# Sahpihnîich (Beaver) Restoration and Recovery in the Klamath River Watershed

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## INTRODUCTION

From winter 2022 to spring 2023, the Karuk Department of Natural Resources (KDNR) Wildlife Team oversaw a beaver restoration and recovery project on Karuk Aboriginal Territory. This project, a collaboration between the KDNR Wildlife Team (KWT) and the University of Washington supports the Karuk Tribe's efforts to recover beaver (*Castor canadensis*, Karuk: *Sahpihnîich*) populations and habitats along Klamath mainstem and lower tributary mouths in Karuk Aboriginal Territory. Specifically, we wanted to collect data on beaver occurrence before the removal of four lower Klamath River dams, scheduled for 2023, to understand how beavers move around and access new habitats after dam removal. Sahpihnîich once thrived along the Klamath mainstem, near the mouths of numerous tributary confluences, and in high-elevation meadows, but were decimated during the fur rush in the 1820s and 30s. They have begun to recover in the Klamath Basin, are widespread in the Sacramento-San Joaquin Delta, and have begun to recolonize coastal and Sierra Nevada streams (Lundquist et al., 2013, Lanman et al., 2013). Until recently, Beavers were erroneously considered non-native beyond the Klamath and Central Valley, and are currently listed as a nuisance and fur-bearing species by California Department of Fish and Wildlife (CDFW, 2023).

The state of California has several policies and laws that are relevant for beaver restoration and recovery. California Department of Fish and Wildlife (CDFW) oversees many projects throughout the state and provides permits to individuals and agencies for various restoration activities. Within these projects, policies and associated permits for beavers have primarily been centered around human-wildlife conflict management between beavers and landowners. Indeed, the state of California did not even think beavers were native to the area until undergoing an updated review of the historic range of beavers in 2013, putting them years behind other states engaged in beaver restoration and recovery (Lanman et al., 2013). Now, the state has acknowledged not only that beavers are endemic to the area, but that they are an important keystone species and ecosystem engineer that make landscapes more resilient to climate change and wildfires, and provide essential habitat for other important species, like the

[1] Two University of Washington graduate students (Maddie Hicks and Hannah King) assisted in this research through the UW School of Marine and Environmental Affairs capstone program, working within the F.R.E.S.H Water Relations Lab. The capstone project was co-designed by Emilio Tripp (Karuk Wildlife Team Manager), Daniel Sarna-Wojcicki (UW Seattle) and Cleo Woelfle Hazard (UW Seattle). Karuk Wildlife staff Ben Saxon, Jessica Conrad, and Jesse Goodwin assisted in project guidance, field work, data analysis, and interpretation.

critically endangered coho salmon (*Oncorhynchus kisutch*, Karuk: *Achvuun*) in California (CDFW, 2023).

Currently, most of the policies and the required permits in California around beavers are centered around pest management and depredation. In such processes, landowners can apply for a depredation permit from CDFW to kill a beaver or remove their dams. As of 2023, there are no permits or laws that allow for beaver relocation in California.

Prior to the 2022-2023 fiscal year, that state of California did not have any funding or projects dedicated to beaver restoration and recovery either. However, in early 2023, CDFW and the State Legislature approved funding for more projects engaged in not just mitigating conflicts with beavers, but also in prioritizing their restoration in watersheds. The state has also committed to partnering with Tribes for future restoration activities and are looking into the feasibility of beaver relocation efforts (Bonham, 2023).

Much of the emphasis about the benefits of beavers in certain areas is centered around their ability to transform watersheds to be more resilient to climate change as well as to assist in salmon recovery and restoration. Beavers are known to enhance and provide critical juvenile salmonid habitat, especially for coho salmon, which are listed as threatened under the Endangered Species Act, because they require slow-velocity pond habitats for juvenile rearing (Beechie et al., 2023; Castro et al., 2017; CDFW, 2023).

With removal of the four major hydroelectric dams on the Klamath River slated for 2023, salmon, beavers, and other culturally important species like Pacific lamprey (*Entosphenus tridentatus,* Karuk: *Akraah)* will be easily able to move up and down the river and access new tributary spawning and rearing grounds. Since beaver can affect habitat conditions for numerous fishes, reptiles, amphibians, and invertebrates, and can improve floodplain habitats for culturally important plant species, it is imperative that the Karuk Tribe develop a baseline assessment of beaver population and habitats along the mainstem and tributary mouths in order to best harness the benefits of this unprecedented restoration initiative.

The dam removal on the Klamath River will be the largest river restoration project ever undertaken. The success of this project will greatly influence the feasibility of large dam removal efforts in the future. The project will provide coho salmon and other species with access to an additional 33 km of tributary habitat and about 50 km of mainstem habitat with an estimated total increased capacity of 105,000 juvenile coho salmon (Ramos et al., 2023). Coho salmon are particularly sensitive to warm water temperatures during their freshwater summer rearing life stage (Belchik, 2003). Beaver dams increase hyporheic flow and provide necessary cold water refugia for juvenile coho during this time (Pollock et al. 2004). While much of the restoration efforts will be focused on newly opened habitat above the dam removal sites, coho salmon will ultimately travel the length of the Klamath river on their way to and from the ocean. Thus, healthy mainstem and tributary habitat downstream within Karuk Aboriginal Territory will also impact their survival.

Developing a baseline beaver population distribution will allow for the KDNR Wildlife Team to monitor and identify changes in population distribution that may be due to dam removal. It will also help to inform future restoration projects aimed at increasing juvenile coho salmon rearing habitat. Understanding beaver population distribution will be critical for siting such stream restoration projects involving beaver or beaver dam analogs. The success of these projects can depend upon knowing where beavers are distributed and how they are already

utilizing the area (K. Lundquist, personal communication, February 6, 2023). This is especially important for projects involving beaver relocation because beavers are territorial. The typical home range for a beaver colony includes about one to two km of waterway with good riparian habitat or about 27 - 62 acres (ODFW, 2017; Duke, 2021). Though beavers have been documented dispersing long distances from their release sites (Castro et al., 2017). Through this capstone project, we supported the Karuk Tribe in developing and piloting research protocols to better understand the presence/absence and habitat conditions for beaver along the Klamath mainstem and select tributaries.

Throughout this capstone project, our team blended Indigenous science and methodologies with western/cosmopolitan science to develop complementary and synergistic methods for further beaver research on the Klamath. Using both methods together, we are able to maximize our understanding of beaver presence and uphold Karuk cultural ways of knowing.

Karuk people have an intimate relationship with their land and have lived on their ancestral territory since time immemorial. With this long standing, deep relationship also comes a responsibility to steward the land in a reciprocal way and with respect to non-human relatives. Indeed, Karuk people view “resources” as relations that must be taken care of and honored. This is reflected in ceremony and “management,” or coexistence. Additionally, since Karuk people have stewarded the land since their creation, the people within the community have a deep knowledge of relations within the ecosystem that have been passed on through generations. This historic observation and working with and on the land make Karuk people researchers. In such, their ways of knowing should be legitimized as research and included in various projects across a multitude of disciplines. It was essential to the success of our project to adequately include Traditional Ecological Knowledge (TEK)/Indigenous science and balance this form of scientific knowledge and methodology with settler-colonial academic research methods. Both methodologies have their benefits and having one without the other is incomplete. The members of our project with settler backgrounds did extensive research on their own and took various classes to ensure we were properly integrating both methodologies in a decolonized way. Additionally, the methods that were ultimately developed were done so in collaboration with and under the direct supervision of members of KWT to maximize eco-cultural revitalization within this project.

Another influence of this relationship with place is the engrained, lived connection that Karuk people feel when there are changes on the landscape, from land ownership and climate change to management practices and policies. There are many, especially those in academia, who ignore TEK and tribal sovereignty and fail to acknowledge the tried and true practices that have been proven successful for thousands upon thousands of years. The direct impacts of all projects and initiatives done on Karuk land are felt by the people, and their inclusion is essential for making sure that these felt impacts are not ones of harm. More so, this intimate relationship also illustrates the need for Karuk people to do Karuk work on Karuk land using Karuk words and practices. Karuk people know the land the most and assert sovereignty each time management practices honor traditional values and include Karuk language.

This responsibility of reciprocity and respect extends to non-tribal collaborators who do work on Karuk land as well. Unfortunately, there is a long history of settlers and collaborators not working in the best interests of tribes throughout the United States (Karuk Tribe, 2023, Smith, 2021). In order to ensure our project honored data sovereignty and protected traditional

knowledge, our team also went through the Practicing Píkyav proposal process outlined by the Karuk Tribe (Karuk Tribe, 2023). This process set up a method for initial and ongoing review of our project by Karuk cultural practitioners and KDNR staff. That Karuk work *píkyav* means "fix it," and, according to the Píkyav Field Institute, it "refers to the Tribe's continuing ceremonial and diurnal efforts to restore the earth and its creatures to harmonious balance" (*Píkyav Field Institute*, 2023). This means not only fixing and managing the land, but also fixing the relationships between outside institutions and the Tribe by following Tribal leadership and minimizing risk to the Tribe. Our proposal explicitly outlined the goals of the project, described how data would be collected and used, how we would minimize risk to Karuk Tribal members, and how we would uphold respect through the entire collaboration. In doing so, we were able to establish a trusting partnership and minimize harm to the Tribe.

The research questions and pilot methods that developed through our collaboration included both TEK and western science. Using community knowledge about the history of beaver in the watershed to inform survey sites was one way we blended these methods together to reach our goals. When we combine these ways of knowing, powerful things can happen for eco-cultural revitalization.

Through a collaborative process, we identified the following research questions:

1. What is the pre-dam removal distribution of beaver along the Klamath river? What tributaries are beavers currently using?
2. What are the best research methods for collecting and analyzing these data?
3. What are potential methods for incorporating community sightings?
4. What recommendations for future avenues in research, restoration, and policy approaches can KDNR use to support beaver restoration and recovery efforts in Karuk Aboriginal Territory?

## METHODS

*Surveys*

During June 2022, our team of collaborators from University of Washington visited Karuk Aboriginal Territory from June 19th - 29th in order to conduct field surveys with KWT. During this time, we divided surveys into two main categories: float surveys and walking surveys.

Three float surveys were conducted on the Klamath mainstem in kayaks. Study reaches were selected in advance by Karuk Wildlife Team in order to cover as many representative river habitats as possible given time and resource constraints. During float surveys, members of the team ventured out in kayaks to search for signs of recent beaver activity. Signs we searched for included recent beaver chew, slides/skid marks, trails, dens, lodges, dams, scat, felled trees, beaver trails, and scent mounds (Figure 1). Members of the team would cover both banks of the river when able and scan the immediate area. If a beaver sign was spotted, we would take a GPS waypoint using a Garmin device. We also took notes about each waypoint in a Rite in the Rain field journal. Then, if we were able to stop the kayak in the river, we would take photos and measurements of the beaver sign. We did not take waypoints of signs of old beaver activity (like old or historic chew), only fresh signs. However, we did make note of all dams and dens on a

separate data sheet that was created by Utah State University and widely utilized by the Karuk Wildlife Team. Float surveys averaged several hours to complete. The average float length was 3.3 miles.


**Figure 1:** Various beaver signs we searched for during float and walking surveys.

Later in the week, Hannah assisted University of Montana PhD student Laurel Genzoli with algal surveys. Together they surveyed two short stretches of river upstream of where the KDNR Wildlife Team had surveyed. One survey was conducted about seven miles upstream of the Brown Bear Access point and the other was about 25 miles upstream of the same site. These surveys were not as thorough since there were only two surveyors and the main focus was on algae. However, a few areas with lots of recent beaver activity were sighted and marked.

