Water security for coastal vineyards and salmon

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Abstract

In 2000 we reported in California Agriculture on the expansion of vineyards into upland coastal watersheds. With this expansion came changes in where, how, and to what extent water is extracted from these watersheds for irrigation, frost and heat protection. Like most wine-grape growing regions around the world, coastal California has a mediterreanean-climate with most of the rainfall occurring in the winter months, followed by a dry period that can last six months. Not surprisingly, in many parts of the Russian River Basin for example, water rights records predict that demand for water during the spring and summer growing season exceeds supply; while streamflow during the wet season exceeds winter water removal estimates. Our monitoring of flow in tributaries of the Russian River reveals dramatic drops in streamflow during spring frost protection periods as well as decreases in flow during extreme hot temperatures. Comparisons between historical and present streamflow data also demonstrate that vineyard development has decreased spring streamflow. Such flow adjustments during the dry season may have consequences to native anadromous salmonids, including sudden drying of gravel bar habitat, higher water temperatures, and changes in the invertebrate prey base. Juvenile salmonids must survive one and sometimes two to three summers in these tributaries before they are large enough to migrate to the ocean, and we show that their survivorship through summer is greatly influenced by streamflow. Increasing winter storage may be one of the only solutions to meet the demand for wine grape production and reduce the impacts

associated with the practice of pumping surface and subsurface stream waters during the dry season. However, hesitance to grant water rights and uncertainties over whether additional reservoirs will lead to cumulative effects on winter flow thresholds necessary to sustain salmonid migration has resulted in a backlog of over 200 requests for additional appropriative rights, many to increase the storage of winter rainfall, since 1990 – creating expensive delays and uncertainty for wine grape growers. We propose a new spatially explicit analysis tool that can help reveal where additional reservoirs for storing winter rainfall are not likely to impact adult salmon passage and evaluate the potential to relieve the observed agricultural impacts on spring and summer streamflow. These decision-support tools are essential to evaluate environmental and economic tradeoffs associated with different water management schemes widely implemented across coastal California, where water for agriculture is not provided by large centrally controlled reservoirs, but relies instead on small water projects.

In 2000 we reported that, due to an increase in demand for premium wine, vineyard acreage had expanded into Sonoma County's uplands replacing natural woodland vegetation (Merenlender 2000). In total, Sonoma County has doubled its acreage since 1995 and the county crop reports an estimate of 60,000 acres of wine grapes. The same is true for Santa Barbara which now has close to 20,000 bearing acres, twice as much as existed in 1996. This represents a significant change in land use for coastal California's watersheds. While some parts of

California have scaled back their wine grape production, this is not the case for the North Coast, which has traditionally produced some of the finest wine. Vineyard development has continued in highly valued appellation areas such Dry Creek and Alexander Valley to meet the demand for high-quality grapes and particular varietals such as pinot noir.

Water supply and demand in watersheds with increasing amounts of vineyard

Like most premium wine-grape growing regions around the world, coastal California has a mediterreanean climate with most rainfall occurring in the winter months, followed by a dry period that can last six months. Precipitation is highly variable, seasonally and inter-annually, leading to an extremely uncertain renewable supply of fresh water. Streamflow follows a similar trend as rainfall with the majority of flow occurring during the winter and early spring, occurring mostly as a series of high-flow events separated by lower winter base flows (**Figure 1**). When rains have concluded, streamflow then recedes gradually to reach or approach intermittence by late summer. Deviations in mean annual flow of 30% or more from long-term annual averages are common, leading to continual uncertainty about water supply year to year (Deitch 2006). In addition to this temporal variability, these regions often have complex tectonic and geologic conditions that may result in high levels of spatial heterogeneity in streamflow within river basins. Natural large freshwater lakes are rare in these areas, and groundwater tends to be deep or restricted to bands along river corridors, so human settlements rely heavily on streams for fresh water.

The separation between the time and location of water availability and the demand from agriculture and other human uses is the primary factor complicating agriculture throughout California, and necessitates water management to allow for a long period of irrigation. (In much of California, these water needs are met through the dissemination of water stored behind large reservoirs. In areas not served by large water projects, which is true for many coastal watersheds where premium wine-grapes are grown, water is often diverted or pumped from the ground, and if possible, stored on site for use during the dry season. In addition to using water for irrigation, grape growers may require water for other purposes such as protection of young buds from frost in early spring, and protection from high summer temperatures in summer.

