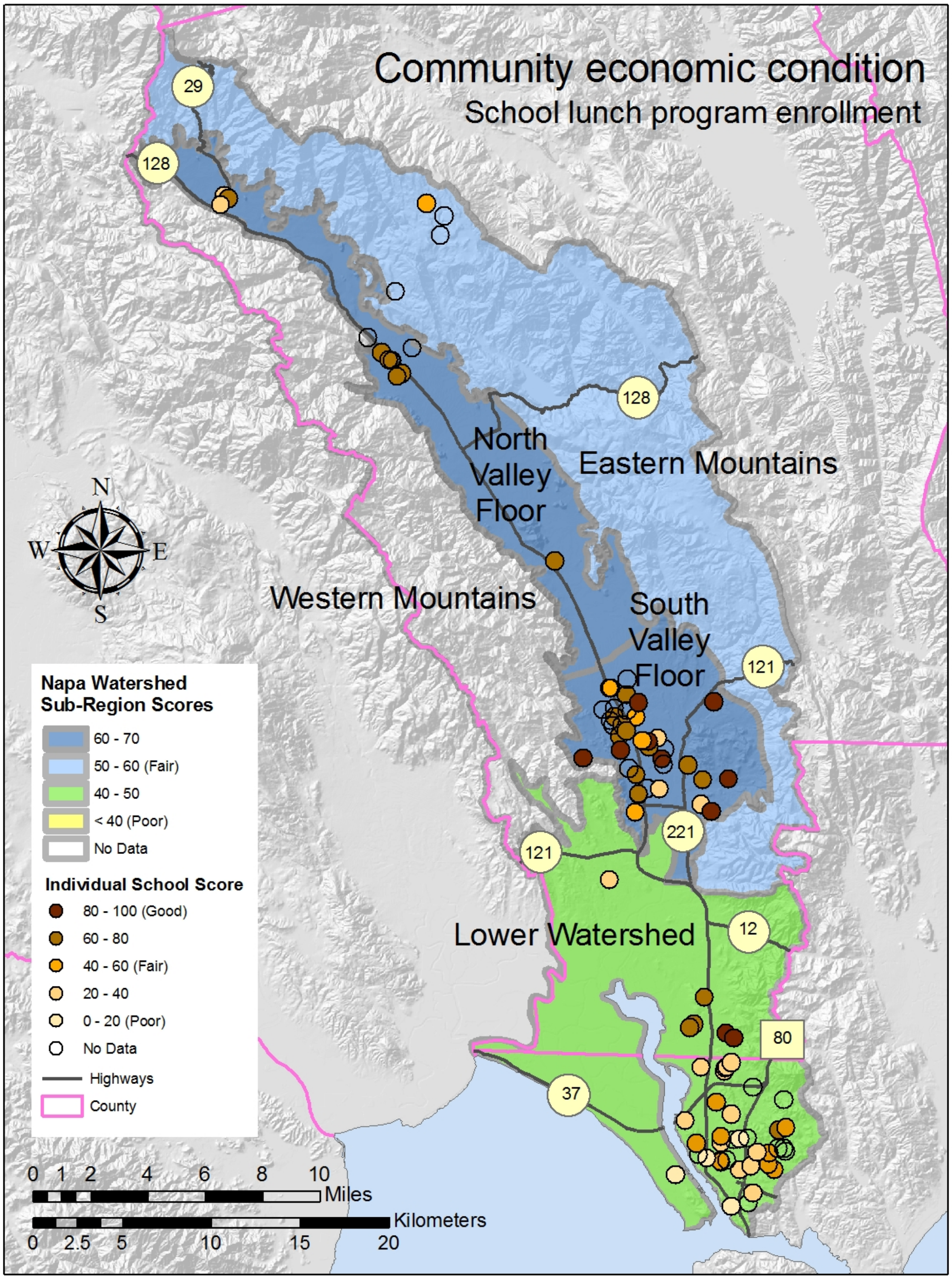

Figure 1. Distribution of schools and economic condition scores per school across subregions.

