RECOMMENDATIONS FOR MONITORING PLANT AND ANIMAL POPULATIONS AT THE LANDSCAPE SCALE

18 February 2021

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Executive Summary

In July 2020, Point Blue Conservation Science, in partnership with San Francisco Estuary Institute and Midpeninsula Regional Open Space District (District) staff (collectively called the Monitoring Team) organized a series of structured conversations and surveys to develop recommendations for taking the first step to address the District's Board approved question:

"How can the District effectively and efficiently monitor changes in plant and animal populations at the landscape scale?"

To guide the monitoring recommendation process the Monitoring Team first defined the desired outcomes, agreeing that "an effective and successful ecological monitoring program on District lands will provide status and trend information on variation in plant and animal populations through time." The team also identified the public, the regional land management community, and the District's Board and staff as target audiences and developed three guiding principles:

1. Have a clear plan for data intake, management, analysis, and interpretation;
2. Know the limits of the data; and
3. Design effective and efficient monitoring that will be sustainable.

In the context of the monitoring question and the framing concepts co-created by the Monitoring Team, District staff aligned on the following two objectives for monitoring:

1. To understand the trends in priority plant and animal populations (status and trends monitoring).
2. To signal when more research is needed and/or when a management intervention is warranted (threshold monitoring).

The following communities were judged important for monitoring: grasslands because of the grazing management that is occurring; ponds, creeks, and wetlands because of their high biodiversity; and forests because of fire; only saltmarsh was excluded as a priority habitat type given its limited extent. In sum, District staff recommend that as many ecological community types as possible be monitored at the landscape scale.

The following recommendations were made based on information collected through this process:

1. Survey the vegetation community across all District and/or regional lands on a regular interval. Our top recommendation is to monitor key components of the natural plant communities (a relatively affordable subset) every 5 years with the full components (e.g., lidar, fuels, water features, infrastructure) every 10 years.
2. Capitalize on existing efforts and combine forces with regional partners. The District's lands and its regional partners lands are already rich with data, be they from existing ongoing monitoring programs, past work, or from the continuous year-round data stream from citizen/community science programs. Hence, given the amount of data currently collected, we believe that the biggest opportunity for programmatic efficiency is to leverage existing data to generate biological trends and to inform the creation of population thresholds that will trigger further research and/or management action.

   The opportunity to leverage community science data (e.g., iNaturalist) is on the leading edge of conservation and monitoring design, and the District with its regional network of partners are in a position to help lead this development.
3. The recommended specific approach for the District and its regional partners is to hire a postdoc for a two-year term to establish the monitoring program and produce initial results. There are many benefits of hiring a postdoc:

   - It is a term position and hence the investment for all parties is clear;
   - Postdocs are typically highly focused and can produce high quality products relatively quickly;
   - There is already a precedent of sharing a postdoc with the District’s regional partners;
   - The nature of this work is highly technical and will require someone on the leading edge of data analysis to be successful;
   - Having someone “in-house” (versus consultant) allows greater access to resources (e.g., data and expertise) and can better link to the regional science and monitoring community.

Introduction

Ecological monitoring is an essential component of natural resource management. In light of ecological stressors such as climate change, invasive species, altered disturbance regimes, human disturbance, and habitat loss, ecological monitoring can provide natural resource managers with information on the status and trends of priority plants and animals to enable better decision making (Jaentos and Kenney 2015, Reynolds et al. 2016). Hence, in July 2020, Point Blue Conservation Science, in partnership with San Francisco Estuary Institute, and The Midpeninsula Regional Open Space District (hereafter Monitoring Team) organized a series of structured conversations and surveys to develop recommendations to begin to address the District's Board approved question: "How can the District effectively and efficiently monitor changes in plant and animal populations at the landscape scale?"

The complexity of natural ecosystems presents inherent challenges to the design and implementation of monitoring programs. Ecological processes (e.g., species dispersal, population dynamics), abiotic processes (e.g., weather), and human activities occur concurrently across the landscape. Ecological indicators can reflect all of these underlying mechanisms and as such are often characterized by a high degree of temporal and spatial variability. While ecological monitoring provides valuable insight into the status and trends of this variability, it is not necessarily appropriate to expect ecological monitoring to identify causes of a change in status or trend. The role of ecological monitoring is often to signal when further research or management intervention is warranted.

