The Case for Prioritizing West Marin as a Beaver Relocation Site

Scientific Rationale and Economic Benefits

Adam Rivers, Marin Beaver Restoration Project, San Rafael, CA, marinbeavers@gmail.com

Executive summary

The California Department of Fish and Wildlife (CDFW) Beaver Restoration Program (BRP) must allocate a limited number of translocations across many candidate watersheds. This paper argues that West Marin, the coastal watershed anchored by Lagunitas Creek, warrants placement in the top tier of the CDFW's prioritization model. West Marin is the rare site that is at once highest-value, lowest-risk, mission-central, cost-effective, grounded in documented native range, and coalition-ready. It holds the southernmost wild population of Coho Salmon on Earth, an irreplaceable evolutionarily significant unit. Its low-elevation coastal setting structurally lacks the apex-predator pressure that drove mortality in CDFW's first-year pilots. It delivers the quantified climate, drought, and wildfire benefits that are the BRP's founding mandate. Beaver-built habitat there substitutes for the engineered restoration on which the local water utility has already spent millions of dollars. Pre-contact beaver presence on the Marin coast is established by physical and archival evidence rather than assumed. Its coalition is already in place: a private landowner, the regional water utility, federal land managers, and restoration nonprofits, with letters of support on file. The following sections quantify each of these claims against the Department's own pilot data and the published restoration literature.

The readiness matrix below summarizes the case at a glance, scoring West Marin against the criteria the Department has named for prioritization.

Figure 1. Readiness matrix against CDFW's stated prioritization criteria

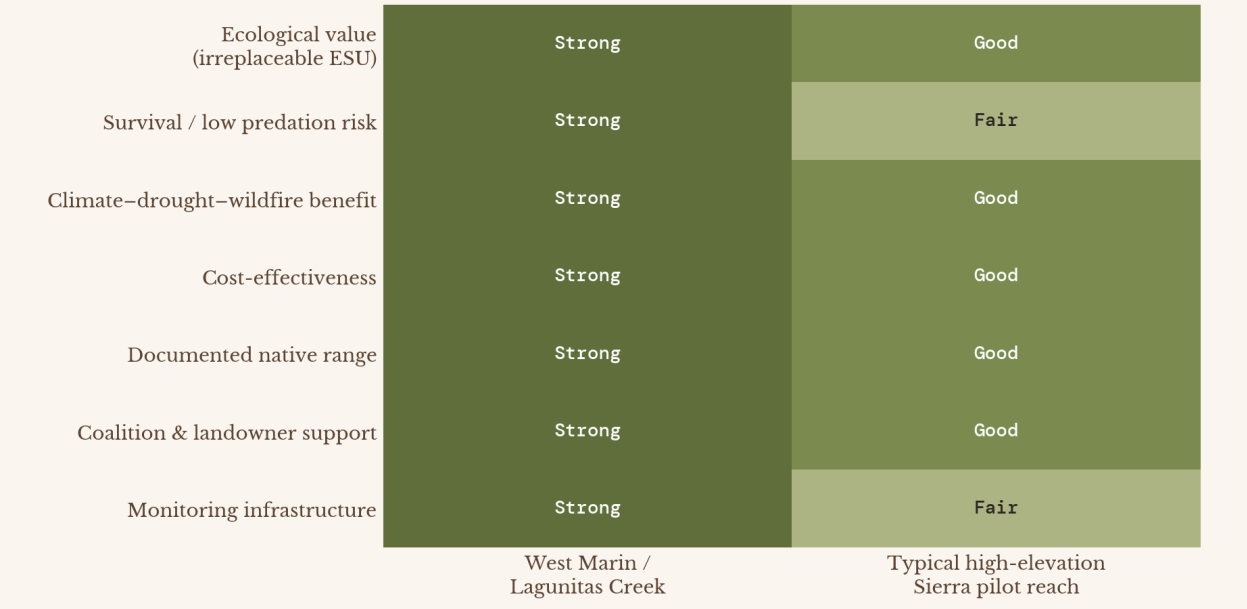

Figure 1. West Marin scores strongly across every stated CDFW prioritization criterion. Qualitative fit scored by the authors against CDFW's criteria (ecological value, survival, etc.). Not a CDFW scoring output.