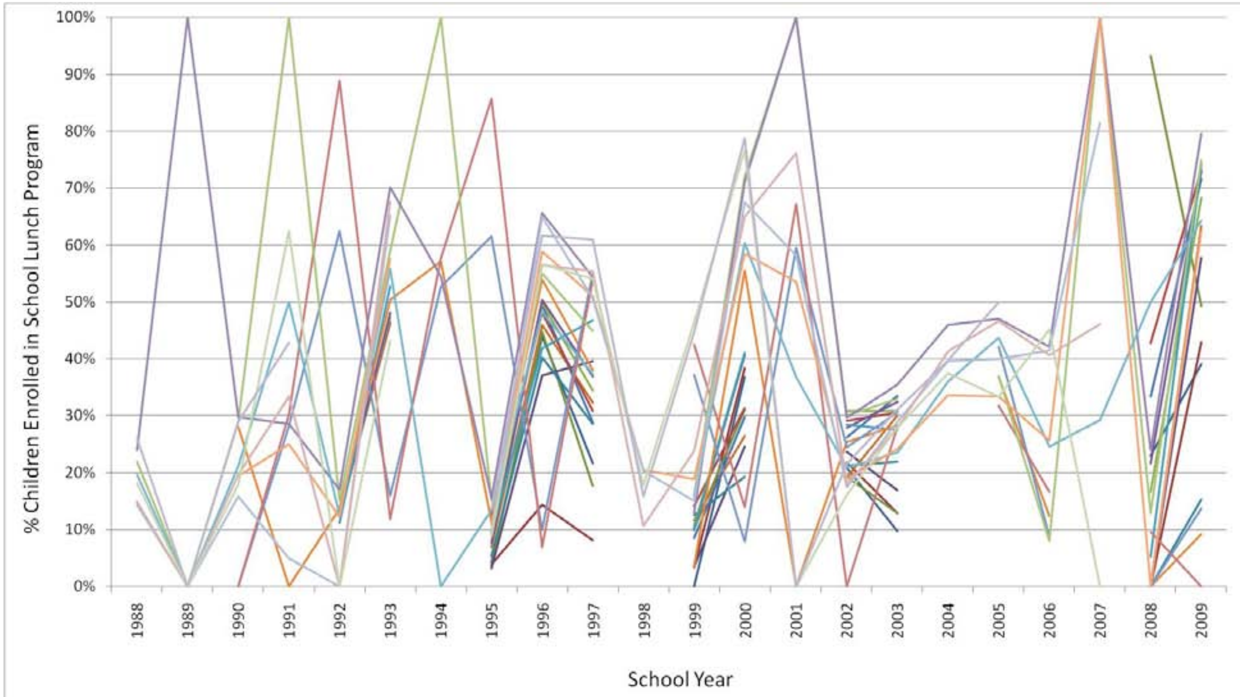

Figure 2. School lunch program enrollment rates for individual watershed schools between 1988 and 2009. The percentages are for the whole school year

Trend Analysis

There was a statistically significant upward trend in school lunch program enrollment in the watershed over the 22-year period ($p < 0.001$), with a 1.0% increase per year. This significant increase in enrollment was true of both Napa County and Solano County schools. In Napa, the increase in enrollment was 0.6% per year and in Solano, 1.6% per year. Forty-two of the watershed's 87 schools individually increased in enrollment ($p < 0.05$), with 41 showing no statistically-significant change, and 4 Napa County schools showing a decrease in enrollment. At a subregional level, there were significant increases in enrollment in 3 of the 4 subregions. In the 4th case, Eastern mountains-Angwin subregion, there was 1 reporting school and no significant trend. In the Lower watershed subregion, there was a significant increase in enrollment ($p<0.0001$) for the whole subregion, with 24 of 37 schools exhibiting significant increases and the remainder having no significant change. In the South valley floor (city of Napa area), there was a significant increase in enrollment ($p<0.0001$) for the subregion, with 13 of 35 schools increasing, 4 decreasing, and the remainder not changing significantly. In the North valley floor subregion, there was a significant increase in enrollment ($p<0.0001$) for the subregion, with 5 of 12 schools increasing significantly and the remainder showing no change.

Temporal and spatial resolution

Because there are data for every school and every year, spatial and temporal resolution for this indicator is moderate. Annual enrollments are reported for each school participating in the program. Therefore, the assessment can be updated annually, unless monthly data were to be collected from individual schools.