Despite the value that ecological monitoring data can contribute to resource management and decision making, it can also be fraught with challenges and can be prone to failure (Field et al. 2007). Awareness of the common causes of failure, including lack of trigger points for action, poor data management, and lack of resources to analyze and communicate the data, can contribute to effective design (Lindenmayer and Likens 2018). Given the potential risks and vulnerabilities of ecological monitoring and the financial investments needed, we recommend an adaptive approach wherein the value and efficacy of the monitoring program is evaluated on regular intervals to identify course corrections to be implemented when feasible and/or warranted (Lindenmayer and Likens 2009).

The Midpeninsula Regional Open Space District (District) has preserved nearly 65,000 acres of land on the San Francisco Peninsula and in the Santa Cruz Mountains Region. Broadly, the ecological communities encompassed by the lands of the District include grasslands, coastal prairie and shrubland, forests, wetlands, and tidal marsh. District lands are host to myriad common, endemic, and rare species of plants and animals and provide extensive open space access to the Bay Area community.

The purpose of this report is to summarize the process and recommendations made to-date and to provide recommendations for the District's Board of Directors (Board) to consider for next steps. During this first phase, the monitoring team completed step 1 and part of step 2 of a monitoring design process recommended by Reynolds et al. (2016) (Figure 1). Subsequent phases of this project should include final design elements (completing step 2) and adaptive implementation (steps 3 and 4) of the monitoring program.

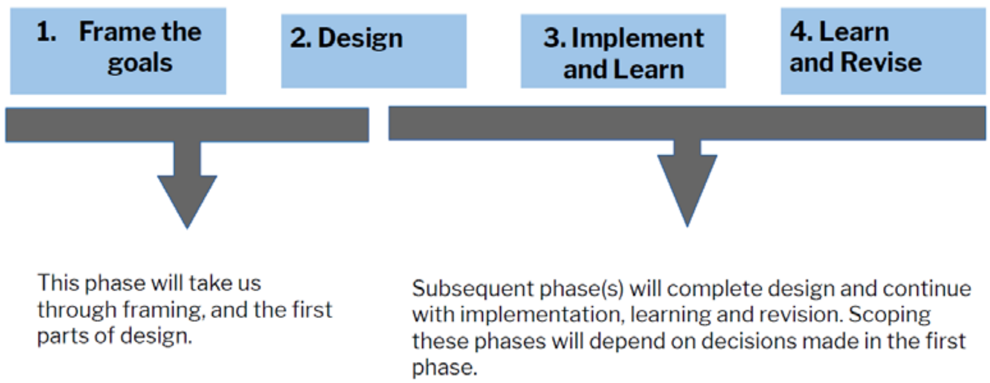

Figure 1: Overview of the design process for ecological monitoring. Adapted from Reynolds et al. (2016)

Framing the Monitoring Objectives

The framework for ecological monitoring should be designed within the context of the District's mission: "*To acquire and preserve a regional greenbelt of open space land in perpetuity, protect and restore the natural environment, and provide opportunities for ecologically sensitive public enjoyment and education.*" On the San Mateo County Coast, the District's mission includes: "*To acquire and preserve in perpetuity open space land and agricultural land of regional significance, preserve rural character and encourage viable agricultural use of land resources*." Given the scope of these missions, and the diversity of landscapes the District stewards, there are many ecological communities that can be included in monitoring.

In the framing stage of this project, District staff identified key elements of a monitoring framework with regards to desired outcomes and target audiences. The Monitoring Team also discussed additional guiding principles that are discussed below.

Desired Outcomes. An effective and successful ecological monitoring program on District lands will provide status and trend information on variation in plant and animal populations through time. This data may be useful in several ways.

- Providing an integrated ecological context that is relevant across preserves and programs.
- Signaling when more research is needed and/or when a management intervention may be warranted.

- Supporting ‘no action’ scenarios in which management interventions are not taken.
- Contributing to research that identifies likely influences of ecosystem drivers such as climate change, species invasions, and management actions.
- Telling natural resources “stories” about the local environment to educate the public as part of the District’s mission.

Target Audiences. District staff identified three primary audiences for the monitoring data.

- *Public.* Monitoring data should be summarized and made available to the public on regular intervals.

- *Regional land management community.* Monitoring should be designed and conducted in a way that the results and conclusions are relevant to the broader regional land management community. Opportunities to coordinate data collection and analyses can provide pathways for coordinated decision-making and have the potential to increase impact of management and conservation actions.

- *Board and staff.* Monitoring can provide District board and staff with greater qualitative and quantitative familiarity with District lands which can support effective stewardship, and inform project planning and decision making.