1. Marin lacks classic beaver predators

CDFW's 2024 *Status Report on Beaver Restoration Pilot Projects* is the Department's best internal evidence on what determines translocation success.[1] Across the first program year, 28 beavers were translocated and 11 were lost, an aggregate mortality of approximately 39 percent. Mortality at the high-elevation Tule River site ran at roughly twice the rate observed at the low-gradient Tásmam Koyóm meadow site. Every documented death is attributable to one of two causes (1) predation, at a site dense with black bear and gray wolf where an entire beaver family was killed, and (2) capture-related illness, including pneumonia, probable post-release tularemia, and capture myopathy. Habitat suitability and the animals' own engineering caused no losses. The meadow beavers built lodges and dams successfully.

The data on beaver predators. Mortality events described in the pilots were the loss of an entire family to a black bear, with gray wolves also present on the Tule River site. Where beavers are a significant part of a large carnivore's diet, it is overwhelmingly the gray wolf. In the wolf-beaver systems of the northern forests, beavers can constitute a substantial seasonal share of wolf diet, and individual wolves are efficient, specialized beaver-pond predators that ambush beavers on land near their ponds.[2] Neither the gray wolf nor the black bear exerts that pressure in coastal Marin. Wolves are mostly absent from the central California coast, and the low-elevation coastal watershed lacks the black-bear density of the Sierra Nevada foothills. The predator that *is* present in Marin is the mountain lion (*Puma concolor*). The best current evidence indicates that mountain lions are dietary generalists but overwhelmingly deer specialists. A range-wide meta-analysis of puma diets found that although pumas consumed at least 232 prey species across the Americas, their intake is dominated by deer and other ungulates, with beavers not among the prey species that form the puma diet at the population level.[3] However, once beaver populations are restored and mountain lions encounter them regularly, we may learn that they are a significant beaver predator after all. For now though, the data to support that claim does not exist. The remaining predators of beavers in coastal California (e.g., coyote, bobcat, and domestic dogs) take primarily dispersing kits and lone sub-adults rather than established family groups in defended ponds, and none produces the family-level losses recorded at Tule River. The practical consequence is that the single mortality driver CDFW has documented in the field is absent from the West Marin landscape.

2. Marin beavers are a lifeline for the most irreplaceable salmon population in California

Lagunitas Creek supports the southernmost wild population of Coho Salmon (Oncorhynchus kisutch) on Earth. Under the U.S. Endangered Species Act, this population is protected as part of the Central California Coast (CCC) coho evolutionarily significant unit (ESU), which is the unit NOAA Fisheries uses to define a Pacific salmon population for listing. The ESU designation is for a group that is substantially reproductively isolated from other populations and represents an

important component of the species' evolutionary legacy. In practice, an ESU is treated as a "species" under the Act, so the loss of the Lagunitas population is a permanent subtraction from the genetic and life-history diversity of the entire coho lineage. Because Lagunitas sits at the warm, dry trailing edge of the species' global range, a population lost here is unlikely to be recolonized from elsewhere. The site functions as the range-edge sentinel for the whole ESU.

Why coho matter in Marin. Coho are not only an endangered species to be preserved for their own sake, they are a significant component of the Marin ecosystem and an important economic driver. As an anadromous salmon, each returning adult imports marine-derived nitrogen, phosphorus, and carbon into the freshwater and riparian food web when it spawns and dies, fertilizing the stream that produced it. Pacific salmon are, in this sense, a keystone species whose carcasses subsidize everything from aquatic insects to riparian trees to terrestrial wildlife.[4] A functioning coho run is therefore a nutrient pump that supports the broader biodiversity of the Lagunitas watershed, including species of concern such as steelhead and California freshwater shrimp that share the same habitat. Economically, wild coho anchor a coastal-California identity that supports the region's recreation, tourism, and agricultural-heritage economy, and they carry deep cultural significance for the Coast Miwok and for the broader public that has invested decades of restoration funding in this watershed. The West Coast salmon fishery, of which coho are an iconic component, supports thousands of jobs and hundreds of millions of dollars in economic activity. Recovering an ESU at its range edge protects both an irreplaceable genetic resource and the public investment already sunk into it.