To complement the longer float surveys, our team also conducted one walking survey on June 24, 2022, on Red Cap Creek from two starting points: an upriver and downriver location. The downriver site location was chosen because a community member reported seeing an old beaver dam in that area to KDNR (S. Beaver, Karuk Community Beaver Reports, Fall 2020). At the downriver site, team members surveyed approximately 0.5 miles upstream and 0.3 miles downstream of the starting point. During the walk, we scanned for the same signs of beaver as in the float surveys. After approximately an hour and a half, the team convened back at the starting point. At the upper site, next to Schnabel's Diggings, KWT and UW team members surveyed the area and walked downstream for approximately 300 meters scanning for beaver signs.

*eDNA Site Selection*

We used the Beaver Restoration Assessment Tool (BRAT) to help inform our site selection process for eDNA sampling from tributary streams. The BRAT model is a planning tool created by the Riverscapes Consortium that assesses a stream's capacity to support dam building by beavers. The model takes into account five parameters: the availability of water, the availability of dam building materials, the base flow of the river, the likelihood of a dam to withstand flooding, and the size of the river. Based on these five parameters the model predicts the maximum dam capacity for each segment of the stream. For the purposes of this project we focused on the two highest categories of dam capacity, frequent and pervasive, representing 5-15 dams/km and 16-40 dams/km respectively.

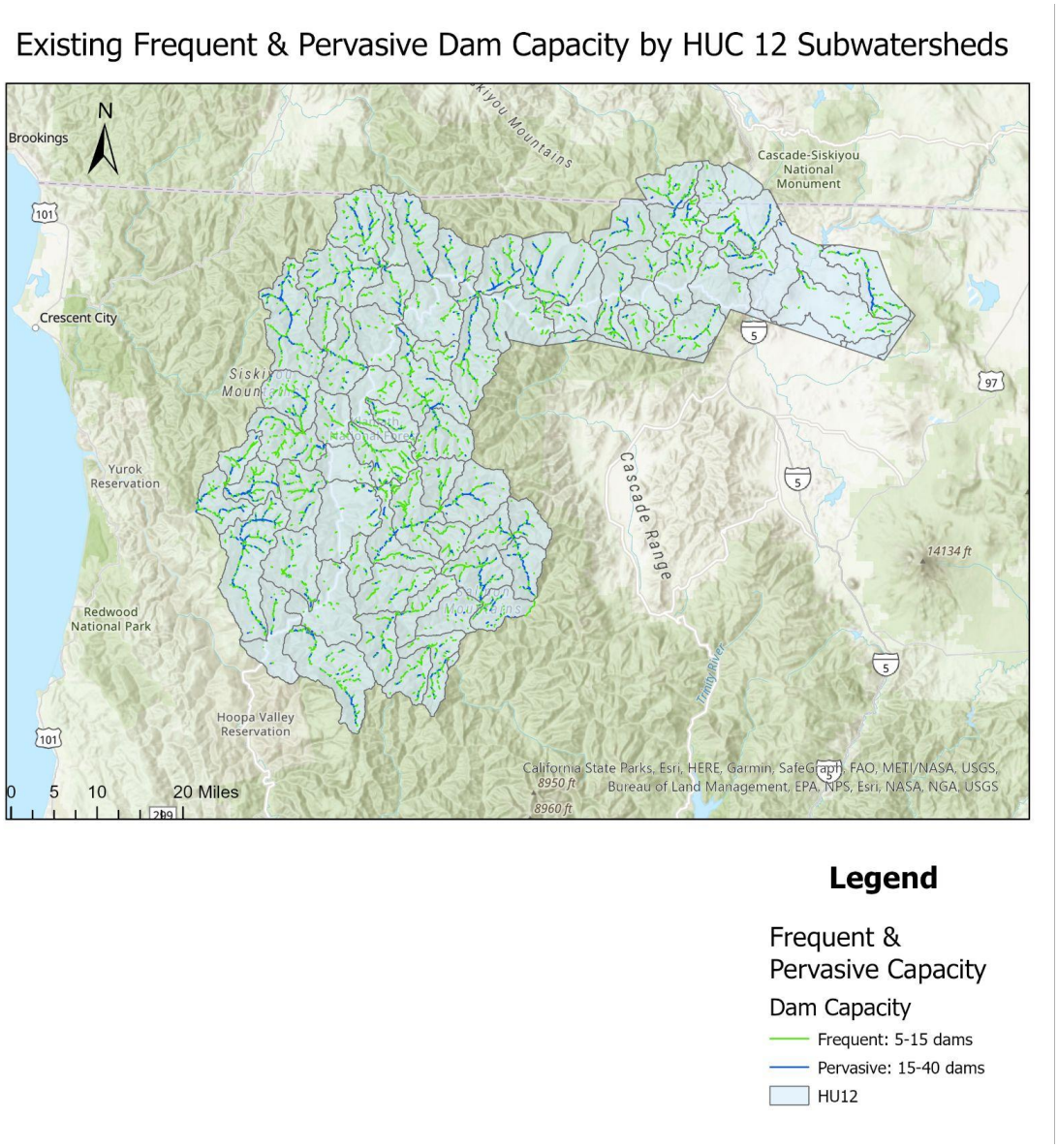


**Figure 2:** Frequent (green) and pervasive (blue) beaver dam capacity as predicted by the BRAT model in Karuk Aboriginal Territory.

We then looked at the total stream length in miles classified as having frequent or pervasive dam capacity within each HUC 12 subwatershed. We planned to focus our sampling efforts on the subwatersheds that had the most frequent and pervasive dam capacity. While not a perfect proxy for beaver habitat suitability, this metric provides information on areas that could be utilized for restoration in the future because of their high dam capacity.

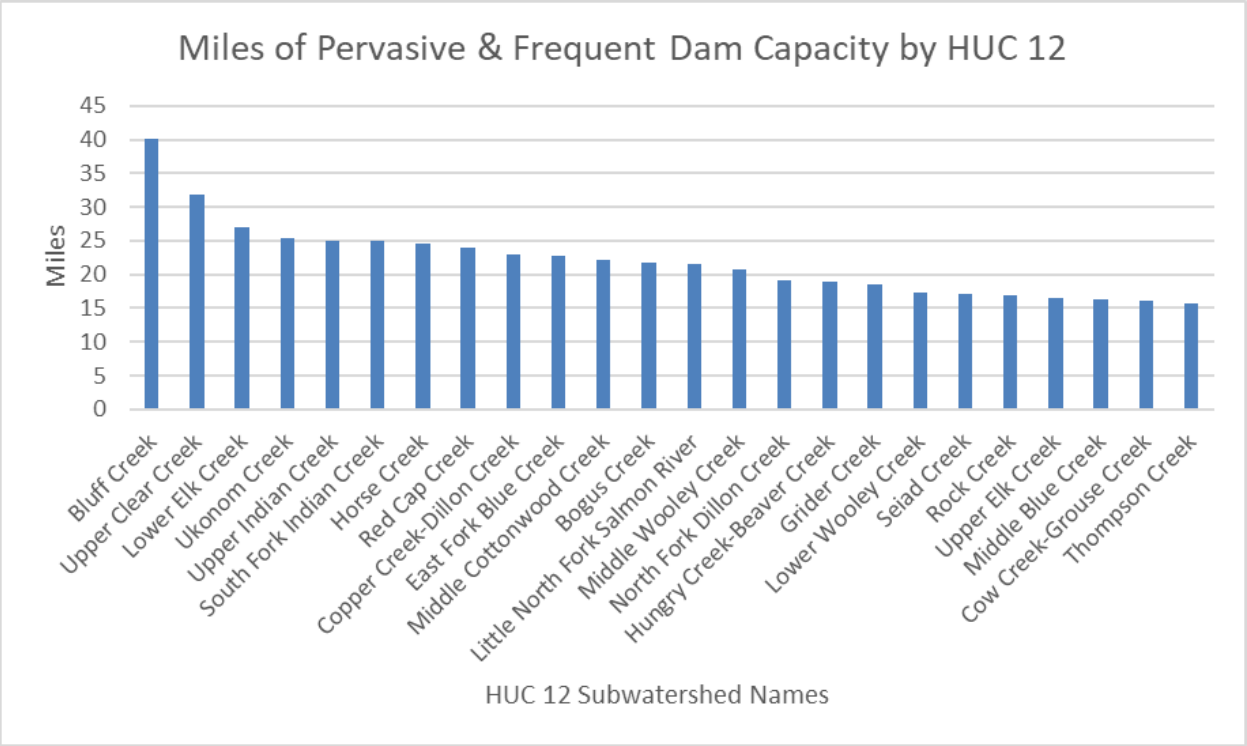


**Figure 3:** Miles of pervasive and frequent beaver dam capacity within each HUC 12 watershed unit in Karuk Aboriginal Territory.

Additionally, we incorporated the TEK and local knowledge of the Karuk Wildlife Team into our site selection process. Based on community reports and sightings the following five streams were known to have recently had beaver: Beaver Creek, Horse Creek, Seiad Creek, Grider Creek and Indian Creek. We considered sampling these five streams more thoroughly than the rest to try and gain an understanding of the population distribution, but ultimately decided that for this pilot project a more broad brush approach would be more beneficial. Our goal was to sample widely and in areas that would otherwise be difficult to access for a float or walking survey. Our list of sample sites was further edited by limited access to some of the streams due to private property or very rugged terrain. Time and resource constraints also caused us to focus our sampling in areas where we were already going to conduct floating and walking surveys. Ultimately we sampled 18 different sites across the region, from Aikens Creek to the Irongate Reservoir. We sampled three creeks at both an upstream and downstream site. These were Beaver Creek, Seiad Creek and Redcap Creek. We took a control sample from the

Sugar Creek restoration site which had an active beaver lodge present and visible fresh sign, including scat.

*eDNA Collection*

As mentioned above, sampling sites were determined based on outputs from the BRAT model as well as input from our collaborators at the KDNR Wildlife Team. Three replicate samples were collected at each sampling site. The number of replicates was chosen based on recommendations from a prior eDNA study involving beaver (Duke, 2021), informal conversations with professionals in the field, and resource constraints. Sample kits were purchased from JonahVentures and samples were collected using standard procedure as outlined in Figure 3. Samples were collected by the collaborators listed above, youth interns at KDNR, and help from Laurel Genzoli. Additional data collected at each sampling site included date, time, latitude and longitude, a qualitative description of stream section sampled, if beaver sign was present, the amount of water sampled in each replicate, and the area of the stream each sample was taken from.