Four of the five subregions had at least one school, but there was a wide difference in number of schools between the Eastern Mountains (1 school) and the Lower Watershed (34 schools), which affects the calculation and meaning of the average score for each subregion.

How sure are we about our findings?

The data used for this indicator are based on school enrollment figures, reported to the California Department of Education. They are complete for 1988 to 2009. The precision of these data is likely very high. The calculated average score for each subregion reflects the average condition for that area, the 95% confidence interval and minimum and maximum scores reflect the variation around the averages, which can be fairly large Table 2).

Enrollment is based on a family being below federal poverty level. This means that the metric is not particularly sensitive to geography-specific cost of living variation (Curran et al., 2006; Heflin et al., 2009), which is a limitation in its use. There may also be an effect of peer-pressure on children's desire for enrollment.

Overall our confidence is high in the precision of the indicator, moderate and variable about how well the average value for each subregion reflects conditions, and moderate to high for how well the indicator reflects community economic well-being.

Table 2. Basic statistics for school lunch program per subregion. Minimum, maximum, Standard deviation, mean, and 95% C.I. are for % of children receiving free lunches in each sub-subregion. "95% C.I." refers to 95% confidence intervals.

Subregion	N	Min	Max	Std-Dev	Mean	95% CI	Score
Lower watershed	34	0.0%	94.4%	23.09%	55.3%	7.76%	44.7
Eastern mountains	1				45.2%		54.8
North valley floor	11	21.7%	61.6%	14.01%	39.0%	8.28%	61.0
South valley floor	29	0.0%	72.2%	19.28%	30.2%	7.02%	69.8

Lower watershed: Carneros Area, Napa River Marshes, Jamieson/American Canyon, and Vallejo. Eastern mountains, including Angwin area. South valley floor, including Napa. North valley floor, including Calistoga, St Helena, and Yountville.

Technical Information

Data sources:

California Department of Education (http://www.cde.ca.gov/ds/sh/cw/filesafdc.asp); USGS Geo-Names Database (http://gis.ca.gov).

Data transformations:

Data were manually assembled from downloadable files. For school years where the year was given by “88/89” or similar, a new column was created and actual year-dates manually entered corresponding to the end of the school year (e.g., “1989”). Only percent of students receiving “free meals”, as opposed to reduced-price, were calculated and used to be consistent over the whole time-span.

Condition Analyses:

The percentage of students receiving free meals was extracted from the CDE database for 2008, the last year with complete data. The subregional location of the school was determined using spatial data from Solano County and Napa County. Each school was attributed with a subregion based on its location. For each subregion, mean, standard deviation, minimum, and maximum percentage of children receiving free lunches were calculated.

Trends Analyses:

The Mann-Kendall Regional trends analysis was used in R, using the methods described in Section 3.

Recommendations

This indicator is most sensitive when put in the context of regional cost of living. For example, if the cost of living is high in a particular community or area, then families that meet the federal poverty level will have a harder time making ends meet than in areas that have a lower cost of living. A feasible improvement for this indicator would be collection of monthly rates of enrollment for each school. This would allow condition assessment at different times of the year when seasonal unemployment may change the economic status of communities.

Citations

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Housing Affordability

Goal:

Support community planning and management actions to further the goal of a happy, healthy and economically just community

Objective:

No specific objective

WAF Attribute:

Economic Condition

Table 1. Score, trend, and reliability for: *Housing affordability*.

Subregion	Score (0 to 100)[1] ± standard deviation	Trend	Reliability of findings[2]
Napa River watershed	58	Declining	Moderate – High
Napa River watershed subregions:			
Western mountains	66	Declining	Moderate
Lower watershed: Carneros region, Napa River marshes, American Canyon, Vallejo	60	ND	High
Eastern mountains	66	Declining	Moderate
South valley floor	57	Declining	High
North Valley floor: North of Oak Knoll Avenue	40	Declining	High

[1]Scores close to zero indicate extremely poor watershed health; scores close to 100 indicate excellent watershed health. The indicator score is developed using one or more metrics described below.
[2] ND indicates that the score or trend was not determined because data were not available or sufficient.
[3] The definition of low, moderate, and high reliability of findings is located in the Reporting Plan, Appendix 8.7.