How beavers build coho habitat. Marin Water's 25-year salmonid monitoring dataset is among the longest continuous coho records in the state, and paired with its juvenile and smolt monitoring, it points to key factors that control juvenile coho abundance. The pattern that emerges is one of flow extremes working against young fish at every life stage. Winter high flows damage and entomb the gravel nests where eggs incubate. Spring flows displace newly emerged fry. And a shortage of cover leaves young fish exposed to predators and to the force of the flow itself. Beaver lodges generate the deep, low-velocity off-channel and pond habitat that buffers those flows and shelters overwintering juveniles. Exactly the habitat that the monitoring record shows to be the most beneficial for coho.

The large magnitude of the effect is described in peer-reviewed papers. *Pollock and colleagues (2004)* worked in the Stillaguamish River basin of Washington State, a Puget Sound river system that, like Lagunitas, produces coho. They combined historical accounts of beaver abundance with a habitat model to estimate how many coho smolts the basin could produce before versus after beaver were trapped out. Historic winter smolt-production capacity was on the order of 7.1 million smolts, against roughly 971,000 today, an 86 percent reduction, and the single largest share of that loss came from the disappearance of beaver ponds (Figure 2).[5] The historical extirpation of beaver was, in effect, the destruction of coho overwintering habitat. *Bouwes and colleagues (2016)* ran the complementary experiment in Bridge Creek, a tributary of the John Day River in eastern Oregon, using a rigorous before-after-control-impact (BACI) design. They monitored a treatment stream and a comparable untreated control stream for years before and after installing beaver dam analogs. Dam analogs are low-cost, human-built structures that mimic beaver dams and encourage beavers to take up residence. Installing these structures raised juvenile steelhead survival by 52 percent and, four years after treatment, juvenile

production by 175 percent relative to the untreated control, at a materials cost below $11,000 per kilometer of stream.[6] Steelhead and coho are closely related salmonids with similar juvenile rearing requirements, so the mechanism of slow-water rearing and overwintering habitat likely transfers directly to the Lagunitas coho problem.