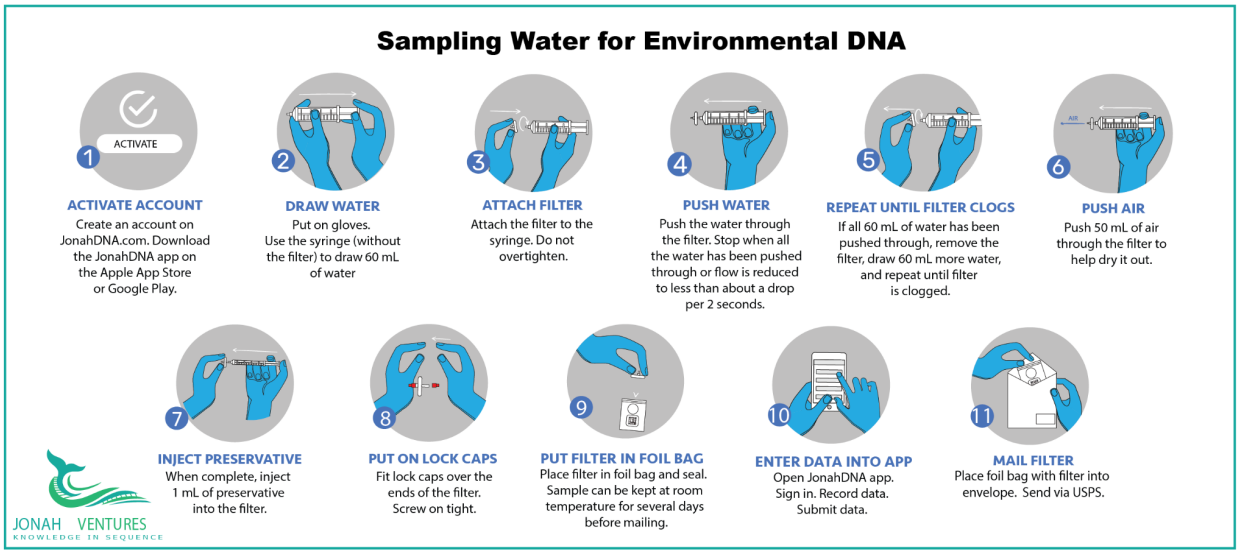


**Figure 4:** Sampling Procedure for eDNA (from JonahVentures).

*Community Surveys and Interviews*

To complement data collected in the field, our team also facilitated community based surveys to better understand where and when people have seen beavers in the watershed both recently and historically. Additionally, KDNR staff have collected unofficial community sighting reports of beaver activity – information that later informed survey site and eDNA site selection – which we summarized and used (Karuk Community Beaver Reports). These reports tracked who shared the information, where they saw the beaver or beaver sign, and when. Though helpful, only ten reports were documented between 2021-2022 and had inconsistent levels of detail. In order to expand on this method and be more intentional with data collection, we wrote up more comprehensive survey and interview questions about beaver sightings in the

community for KDNR to use should they want to. Then, UW team members hosted a short Zoom seminar with Stormy Staats to review interviewing methods and practices with KDNR youth interns. Under the direction of Staats, youth interns conducted interviews with members of the Wildlife Team in order to get a compilation of community knowledge that was passed on to KDNR from various community members. This method of intergenerational knowledge transfer with youth interns fosters capacity building within the tribe and asserts sovereignty.

*Knowledge Sharing*

Throughout the project we had several opportunities to share knowledge with others and gain important insight into our project and the broader beaver restoration and recovery world. Through unofficial interviews and conversations with other people working on beaver projects, presenting at the Klamath Basin Monitoring Program (KBMP), and a meeting with members from Tulalip Tribe's Beaver Program, we joined a network of interested people and received feedback on our project from various sources.

Part of this exchange of knowledge started with a 50 minute interview with Charna Gilmore from the Scott River Watershed Council about beaver policy and management. Charna works on a beaver restoration and recovery project just south of Karuk Aboriginal Territory, in Shasta Aboriginal Territory associated with the Quartz Valley Indian Community. UW team members were able to discuss best practices for beaver projects in the area and for mitigating conflict with landowners. This interview was recorded and transcribed for later reference.

After we returned from the river, we had an opportunity to share our findings with the broader Klamath Basin community in the Klamath Basin Monitoring Program. Capstone students and KWT member Jessica Conrad presented at the Fall 2022 meeting. After the presentation, we received several emails from audience members who provided input on additional papers for us to read and suggested other potential future research methods, many of which are addressed in our recommendations.

In order to gain a better understanding of beaver policy and projects in the California area, team members also conducted an unofficial interview with Kate Lundquist and Brock Dolman from the Occidental Arts & Ecology Center (OAEC) in California over Zoom. Through this conversation, we were able to supplement our recommendations to KDRN with information and brainstorming about projects from other people working with beavers in the state.

To further knowledge transfer and ensure KDNR's successful continuation and expansion of this project, the UW team obtained funding from the Center for American Indian and Indigenous Studies: Native Knowledge Award to fund KDNR staff members Jessica Conrad and Ben Saxon to visit the Tulalip Tribe in Washington to learn about their beaver program. In March 2023, we met at Tulalip's Administrative Building to discuss the future of beaver projects in Washington and California as well as facilitate future collaboration and knowledge sharing efforts. In the future, Tulalip Tribe has expressed interest in collaboration on elk projects, fire modeling, and beavers.

## RESULTS

We conducted five float surveys on the mainstem of the Klamath River, one walking survey on a tributary and sampled for beaver DNA at 18 different tributary sites across the

region. We found evidence of fresh beaver sign on all of our float surveys. We documented an abandoned beaver dam and old beaver sign on our walking survey but found no indication of fresh sign. Four of the 18 eDNA sites sampled indicated the presence of beaver DNA.

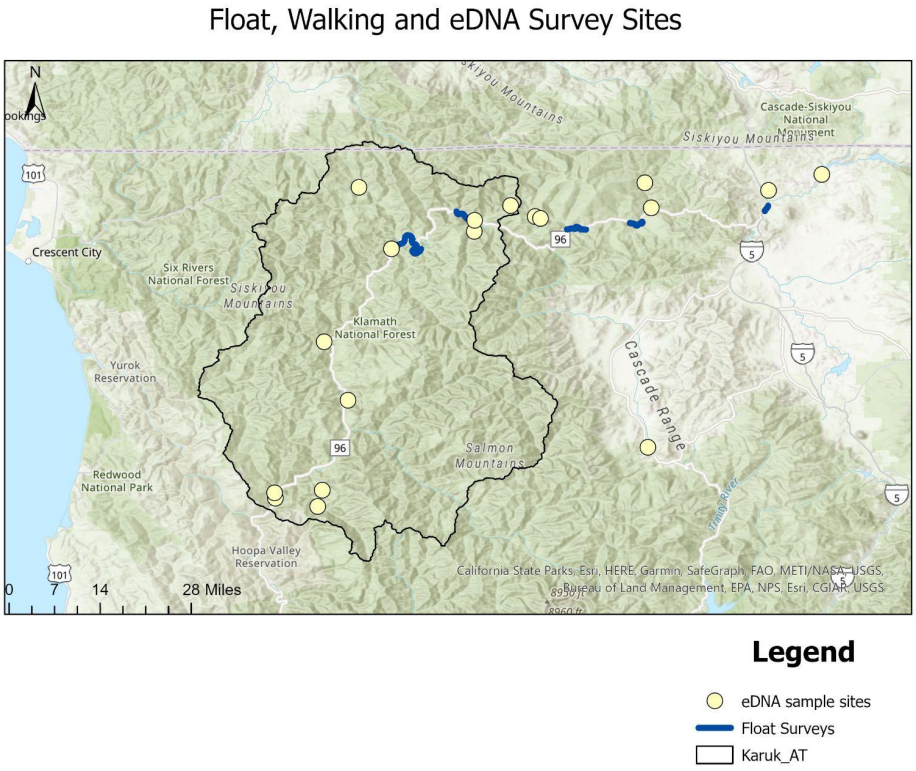


**Figure 5:** Summary of all float, walking and eDNA sample sites within and outside of Karuk Aboriginal Territory. Note: The walking survey does not show up at this scale.

*Float Survey Results*

Float surveys ranged from about one to eight miles and were conducted with between two and six surveyors. The time taken to survey each reach varied based on the length of the float and the ease of the shuttle but ranged from two to eight hours. We found evidence of recent beaver activity on all float surveys, though the number of active sites identified varied greatly between surveys. Even when standardized by mileage there was variability in the amount of fresh sign recorded from 0.33 to 1.5 beaver sign/mile (Table 1). The most common beaver sign seen was recently chewed branches, typically willow and alder. One bank den with recent activity around it was identified on the Gordon's Ferry float. Additionally, a site with very high activity in an off channel slough was noted on the Brown Bear to Horse Creek float, right before the takeout point and after the Horse Creek Bridge. This area had felled trees and some of the largest diameter chews we recorded - approximately two to three inches per branch. KDNR later deployed a game camera that confirmed beaver activity at the site. Many bank trails, slides and underwater channels through vegetation were also seen on our floats; however we were less confident in our ability to distinguish these signs from similar signs left by otters or

muskrats (*Lontra canadensis*, Karuk: *Pay saruk*; *Ondatra zibethicus*, Karuk: *Ishkeesh achnaat* respectively) and so this data was not included. We also saw signs of old beaver chew, but did not include this data unless there was also recent activity in the area. See Figure 6 and Table 1 for additional information.

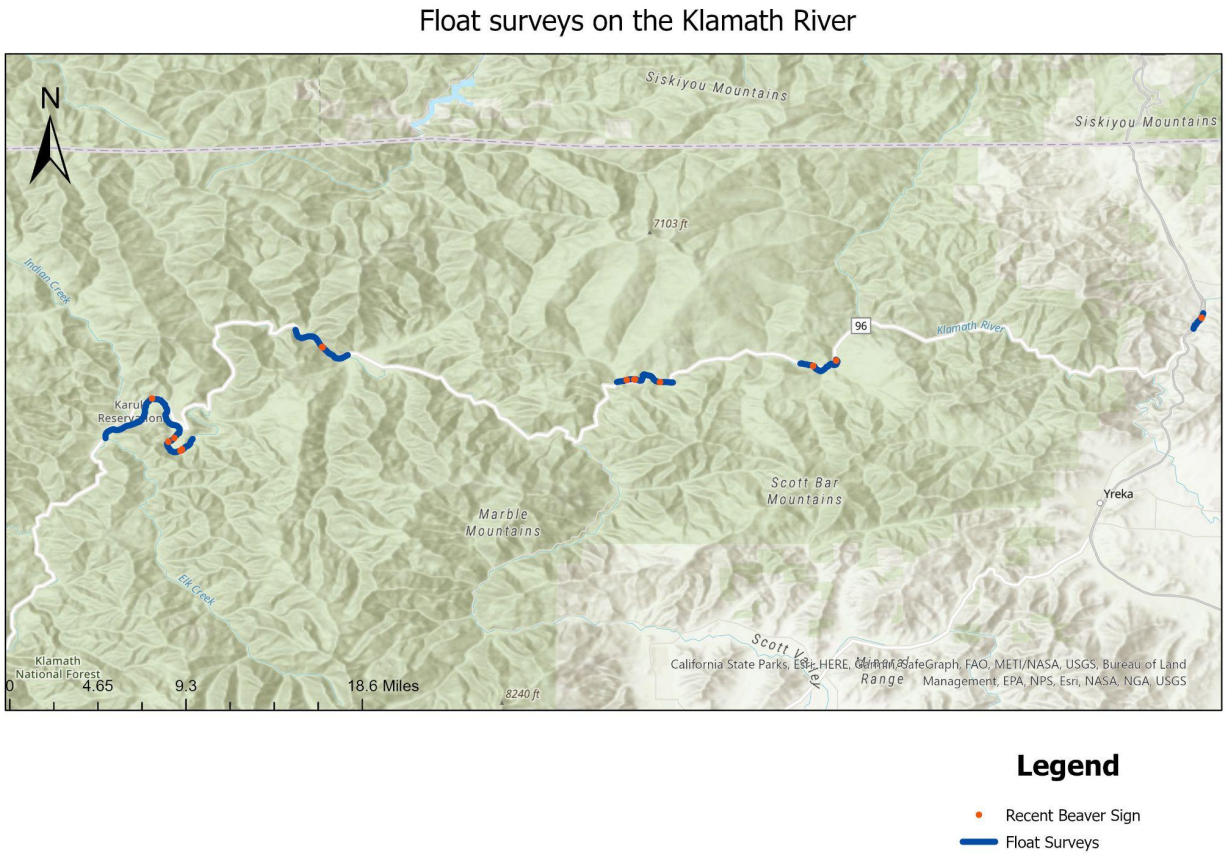


**Figure 6:** Float surveys on the mainstem of the Klamath River and recent beaver sign identified on each float.

**Table 1:** Summary table of float and walking surveys including distance surveyed, beaver sign identified and survey effort.

| Survey Reach Name | Distance Surveyed in Miles | Number of Beaver Sign Observed | Beaver Sign/mile | Beaver Sign Quality | Number of Surveyors | Estimated time for survey in hours |
|---|---|---|---|---|---|---|
| Red Cap Creek Walking Survey | .73 | 1 | 1.37 | Average- abandoned dam | 4 | 2.5 |
| I5 Reach | .93 | 1 | 1.08 | Average | 2 | 2 |
| Community Center to Walker Bridge | 2.05 | 2 | .98 | Average | 2 | 3 |
| Brown Bear to Horse Creek | 2.67 | 4 | 1.50 | High- one hot spot where game cam was deployed | 4 | 4 |
| Sleuis Box to Portuguese creek | 3.02 | 1 | .33 | Average | 4 | 4 |
| Gordon's Ferry to Elk Creek | 7.99 | 7 | .88 | High- including one active bank den | 6 | 8 |

*Walking Survey Results*

The entire Red Cap Creek walking survey covered about 0.75 miles and found no evidence of recent beaver activity. An abandoned beaver dam was identified and observations were made using the Beaver Dam Complex Monitoring Form from Utah State University. The maximum dam height was three feet and the maximum pond depth was two feet. The extent of the dam complex was between 50 and 100m. The dam was constructed of primarily woody branches of varying sizes and grasses. The dam was estimated to be one to three years old and had major breaches on both sides that appeared to be fairly recent- likely from high water during the fall/winter 2021-22. While no recent evidence of beaver activity was present it was thought to be possible due to anecdotal evidence. Water samples taken from the dam complex site did not contain beaver DNA.