NOTE: The indicator score is developed using multiple metrics described below. Because the score reflects the joint distribution of these metrics, the SD is difficult to interpret and is not reported here. The “trend” reported in the table is for the period 2000 to 2007. The score for the watershed as a whole is an estimate obtained by averaging the values for the two most populous subregions.

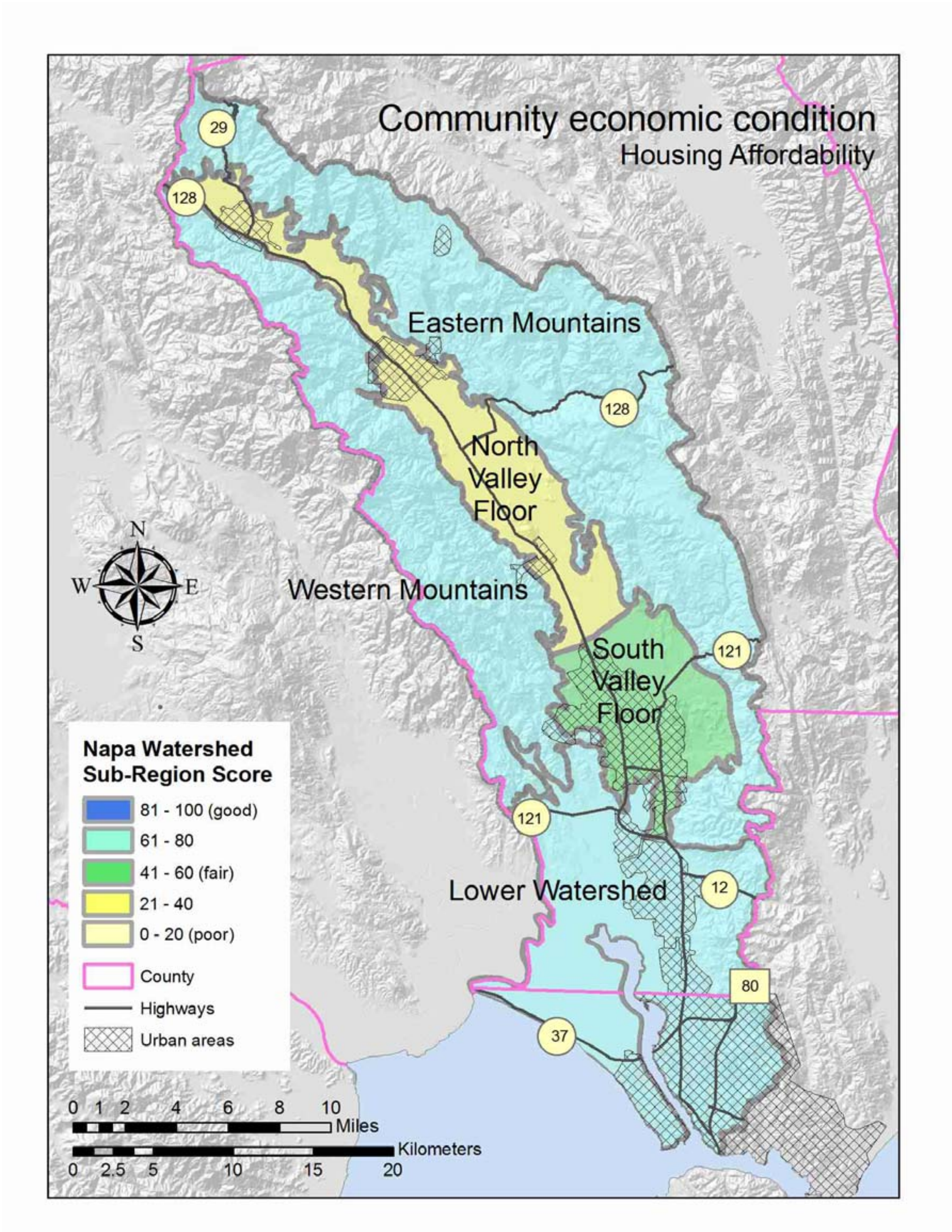

Figure 1. Scores for Housing Affordability indicator

What is it?

