

**SAN FRANCISCO BAY AREA NETWORK
AMPHIBIAN AND REPTILE MONITORING WORKSHOP**



*Western Toad, Chalone Creek, Pinnacles National Monument
photo: Paul G. Johnson II*

**National Park Service
San Francisco Bay Area Network Inventory and Monitoring Program
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Summary

During the week of August 30th 2005 the San Francisco Bay Area Network (SFAN) Inventory and Monitoring Program hosted a 1.5 day workshop to identify and prioritize long-term monitoring questions for amphibians and reptiles on network park lands. Previous network workshops had identified monitoring of these taxa to be the 8th most important priority for the program. The August workshop included biologists from Golden Gate National Recreation Area (GOGA), Pinnacles National Monument (PINN), Point Reyes National Seashore (PORE), Santa Monica Mountains National Recreation Area, SFAN, the National Park Service Pacific West Region, and the United States Geologic Survey Biological Resources Division (see Appendix A for list of participants).

The group first reviewed objectives for the National Park Service (NPS) Inventory and Monitoring Program, and the status of the program within that context. They then outlined known information about amphibian and reptile species within SFAN parks. This discussion focused primarily on herpetofauna at the three largest SFAN parks: GOGA, PINN, and PORE; but also included information about amphibian and reptile species at two smaller SFAN parks: John Muir National Historic Site (JOMU) and Eugene O'Neill National Historic Site (EUON). The group then reviewed and updated the checklist of SFAN amphibian and reptile species (Appendix B).

The group discussed the most desired characteristics of a long-term herpetofauna monitoring program for the network. They then formulated a list of the six most important amphibian and reptile monitoring targets for SFAN parks:

- Pond-breeding amphibians
- San Francisco gartersnake
- Stream-inhabiting amphibians and reptiles
- Terrestrial amphibians and reptiles
- Western pond turtle
- Coast horned lizard

For each of these six targets the group discussed *monitoring questions*, *focal taxa*, *monitoring objectives*, *monitoring techniques*, *monitoring locations*, *sampling design*, and *monitoring regime*. The group also discussed considerations common to all six targets such as observer training, photo-documentation, and collection of voucher and tissue specimens.

This report documents the workshop participants' discussions and summarizes their recommendations. The report also provides suggestions to the SFAN board of directors, technical steering committee, and Inventory and Monitoring Program coordinator regarding next steps for completion and implementation of a long-term amphibian and reptile monitoring protocol.

1. Introduction

The National Park Service Inventory and Monitoring Program seeks to facilitate the protection of natural resources by tracking long-term trends in park ecosystems. Because not all components of the parks' complex ecosystems can be studied and understood, the program focuses on monitoring "vital signs" - those processes and ecosystem components that can provide a clear signal of meaningful changes in the environment, and provide managers with an early warning of declining environmental quality. The San Francisco Bay Area Network of Parks - which includes Point Reyes National Seashore, Golden Gate National Recreation Area, Pinnacles National Monument, John Muir National Historic Site, and Eugene O'Neill National Historic Site - has prioritized a set of vital signs to be studied in a long-term ecological monitoring program. Trends in amphibian and reptile populations is the 8th highest priority for the network.

Network parks host 49 amphibian and reptile species:

- 8 salamander species - including Pacific giant salamander and California newt;
- 6 frog and toad species - including California red-legged frog, Pacific treefrog and Western toad;
- 7 turtle species - including both marine and freshwater species;
- 10 lizard species - including Western fence lizard; and
- 18 species and subspecies of snakes - including common kingsnake, several gartersnake species, and Western rattlesnake.

Of these taxa, five species which breed in the park have special legal status: San Francisco gartersnake (federal endangered), red-legged frog (federal threatened), Western pond turtle (California species of concern), coast horned lizard (California species of concern), and San Joaquin coachwhip (California species of concern). An additional four species have federal legal protection, but are only transient visitors to SFAN parklands: loggerhead, green turtle, leatherback, and olive ridley. These turtle species spend nearly their entire lives at sea, and do not lay eggs on SFAN beaches. Additionally, the California tiger salamander (federal endangered) lives in the vicinity of PINN, and may occur in the park, and the foothill yellow-legged frog (California species of concern) is extirpated from PINN. PINN staff hope to restore foothill yellow-legged frog to parklands in the future. Three of the network's forty-nine amphibian and reptile species are non-native and invasive, creating conservation concerns for native biota: bullfrog, snapping turtle, and common slider.