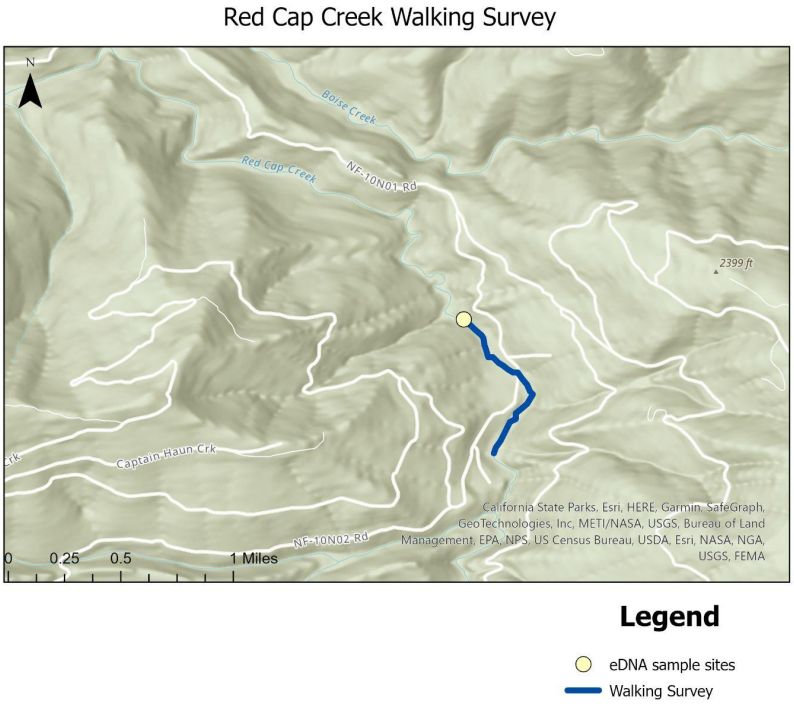


**Figure 7:** Red Cap creek walking survey, eDNA sampling conducted at abandoned dam complex.

*eDNA Results*

The eDNA samples were processed by JonahVentures and the results are shown below (Figure 8, Tables 2 & 3). Each sample was tested for beaver DNA three times. Figure 8 and Table 2 show the percent detection per sample site. Thus, 100% detection means that all three replicates from the same sample contained beaver DNA and all three samples from the same site had 100% detection. Two of our sites showed 100% detection, the mouth of Beaver Creek and the control site on Sugar Creek*. Two sites showed 11% detection. This meant that out of the three samples collected and three tests run on each sample only one test came back positive for beaver DNA. These sites were Rogers and Horse Creeks. At Rogers Creek, this result can be explained by sampling error. It was noted during sampling that one of the samples was actually collected from an area where Rogers Creek mixed with the main flow of the Klamath River. This was the one sample from Rogers Creek that came back with one positive test result. We are unable to explain the one positive test result for Horse Creek. It seems unlikely that cross contamination occurred. It would be interesting to further sample at Horse Creek to see if any more positive results would be found.

*Note: Only one sample was collected from Sugar Creek and the Horse Creek off channel pond. Three samples were collected at all other sites.

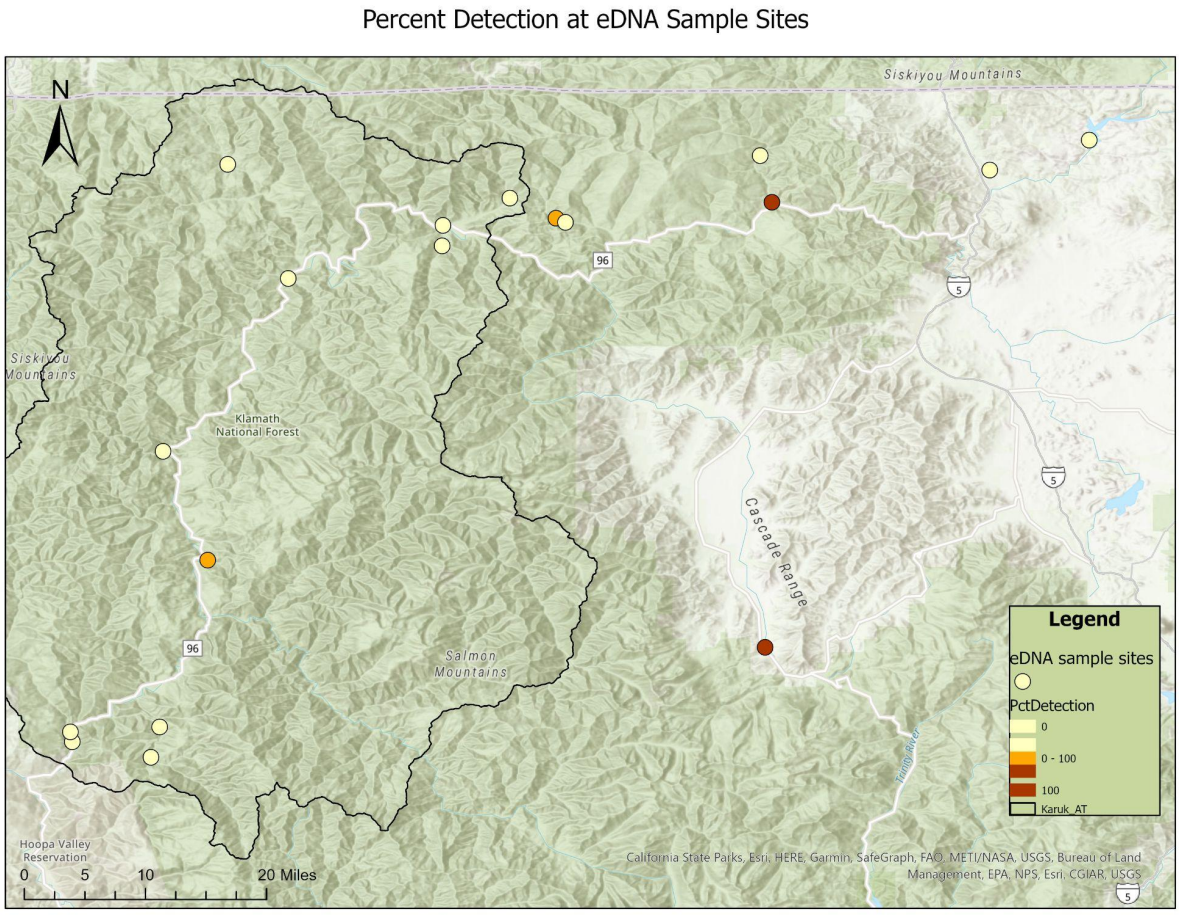


**Figure 8:** Percent detection of beaver DNA at all sampling sites. 100% detection refers to beaver DNA being identified in all three samples collected and all three replicates tested from each sample.

**Table 2:** This table shows the % detection of beaver DNA at each sample site. Three samples were taken from most sites and each sample was tested three times.

| Sample Site | % Detection |
|---|---|
| Aikens Creek | 0 |
| Beaver Creek Mouth | 100 |
| Beaver Creek Upper | 0 |
| Bluff Creek | 0 |
| Cottonwood Creek | 0 |
| Dillan Creek | 0 |
| Elk Creek | 0 |
| Grider Creek | 0 |
| Horse Creek | 11 |
| Horse Creek: off channel pond | 0 |
| Indian Creek | 0 |
| Iron Gate Reservoir | 0 |
| Red Cap Creek Lower | 0 |
| Red Cap Creek Upper | 0 |
| Rogers Creek | 11 |
| Seiad Creek Lower | 0 |
| Seiad Creek Upper | 0 |
| Sugar Creek | 100 |

Table 3 details the samples that showed positive results. It contains the further breakdown of each sample taken from every site and shows which tests detected copies of beaver DNA. The percent detection is shown for each sample rather than each site as in Table 2. Only one sample was collected from the control, Sugar Creek. But, it is interesting to note that the number of copies of beaver DNA detected in each replicate are much higher in the control than anywhere else. This is to be expected as the control site was a pool of more still water and had very obvious recent beaver sign, including visible scat and an active lodge.

**Table 3:** Summary table for all samples containing beaver DNA. Each sample was analyzed for beaver DNA three times, Rep1-3 show the number of beaver DNA copies found per 100mL of water. The average DNA copies for each sample is also reported. The PctDetection refers to the percentage of tests for each sample that came back positive.

| Stream Name | Rep1 | Rep2 | Rep3 | AvgCopyNum | PctDetection |
|---|---|---|---|---|---|
| Beaver Creek Mouth | 20 | 88 | 86 | 64.67 | 100 |
| Beaver Creek Mouth | 36 | 31 | 69 | 45.33 | 100 |
| Beaver Creek Mouth | 31 | 58 | 152 | 80.33 | 100 |
| Horse creek | 0 | 0 | 65 | 21.67 | 33.33 |
| Horse creek | 0 | 0 | 0 | 0 | 0 |
| Horse creek | 0 | 0 | 0 | 0 | 0 |
| Rogers creek | 0 | 0 | 36 | 12 | 33.33 |
| Rogers creek | 0 | 0 | 0 | 0 | 0 |
| Rogers creek | 0 | 0 | 0 | 0 | 0 |
| Sugar creek | 249 | 317 | 251 | 272.33 | 100 |

*Community Surveys and Interviews*

In 2021 and 2022, KDNR tracked community reports of beaver sightings and compiled a document of reports (Karuk Community Beaver Reports). These were essential for determining survey site locations. Karuk community members hold extensive knowledge of the land and should be utilized as a valuable resource for help in understanding beaver activity along the mainstem and select tributaries. Community members reported beavers in several areas in the Klamath mainstem around Orleans and Happy Camp. One such example of a community report comes from Kenneth Brinks (Binks) for Karuk Fisheries. The report states:

> "Binks (with Mike) has been doing weekly Chinook Redd and Carcass surveys all Fall 2021 on the Mainstem Klamath and has been doing them annually for 20 years or so. He said that there is Beaver sign at every river access point above Happy Camp in the mainstem. He said there is sign below Happy Camp but it increases as you go up from Happy Camp" (K. Brinks, Karuk Community Beaver Reports, Fall 2021).