Figure 2. PLACES, Napa Valley Community Housing, Yountville

Housing affordability is generally measured as a function of a household's income and the current costs of housing. Income is calculated in terms of disposable income (i.e., after taxes) while housing costs include monthly principal and interests costs, along with property taxes and insurance. Because an affordability index is constructed with measures of both household income and housing prices, it serves as a useful indicator of the economic well being of a community. Such an index can also provide information on well being across various income classes, by distinguishing the housing cost burden or affordability across household incomes. Indices keyed to income categories can thus offer insight into the economic equity found within a community. For example, an index indicating an increase in affordability across lower income classes would signal that a community is progressing in terms of both overall economic well-being and economic equity. Similarly, indices of affordability across communities can suggest if there are disparities in housing affordability, and if so, what local policy makers can do to help improve the distribution of affordable homes.

Why is it Important?

Access to affordable housing is identified as a fundamental human right by the UN Millennium Assessment. Within the US, home ownership is considered important to the development of stable communities and is believed to lead to citizen involvement in the management and governance of local communities. In addition, increasing the level of home ownership is viewed as a socially desirable outcome in terms of the economic well being of both the citizens who purchase such homes and those who construct homes. As a result of these positive externalities from home ownership, government at all levels encourages home purchases through favorable tax policies, implicit subsidies on mortgage loans, preferential zoning for low income housing and other programs.

The purpose of the varied government incentives for home ownership is to make housing accessible to a broad segment of society. In general, the more people who can afford a home, the better the economic and social situation within that community. As noted above, access to a home is typically a function of household incomes, housing prices and the cost of home ownership, such as mortgage payments and property taxes. Data on these inputs are commonly available, making construction of indices of housing affordability for a community a straightforward process.

What is the target or desired condition?

A favorable condition or outcome is increasing housing affordability within a community. Any concept of affordability must recognize that some households are willing to commit more of their disposable income to the servicing of household debt and costs than are other households. Thus, some households may be willing to commit a conservative portion of their disposal income to housing costs, whereas others may be willing to bear a greater cost burden, i.e.; commit a greater share of income to housing. Assessments of "affordability", such as those used by HUD, generally measure this housing cost burden in such percentage terms; i.e., if the burden or share exceeds 30 percent of household disposable income, the level of affordability is interpreted to be diminishing (or, according to HUD, the burden of household ownership is shifting from comfortable-less than 30 percent, to severe-more than 50 percent). While it is unlikely any community will achieve an index or outcome where every household can comfortably afford a home (spend less than 30 per cent of disposable income on housing), if incomes are rising faster than housing prices and associated costs of housing, the level of "affordability" will be increasing.

What can influence or stress the condition?

As noted above, housing affordability indices reflect the interaction of household incomes and housing costs. Thus, any increase in incomes, combined with static or declining housing costs, would increase housing affordability. Conversely, static or declining incomes in the face of rising housing costs will lower the level of affordability.

Both of the drivers of affordability, incomes and housing costs, are in turn a function of macroeconomic forces that often are beyond the control of local policymakers or stakeholders. However, some facets of housing costs, such as land available for development and thus the stock of housing, may be influenced by local land use policies. Similarly, policies to encourage creation of high wage jobs within a community could also assist potential homeowners through the increase in incomes that may flow from such jobs.

What did we find out?

A recent report by Bay Area Economics (BAE), entitled "County of Napa Housing Element Update, Housing Needs Assessment" provides measures of housing affordability for a number of communities and locations within Napa County (see tables 4, 5 and 14). These indices report the levels of households able to afford a home in terms of the housing cost burden assumptions employed and suggest that Napa County, in general, has less affordable housing, when measured across various income categories, than some neighboring counties. For example, households with low to moderate incomes in Napa County spend a larger portion of their household disposal income to afford a home than in adjacent counties. In fact, of households in unincorporated areas of the county with moderate to above average household incomes, only 66 percent can "comfortably" afford a home (30 percent or less of their disposable household income spent on housing). Averaged across all households in unincorporated areas, only 54 percent of households can afford a home under this level of burden.

Using data reported in the BAE study on income and housing prices by location within the county, we constructed affordability indices for the five subregions within the county. As indicated in Table 1, the percentages of affordability are lower for the communities within the county than for the unincorporated areas reported in the BAE report because these locations have either lower incomes, higher home prices, or both, than the unincorporated areas.