Additional Guiding Principles. In addition to the above guiding elements, the Monitoring Team discussed the following principles that should guide the monitoring program:

- *Have a clear plan for data intake, management, analysis, and interpretation.* One of the most common pitfalls of ecological monitoring is that because budgetary and staff resources can be scarce, data collection is prioritized at the expense of data management, analysis, and interpretation and the stories of the data go untold. Among the most important elements of a monitoring program is a clear plan and commitment to analyzing and reporting the data on regular intervals. To this end, it is vital to collect only data that are needed for the objectives and to have a good data management plan in place (Sutter et al. 2015).

- *Know the limits of the data*. Be clear about what the data can - and cannot - say. Any single ecological monitoring program will not reveal all we want to know about natural communities. Given the observational nature of most monitoring programs, understanding mechanisms of change is not a reasonable expectation of monitoring. It is most appropriate to think of monitoring as an early detection system that can signal when further research or a management intervention are needed (Davies and Gray 2015).

- *Design effective and efficient monitoring that will be sustainable*. Many monitoring programs are intended to continue for long periods of time, and many fail. One main reason for failure is that the program is overly costly or complicated (Caughlan and Oakley 2001). Successful monitoring programs are efficient by design. Efficiencies can include leveraging some of the many existing and on-going data collection efforts currently managed by District staff and partner agencies, including compliance monitoring and data contributed by volunteers and community members.

While these data collection efforts were not designed for this purpose, there are examples of the flexibility of monitoring in addressing emerging questions (Porzig et al. 2011). This is discussed further below.

Monitoring Question and Monitoring Objectives. The overarching monitoring question was developed prior to this process by Point Blue Conservation Science, San Francisco Estuary Institute, and District staff, and was approved by the District Board: **How can the District effectively and efficiently monitor changes in plant and animal populations at the landscape scale?** This question, while broad, does provide specific guidance that this recommendation framework will *only* focus on plants and animals (versus ecological processes) that have been prioritized by the Monitoring Team (see below) and that inference will be at the landscape scale and hence may not provide robust information at smaller scales and hence may be insufficient for plants and animals with limited distribution and/or small populations. The monitoring team did judge that future efforts to monitor ecological processes may be important to monitor large-scale stochastic changes such a landslides, wildfire, or the cumulative effects from land-use change but that was beyond the scope of this phase.

In the context of the monitoring question and the framing concepts co-created by the Monitoring Team, District staff aligned on the following two objectives for monitoring:

1. **To understand the trends in priority plant and animal populations** (status and trends monitoring)
2. **To signal when more research is needed and/or when a management intervention is warranted** (threshold monitoring)

These objectives will inform sampling design, analysis, and communication of the data and results.

Monitoring Design

In conjunction with the identification of objectives of monitoring for the District, the group discussed several design elements that are relevant to decision making within the monitoring framework. These elements include identifying existing relevant data collection, identifying the spatial scope of monitoring, differentiating between the different types of monitoring and research, creating a conceptual framework (Figure 2), and identifying taxa to monitor.