Through our float surveys we were able to confirm beaver signs above Happy Camp, information that was consistent with community sightings from reports from individuals, like Brinks in Karuk Fisheries.

Further surveys and interviews can be conducted in the future by youth interns. The training program with Stormy Staats provided youth interns with the necessary skills to facilitate data collection in the future. As part of this training, the UW team provided a list of potential interview questions the youth can ask to collect data on community sightings for beaver. Having youth interns conduct community surveys in the future builds capacity within the Tribe and department and honors and protects data sovereignty. Having Karuk Tribal members leading this process will likely produce more thorough information due to more equal power dynamics and established trust. Additionally, we developed a draft survey that can be distributed widely to community members as a "citizen science" initiative. These interview questions and the draft survey flowchart can be found in the Appendix.

*Knowledge Sharing*

Another significant aspect of this project was being able to join the network of other people working on beaver projects in the state of California and beyond. Sharing knowledge between agencies and having fruitful discussions full of rich feedback was pertinent to expanding future avenues for collaboration and project expansion. Part of this process also involved diving deeper into beaver related policies and management practices. Our interview with Charna Gilmore provided us with information about coexistence tools between beavers and landowners as well as about beaver dam analogs and the BRAT model. Charna emphasized that working with landowners can be a challenge, but by working with them to solve their problems and find strategies to live with the beavers rather than just push their benefits was a useful approach for making progress in proving coexistence. She also provided us feedback about the BRAT model and gave us resources for researching an alternative modeling system created by Ben Dittbrenner and Michael Pollock for beaver research (C. Gilmore, personal communication, June 2022).

Another way we received feedback on our project was by presenting at the fall 2022 KMBP meeting. Through this meeting, we were able to inform the greater Klamath Basin community about the beaver project, an important task for contributing knowledge to the future advancement of beaver restoration projects in California and developing networks within the area. From this presentation – which is linked in the Appendix – we received suggestions from the audience about our recommendations for methods and future steps in the project. One such recommendation was using drones along tributaries that are hard to access otherwise. Another recommendation was to partner with Karuk Fisheries in doing snorkeling surveys to look for underwater dens and lodges or other signs of beavers while the fisheries crew is doing fish surveys with the same method. These suggestions and recommendations are discussed further in the discussion of this report.

California is still relatively new in developing beaver programs, but many groups of people and agencies are enthusiastic about the future of beaver restoration in the state and have recommendations and feedback for beaver projects. One such organization is the Occidental Arts and Ecology Center (OAEC), who UW team members unofficially interviewed in 2023. During our unofficial interview with Kate Lundquist and Brock Turner, we were able to enhance our working recommendations for the future of the project and gain insight into other beaver projects in California. One recommendation for future studies they mentioned involved conducting future surveys on Boise Creek, which has an off channel where beavers are often sighted, with Karuk Fisheries by doing snorkel surveys (K. Lundquist & B. Turner, personal communication, February 6, 2023). Collaborating with Karuk Fisheries is a valuable resource for the future expansion of this project by tapping into their resources, knowledge, and capacity.

Our final method of knowledge sharing and collaboration occurred in Spring 2023 in Seattle, Washington. When Conrad and Saxon from KDNR were able to come to Seattle, Washington for the "The Living Breath of wəɬəbʔaltxʷ" Indigenous Foods and Ecological Knowledge Symposium at UW, UW team members were able to help facilitate a meeting with the Tulalip Tribe to discuss their beaver program and other avenues for future collaboration in wildlife management. Though some of the conversation shifted to elk, prescribed burning, climate modeling, and eDNA, we were able to receive helpful information and establish a connection with Mike Sevignty and Molly Alves. Notably, we learned that Tulalip has a

Memorandum of Understanding with the Forest Service that allows them to trap beavers in problem areas and relocate them to areas where they will be able to benefit the watershed and salmonid habitat. The Tribe aims to trap and relocate entire family groups and use their hatchery as a transition site to help beavers find potential mates if they don't have a family group, or to prepare them for relocation. Using the Beaver Intrinsic Potential Model (BIP), they select a site before ground truthing it and getting it vetted by the Forest Service. Primarily, they trap from June to October. Sevignty and Alves also provided us with important contacts working in climate modeling and suggested a connection with Phil North (M. Sevignty & M. Alves, personal communication, May 4, 2023).

## DISCUSSION

### *Sampling Design and Data Collection*

A significant portion of our efforts involved on the ground decision making about methods which resulted in some trial-and-error process for data collection. Here, we will outline all the potential sources of error and problems that arose during data collection and how to address them in the future.

Although much was accomplished in a short period of time, our team faced some limitations due to time and resource constraints. The UW team was only able to visit KDNR for data collection from June 19 – June 29, 2022. This limited how much time we were able to spend surveying the river. We were constrained to traditional working hours and were unable to conduct surveys during dawn and dusk, which are peak times for beaver sightings. Additionally, we were limited in our resources by how many people could be out floating the river at a time. Although we had several inflatable kayaks and most of the wildlife crew, having additional people on the river would have ensured more accurate sightings of beaver signs. Finally, we ran into issues during our river float when an iPad that was being used for data collection got wet in the river and broke. In the future, having waterproof materials for photographing, marking waypoints, and taking notes will be extremely helpful for streamlining data collection.

We had a very flexible and dynamic approach to choosing our sample site locations for eDNA and the river floats. On days we had less time on the river, we had to adjust sampling sites accordingly and sometimes needed to shorten the length of a river float. Additionally, river access played a large role in where we were able to establish put-in and take-out locations for our river floats.

Habitat suitability modeling can be a useful tool for identifying areas for surveys as well as potential restoration sites. Multiple models have been created for this purpose including the BRAT model that we used. The BRAT model is beneficial because it is very user friendly and you can download the GIS model package for multiple states and run it for your area of interest. However, we did learn about some limitations of the BRAT model. First, the model utilizes the Landfire vegetation layers which maps vegetation at a coarse spatial resolution compared to what is actually on the landscape. Additionally, as Dittbrenner et al. (2018) point out, using intrinsic beaver potential models that predict quality beaver habitat based on geomorphic variables may be more effective for siting restoration projects given that beavers can change the vegetation characteristics at a site. Thus, models that use vegetation as a parameter for where beavers could successfully establish (like the BRAT model) may overlook many sites that with

some restoration work could become high quality beaver habitat (Dittbrenner et al., 2018). Personal communication with Charna Gilmore (Scott Valley Watershed Council) revealed that dam capacity is not always a great metric for how dams will impact the ecosystem (C. Gilmore, personal communication, June 2022). A specific stream reach may have high dam capacity, but if it is confined to a narrow valley those dams will not have wide ranging ecosystem impacts. A different stream reach may have low dam capacity, but those few dams will cause water to spread widely across an open valley bottom creating much greater ecosystem impacts. To the best of our knowledge an intrinsic potential beaver model has not been run for the Klamath Basin. This would be a good avenue for further research.

Using a Garmin to record waypoints for beaver signs proved to be extremely useful, however, some sources of error occurred. For instance, there seemed to be a lag when the Garmin started recording data points in a new location. This was identified when cleaning the data and noticing that our written records and waypoints didn't always match. For example, the first waypoint on a couple of the floats was recorded with the same latitude and longitude as the put-in site, though our notes clearly showed that it was a significant way downstream from there. Luckily, detailed note taking allowed us to catch and correct these errors by manually finding some of our survey locations on the map and marking them. This process was time consuming and should be avoided if possible. In the future it will be important to check the Garmin before a float to ensure it's working properly to provide the most accurate data. Additionally, various team members followed different procedures for collecting and recording waypoints. In the future, having a consistent method for recording data would be best.

There are many strategies for improving consistency in data collection that could be implemented. For example, if continuing to use our methods with the Garmin device, establishing a shorthand for what sign is being recorded would be helpful for data sorting. Surveyors should agree on how they plan to identify old or new chew, chewed trees vs sticks, or even the occasional turtle spotting to make it more clear what each waypoint refers to. This shorthand should be incorporated as soon as the waypoint is marked on the Garmin and should be consistent among all team members and Garmin devices. We developed a Beaver Activity Monitoring Form that could also be used to help standardize data collection on float or walking surveys (see Appendix). These could be printed on Rite in the Rain paper and carried by surveyors on the water. Avenza, or a similar data collection platform, might be able to provide the same consistency in a very efficient manner if it can be accessed on a waterproof device.

As mentioned, having a backup of handwritten notes and photos that correspond with waypoints proved to be extremely effective as a backup method. We recommend using the following methods to do so. If in the Garmin device the waypoint #45 is labeled "new chew left bank," there should be a section in the notebook labeled "waypoint 45 new chew left bank" with notes associated with that sighting. Photos should be taken and saved in a similar manner. All latitude and longitude waypoints should also be recorded in a consistent method of using decimal places, not minutes and seconds. Because it's challenging to take notes and paddle a kayak at the same time, we also recommend having individuals pair up in a double kayak if possible where one person paddles and the other takes notes. This method might be less efficient for youth with minimal kayaking experience, but can be adjusted accordingly. We recommend making sure both sides of the river bank are being surveyed by at least two people, both for safety and to ensure beaver signs are not missed. We also recommend importing and

sorting all collected data as soon as possible so all sites can be double checked while information is fresh.

In the future, we also recommend planning for more interviews or surveys with the broader community. In our project, the youth interns interviewed members of the wildlife team. Having interviews or surveys prepared when community members report seeing beaver would make it easier to follow up with those individuals and reduce bias that comes from interviewing a small sample size within KDNR. Establishing a consistent method for following up with reports would also provide KDNR with more accurate data about recent beaver sightings.

*eDNA Interpretation and Considerations*

Most of the studies done on environmental DNA have been with fully aquatic species, such as fish or aquatic invertebrates. There is less known about how eDNA monitoring will work with semi-aquatic species such as beaver. Currently, (as of May 2023) only two published studies have been done using eDNA to detect the presence of beaver. One of these studies collected DNA from recently chewed sticks and wood chips in Finland to detect the presence of the North American Beaver, which is considered an invasive species there (Iso-Touru et al. 2021). The other study collected water samples from wetlands in the Methow Valley and Gifford Pinchot National Forest in Washington state and compared the results to visual surveys of the sites. They detected beaver DNA in 81% of the sites at which they also saw fresh beaver sign, 47% of sites with old sign, and 40% of the sites with no beaver sign (Duke, 2021). This shows that while eDNA is not a perfect tool, it can still be very useful. This is particularly true in areas where little is known about beaver population distribution, such as the Klamath basin. The most important findings may be from the sites that give positive eDNA results but have no visible beaver sign. These sites would have been overlooked by all other survey methods.

Interpreting eDNA results in regard to species distribution on the landscape is extremely difficult and is complicated further due to the lack of eDNA studies specifically on beaver. Different species and even different individuals shed DNA at different rates. Without studies specifically on the amount of eDNA shed by beavers it is hard to estimate this. Additionally, the rate at which DNA decays in the environment is dependent on many factors including temperature, pH and UV exposure (Duke, 2021). The amount of time the animal spends in the water and the form that the eDNA is in also impacts its transport through the environment and impacts how long it will persist. For example, a feces pellet will move through a stream differently than a single cell. The rate of stream discharge will also greatly impact how long the eDNA will be detectable from a water sample and how much lateral dispersion will occur (Li et al. 2019, Laporte et al, 2020, Thalinger et al. 2021). Environmental DNA has been documented lasting up to three weeks in certain conditions and being found over three miles from where it originated in river systems (Laporte et al. 2020). However, these findings are considered the extremes and this is based on research with fully aquatic species. Samples that tested positive for beaver DNA were most likely due to beaver activity occurring less than one km away from the sample site and within 48 hours of beaver presence (Allan, 2021, Li et al. 2021).