Wine grape growers have used small-scale water projects to meet water needs for over 100 years and records maintained by the State Water Resources Control Board indicate thousands of requests for riparian and appropriative water rights in the northern California wine country. Recently, the State has hesitated to grant water rights in part because of uncertainties over whether additional reservoirs will lead to cumulative effects on winter flow thresholds necessary to sustain salmonid migration. This inaction has resulted in a backlog of over 300 requests for additional appropriative rights, many to increase the storage of winter rainfall, since 1990 – creating expensive delays and uncertainty for wine grape growers.

Crises over natural resources can arise when there are high risks to both biotic diversity and security of resource supply for humans. These crises are even more likely to occur when water is scarce during a period of drought, such as occurred over salmon declines in the Klamath basin in California (Woodward and Romm 2002). Our research and education program is focused on increasing our understanding of the coupled human and natural system of the coastal Russian River basin (**Figure 2**) in order to better balance the need for water by agriculture and ecosystem processes, with a goal of improving salmon restoration efforts and avoiding environmental crises. More specifically in this paper we reveal how water management for vineyards along tributaries to the Russian River influences streamflow which can impact fresh water ecosystems and the salmonids that rely on them. This is of great importance to water management throughout California's premium wine country.

Fish need water: maintaining ecological flows

Despite the harsh conditions of winter flooding and summer drought that the Mediterranean-climate places on aquatic ecosystems, the life cycles of steelhead trout and coho salmon are well-adapted to the natural hydrologic regime of the region (Moyle 2002) (**Figure 1**). Winter floods maintain appropriate sediment distributions and prevent vegetation encroachment, and provide an environmental signal for adults to migrate from the ocean to coastal streams; lower-velocity winter base flows between storm events allow adult salmon to swim upstream to spawning sites and provide suitable hydrologic conditions for redd construction and egg incubation; spring flows maintain instream connectivity, allowing for smolt out-migration, aerating redds until alevins emerge and providing food resources via downstream drift; and summer flows maintain connectivity until streams approach or reach intermittence, whereby pools continue to provide over-summering habitat until flows resume again with the onset of winter wet-season rains that once again trigger the movement of adult salmon.

Surface water diversions may have the most substantial impacts on aquatic biota during the spring and summer because streamflow is naturally low: the limited water available is critical for maintaining suitable habitat conditions, yet streamflow at this time is most susceptible to impacts by diversions. In watersheds where water demand is high, the cumulative impacts of surface water diversions have the potential to accelerate drying over substantial stream reaches, reducing habitat availability for juvenile salmon and other aquatic species. Secondary effects of stream drying, such as increased competition, higher water temperatures, and increased predation risk may also occur where flows are reduced.

Juvenile salmonids must survive one, and up to four summers, in tributary streams before they are large enough to swim to the ocean. Due to the overall degradation of aquatic habitat conditions throughout the Russian River basin, native fish populations are likely less resilient to water stress than they were historically. We hypothesize that increased water diversions are leading to high levels of juvenile salmon mortality and that summer water availability may be an important limiting factor to salmon population recovery in Mediterranean-climate coastal streams.

Our retrospective analysis of juvenile salmonid counts in several Russian River tributary streams indicates that over-summer survival declines in dry years and is most impaired in sub-watersheds with high estimated water demand by agricultural and domestic water users. While habitat conditions, such as instream shelter availability and riparian shading, are also important factors that affect juvenile summer survival, the findings suggests that summer water availability is critical for salmon persistence in these streams.

Studies on streamflow and vineyard water use

Electronic records maintained by the State Water Resources Control Board illustrate that more than 1900 requests for water rights have been submitted in the Russian River watershed since 1918 (**Figure 3**), and approximately 50 percent of all water rights requests throughout all of California from 2000 to 2005 describe actions from streams in either Napa, Sonoma, or Mendocino County. Not surprisingly, in many parts of the Russian River Basin, water rights records predict that demand for water during the spring and summer growing season exceeds supply; while normal-year discharge during the wet season exceeds annual water removal estimates by an order of magnitude (**Figure 4**). This makes it clear that demand for water and the associated permitted rights to divert water in the spring and summer far exceeds fresh water supply during that time. However, the sum of diversions in a watershed represent what people have a right to take not what they actually remove and the impacts of these extraction on streamflow during the dry season remained unknown.

We installed several streamflow gages in two sub-watersheds of the Russian River to explore how streamflow and salmonid habitat change with upstream watershed area. Streamflow trends were similar among all sites, with the frequency and duration of peak flow events nearly identical whether in far headwater streams draining 2 square kilometers or large downstream reaches draining over one hundred square kilometers. We also detected some important differences along the spatial gradients studied: when standardized by watershed area, headwater gauges recorded higher peak flows and lower base flows than downstream gauges consistently through most of the water year. This indicates that catchment processes governing streamflow tend to concentrate flow in headwaters following rainfall events more than in lower reaches, and therefore, flow in small streams may not be described simply by linear scaling according to data collected downstream, as is currently done by the State regulatory agencies; but requires some data from smaller streams to calibrate streamflow models more accurately.