Figure 2. Beaver-built slow water creates salmon habitat

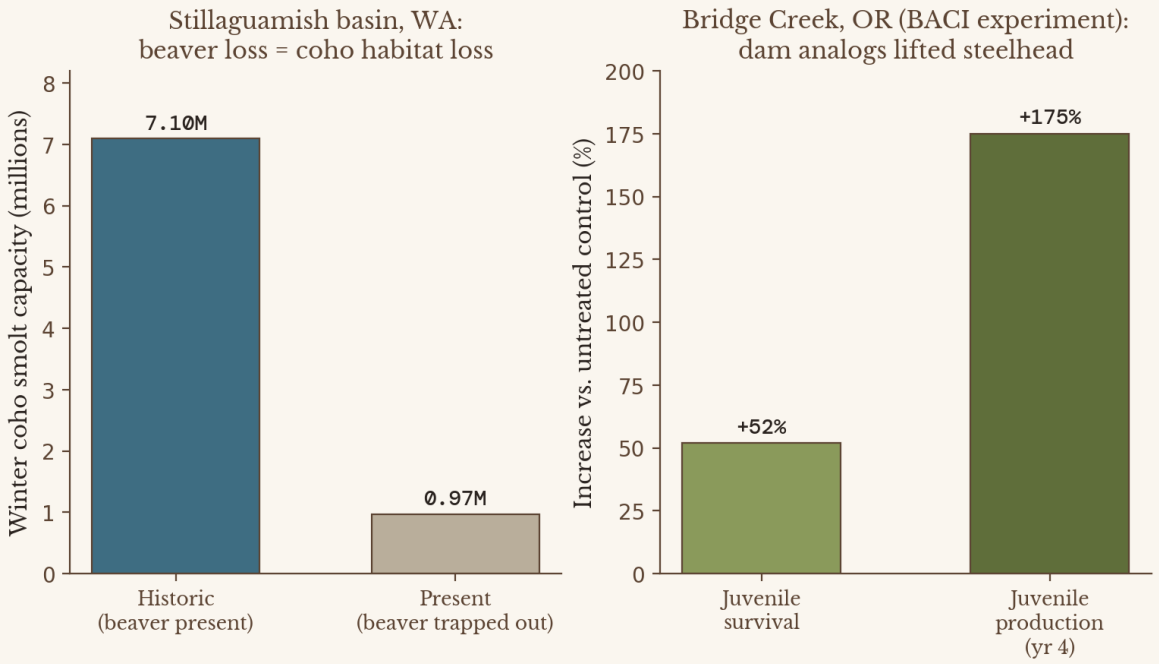

Figure 2. The disappearance of beaver removed most of the basin's coho capacity; restoring dam habitat reverses it. Sources: Pollock et al. 2004 (Stillaguamish smolt capacity) and Boures et al. 2016 (Bridge Creek steelhead).

We believe no other site in the Department's portfolio pairs a more imperiled and less-replaceable population with a limiting factor this precisely matched to beaver ecology, alongside a utility partner already expending millions on the exact function beavers provide at no public cost.[17]

3. Extreme wildfire risk in West Marin

The BRP's founding mandate, under the Governor's Nature-Based Solutions initiative, is to improve climate change, drought, and wildfire resilience. West Marin is a high-consequence wildfire landscape. The 2020 Woodward Fire burned 4,929 acres within Point Reyes National Seashore, threatened well over a thousand structures at its peak, and drew a Type I incident management team.[18] Beaver-built wetland corridors form a documented, self-maintaining refugia network to defend against wildfire hazard. Fairfax and Whittle (2020) used satellite imagery to

measure vegetation greenness, the Normalized Difference Vegetation Index (NDVI), a standard remote-sensing proxy for how green and hydrated plants are, along riparian corridors before, during, and after five separate wildfires across the western United States. For each fire they compared stream reaches that had beaver damming against otherwise similar reaches on the same streams that did not. They found that the fire-season decline in NDVI was 3.05 times larger in the reaches *without* beaver. Beaver-dammed reaches stayed greener through the burn compared to adjacent undammed reaches.[7] The mechanism is thought to be that beaver dams spread water laterally and raise the water table, keeping riparian soils and plants too wet to carry fire, so the dammed corridor becomes a fire-resistant refuge for vegetation, wildlife, and water. Subsequent work has extended the finding from vegetation greenness to riverscape burn severity itself during recent megafires.[8] For a landscape like Point Reyes that has already burned once this decade and will burn again, a self-maintaining network of green, wet refugia distributed along the creeks is a durable resilience element that no current human effort can match. The broader hydrological literature outside of the U.S. also documents the associated drought and base-flow benefits of beaver-engineered systems.[9]

4. Beavers benefit the Marin economy

The economic argument for beavers in Marin rests on two calculations: (1) the cost to build wetland habitat by engineering, and (2) the value of the services that habitat delivers each year. On the cost side, a review of the economic benefits of beaver-created habitat prepared for the Oregon State Legislature estimated constructed-wetland costs on the order of $10,000 to $100,000 per acre to build, with the range reflecting how much earthmoving, grading, planting, and water-control structure a given site requires.[10] That figure is corroborated by the broader wetland-restoration literature. Engineered stream and wetland restoration in the western United States routinely runs from tens of thousands to well over one hundred thousand dollars per acre once design, permitting, heavy equipment, materials, and multi-year maintenance are included. The local evidence of this cost is Marin Water's own program.[19] The utility has secured more than $6.6 million in state and federal funds to install 278 anchored logs and spawning gravel across 13 sites below Peters Dam, engineering the pools, large-wood structures, and off-channel complexity that beavers would build and maintain for free, a direct, site-specific demonstration of the avoided cost.

On the value side, the same Oregon review valued the ecosystem services flowing from an acre of aquatic beaver-pond habitat at roughly $4,000 per acre per year.[10] “Ecosystem services” is the dollar value of real-world functions the pond performs that society would otherwise have to pay for, including water storage and slow release that supplements late-season flow, groundwater recharge, sediment and nutrient capture that improves downstream water quality, flood-peak attenuation, carbon storage in pond sediments, and rearing habitat for fish and wildlife. Beavers deliver these services continuously and adapt them to changing flows for nearly no cost. A single successful colony that establishes and maintains even a few acres of pond and off-channel complexity therefore both offsets a construction expense measured in the hundreds of thousands to millions of dollars *and* produces an annual return comparable to compounding interest.