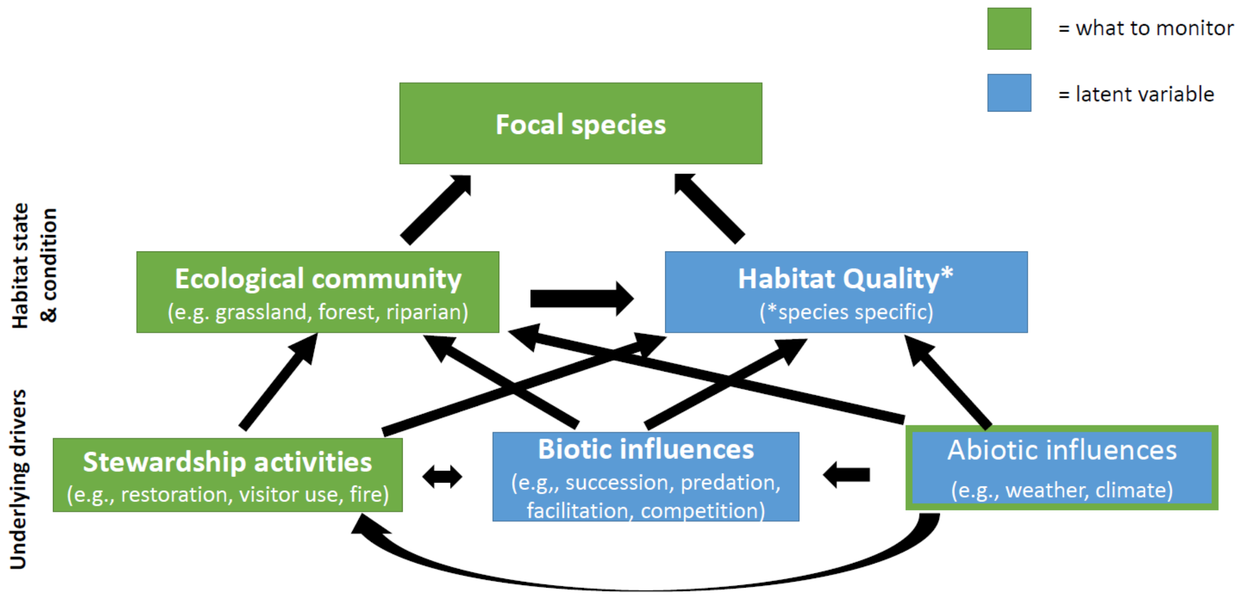

Figure 2. A conceptual model describing the relationship between elements of the ecosystem relating to trends and thresholds. The diagram shows three general categories of underlying drivers of ecological change: stewardship activities, biotic influences, and abiotic influences. These interact with each other and, in part, determine the type of ecological community and the degree to which that ecological community confers fitness to the organisms that live among it (i.e., habitat quality). Focal species are a subset of the ecological community that are chosen to monitor because they are efficient to study and are representative of the broader community. In service of trend and threshold monitoring, the green shaded boxes show which elements of the system should be measured.

Existing Data Collection Efforts. District staff currently oversee many different individual monitoring programs that serve distinct and separate purposes. These programs are predominantly focused on special status species inventory and/or recovery (e.g., red-legged frog, *Rana draytonii*) and monitoring for compliance purposes (e.g., mitigation requirements). While the sampling design and location of these monitoring programs may preclude their relevance to the objectives of this program, it is possible that some of these data can inform the broader ecological monitoring goals of this program. The potential for broader application and utility of data that is already being collected to create efficiencies warrants close consideration of these data sources. A worthwhile next step may be to evaluate the ability of these data to be summarized from the perspective of status and trends of particular species and the potential to inform threshold monitoring.

In addition to the data collected by District staff for other specific purposes, a large amount of data are also collected on District lands through outside researchers and community science (a.k.a. citizen or community science) programs. The growing popularity of programs such as iNaturalist, eBird, and CALeDNA are opening up new possible data sources for natural resource managers (e.g., Callaghan and

Gawlik 2015, Meyer et al. 2019, Whitman et al. 2019). While iNaturalist data is already being used by District staff for specific projects (e.g., invasive species presence, to time rare plant surveys, permitting), recent advances in data analytics to account for sources of variation and bias are opening up new potential uses for these data. For example, SnapShot CalCoast is an early warning and forecasting system designed to monitor key indicators of biodiversity among California Marine Protected Areas. The development of quantitative tools that correct for lack of standardization across space and time have enabled the use of iNaturalist data for the purposes of status, trend, and threshold monitoring (Rapacciuolo et al. 2017). Indeed, given some of the recent statistical advances in the use and application of iNaturalist data, it is quite likely that this tool will be increasingly called upon to inform conservation decision making, and the District is well-positioned to continue to be a part of this development. Furthermore, community science programs like CALeDNA can monitor organisms not well sampled by other methods (e.g., soil microbes, rare species) and as such could be a good complement to visual and auditory methods (Meyer et al. 2019).

Spatial Scope of Monitoring and Prioritization of Habitat Types. In light of the many existing monitoring efforts that occur on District lands for compliance and specific project purposes, the emphasis of this project is the landscape scale of District lands. The District landscape encompasses several ecological communities. A portion of our Monitoring Team workshops was focused on discussing the relative importance of different District natural communities in stewardship decision making. District staff discussed the relative merits of the major types to help focus monitoring efforts. In sum, the following communities were judged important: grasslands because of the grazing management that is occurring; ponds, creeks, and wetlands because of the high biodiversity in them; and forests because of fire; only saltmarsh was excluded as a priority habitat type given its limited extent. In sum, District staff recommend that as many ecological community types as possible be monitored at the landscape scale.