Amphibian and reptile populations are often cited as ideal vital sign indicator organisms. They can be particularly sensitive to environmental degradation, and occupy a mid-trophic niche sensitive to changes in plant and animal communities both higher and lower trophic levels. Amphibian and reptile populations in SFAN parks are under pervasive threats. These include invasive plant and animal species, urbanization and historic habitat loss, light pollution, ecological changes due to fire suppression, air and water quality degradation, park operations, disease, and climate change.

During the week of August 30th 2005 SFAN hosted a 1.5 day workshop to outline the broad form of a monitoring program for tracking long-term changes in SFAN amphibian and reptile populations (Appendix A: workshop participants). The workshop had the following proposed outcomes:

- Define the highest-priority monitoring questions regarding the status of amphibian and reptile populations in SFAN parks.
- Determine focal taxa for addressing monitoring questions.
- Define monitoring objectives for those taxa.
- Broadly define where those taxa would be monitored.
- Outline potential monitoring techniques for addressing monitoring questions, and review relative strengths/weaknesses of techniques.
- Brainstorm criteria for selecting sampling locations and sampling regimes.
- Discuss potential data analysis techniques.
- Review previously completed amphibian and reptile monitoring plans from other networks and parks, review previous relevant research previously conducted in SFAN parks.
- Create a carefully-reviewed herpetofauna species list for SFAN parks.

Designing a monitoring program for cryptic and highly-variable species such as amphibians and reptiles is challenging. Workshop participants agreed that a good monitoring program tracks both common and rare species; focuses on charismatic species and also inconspicuous-but-ecologically-critical biota; never picks the “wrong” target species to track (*e.g.*, one that becomes extirpated early, or one that does not follow general trends); doesn’t neglect rare species that are not protected under endangered species legislation; tracks both communities and single species; addresses questions that have management solutions; concentrates on both roadless Wilderness and urban-adjacent lands; engages park partners; *and*, additionally, creates excellent, publishable ecological data. Given this optimistic wish list, the workshop participants created a sound, manageable set of monitoring targets for the network to build a long-term amphibian and reptile monitoring program upon.

2. Overview of Proposed Monitoring Program

2.1 Monitoring targets

Workshop participants first identified the six highest-priority amphibian and reptile targets for the SFAN long-term monitoring program. They concluded that an ideal program would track both special status species and assemblages of more common amphibians and reptiles. The identified targets are:

- 1) Pond-breeding amphibians
- 2) San Francisco gartersnake
- 3) Stream-inhabiting amphibians and reptiles
- 4) Terrestrial amphibians and reptiles
- 5) Western pond turtle
- 6) Coast horned lizard

Workshop participants did not use formal criteria to create and prioritize this list. They reached a firm common consensus - based on professional judgment and knowledge of SFAN natural resources - that all of these targets should be included in the SFAN Inventory and Monitoring Program and that funds should be allocated to these targets in the priority order given above. This consensus was not controversial, and the group felt that the list above would be robust even in the event that additional subject-matter experts were asked to contribute to prioritizing herpetofauna monitoring needs for the network.

Habitat-dependent assemblages of animals (the focus of targets 1, 3, and 4) were included for their potential to call attention to broad ecological trends in SFAN parks. For example, due to their aquatic habitats and permeable skins, amphibians may be particularly sensitive to environmental degradation, such as air and water pollution. Because amphibians and reptiles are mid-level predators, changes in their populations may provide warning of trends in faunal populations at both higher and lower trophic levels.

Participants concluded that monitoring common and widely distributed species (*e.g.*, Pacific treefrog, Western toad, fence lizard) as part of a habitat-dependent guild has several advantages: because they are relatively easy to observe at this time, trends into the future can be monitored with a reasonable amount of effort. These more common species can also yield information about spatial patterns of changing environmental quality. For example, if monitoring data suggest that a commonly-found animal is becoming rare at one site but not at others this may indicate localized ecosystem changes. Furthermore, monitoring suites of common species, rather than single species only, can minimize the risk that the resulting data are not representative of ecosystem-wide trends. Finally, blanket surveys for multiple species can efficiently cover large geographic areas to reveal trends that can direct specialized (either species-specific or localized) research efforts.

Conversely, three of the six targets listed above single out special status species for focused monitoring efforts: San Francisco gartersnake (federal endangered), Western pond turtle (California species of concern), and coast horned lizard (California species of concern). These species either have such limited ranges (San Francisco gartersnake), or localized habitats (Western pond turtle,

coast horned lizard), that monitoring them as part of a suite of species would be impractical. However, workshop participants agreed that it is important for the network to track these populations with species-dedicated programs, due to NPS responsibilities under species-protection laws and policies, and because the success or failure of these sensitive species may indicate general ecosystem trends. Workshop participants concluded that SFAN's remaining special status amphibians - California red-legged frog foothill yellow-legged frog (if reintroduced to PINN), and California tiger salamander (if observed at PINN) - may be effectively monitored along with other species in pond and stream habitats. PINN's special-status snake - San Joaquin coachwhip - may be monitored along with a guild of small terrestrial vertebrates using artificial habitat (see section 2.7.1.4 below); detection rates for this species will probably be low.