We did not detect beaver presence on some of the creeks that we expected to based on local knowledge and community sightings. However, due to the temporal nature of eDNA, the conclusions about beaver absence on these streams that can be drawn are limited. It is possible that our sampling was conducted at too small of a scale to detect beaver presence if it was

intermittent. The negative results could have been due to the sampling sites chosen, i.e. there could have been beaver present downstream of our sampling sites that would not have been detected by eDNA. It's also possible that the community beaver sightings were older and that there hadn't been recent beaver activity in the area. In the future, it would be helpful to have more detailed information about where and when sightings occurred.

Based on our findings from this eDNA pilot program, we believe that with additional research and carefully planned sampling, eDNA could become a useful tool for assessing beaver populations and siting restoration projects in the Klamath Basin. We found that as a broad brush tool eDNA was fairly successful in locating potential sites for further study. For example, we found 100% detection rates at the mouth of Beaver Creek but had zero detection a couple of miles upstream. It would be interesting to then conduct a walking survey upstream of the positive detection to see if we could find recent beaver sign. There was not time to do this immediately after the results came back. A future walk could still prove fruitful, but because of the temporal nature of eDNA it would have been ideal to conduct such a survey over the summer.

Beaver monitoring with eDNA is much less resource intensive than other survey methods in terms of time and effort. The cost of 50 samples + analysis from JonahVentures was about $2500. While this is fairly costly, the actual data collection process can be conducted by one person in under an hour at each site. Most of our sites took longer to drive to than to actually collect samples from. Float surveys are not feasible on the tributaries and walking surveys tend to be very slow because of the steep terrain, dense vegetation and high stream flow in some areas. Thus, eDNA may be the best way to sample in certain areas that are very difficult to access otherwise.

We recommend the following techniques for eDNA collection in future studies. Three to five replicates should be collected at each site. More samples are likely better if the resources are available. This is particularly important in areas where beaver abundance is low or unknown, because it will increase the probability of detecting beaver at a site. Two of our sites, Rogers and Horse Creeks, tested both positive and negative for beaver DNA even within the same samples. Perhaps more samples at these sites would have provided further information about this variation. We found that it is important to vary the area of the stream in which the samples are taken from. Again, one of the samples taken from Horse Creek showed beaver DNA but not the others. This DNA would likely have been missed if we had not spread out across the stream. Other studies have shown that there is not always much lateral mixing of eDNA, particularly near to its sources, so it is important to test different areas in the pond or stream (Thalinger, 2021). We also recommend sampling at least one liter of water in each sample if possible. The more water you can push through the filter, the higher the probability of detecting beaver will be (Duke, 2021). Thus, try to find a relatively clean and clear area to sample so the filter doesn't clog too quickly.

There are many interesting and important future studies that can be conducted to better understand how to use eDNA for beaver monitoring. Conducting eDNA sampling downstream of a known beaver complex in order to better understand the spatial and temporal persistence of beaver DNA in streams should be the main priority. It would be important to also collect flow data, pH, cloud cover (as a proxy for UV) and water temperature in this study to understand the relationship with stream discharge, water quality and eDNA persistence. Ideally sampling sites

could be sampled multiple times, perhaps once during the day and once at night. Siting a game camera at the beaver complex to record activity could give additional insight into differences in eDNA results. It would also be interesting to try using eDNA to assess population distribution at a finer scale. On some of the creeks with known beaver sightings, we could sample at multiple sites in order to assess how far upstream or around the complex their habitat extends. Another interesting potential use could be to test the same site on a daily or weekly basis for a month to see how much of a temporal effect there is on finding beaver presence. Another question that remains is regarding the level of dilution and how that impacts a negative or positive result. To test this theory it could be interesting to sample the Klamath mainstem at several locations and see if we get consistent detection of beaver DNA.

*Community Sightings Data Collection*

A streamlined data collection system for community sightings and reports could provide a lot of great crowd sourced information. One such tool exists that is specific to beaver. It is an app called iBeaver through the Survey123 platform. Community members can log their beaver sightings containing photos etc. and opt to make the data publicly available or keep it privately accessible to only the KDNR Wildlife Team. This could be one possible solution to gather additional data from community members in an organized and non resource intensive way. It is unclear whether or not it would get much use, but may be worth a trial run. Perhaps a tool of a similar design could be created on a platform already in use by community members, such as a Facebook group/page.

Another option for streamlining this data collection would be to conduct more formal surveys and interviews with community members to try and gather additional sightings data. This would help to standardize the data collection process and might provide more information on beaver distribution and activity in the area. These surveys could be focused on just beaver or include other species of interest to the KDNR Wildlife Team. Examples of possible survey and interview questions are in the Appendix. Members of KDNR or youth interns would be ideal interviewers.

*Next Steps*

Throughout this project, we learned many lessons about the best methods for continued beaver monitoring, restoration, and recovery. For the continuation of this project, we recommend several next steps based on lessons learned.

The KDNR Wildlife Team plans to continue monitoring beaver populations within Karuk Aboriginal Territory and beyond in order to assess how dam removal impacts population distribution and to inform future restoration efforts. We had hoped to find an existing methodology for conducting a beaver population estimate, but this proved more difficult than we imagined. From conversations with experts in the field, we learned that we are not the only ones attempting to do so. Currently, California Department of Fish and Wildlife (CDFW) is trying to answer this same question as they begin their new Beaver Program (M. Alves, personal communication, May 4, 2023). In the past, beaver population estimates have been calculated based on the number of dams in an area, the number or size of lodges in an area, the number of food caches, the number of scent mounds, or through actual capture and tagging methods.

A foundational study from the Rocky Mountains found that numbers of dams, lodges, and scent mounds do not correlate with population density (Hay, KG, 1958). The size of beaver colonies typically varies from two to ten individuals and a single colony may build many dams, lodges and scent mounds. Additionally, if you are conducting aerial surveys or surveying aerial imagery, these structures may be difficult to identify in riverine systems and may persist long after being abandoned (Robel et al., 1993). In areas where beavers create food caches, surveying for such caches is the best way to estimate the population because each colony creates only one food cache (Hay, KG, 1958). Food caches are less common in riverine systems and in systems that do not completely freeze overwinter, and are thus not likely useful in the Klamath Basin unless perhaps for some high elevation wet meadow habitat (Robel et al., 1993).

Population estimates are complicated further in the Klamath region because of the prominence of bank dens and non-dam constructing beavers that live in the mainstem of the river. There is very little literature on such beaver populations. From personal communications with experts at the Methow Beaver Project we know that individual beavers have been tracked traveling up to 80 miles from their release sites. On our float surveys we saw lots of old and new beaver chews and identified one active bank den. Many questions remain about how the signs observed can translate to population density. For example, “how large is a beaver’s range on the Klamath mainstem?”, “How often do such ranges overlap?”, “How many beaver typically inhabit the same area on the mainstem?”, “Do beavers in the Klamath Basin create food caches, and is this a viable way to estimate population in this area?” More research and collaboration needs to be done to answer these outstanding questions before an attempt at a population assessment can be made.

With additional funding, we could build off of our initial survey and eDNA results and hone in on certain areas to gain more information. The game cameras already set up by the KDNR Wildlife Team will help to answer these questions. Ideally, more game cameras would be set up in areas that appear to have high beaver activity. We also recommend using beaver lure (pheromones) to attract more beaver from the area to the game camera sites. It would be helpful to conduct additional float surveys along the Klamath and return to the sites we have already surveyed to see if we can detect any changes in beaver activity due to their nomadic behavior. Our float surveys focused on the area upriver of Happy Camp. It would be good to survey additional areas between Happy Camp and Orleans. If time and resources allowed, it would be interesting to conduct float surveys in the early morning and evening to have a better chance of spotting beavers while they are active. Moreso, doing surveys during different seasons of the year could provide different levels of beaver activity and use. However, this could be difficult due to the higher flows during the fall and winter. The safety of the surveyors should always be top priority and surveys should not be conducted in unsafe waters. There are options available for Swift Water Rescue training or general water safety courses in rivers that KDNR staff might consider if funding is available to increase safety measures during river floats in changing river conditions due to seasonality, climate change, and dam removal. Additional tributaries could be sampled with eDNA and some of the original sample sites that gave variable results should be retested. Walking surveys should first be conducted at sites that tested positive for beaver DNA during the first round of eDNA sampling. Ground surveys could then be extended to sites that community members identified as having beaver. Research into other

non-invasive tracking methods, such as the use of hair snares or mark and recapture techniques, will be important to guide the efforts moving forward. Efforts are being made to utilize machine learning and artificial intelligence to recognize beaver dam complexes from aerial imagery. This project is known as EEAGER and is being led by Emily Fairfax (Tripathy-Lang, 2023).

There is currently a lot of enthusiasm for and momentum around beaver restoration projects. It will be important to continue to collaborate with other organizations and governments and to stay abreast of what new research is conducted. Additionally, there may be opportunities to build upon existing collaboration between programs within KDNR. The fisheries department is already surveying many of these sites and could be a good source of information on beaver activity. A 2016 Master's Thesis by Marisa Parish found that snorkel surveying was an effective method for identifying beaver sign, particularly bank dens, on the Smith River. From personal communication with Justin Garwood (CDFW, Environmental Scientist) we learned that on the Smith River beavers alter their behavior seasonally with flow. In the summer and fall they primarily use the mainstem of the river and the large tributaries. Dams built in these larger tributaries almost always blow out during high winter flows. In the winter, beavers move into the smaller tributaries where they will sometimes build small dams (J. Garwood, Personal Communication, November 2022). The Smith River is an undammed river with high seasonal fluctuations in flow. It will be very interesting to see if beavers on the Klamath River develop similar behaviors post dam removal.

Little data exists on how beavers respond to large scale dam removal projects. At the time of its removal in 2012 the Elwha River dam removal was the largest such project ever undertaken. There have been many studies on the biological response of salmonid species to the dam removal that have shown increases in coho, Chinook and steelhead (McHenry et al., 2017; Duda et al., 2019; Liermann et al., 2017). Fewer studies have focused on the response of wildlife to the dam removal. Monitoring efforts conducted by the Lower Elwha Klallam Tribe have documented recolonization of the former reservoirs by beavers (Northwest Treaty Tribes, 2017). Currently no published data exists to document the exact results of these monitoring efforts. Connecting with the Lower Elwha Klallam Tribe to discuss methods and results could be an interesting avenue to pursue in the future.

**CONCLUSION**

The Karuk Tribe's beaver project is still in its beginning stages and we were honored to help the Tribe pilot research methods for the continuation of their beaver project. It is our hope that this report and the documents in the associated Appendix can serve as an unofficial "Karuk Beaver Restoration Guidebook" that is specifically tailored to the needs and capacity of the Karuk Tribe. By blending research methods that include TEK and western science we were able to maximize our understanding of beaver activity in the Klamath watershed pre-dam removal. In the future, continuing to incorporate TEK through community surveys and interviews, using updated modeling systems, taking eDNA samples, and doing float and walking surveys will provide a comprehensive overview of beaver activity and can set the groundwork for leveling up the project to include habitat restoration sites, relocation sites, and even population estimates. In fact, in summer of 2023, members of this project will take another trip the Klamath River to

help do more surveying and training with Tribal members and KDNR Youth Interns. This capacity building will open the doors for new innovation and will assert Karuk Tribal sovereignty by honoring traditional cultural values and prioritizing Karuk people doing Karuk work in Karuk lands. Outside collaborations can be useful, as we hope we demonstrated here, but the ultimate goal is to remove the need for external institutions to do this kind of work in Karuk Aboriginal Territory.

Additional information on select topics can be found in the Appendix below.