We used the flow data that we collected along with physical channel cross-section measurements to quantify the amount of streamflow required for an adult steelhead to migrate through a riffle upstream as compared to further downstream – thereby improving our understanding of flow requirements or thresholds to support particular ecological processes (*environmental flows*). Our data indicated that the flow required for upstream migration was met at all sites studied, but occurred much more often in lower reaches than in headwaters. The difference between the duration for fish bypass in the smallest watersheds (2 km^2) is twenty fold less days than lower in the watershed (100 km^2).

The streamflow data we collected in eastern Sonoma County also provided us with important insights into how water management practices affect streamflow locally and at the catchment scale. At the local scale, flow in streams with vineyard development in the catchment upstream dropped dramatically during periods when wine grape growers need large volumes of water over a very short time to protect grapes from specific weather conditions (specifically, in spring for frost protection and in summer for heat protection; **Figure 5**). In fact, flow in spring, when grape growers may divert for frost protection, receded by as much as 90 percent over hours at one site (Deitch et al., in press). Such flow adjustments during the dry season may have consequences to native anadromous salmonids, including sudden drying of gravel bar habitat, higher water temperatures, and changes in the invertebrate prey base.

The data we collected also suggested that water use associated with vineyards influenced streamflow at larger spatial and temporal scales. One of the primary reasons we chose the Franz Creek and Maacama Creek watersheds as our primary study watersheds was because they were gauged historically by USGS, providing us with a baseline for comparing streamflow in periods of little vineyard development with today's land use patterns. Through comparisons of our 2004-2005 flow data to historical USGS data taken in the 1960's, our analyses indicated that streamflow in winter, as a function of observed rainfall, is the same as during the historical period of record, but flow in spring and summer is significantly different than what historical relationships would predict based on the amount of rain that fell during the study period (**Figure**

6). So, we observed reductions in streamflow at individual sites where water extracted from the surface and sub-surface stream network resulted in sudden drops in streamflow and lower overall expected streamflow during the growing season since vineyards were established in the Maacama and Franz Creek drainage networks.

The need for cumulative impact analysis of water management options

Recent vineyard development has increasingly had to rely on pumping ground and surface water resources as needed since concerns over salmon recovery prevents the State from issuing appropriative water rights to store water during the wet season for use in the dry season. Increasing storage of winter rainfall and runoff using small off-stream reservoirs may be one of the only solutions to meet the demand for wine grape production and reduce the impacts associated with the practice of pumping surface and subsurface stream waters during the dry season. However, existing analyses to estimate the effects of permitted appropriative water rights on streamflow frequently suggest that the watersheds within premium appellation areas are over-allocated and additional appropriative rights should not be granted. Yet, these estimates are made by aggregating the permitted rights to remove water across the entire year and totaled for entire watersheds. Given the temporal and spatial variability of these systems described above, it is essential that the impact of water diversions on streamflow be analyzed at sufficiently fine spatial and temporal scales (e.g. weekly); otherwise, the demand is assumed to be constant over time and the impacts uniform over space, which over-estimates the geographic extent of the impacts and potentially under-estimates local affects.

To address this problem, we are developing spatially explicit analysis tools, using a Geographic Information System, to examine the cumulative impact of existing water storage projects on winter flows; and to estimate how much water must be extracted during the dry season in places where winter rainfall storage is insufficient to meet the agricultural demand. These analyses will ultimately be used to evaluate trade-offs between allocating additional small-scale projects for collecting winter streamflow and continuing to pump during the dry season to meet the demand for wine grape production in upland coastal watersheds. The resulting maps will help determine where existing and potential future water projects should and should not be placed in order to minimize impacts of water use on environmental flows for salmon survival.

Specifically, these spatially explicit models project changes to expected streamflow based on empirical streamflow data and subtractions from the existing stream network caused by the many small reservoirs that exist in Russian River tributaries in Sonoma County; locally and cumulatively through the drainage network. The results indicate that streamflow across large portions of the upper watershed may be reduced by as much as 20%; and thus early-season rains may not result in as much streamflow as would be expected in the absence of small reservoirs (**Figure 7A**). The impact diminishes as the rainy season progresses: streamflow is reduced by less than 10% by the end of December for almost all reaches in normal rainfall years because most reservoirs have filled by this point (**Figure 7B**). Because the reservoirs common in the Russian River watershed are focused in headwater streams and the window for upstream bypass is larger lower in the watershed as compared to upper tributaries, these reservoirs are less likely to impact the ability for salmon to migrate through lower reaches to find suitable spawning tributaries.