A Closer Look at the Complementary Roles of Research and Monitoring. Through the course of the workshops, discussion of the differences between research and monitoring came up several times and warrant consideration here. Research and monitoring are different but complementary forms of scientific inquiry (figure 3). Research is typically focused on a single specific question, is relatively short-term, and can include manipulative experiments that are designed to elucidate causal mechanisms. Monitoring, in contrast, is often broad in temporal or spatial scale, and is typically observational, and repeats data collection over a long period of time. As such, monitoring often does not answer questions of mechanisms or attribution directly, but is more appropriately considered to be an early warning system that can trigger further research or action. A classic example of the complementary roles of monitoring and research is the decades-long monitoring of the Keeling curve of atmospheric carbon dioxide at Mauna Loa and the complementary research that provided attribution of this change to anthropogenic activity (Keeling and Whorf 2005).

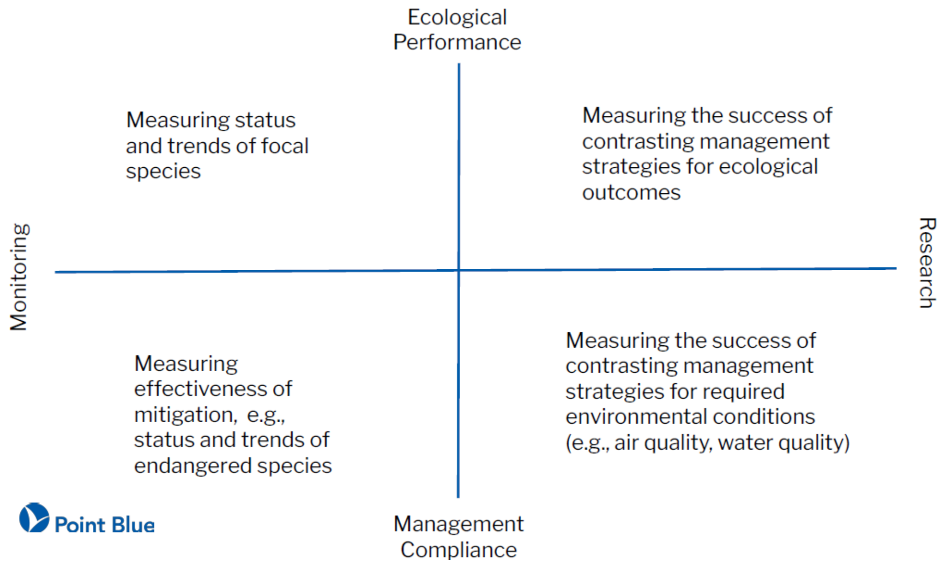

Figure 3: Conceptual diagram showing the contrasting relationships between monitoring and research and ecological performance and management compliance measurements. Examples of different types of data collection that vary across these two axes are provided.

In addition to the differences between research and monitoring, the Monitoring Team also discussed the differences between data collection that is focused on management compliance as opposed to data collection that is focused on ecological performance. Compliance monitoring most often stems from regulatory requirements and often concerns a single species such as an endangered species, or a critical habitat, such as monitoring that is associated with habitat mitigation. In contrast, ecological performance monitoring can include groups of relatively common species, often referred to as focal species, and is typically motivated by a desire to understand patterns in species occurrence more broadly. Given the different purposes of compliance monitoring and ecological performance monitoring, the sampling designs that support these two forms of inquiry can preclude the application of data from one to the other. However, this is not necessarily the case, and depending on the geographic scope of compliance monitoring, data can often be applied to multiple purposes.

Selecting Taxa to Monitor. A primary focus of the second and third workshop was the discussion of prioritization of plant and animal taxa. The Monitoring Team went through several exercises to identify criteria to use in evaluating the relative strengths and weaknesses of potential priority species. These criteria included:

1. *Landscape Occurrence.* The taxonomic group or species can be found on the majority of Midpen lands.
2. *Major Ecological Importance.* The taxonomic group or species is likely to have a major role in protecting or enhancing the structure or function of a local ecosystem and/or the abundance or stability of another species or taxonomic group. Decline or loss would have deleterious consequences for a local ecosystem or for another species or taxonomic group.

3. *Ease of Detection.* The species or the majority of species with the taxonomic group can be easily identified from similar species with minimal training and probability of detection is high.
4. *Existing Monitoring Programs.* The taxonomic group or species is well covered by an existing monitoring program with freely available protocols and data management systems. Implementing these programs would require investing in someone to implement and coordinate this effort internally and perhaps with regional partners.
5. *iNaturalist or eBird.* The taxonomic group or species is well sampled by community science programs. Monitoring with these programs would require investing in training, data analysis and coordination functions.
6. *Economically Feasible.* All aspects of the monitoring program from data collection to data interpretation and presentation can be accomplished for $100k or less annually. This value was provided by District staff as an estimate of resources that might likely be available.