Appendix Table of Contents:

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# APPENDIX

# Beaver Policy and Management in California

## General Policy Information

The state of California has several policies and laws that are relevant for beaver restoration and recovery. California Department of Fish and Wildlife (CDFW) oversees many projects throughout the state and provides permits to individuals and agencies for various restoration, handling and management activities. Within these projects, policies and associated permits for beavers have primarily been centered around human-wildlife conflict management between beavers and landowners. Indeed, the state of California did not even think beavers were native to the area until undergoing an updated review of the historic range of beavers in 2013, putting them years behind other states engaged in beaver restoration and recovery (Lanman et al., 2013). Now, the state has acknowledged not only that beavers are endemic to the area, but that they are an important keystone species and ecosystem engineer that make landscapes more resilient to climate change and wildfires, and provide essential habitat for other important species, like the critically endangered coho salmon in California (CDFW, 2023).

Currently, most of the policies and the required permits in California around beavers are centered around pest management and depredation. In such, landowners can apply for a depredation permit from CDFW to kill a beaver or remove their dams if they are causing damage. There are currently no permits or laws that allow for beaver relocation in California.

Prior to the 2022-2023 fiscal year, that state of California did not have any funding or projects dedicated to beaver restoration and recovery either. However, in early 2023, CDFW and the State Legislature approved funding for more projects engaged in not just mitigating conflicts with beavers, but also in prioritizing their restoration in watersheds. The state has also committed to partnering with Tribes for future restoration activities and are looking into the feasibility of beaver relocation efforts (Bonham, 2023).

## Current Permitting System

*Depredation Permit* – CDFW
An individual or agency may apply for a depredation permit through CDFW. When a beaver is listed as causing damage or nuisance to an area of land, an individual may apply for this permit to trap and kill the beaver as a method of control.

*Trapping Permit* – CDFW
Trapping permits are required for beavers, however these permits are currently designed for euthanization. They emphasize trapping the animals in the most humane way possible and prohibit the use of dangerous traps and snares that could injure or kill the animals in an inhumane way. Once a beaver is trapped, it must be immediately euthanized according to the

guidelines in this permit. Although the state does not currently have an established relocation policy for trapped beavers, generally translocations must happen within a species' indigenous range.

*Scientific Take Permit*
If the beaver capture is for scientific research purposes, a Scientific Collecting Permit is generally required. This permit is issued by the California Department of Fish and Wildlife (CDFW) and authorizes individuals or research institutions to capture and handle wildlife, including beavers, for scientific study. The permit application process typically involves providing detailed information about the research objectives, capture methods, and intended outcomes.

Note: Although ODFW has an established permitting system for beavers in the state, in order for the Tribe to fully exercise their sovereignty and jurisdiction over wildlife and land on their territory they should not be held to the same regulations as the state. A Memorandum of Agreement or Understanding between ODFW and the Karuk Tribe would ensure that the Tribe could make their own decisions on their land without adhering to state or federal regulations.

## Current Policy, Management, and Restoration Efforts

*Human Wildlife Conflict Mitigation*
Primary policy efforts related to beavers are centered around the conflict the animals pose for landowners who consider the animals to be pests. The beavers will chew up property and impede farming efforts as well as impact the water flow of a farm. Because of these conflicts, the policies and permits listed above focus on depredation and killing beavers.

Fortunately, there are numerous strategies available to foster harmonious coexistence between people and beavers. Farmers can employ protective measures, such as fencing or applying a mixture of latex paint and sand to tree trunks, which deters beavers from gnawing on them and safeguards their trees and crops (CDFW, 2023). Similarly, the installation of fencing near culverts and tide gates can effectively prevent beavers from obstructing these vital water passages, mitigating the need for destructive measures like dynamite to remove dams. The Methow Beaver Project in Washington also proposes an innovative solution to flooding through the use of flow devices, enabling control of flooding on agricultural land caused by beaver dams (Methow Beaver Project, 2023). If necessary, as a last resort, beaver relocation can be considered to address situations where beavers are causing significant harm to landowners. In this regard, the Tulalip Tribe in Washington has emerged as pioneers in strategic beaver relocation efforts, moving beavers to areas where their presence can best contribute to the ecosystem's overall health and balance (Tulalip Tribes, 2023).

*Beaver Dam Analogs*
Beaver Dam Analogs (BDAs) are a great tool for restoration in order to facilitate beavers moving into a stream. BDAs are essentially a human mimic of natural beaver dams and are created with the idea of, "If we build it, they will come." BDAs can also be sites to bring relocated beavers to. There are many steps for creating a successful BDA, but many people have practice in

implementing this strategy. In the Scott Valley, the Scott River Watershed Council implemented a BDA with the assistance of Michael Pollock from NOAA (Charnley, 2018). Beavers have started to utilize and maintain the BDA they created at Sugar Creek.

**Other Useful Links:**

CDFW Budget Change Proposal for the 2022-2023 Fiscal Year
FGC § 4000-4011. Trapping Provisions
FGC § 4181. Depredators
CCR § 401. Issuance of Permit to Take Animals Causing Damage
FGC § 1602. Fish and Wildlife Protection and Conservation
CCR § 463. Beaver
Policy and Procedures for Conservation Translocations of Animals and Plants (2017)

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*Methow Beaver Project – Storing water for the future one beaver at a time*. (2023). Methow Beaver Project. https://methowbeaverproject.org/

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# Floating and Walking Surveys: Best Methods

**Materials Needed**

- Kayaks, life vests, paddles, pumps
- Data collection sheets printed on waterproof paper or a Rite in the Rain notebook where you can take detailed notes
- Pencil or other waterproof writing utensil
- Waterproof camera (GoPro or iPad/phone in a sealed waterproof bag or case)
- Gamin or other GPS system for indicating latitude and longitude
- Crew/staffing needs: ideally four people for a float survey and two for a walk survey

**Float Surveys**

To conduct a float survey, first gather the materials needed and make a plan on where to survey based on TEK of community members from interviews and surveys, eDNA data, or other knowledge sources that can help guide the best survey locations. After that, the methods are as follows:

1. Indicate the latitude and longitude of the put-in spot
2. Put surveyors on each side of the river if possible
3. Scan the riverbank and associated vegetation for signs of beaver or beaver activity (examples below)
4. When a beaver sign is spotted, pull to the side and stop as close to it as possible if it is safe to do so
5. Indicate the latitude and longitude where the sign was found. If using a Garmin, you may choose to write down the given waypoint number and/or write the latitude and longitude on the datasheet
6. Fill out the appropriate data sheet for the type of beaver activity that is seen. If a dam, den, or lodge is spotted, fill out that data sheet as well (see below for the type of information that should be included in the data sheets or notes)
7. Take photos if possible. Edit the information in the photos to indicate what data point/waypoint the photo is associated with. Adding the waypoint number as a caption in the photo might help with this
8. Continue down river
9. Garmin mark other desired animals or points of interest. If doing this, be sure to establish a short and consistent method for collecting this information. Having an established short-hand for other animals within the Garmin system or your notes will be helpful (ex: red eared slider = RES, muskrat = MUSK, salmon fry = FRY, etc.)
10. Indicate the latitude and longitude of the take-out spot

General information that should be recorded in the data sheet or in notes include:

- Beaver sign type and if it's old or new activity
- Location (lat/long) of the sign/activity
- If it's beaver chew, include measurements and vegetation type
- What the vegetation and river/tributary look like at the spot of activity

Other things to consider:

- 2 people per kayak with 1 paddler and 1 data collector/recorder proved to be a useful way to organize personnel. This means the minimum number of people that would be best for this type of surveying is 4 (a pair per riverbank). However, this might not be so useful with the youth.
- Be careful to not get waypoints mixed up or leave them unlabeled within the Garmin. Have a clear and consistent method for keeping track of what lat/long/waypoint is associated with what type of beaver activity. Label the same sign consistently and use the same labeling system in the Garmin, in your notes, on the data sheet, and on photos. Use the data sheets as a guide to help with this organization
- Data sheets and organization structure provided in this guide may not be necessary when using developed applications like Avenza as long as all the information is recorded

**Walking Surveys**

During walking surveys, follow the same methods as the float survey. Be sure to indicate if travel is upstream or downstream, the starting and ending latitude and longitude of the survey, and any signs of beaver or beaver activity (below). Record information on the provided data sheets.

**Other Data Collection Methods**

There are several applications that have been developed that might make it easier to track beaver activity. If the data sheet is not the best method for field data, look into these alternatives:

Utah State Beaver Monitoring Application Protocol
Survey 123 - iBeaver

**Guide For Spotting Beaver Sign**


Beaver slide


Bank den/lodge


Lodge


Felled/chewed trees and shavings (corn on the cob)


Scat


Trail (land or in water)


Scent mound


Beaver Dam


Gnawed sticks and branches (chew)

## OBSERVATION INFO

Observer Name: _____
Site ID: _____
Observation Date: _____

GPS Easting: _____
GPS Northing: _____
Garmin Waypoint #: _____

**BEAVER SIGHTING?**

- ☐ Yes
- ☐ No

**EVIDENCE OF BEAVER? -** No sighting

- ☐ Yes
- ☐ No

## EVIDENCE OF BEAVER ACTIVITY

**OBSERVED SIGN**

- ☐ Chew
- ☐ Scat
- ☐ Bank slide
- ☐ Trail - underwater or on land
- ☐ Scent mound
- ☐ Felling of trees
- ☐ Signs of foraging (corn on the cob)
- ☐ Other: _____

**For bank lodges, beaver dens, and beaver dams, see BEAVER DAM COMPLEX MONITORING FORM - ADVANCED**

**CONFIDENCE IN SIGN**

- ☐ Certain - Documented Evidence
- ☐ Probable - Strong Evidence
- ☐ Possible - Anecdotal or Inconclusive Evidence
- ☐ Unsure - Just a guess
- ☐ No Evidence of Activity

**STATUS**

- ☐ Active or Recently Active
- ☐ Slightly Old
- ☐ Old or Abandoned
- ☐ Historic/Relic

**IS THERE A PHOTO ASSOCIATED WITH THIS SIGN?**

- ☐ No
- ☐ Yes - provide details for finding the correct photo: _____

## BEAVER CHEW ATTRIBUTES (and other signs where applicable)

**SINGULAR OR MULTIPLE SIGNS? -** multiple chewed branches etc.

- ☐ Singular
- ☐ Number of sings: _____

**VEGETATION TYPE**

- ☐ Willow
- ☐ Alder
- ☐ Other: _____

**VEGETATION SIZE**

- ☐ Small - twig sized
- ☐ Medium - branch sized
- ☐ Large - tree sized
- ☐ Record diameter: _____

## RIVER/TRIBUTARY ATTRIBUTES

**LOOKING DOWNRIVER, WHAT RIVER BANK WAS THIS OBSERVATION ON?**

- ☐ Right
- ☐ Left

**ARE THERE MULTIPLE CHANNELS HERE?**

- ☐ No
- ☐ Yes - provide details: _____

**RIVER FLOW**

- ☐ High - rapids, cannot stop or get out
- ☐ Medium - can stop for a short amount of time, unsteady to stand
- ☐ Low - can stop and get out for detailed observations

**OTHER DETAILS:** _____

## RECOMMENDED FOLLOW-UP

- ☐ Future Habitat Restoration Sight
- ☐ Future BDA Sight
- ☐ Future Relocation Sight
- ☐ Future Game camera Sight
- ☐ Future eDNA Sight
- ☐ Other: _____
- ☐ No follow-up

## OTHER OBSERVATIONS AND NOTES

_____

_____

_____

# Interviews and Surveys: Tracking Community Knowledge

This project will benefit from including information about beaver activity and sightings from community members within the Karuk Tribe. From the beginning of this project, people have been verbally sharing their experiences and encounters with beavers with the KDNR wildlife team. This data needs to continue to be collected and streamlined for future use. When someone shares information about beavers, this should be documented with the name of the person, what they saw (beaver/dam/sign of beaver), when they saw it, where they saw it, and if beaver activity is still occurring or an estimate of how long it has been since the activity. People should indicate if they're willing to be officially interviewed as well, however this information will likely suffice on its own.