These spatially explicit tools can help reveal where additional reservoirs for storing winter rainfall may be placed to minimize the impact to adult salmon passage and evaluate the potential to relieve the observed agricultural impacts on spring and summer streamflow. These models can be run using hydrographs based on low, moderate, and high rainfall years to evaluate impacts of water management across the high levels of year to year variability in rainfall patterns discussed above. Assumptions about reservoir management and amount of water used during the growing season are made based on existing survey data but will be improved upon by working with growers to parameterize the models based on their actual practices (see sidebar on collaborative conservation).

Establishment costs for vineyards are extremely high (40,000-75,000 acre) and this investment requires reliable water delivery especially in the early years of establishment and during frost periods. Providing additional storage of winter streamflow would greatly increase certainty for wine grape growers both by providing a more reliable water supply during the growing season for frost protection and irrigation and by establishing more secure water rights. Current debate has arisen over the need for an appropriative right to pump subsurface streamflow, which in California is generally referred to as “ground water” and therefore not regulated or monitored by the State or local government (Sax 2002). Even the threat of declaring thousands of land owners who rely on wells adjacent to streams without appropriative rights out of compliance is unnerving to say the least. However, given the costs associated with environmental cumulative impact studies ($300,000 and up) required for an appropriative right and the extremely low likelihood of being granted an appropriative right by the State, many private sector interests are faced with an uncertain future when it comes to water availability.

In summary, the progress we have made to date, with help from the Salmon Coalition (see side bar on collaborative conservation), has established a better framework for water management decision-making. This framework uses models that quantify the tradeoffs for both the wine grape growers and salmonid recovery efforts between storing more water in the winter and pumping on demand year round to meet agricultural and residential water needs. These tools point to areas where potential solutions can be found for ecological and economic interests in the region, and help prevent future regional environmental and social crises that can arise around salmon and other endangered species recovery programs.

SIDEBAR

Collaborative Conservation to achieve regional water quality and quantity goals

Land and water conservation in places such as coastal California, which is almost entirely comprised of private land, cannot occur without landowner participation. Therefore, we are engaged in the collaborative conservation processes, with a public interest group called the Salmon Coalition, to facilitate public participation in transformative restoration. This coalition represents a growing demand for a more adaptive local approach to resource management through collaborative conservation. This approach can often result in increased environmental and social benefits across a variety of complex situations

The Salmon Coalition is a stakeholder group that was recently formed to increase communication among private land owners of Dry Creek and Alexander Valleys (northern

Sonoma County), resource agency staff (NOAA and Calif. Dept. of Fish and Game), and the Sonoma County Water Agency and their urban clients (9 water districts serving cities and towns in Sonoma and Marin Counties). The goal of the Salmon Coalition is to set restoration priorities for salmon recovery while protecting and hopefully improving water security for rural and urban uses and lessening the burden on private land owners posed by the Endangered Species Act. The Salmon Coalition is a good example of a policy-based initiative which involves stakeholder participation to design plans that are intended to protect habitat as compensation for regulatory protection against potential violations under the Endangered Species Act -- similar to the Habitat Conservation Planning process (Cestero 1999).

This type of collaborative conservation is increasing in popularity as decision-authority about how to implement species recovery devolves from government resource agencies to public stake-holders. An increased emphasis on farmers participation in water management planning is being proposed in the 2007 farm bill in the form of the Regional Ground and Surface Water Enhancement Program which proposes to change the purpose of the existing ground and surface water conservation program to allow cooperative agreements between the Secretary, producers, government entities and Tribes in achieving regional water quality and quantity goals in water quality priority areas. If included, this program would provide $100,000,000 for each of fiscal years 2008 through 2012, contingent upon availability of the reserve fund. Otherwise, $60,000,000 will be available for each fiscal year 2008-2012. Collaborative conservation will provide the basis for these cooperative agreements.

The outcomes of collaborative conservation generally remain untested. In an attempt to define a common language for this approach to decision-making and to share lessons learned from case studies, the Sonoran Institute published a very useful report titled “Beyond the

Hundredth Meeting: A Field Guide to Collaborative Conservation on the West's Public Lands (Cestero 1999). Although focused on public land issues, this investigation offers helpful guidelines to improving the success of public processes that are a necessary part of planning most corridor projects. Efforts that are place or community-based are distinguished from those that address a specific policy or interest-based initiative as is the case for the Salmon Coaltion.