The economic case is bolstered by potential biodiversity improvements. Marin County is one of the most biologically significant landscapes in California. The West Marin coastal zone and its protected lands support on the order of several dozen rare, threatened, and endangered species and dozens of plant taxa endemic to the region, host several hundred bird species along the Pacific Flyway, and lie within the UNESCO-designated Golden Gate Biosphere Reserve, one of the first such reserves established in the United States.[11] Beaver-created wetland complexity would act as a force multiplier across that entire Marin landscape. The same ponds that rear coho also support amphibians, waterbirds, and native plants, extending the return on a single translocation well beyond the target species.

5. Documented native range and a ready coalition

Two practical hurdles that have the potential to stall beaver relocation proposals are already cleared in West Marin. First, the evidence that beavers were once native to the Marin coast is strong and multi-faceted. Lanman and colleagues assembled zooarchaeological beaver remains from coastal California archaeological sites, first-person accounts from early explorers and settlers, nineteenth-century fur-trapping records, and ethnographic evidence to demonstrate that beaver were indeed native to coastal drainages of central and northern California.[12] For the Marin coast specifically, that record includes beaver remains and reports from nearby coastal watersheds, an 1811 first-person account of an abundance of beaver at Bodega Bay just north of Marin, sustained nineteenth-century trapper harvests, and Coast Miwok and Southern Pomo oral histories and place-names. Reintroduction to Lagunitas Creek is therefore the restoration of a native species to documented former range. Second, a beaver coalition already exists in Marin. A private landowner near Olema, who was previously willing to host translocated beavers on their property, offers approximately 2.5 miles of streamside ownership, and combined with more than eight miles of publicly owned creek, this places a significant portion of the Lagunitas Creek land managers in support of reintroduction. The regional water utility (Marin Water), federal land managers (National Park Service / Golden Gate National Recreation Area), and restoration partners are engaged, with letters of support on file. The largely protected and agricultural character of West Marin watersheds keeps the potential for human-beaver conflict low relative to urban candidate sites.

The restoration also advances tribal co-stewardship. Coast Miwok oral histories and place-names are themselves part of the native-range record, and the Federated Indians of Graton Rancheria are a natural partner in a project that restores a culturally significant native species.[12] Reintroduction here is consistent with the tribal engagement the Department has built into its statewide beaver planning, and it advances a shared cultural and ecological objective.

6. High flows are the reason to act, not a reason to wait

A March 2025 West Marin site assessment by CDFW concluded that the proposed site was not suitable due to high, flashy flows. Winter high flows reaching approximately 20 feet of stage have historically dislodged chained-in beaver dam analogs (BDAs). BDAs are low-cost, woven-post-and-brush human-built structures, that mimic a beaver dam to jump-start pond habitat and to encourage beavers to settle and take over maintenance. The flashy winter high flows that limit

Lagunitas coho and that threaten fixed BDAs are precisely the problem that beaver dams attenuate.

The strongest evidence is a multi-site study by Puttock and colleagues, who instrumented streams in England before and after beaver were reintroduced and analyzed more than 1,000 storm events. Beaver damming reduced total stormflow, lengthened the lag between peak rainfall and peak streamflow, and reduced peak flows, making the streams measurably less flashy. Critically, the attenuation persisted through the largest storms monitored, with beaver dam sequences reducing average flood peaks by up to roughly 60 percent.[13] Beaver colonies tend to build more than one structure and then repair them continuously. So instead of a fixed BDA that a 20-foot flow might destroy, beavers contribute a self-repairing, distributed system that actively reduces those flow peaks over time.