We also recommend expanding this process to include conducting intentional interviews and distributing targeted surveys to collect more data from community members on beaver sightings. Interviews can be conducted with individuals who have a lot to share about beaver activity in a particular area. We believe interviews would provide useful information about historic activity, but targeted surveys about recent activity that can be widely distributed would be more useful for the sake of this project.

**Interviews**

If conducting an interview, be sure to ask for permission to use recording devices. Take detailed notes of the answers to your questions. Some potential questions to ask in an interview include:

- Have you seen any beavers on Karuk Aboriginal Territory in the last year?
- Where? How many? What were they doing? What size were they? What other animals were around when you saw them? What time of day was it?
- If not, when was the last time you saw beaver or signs of beaver in Karuk territory? Where/when?
- Where have you seen beaver sign? What sign(s) did you see? When?
- Are there places where you have heard there used to be beavers?
- Are there any places that would be good habitat for beavers, or where you think they should be introduced?
- What kinds of habitat restoration projects do you think would be good to do to encourage beavers?

**Surveys**

Surveys are likely the most effective method for collecting community knowledge about beaver sightings. These surveys can inform future efforts for the wildlife crew to take, by indicating potential spots for river floats, walking surveys, game cameras, or eDNA collection. Surveys could be facilitated through programs like iBeaver or Survey 123. Information to collect in surveys includes:

- In the last year, have you seen any beavers/sign of beaver on Karuk Aboriginal Territory?

- How many beavers/beaver signs have you seen on Karuk Aboriginal Territory in the last year?
- For each sighting, how many beavers were there? Were there signs of beaver nearby?
- Approximately where and when (month/time of day) did you see the beaver(s)/sign of beaver?
- What was the beaver doing?
- Were there any other signs of beaver activity nearby? (i.e. dam/lodge, freshly cut trees and shrubs, wood chips/shavings near cut trees, teeth marks on trees, slide marks by the water, fecal droppings, beaver sounds, beaver ponds and channels etc.)
- What sign(s) did you see?
- Were there other animals nearby? If so, what?
- Is there anything else you would like to tell us about what you saw?

A sample survey flowchart with these questions is drafted here.

# Using eDNA for Beaver Monitoring

## eDNA Basics

Environmental DNA or eDNA is DNA that is released from an organism into the environment. This process happens continuously through the shedding of hair and skin cells and from the animal's feces or mucus. Environmental DNA can be collected from air, soil or water samples. DNA does not persist long in the environment (typically from about two days to two weeks depending on conditions), so eDNA provides a snapshot of species recently in that environment. After collection, the DNA is then extracted, amplified and analyzed at the lab through either the qPCR or metabarcoding processes. This analysis identifies if there is beaver (or other species of interest) DNA in the sample and how abundant that beaver DNA is.

## Methods

Water samples should be collected following the instructions provided by the company that will be processing samples. Below is an example of the procedure from JonahVentures.

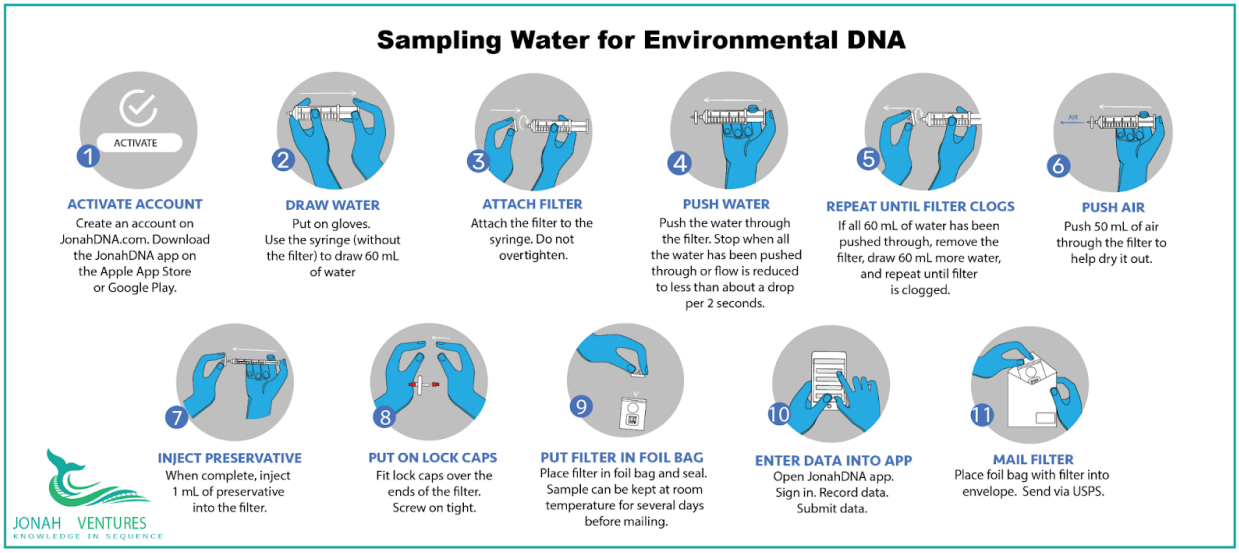


**Figure 1**: Sampling Procedure for eDNA (from JonahVentures).

Best Practices:

- Take a minimum of three samples from each sample site. More samples are better if the resources are available. This is particularly important in areas where beaver abundance is low or unknown, because it will increase the probability of detecting beaver at a site.
- Vary the area of the stream in which the samples are taken from. Studies have shown that there is not always much lateral mixing of eDNA so it is important to test different areas in the pond or stream (Thalinger, 2021).
- Try to sample at least 1 liter of water. The more water you can push through the filter the higher the probability of detecting beaver will be (Duke, 2021). Thus, try to find a relatively clean and clear area to sample so the filter doesn't clog too quickly.

## Interpreting Results

*What does finding beaver DNA in a water sample tell you?*

The very simplified answer to this is that a positive result means that there was likely a beaver, or multiple beavers, upstream within about 1 kilometer of the sampling site within less than 48 hours of the sampling time (Li et al. 2019; Allan, 2021). Additionally, the sample results will show the relative abundance of beaver DNA from each site, but there is currently no way to translate that into how many beaver are at each site.

In reality the actual answer is much more complicated. Different species and even different individuals shed DNA at different rates. Without studies specifically on the amount of eDNA shed by beavers it is hard to estimate this. (The Tulalip Tribe Beaver Program is working on a study about this! Follow up with them in the future.) Additionally, the rate at which DNA decays in the environment is dependent on many factors including temperature, pH and UV exposure. The amount of time the animal spends in the water and the form that the eDNA is in also impacts its transport through the environment and impacts how long it will persist. For example, a feces pellet will move through a stream differently than a single cell. The rate of stream discharge will also greatly impact how long the eDNA will be detectable from a water sample.

Most of the studies done on eDNA have been with fully aquatic species, such as fish or aquatic invertebrates. There is less known about how eDNA monitoring will work with semi-aquatic species such as beavers. Currently, (as of May 2023) only two studies (not including the KDNR/UW pilot study!) have been done using eDNA to detect the presence of beavers. One of these studies collected DNA from recently chewed sticks and wood chips in Finland (Iso-Touru et al. 2021). The other study collected water samples from wetlands in the Methow Valley and Gifford Pinchot National Forest in Washington State and compared the results to visual surveys of the sites. They detected beaver DNA in 81% of the sites at which they also saw fresh beaver signs, 47% of sites with old signs, and 40% of the sites with no beaver signs (Duke, 2021). This shows that eDNA is not a perfect tool, but that it can still be useful. The most important findings may be from the sites that give positive eDNA results but have no visible beaver sign.

## Future Study Ideas

It will be important to conduct eDNA sampling downstream of a known beaver complex in order to better understand the spatial and temporal persistence of beaver DNA in streams. It would be important to also collect flow data. Ideally sampling sites could be sampled multiple times, perhaps once during the day and once at night. Siting a game camera at the beaver complex to record activity could give additional insight into differences in eDNA results. This type of calibration of eDNA as a tool, specifically to beaver and the Klamath River Basin, will be critical for interpreting future results of eDNA beaver monitoring.

## Recommendations

If funding allows, eDNA could continue to be a useful tool for monitoring beaver populations.

- Sampling with eDNA could be continued to be used to sample tributaries where beaver presence is unknown; however, it would be good to include more sample sites on each

tributary ideally about 2 km apart. This would provide a much more thorough survey of each tributary.
- Focus sampling efforts at or near specific sites that have high potential for beaver in terms of stream gradient, flow etc.
- In addition to tributaries, it could be useful in wet meadow habitat or side channel habitat.
- Environmental DNA sampling could be very useful in determining beaver presence around potential restoration or relocation sites. This is very important because beavers are known to be territorial and past studies have detected beaver presence in areas where no beaver sign was visible.
- For continued monitoring, return to a subset of originally sampled sites to monitor changes in beaver activity over time.
    - Ideally, monitoring would occur seasonally to detect changes in use. Funding may constrain this to be biannually or even annually.
    - Monitoring plans should be designed with specific objectives in mind.

Environmental DNA is a relatively new tool and the literature surrounding it is quickly evolving as more is learned about how to best use it for ecosystem monitoring. Consulting with experts in the field or reviewing literature prior to future implementation may be necessary to stay up to date.

**Learn More:**

**This is a helpful blog post:**

Allan, Eily. 2021. But where did the eDNA in my water sample come from? Thoughts on eDNA transport.http://kellyresearchlab.com/edna-blog/2021/6/29/but-where-did-the-edna-in-my-water-sample-come-from-thoughts-on-edna-transport

**eDNA Beaver Studies:**

Duke, A. (2021). Smooth-coated otter and North American Beaver Detection with Environmental DNA: Informing Sampling Design for Conservation and Management. Washington State University; Master of Science (MS), Washington State University. DOI: https://doi.org/10.7273/000003150

Iso-Touru T, Tabell J, Virta A, Kauhala K. 2021. A non-invasive, DNA-based method for beaver species identification in Finland. Wildlife Biology, 2021(3):wlb.00808. https://doi.org/10.2981/wlb.00808

**Other eDNA Studies of Interest:**

Li, J, Lawson Handley, LJ, Harper, LR, et al. Limited dispersion and quick degradation of environmental DNA in fish ponds inferred by metabarcoding. *Environmental DNA*. 2019; 1: 238– 250. https://doi.org/10.1002/edn3.24

Laporte, M, Bougas, B, Côté, G, et al. Caged fish experiment and hydrodynamic bidimensional modeling highlight the importance to consider 2D dispersion in fluvial environmental DNA studies. *Environmental DNA*. 2020; 2: 362– 372. https://doi.org/10.1002/edn3.88

Thalinger, B, Kirschner, D, Pütz, Y, et al. Lateral and longitudinal fish environmental DNA distribution in dynamic riverine habitats. *Environmental DNA*. 2021; 3: 305– 318. https://doi.org/10.1002/edn3.171

# Presentations, Recordings, and Important Links

Klamath Basin Monitoring Program Presentation
https://youtu.be/c6A4x4dFu9s

Google Drive link:
https://drive.google.com/drive/folders/1dxtvsY4DZxDreaasRPnE-jGu_p2hS988?usp=sharing

Link to Capstone Presentation Slides:
https://docs.google.com/presentation/d/1jnyXbfpuyE2HQP0cwQuJsijcdSsjyIlNdeymxfXk9yQ/edit#slide=id.p