The Monitoring Team discussed the relative merits of approaches that focus on monitoring individual at-risk species, common species, taxonomic groups, ecological communities, or combinations of these. We used the above criteria to guide these conversations acknowledging that ultimately what to monitor is a product of the District's values and priorities.

A critical consideration that emerged during these discussions, and one that reflects District staff's guidance that monitoring be economically feasible, is that the choice of what to monitor be efficient and should limit the need for additional time of existing staff. Point Blue fully concurs with this desire as it is our experience that monitoring program efficiency is related to long-term sustainability.

District staff expressed interest in monitoring species likely to be most impacted by climate change and open to any combinations that will be useful for management purposes. Of the many options discussed a focus on plant communities appeared to have the most support followed by pollinators. In sum however, it appeared the desire of District staff was to maximize monitoring for as many taxa as possible, from at-risk to common, in as many ecological communities as possible.

Recommendations

The following recommendations are based on the information gathered at each workshop, from the District provided information on current and past monitoring efforts, our general research on ecological monitoring, and on Point Blue's extensive experience designing, implementing, and maintaining long-term monitoring programs.

Survey the Vegetation Community Across All District Lands on a Regular Interval. Our top recommendation is to monitor key components of the natural plant communities (a relatively affordable subset) every 5 years with the full components (e.g., lidar, fuels, water features, infrastructure) every 10 years. Such mapping efforts are foundational to resource management as they can detect changes in the landscape over time and they can be used to understand changes in wildlife populations, target management actions such as fire and flood hazards, identify priority areas for habitat restoration, improve climate change resilience, and so much more.

Capitalize on existing efforts and combine forces with regional partners. The District's lands are already rich with data, be they from existing ongoing monitoring programs, past work, or from the continuous year-round data stream from citizen/community science programs. Additionally, the District's regional partners have existing data and similarly data are being collected by citizen/community science programs on their lands. Hence, given the amount of data currently collected, we believe that the biggest opportunity for programmatic efficiency is to leverage existing data to generate biological trends and to inform the creation of population thresholds that will trigger further research and/or management action. Combining forces may also allow cost sharing among regional partners and hence greater economic efficiency for all. Further, because of the lack of a strong prioritization signal from District staff toward particular taxa or groups of taxa, community science can be explored to assess trends for multiple species. Additionally, using existing community science programs has built-in data management and curation capabilities which is a major cost savings. Finally, these community science programs can also enable larger-scale analyses (e.g., to put results from District lands in context with the region or the state) and they are actively building and displaying powerful data analyses and resultant visualizations.

The opportunity to leverage community science data (e.g., iNaturalist) to inform trend and threshold monitoring is on the leading edge of conservation and monitoring design, and the District with its regional network of partners are in a position to help lead this development. Such an investment would not only open up the opportunity to create a robust, efficient and sustainable monitoring system, but would also position this system to tie in well with other ecological monitoring efforts at various scales.

We recommend that the District and its regional partners hire a postdoc for a two-year term to:

1. Catalogue all existing datasets;
2. Evaluate the degree to which iNaturalist and eBird along with the data already being collected for specific purposes (e.g., compliance, mitigation) can be applied to the specified monitoring objectives;
3. Develop biological thresholds which if crossed could trigger investment in research and/or management action;
4. If necessary, make recommendations for how to bolster community science efforts to better meet monitoring objectives (e.g., coordinate special surveys to be conducted by community scientists, set up CALeDNA plots and recruit community scientists);
5. Develop and publish (e.g., GitHub) code necessary to extract and analyze monitoring data; and
6. Conduct trend analyses and produce results the will help tell the story of the impact of the District's work.

There are many benefits of hiring a postdoc over other options like a consulting firm including: (1) that it is a term position and hence the investment for all parties is clear, (2) postdocs are typically highly focused and can produce high quality products relatively quickly, (3) there is already a precedent of sharing a postdoc with the District's regional partners, (4) the nature of this work is highly technical and will require someone on the leading edge of data analysis to be successful, (5) having someone "in-house" (versus consultant) allows greater access to resources (e.g., data and expertise), and (6) can better link to the regional science and monitoring community (versus a consultant).

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