Figure 3. Farmworker housing, River Ranch, St. Helena

Temporal and spatial resolution

The results reported in Table 1 reflect data for 2007/2008. As noted below, we suggest that the trends in housing affordability are best measured over sufficiently long time periods to allow macroeconomic trends and local policies to be fully incorporated. This may require that the trends be based on changes over multiple years, for example, up to a decade (to coincide with Census data).

Spatial resolution is limited by the scale at which housing cost and income data are collected. Fortunately, income and housing data are location (community) specific within most counties. This allows the construction of indices for subregions within Napa County.

How sure are we about our findings

The affordability indices reported here are based primarily on governmental data sources and on simplifying assumptions concerning incomes (median) and housing prices (median) at various locations within the county. One could construct a range of affordability indices for each community, based on the distribution of incomes and housing costs within each locale. Selection of which to construct and report would depend on the overall purpose of such an indicator. We feel that the use of median incomes and housing costs provides reasonable information with which to assess general economic conditions related to affordability. However, if distributional issues are of greater importance to policymakers, then future assessments may wish to focus on lower income households.

Technical Information and analysis

We suggest using the protocols and data sources defined within the BAE report to develop and maintain an ongoing indicator of housing affordability for locations within Napa County. Specifically, BAE uses HUD reports and Census data to obtain data on household income, by locale, as well as data on housing prices from local sources, and interest and other parameters the determine housing cost burdens from state sources. For ease of use and as an initial starting point in the implementation of the WAF process, we suggest using the percent of households with median household incomes (defined by HUD as 80 to 120 percent of the Average Median Family Income or AMFI) who fall within the 30 percent or less housing cost burden as a measure of affordability for the communities (and unincorporated areas) of Napa County.

Since the level of housing cost burden or affordability is not likely to change as rapidly as some other indicators within the WAF process, it is also suggested that the affordability measure be updated less frequently. This may be done according to Census years (thus once every 10 years) to take advantage of those data. If a more frequent update is desired, this housing cost/affordability measure can be updated by adjusting the income levels for each location within the county using California Department of Finance data, along with DataQuick or other sources of current housing costs.

Citations

Bay Area Economics, 2009. County of Napa Housing Element Update, Housing Needs Assessment. June 23, 2009. For protocols to construct and modify housing cost burden measures)

California Department of Finance (for county specific measures of income and inflation changes).

DataQuick.com. 2008 (for real estate price changes)

Department of Housing and Urban Development. 2000 Comprehensive Housing Affordability Strategies (CHAS). Accessible at huduser.org, 2008

US Department of Commerce, US Census, 2000

5. Interpretation

Discussion of findings

The discussion here is limited to issues which are currently evident to the project team. In Future work, either by the state, Napa County or members of the project team, we hope to build upon what is presented here and to continue the discussion and use of indicators for determining and monitoring watershed condition.

Are we reaching our goals?

The watershed scores across all 14 indicators are not extreme, in the positive or negative sense; all of them lie between 38 and 97. However, conditions overall are fair relative to goals for the watershed. In summary, we are only partially meeting our goals for a healthy watershed.

How healthy is the watershed?

Based on the objective measures used here, watershed health can be described as fair. For certain indicators and certain subregions, conditions are good. For example, terrestrial and aquatic conditions tend to be better in the less disturbed eastern and western mountains. For other indicators and subregions, conditions tend to be poor. For example, aquatic and biological conditions in the developed valley floor tend to be worse than the mountains. This does not mean that conditions in the Napa River watershed are worse than other watersheds in California. Many of these watersheds are in fair or worse condition. What should be of most concern to Napa River watershed residents is that conditions are only fair and that for many indicators, there is a measurable decline in condition. Of the four indicators for which a trend could be calculated, three are shown as declining while the other is level. This leaves out of account the *Groundwater* indicator, which by definition reflects a decline in the water table, although for technical reasons no trend is shown. Of course, the larger issue is that no trend could be ascertained for about half the indicators. Knowledge gained about these measures of watershed vital signs can help turn these declines around and encourage a trajectory toward a healthy watershed.

How reliable are the indicators and findings?

The reliability of findings varies dramatically among the 14 indicators we have scored. there is one indicator (*Persistence of Sensitive Bird Species*) for which the reliability of findings is low for all five subregions, and one (*Landscape Fragmentation and Connectivity*) which enjoys uniformly high reliability. The others lie in between. When evaluating results for each indicator, it is important to note the information on reliability in Table 1 for that indicator.