Cestero (1999) also reports that place-based efforts work best if they are led by local participants rather than by government representatives, and take place in an open and inclusive process that can accommodate a full range of perspectives, including government representatives. It is also better if participants do not try to represent a larger interest group, because confusion can arise when individuals are held accountable for a large diverse interest group, some of whom will feel their interests were not well-represented. In addition to completing the desired projects, collaborative conservation can lead to increased capacity of community residents to respond to external and internal stresses that will inevitably arise. This capacity can help avoid future problems from becoming crises.

One clear conclusion from those who have studied examples of collaborative conservation is that groups focused on smaller areas are more likely to succeed (Cestero 1999). This is because those involved can relate to the landscape in question, and regular participation from people spread across a large geographic area is not required. The Quincy Library Group in northern California is an example of where a group of approximately 30 people developed a plan for 2.5 million acres of public forestland that in the end did not adequately attend to the diverse interests represented in this large and relatively populated area (Duane 1997). Such larger scale conservation projects are better addressed through a network of local efforts (Cestero 1999). In our case, the Salmon Coalition is primarily focused on only two sub-watersheds within the Russian River which will help the restoration planning process.

Equally important, the Coalition has agreed to a participatory research effort that will greatly increase our understanding of the various ways that water is managed across private lands. Having a group begin by collecting and evaluating existing information that will increase their understanding of the system is one way to empower a group early on (Cestero 1999). This group has offered their assistance in collecting information from wine grape growers on water management practices and for access to private lands required for further streamflow monitoring. Without this cooperation, we would not be able to collect local information and would continue to have to rely on coarse assumptions about the system and management models that are ill-suited for such a complex issue. The data describing hydrology and water management that we are collecting with the help of the Salmon Coalition will enhance our understanding of human-ecosystem interactions – a necessary step to better inform future water management and policy decision-making.

Together we are working toward solutions that better balance environmental and social outcomes through collaboration among local experts, resource agency professionals, and landowners. We intend for these efforts to help the State Water Resources Control Board and local stakeholders resolve problems over additional requests for appropriative rights to store more water during the rainy season. Our data analysis and models will also be used by Sonoma County Water Agency to improve their estimates of available flows for ecological processes (thus enhancing salmonid recovery efforts) and municipal uses.

Literature Cited

Aschmann, H. 1973. Distribution and peculiarity of Mediterranean ecosystems. In diCastri, F, and H.A. Mooney (eds). Mediterranean-Type Ecosystems: Origin and Structure. Springer-Verlag, New York, pp. 11-20.

Cestero 1999 Sonoran Institute published a very useful report titled “Beyond the Hundredth Meeting: A Field Guide to Collaborative Conservation on the West’s Public Lands.”

Deitch, M.J. 2006. Scientific and Institutional Complexities of Managing Surface Water for Beneficial Human and Ecosystem Uses under a Seasonally Variable Flow Regime in Mediterranean-Climate Northern California. PhD Dissertation, University of California, Berkeley, California USA.

Deitch, M.J., G.M. Kondolf, and A.M. Merenlender. In press. Hydrologic impacts of small-scale instream diversions for frost and heat protection in the California wine country. River Research and Applications.

Merenlender, A. M. 2000. Mapping vineyard expansion provides information on agriculture and the environment. California Agriculture 54(3):7-12.

Moyle, P.B. 2002. Inland fishes of California. University of California Press, Berkeley, CA.

Sax, J.L. 2002. Review of the Laws Establishing the SWRCB’s Permitting Authority Over Appropriations of Groundwater Classified as Subterranean Streams and the SWRCB’s Implementation of Those Laws. State Water Resources Control Board, Sacramento, CA.

Woodward, G., and J. M. Romm. 2002. "Policy Assessment of the 2001 Klamath Reclamation Project Water Allocation Decisions." Water Allocation in the Klamath Reclamation

Project, 2001. Ed. W. Braunworth, T. Welch, and R. Hathaway. Oregon State University Extension Service. 337-364.

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Acknowledgements

This research was funded in part by US EPA (STAR grant G4K10732), the University of California Water Center, the Sonoma County Water Agency, and the Integrated Hardwood Range Management Program. Our colleagues at Berkeley have been instrumental in developing some of these ideas: G. Matt Kondolf, Vince Resh, Juliet Christian-Smith, David Newburn, Ted Grantham and Ruth Langridge. Our thanks also go to members of the Salmon Coalition and Carolyn Wasem for their interest in our research and Brian Johnson at Trout Unlimited.