Although GOGA and PORE support populations of migrating marine turtle populations (see Appendix B for a list of species), workshop participants decided against monitoring these animals for several reasons: monitoring marine turtles would be a very costly undertaking, park partners are already tracking these populations, and SFAN parks have no management options for responding to any perceived population trends. Furthermore, monitoring programs for marine turtles generally rely on tracking egg production on nesting beaches; SFAN beaches do not include suitable egg-laying habitat for marine turtles.

2.2 Focal taxa

After identifying the highest priority monitoring targets, workshop participants then narrowed the focus in order to specify all species or taxa of interest for each target. For example, for the proposed Western pond turtle and coast horned lizard monitoring, the ideal protocol would track both the special status animals *and* non-native species which are threats to the animals of interest.

For habitat-dependent targets (monitoring targets 1, 3, and 4), monitoring protocols will focus on animals which can be detected with established monitoring techniques - for example: animals which can be detected under cover boards, in visual encounter surveys, or in dip-net surveys. This will necessarily exclude monitoring of animals which are very rare, difficult to observe, or just cover board or dip-net wary. Because of fiscal constraints, however, the protocol cannot seek to track all SFAN herpetofauna; instead, the suite of more-easily detectable species will serve as indicators for entire assemblages (*e.g.*, terrestrial amphibians, stream-inhabiting reptiles), with the understanding that trends within individual populations may be missed by the protocol.

2.3 Monitoring questions

For each of the six monitoring targets listed above, workshop participants framed one or more monitoring questions. Monitoring questions define what the program would seek to understand about each of the six monitoring targets. The questions specify the monitoring location and which aspect(s) of the target will be tracked over time.

2.4 Monitoring objectives

For each monitoring question, workshop participants defined a specific monitoring objective. These objectives identify quantitative parameters for monitoring, including the minimum change

which the protocol should be able to detect and the tolerance for making an error due to sampling (Fancy 2004). Monitoring objectives determine the number of observations needed in order to answer the monitoring questions.

The *minimum detectable change* parameter set by workshop participants is intended to be fiscally realistic, biologically significant, and sensitive enough to inform management. For example, detecting a 2% change in the abundance of a population may be both cost-prohibitive with respect to the number of samples needed (if feasible at all) and less than biologically significant. On the other hand, a protocol which could only detect an 80% or greater decline in a population may be inexpensive, but would be inadequate for providing timely information to managers.

Similarly, tolerance for *sampling bias* must be fiscally realistic and also provide managers with reasonable certainty about the results of the monitoring program. Workshop participants agreed that, as a general guideline, a 10% chance of error due to sampling bias is an acceptable risk for all monitoring objectives in this document. However, participants also agreed that this risk tolerance will need to be re-evaluated after analysis of pilot data for each monitoring target, to determine feasibility.

Finally, the ability to meet monitoring objectives is heavily dependent on data variability and available monitoring techniques: monitoring programs proposed in this document will need to be evaluated through a pilot sampling period. If pilot data are highly variable then the stated monitoring objectives may not be achievable. In this case either the monitoring objectives will need to be less stringent or the sampling protocol will need to be revised.

2.5 Monitoring locations

The protocol will include monitoring programs for the five SFAN parks with herpetofauna habitat: Eugene O'Neil National Historic Site (EUON), Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Pinnacles National Monument (PINN), and Point Reyes National Seashore (PORE). Monitoring effort will be unequally distributed among these parks; the three larger parks (GOGA, PINN, PORE) will receive more attention than the two small historic parks (EUON, JOMU).

The protocol will be conceptually divided into three units: northern SFAN parks with substantial natural lands (GOGA, PORE); the southernmost park, also with substantial natural lands (PINN); and the two smaller units, which both have very limited natural lands (JOMU, 340 acres in three parcels; EUON, 13 acres). In general, due to their ecological and species composition similarities, GOGA and PORE can share many monitoring protocols. One exception to this will be the monitoring protocol for the San Francisco gartersnake, because the snake occurs on GOGA, but not PORE, lands. Also, because PINN is unique within the network with respect to its ecology and herpetofauna diversity, it will not share herpetofauna monitoring protocols with the other parks. Trends may be compared between parks, but data will not be combined. Furthermore, because JOMU and EUON have such limited habitat, their monitoring protocols and datasets will be created and analyzed separately from the other parks and from each other.