A substantial behavioral and modeling literature shows that beavers select dam sites with skill. They preferentially build on lower-gradient, appropriately confined reaches where damming is energetically favorable and dams are likely to persist. The classic ethological finding is that dam-building is triggered by the sound and sensation of running water, beavers move to the source of the sound and build to silence it, an efficient mechanism for locating exactly the spots where a dam will hold back flow.[14] This site-selection ability is reliable enough that it has been formalized into predictive tools: the Beaver Restoration Assessment Tool (BRAT) and intrinsic-potential habitat models estimate where the landscape can support dams and where beavers are likely to build, and these models are validated against where beavers actually settle.[15,16] The implementation task is to place them where their own habitat-selection instincts and the BRAT/CASTOR outputs already agree. This defines a defensible implementation strategy to prioritize the watershed and site the release deliberately. BRAT and CASTOR outputs, combined with the high-flow record, can identify lower-energy, higher-refuge reaches, deep perennial pools, valley-bottom storage, and off-channel complexity, in preference to flashy mainstem segments, aligning the release with the same reach characteristics beavers select for themselves.

7. Conflict is expected to be low

The largely protected and agricultural character of West Marin keeps human-beaver conflict low relative to urban candidate sites, and where conflict does arise, the mitigation toolkit is well established and inexpensive. Flow devices, sometimes called pond levelers, hold pond height below a set point so beavers can remain without flooding roads or culverts. Culvert-protection fencing prevents blockage of road crossings. Wrapping individual specimen trees, or painting trunks with an abrasive slurry, protects high-value plantings. These coexistence tools are standard practice in the Pacific Northwest programs on which California's effort is modeled, and they are the subject of the Department's own coexistence training.

8. West Marin is the Beaver Restoration Program's best site to demonstrate success

A restoration program advancing under scrutiny needs a place where its results can be measured cleanly and credibly. West Marin is that place. Marin Water maintains one of the longest continuous coho monitoring records in the state, a 25-year salmonid dataset paired with juvenile

and smolt monitoring, and the utility has offered to take a leading role in monitoring the effectiveness of a reintroduction. That existing baseline is what turned the Bridge Creek project into rigorous, publishable evidence, because a before-after-control-impact design is only possible where years of pre-treatment data already exist. Few candidate watersheds in the state pair a defined endangered species restoration effort with a decades-deep monitoring record held by a willing partner. Placing an early beaver translocation here would let the Department document that their return moves the needle on an important listed endangered species, the outcome the Program was created to demonstrate.

9. Recommendation

West Marin and Lagunitas Creek should be ranked in the top tier of CDFW's prioritization model. It is the rare candidate that is at once highest-value (the southernmost wild coho, an irreplaceable ESU), lowest-risk (no apex-predator mortality driver), mission-central (quantified climate, drought, and wildfire benefit), cost-effective (beaver-built habitat substitutes for millions of dollars in engineered restoration), grounded in documented native range, and coalition-ready. Paired with deliberate site selection to manage the constraint of winter high flows, it stands as the Program's strongest candidate to demonstrate that beaver restoration recovers an endangered species, while delivering measurable biodiversity and economic returns.

References

1. California Department of Fish and Wildlife. (2025). 2024 Status Report on Beaver Restoration Pilot Projects. Sacramento, CA: CDFW Nature-Based Solutions / Beaver Restoration Program. https://wildlife.ca.gov/Conservation/Mammals/Beaver

2. Gable, T. D., Windels, S. K., Bruggink, J. G., & Homkes, A. T. (2016). Where and how wolves (Canis lupus) kill beavers (Castor canadensis). PLoS ONE, 11(12), e0165537. https://doi.org/10.1371/journal.pone.0165537

3. Karandikar, H., Serota, M. W., Sherman, W. C., Green, J. R., Verta, G., Kremen, C., & Middleton, A. D. (2022). Dietary patterns of a versatile large carnivore, the puma (Puma concolor). Ecology and Evolution, 12(6), e9002. https://doi.org/10.1002/ece3.9002

4. Schindler, D. E., Scheuerell, M. D., Moore, J. W., Gende, S. M., Francis, T. B., & Palen, W. J. (2003). Pacific salmon and the ecology of coastal ecosystems. Frontiers in Ecology and the Environment, 1(1), 31-37.