Missing Data

Sometimes a given indicator has no score for a particular subregion; this may be because it does not apply there or because there are insufficient data to support a score. For example, there are no schools in the Western Mountains subregion, so the *School Lunch Program Enrollment* indicator was not scored for that subregion; and the *Water Temperature* indicator, to choose one example from several, has no score for the Eastern Mountains subregion for lack of sufficient data. Of the four subregions for which the *Water Temperature* indicator does provide a score, the reliability is rated variously as high, moderate, or low, depending on the available data. As one would expect, the three lowland subregions (Lower Watershed, North Valley Floor, and South Valley Floor) have better data and thus better reliability ratings for this indicator. The reader should note the variability in reliability of an indicator over different subregions.

Targets and scoring

Setting targets and scoring the indicators presented a number of unique challenges. As described in Section 3.2, we defined a reference or target condition for each indicator, with which the value of the indicator metric could be compared. The aim was to present a score on the scale of 0 to 100, where 0 means a very poor condition and 100 means a very good condition. The *Water Temperature* indicator report presents a scaling curve, to convert values of water temperature, over the range of meaningful variation for salmonid habitat, into a linear scale. This means that a score of 50, for example, can be interpreted as halfway between the two extremes. Something similar was attempted for every indicator, and the means chosen were necessarily as various as the indicators. The selection of scoring range endpoints (0 and 100) was sometimes difficult. For several indicators, one endpoint or the other was defined by the historical data available. In *Water Use Efficiency*, for example, which is focused on residential water conservation, the 0 endpoint was defined by the highest daily per capita use in the years before the drought of 1987-92.

We defined a scoring range from 0 to 100 that would correspond roughly to the terms poor – fair – good, and in several of the reports these verbal descriptors have been applied to the results. In a general way, the various indicators can be compared in this fashion. Because each indicator is re-scaled to a 0 to 100 scale based on comparison with poor and good references, the indicator scores are comparable to each other.

Independence of indicators

Ideally, all indicators would be independent of each other; that is, their scores would be affected by different external forces such as watershed management actions, weather, fire, or economic conditions. In reality, none of the indicators analyzed is strictly independent of the others; the question is one of degree. The project team believes that each is different enough from the others to reflect a useful aspect of watershed health.

Findings for subregions

The findings for the subregions should be viewed in light of their physical differences. The Napa River watershed is divided into three lowland sections along the main stem of the river (North Valley Floor, South Valley Floor, and Lower Watershed), and two mountainous ones, Eastern Mountains and Western Mountains. As a result, there are a number of systematic differences to be observed among the five subregions. The urban centers and agricultural areas are primarily in the lowlands, although there is one significant center of population in the Eastern Mountains (Angwin) and significant agriculture throughout the Eastern and Western Mountains. The difference between the mountains and the valley underlies several systematic differences between the subregions as analyzed in this project, such as the following:

- *Recreational Access to Open Space* has dramatically different results in the mountains and in the valley.
- There are few schools in the mountains, so *School Lunch Program Enrollment* comparisons between subregions are difficult.
- Fewer observations of *Water Temperature* are made away from the main stem of the Napa River, which lies in the lowlands.
- Bird observations are not representatively distributed over all subregions, but tend to be concentrated in the lowlands.

Because of such differences, there are fewer scores for the mountain subregions, and the scores that are given for those subregions are sometimes less reliable. An interesting consequence of the distribution of bird data is that all scores for *Persistence of Sensitive Bird Species* have low reliability.

There are several indicators that do not lend themselves to subregional analysis, because they are not distributed in that manner. For example, the *Local Media Coverage* indicator makes use of the sole local newspaper of widespread circulation in the Napa River watershed, which is the *Napa Valley Register*, published in Napa. For this indicator, no subregional scores can be given. For *Water Use Efficiency*, which looks at residential water use, the only useful data are from the City of Napa. Another recent watershed health indicator project, the Napa-Sonoma Scorecard (SEC and Napa RCD, 2010), treated this one water purveyor as a proxy for the entire human community in the watershed; the present project has not made that simplifying assumption, but has instead associated the City of Napa with its local subregion.