5. Pollock, M. M., Pess, G. R., Beechie, T. J., & Montgomery, D. R. (2004). The importance of beaver ponds to coho salmon production in the Stillaguamish River basin, Washington, USA. North American Journal of Fisheries Management, 24(3), 749-760. https://doi.org/10.1577/M03-156.1

6. Bouwes, N., Weber, N., Jordan, C. E., Saunders, W. C., Tattam, I. A., Volk, C., Wheaton, J. M., & Pollock, M. M. (2016). Ecosystem experiment reveals benefits of natural and simulated beaver

dams to a threatened population of steelhead (Oncorhynchus mykiss). Scientific Reports, 6, 28581. https://doi.org/10.1038/srep28581

7. Fairfax, E., & Whittle, A. (2020). Smokey the Beaver: beaver-dammed riparian corridors stay green during wildfire throughout the western USA. Ecological Applications, 30(8), e02225. https://doi.org/10.1002/eap.2225

8. Fairfax, E., Whittle, A., & colleagues. (2024). Beaver dams and riverscape burn severity during recent megafires. Geological Society of America (Special Paper 2562, ch. 07). https://doi.org/10.1130/2024.2562(07)

9. Brazier, R. E., Puttock, A., Graham, H. A., Auster, R. E., Davies, K. H., & Brown, C. M. L. (2020). Beaver: Nature's ecosystem engineers. WIREs Water, 8(1), e1494. https://doi.org/10.1002/wat2.1494

10. Oregon State Legislature (report to the Oregon legislative assembly). Economic Benefits of Beaver-Created and Restored Habitat. https://www.oregonlegislature.gov/marsh/Documents/EconBenefitsBeaver.pdf

11. UNESCO Man and the Biosphere Programme, Golden Gate Biosphere Reserve (designated 1988); and Marin County / Point Reyes National Seashore biological-resource inventories documenting the region's concentration of rare, threatened, and endangered species, endemic plants, and Pacific Flyway avifauna. See also National Park Service, Point Reyes National Seashore species inventories.

12. Lanman, R. B., Perryman, H., Dolman, B., & James, C. D. (2013). The historical range of beaver (Castor canadensis) in coastal California: an updated review of the evidence. California Fish and Game, 99(4), 193-221.

13. Puttock, A., Graham, H. A., Ashe, J., Luscombe, D. J., & Brazier, R. E. (2021). Beaver dams attenuate flow: A multi-site study. Hydrological Processes, 35(2), e14017. https://doi.org/10.1002/hyp.14017

14. Wilsson, L. (1971). Observations and experiments on the ethology of the European beaver (Castor fiber L.): dam-building triggered by the sound of running water. Viltrevy (Swedish Wildlife), 8, 115-266.

15. Macfarlane, W. W., Wheaton, J. M., Bouwes, N., Jensen, M. L., Gilbert, J. T., Hough-Snee, N., & Shivik, J. A. (2017). Modeling the capacity of riverscapes to support beaver dams. Geomorphology, 277, 72-99. https://doi.org/10.1016/j.geomorph.2015.11.019

16. Dittbrenner, B. J., Pollock, M. M., Schilling, J. W., Olden, J. D., Lawler, J. J., & Torgersen, C. E. (2018). Modeling intrinsic potential for beaver (Castor canadensis) habitat to inform restoration and climate change adaptation. PLoS ONE, 13(2), e0192538. https://doi.org/10.1371/journal.pone.0192538

17. Marin Municipal Water District (Marin Water). (2023, November 8). Marin Water secures $4.6M state grant for restoration of Lagunitas Creek [Press release]. https://marinwater.org/marin-water-secures-4-6m-state-grant-for-restoration-of-lagunitas-creek/

18. National Park Service. (2020). Reflections on the 2020 Woodward Fire: Understanding the impacts of fire on Point Reyes ecosystems. U.S. Department of the Interior.

19. Marin Water 2023 (see note 17). The utility's published figures document more than $6.6 million committed to installing 278 anchored logs and spawning gravel across 13 restoration sites below Peters Dam. See also Occidental Arts & Ecology Center, Lagunitas Creek Beaver Feasibility Assessment (https://www.eacmarin.org/beavers), noting that local, state, and federal agencies have spent millions of dollars to restore West Marin watersheds, much of it on streambed alterations such as inserting large woody debris, “sometimes at great expense.”