It is natural to consider aggregating results for individual subregions, to ask what the watershed health score is for a subregion. To the extent that we have scores within subregions that are reliable and comparable, in the sense that they use the same scoring scale, one can consider aggregating them. However, we have not yet taken that step.

Aggregating indicators to goal or WAF attribute

Another way to interpret the data is to aggregate the results for indicators into a composite score for each goal or WAF attribute. This procedure has the disadvantage that the typical number of indicators associated with a goal or WAF attribute is only two, so the value of averaging is not great. Perhaps the most promising place to try this is for the five indicators under the third goal, with the possible addition of *Stream Temperature*.

Applying this approach to other geographic scales

The approach used here is scalable in the sense that it can be used at virtually any geographic scale. The approach used here, including most or all of the indicators, could be replicated in the other watersheds of the North Bay and possibly the whole Bay Area. The main scoring approaches and framework used could be applied to the Bay and Delta as whole, with the recognition that specific goals, objectives, and indicators might vary across this region. Using similar or identical indicator frameworks and scoring systems among regions is very useful because it allows for comparability. One test for the applicability of this approach to other geographic scales is that so far it has been used to evaluate conditions in the much larger Feather River basin (Sacramento River Watershed WAF project) and is currently being used in the Los Angeles River basin (Los Angeles San Gabriel Rivers Watershed Council WAF project).

There are several attributes of the approach that provide for scalability and comparability: 1) conditions are evaluated based on regional goals and objectives for the combined natural and social system; 2) condition assessments are normalized relative to described poor and good conditions, so that indicator scores all reflect the distance to a target condition; 3) comparable indicator scores on a common scale (0-100) can be easily aggregated with each other; and 4) analyses at hierarchically nested scales (watersheds within watersheds, within regions) can be rolled up more easily.

6. Recommended Next Steps

This chapter provides a summary of recommendations revealed during indicator analysis and the reporting of findings (Section 4), as well as some overall recommendations regarding the application of the WAF.

Improving the quality of results from the data

- Most importantly, conduct peer review of the indicator reports and review the interpretation and recommendations; this may also include some or all of the project processes undertaken.
- Review all targets and scoring to verify that they are structured in a standard manner that makes scores of 0, 50, or 100, for example, mean the same level of watershed health across all indicators.

Improving the basis for the next iteration of scoring:

- Share the results from the project with the stakeholder groups whose goals and objectives were used, and obtain feedback on the appropriateness of the targets selected; this is important because the selection of targets represents a value judgment, which can be guided by science but must ultimately derive from the values of those in the community.
- Consider the appropriate frequency for recalculating results for each indicator. This frequency may be as long as a decade for indicators that change slowly and are conveniently measured by surveys such as census data, but it may be much shorter for other indicators.
- Try to include all the first-tier indicators during the next iteration, including ones that for various reasons didn't make it this time. Data for some indicators may need to be collected. Future monitoring should be evaluated and modified to address this need where practical.
- For a number of the indicators, new and better data are needed. These needs are described in the various Indicator Reports (Section 4). One strong need is for a reliable, meaningful metric and protocol for monitoring summer and fall streamflow levels.

Salmonid populations are another area that needs better data. The latter will be greatly aided by data from the Rotary Screw Trap installed in the Napa River by Napa County RCD in 2008, which will greatly aid in estimating fish populations by direct sampling. Such efforts as this need to be encouraged and continually funded.

Applying the WAF:

The strength of the WAF approach is that it provides a structure that can be applied uniformly across a region of the state. The advantage of our modification to also base evaluations on goals and objectives still permits this broad application. A powerful addition to the state's toolkit would be to use this approach statewide, with either basin or regional goals and objectives setting the stage for objective evaluations of conditions and trends.

Napa County led this WAF effort and can serve as a model for other counties with similar or greater technical capacity to carry out a structured indicator-based evaluation of condition. The approach described here could also be used for non-watershed units.

Obtaining quality data was challenging for this project. If a broader application of this approach is going to be effective, monitoring will need to occur. State and local funding should be set aside to fund coordinated watershed monitoring over the long-term.

7.Citations

NOTE: Citations found in the Indicator Reports in Section 4 are provided at the end of each report.

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