Workshop participants agreed that monitoring should not be limited to areas perceived to be “natural.” The monitoring protocol should address herpetofauna trends in landscapes ranging from roadless Wilderness to core urban areas. Siting of sampling locations should take into account some of the more subtle threats to natural communities, such as light and noise pollution, and the presence of anthropogenic chemicals (*e.g.*, caffeine, pharmaceuticals, petrochemicals) in aquatic habitats.

2.6 Dispersal of monitoring locations

For each monitoring question workshop participants discussed, generally, how monitoring locations might be located in the landscape. They identified ecological factors that would have the potential to cause different trends in different locations. Examples include: pond size and depth, surrounding vegetation community, persistence of stream flow, amount of urbanization in the watershed. Identifying potential stratification criteria early can assist with initial selection of sampling locations; later, analysis of data from a pilot period can help refine the preliminary stratification schemes. In the final monitoring design, appropriate stratification of monitoring locations, in order to determine how data should be analyzed, can reduce variability within datasets and help illuminate trends.

2.7 Monitoring techniques

Workshop participants discussed potential monitoring techniques in depth. The following section briefly summarizes the techniques proposed as appropriate for a long-term SFAN herpetofauna monitoring program, and explains why some standard techniques were rejected for this program.

2.7.1 Proposed monitoring techniques

2.7.1.1 Visual encounter surveys

General description:

Several of the herpetofauna monitoring targets listed below will be detected with visual encounter surveys (VES): observers walk through a sampling location for systematically searching for target animals. The area sampled can be geographically-bounded with observers walking randomly within the area, or observers can walk a delineated transect. Observers record the number and type (species) of animals encountered, along with life history stage.

The technique is used to estimate species diversity and obtain an index of relative abundance of each species (relative over time and between sites). Observations are recorded as presence/non-detect and number of animals encountered. The precision of the data can be improved by conducting several closely timed repeat surveys, in order to determine how “detectable” animals are in a specified habitat.

VES are used to detect reptiles and adult amphibians in terrestrial and aquatic habitats (*e.g.*, riparian zones, forests, grasslands, ponds, streams). Monitoring programs use this technique

to detect animals that are visible on the ground (*i.e.*, not primarily fossorial or arboreal) and have sparse and/or highly clumped distributions. VES can also be employed to monitor animals occupying aquatic or aquatic-edge habitats, such as basking turtles or amphibian metamorphs along shorelines. In addition, VES can be used to observe amphibian egg masses, either from shore or from a boat. Egg masses can be marked with flagging tape on nearby vegetation or wire flags to avoid recounting during subsequent visits.

Sampling design considerations:

VES results are heavily dependent on habitat characteristics: in habitats with low, sparse vegetation and few cover objects observers will see a higher percentage of all animals present; in habitats with dense vegetation and ample cover observers will see few of the animals actually present. Microhabitats within sampling areas will yield different detectabilities for different species. VES data are also weather and time-of-day dependent: poor lighting will reduce detectability, and varying weather conditions will affect the number of animals present on the ground surface. VES are heavily influenced by variation between observers. Sampling protocols must be very detailed to assure the highest possible conformity in sampling effort between observers and between sampling events. Protocols must include careful detail about training procedures for observers and observers must be well-trained.

Some visual encounter studies have focused on recording attribute data such as sex, weight, or length for the animals observed. Workshop participants agreed that, while such information may be useful for short-term research, a SFAN long-term monitoring program should focus on efficiently sampling as many sites as possible, rather than gathering animal-specific attribute data, in order to best detect long term trends in distribution and relative abundance.

Assumptions:

- 1) Equal visibility of all animals present for each species
- 2) Equal visibility of all animals for all sampling events and at all locations
- 3) No individual animal or egg mass is counted twice during a single sampling event
- 4) For sampling at breeding habitats: a similar proportion of the overall adult breeding population visits a site year-to-year
- 5) No observer bias

References:

- Campbell HW, SP Christman. 1982. Field techniques for herpetofaunal community analysis. *in*: NJ Scott (ed.), Herpetological Communities. US Fish and Wildlife Service Wildlife Resources Report. pp. 193-200.
- Corn PS, RB Bury. 1990. Sampling methods for terrestrial amphibians and reptiles. *in*: AC Carey and LF Ruggiero (eds.), Wildlife-Habitat Relationships: Sampling Procedures for Pacific Northwest Vertebrates. US Department of Agriculture, General Technical Report PNW-GTR-256. pp. 1-28.
- Crump ML, NJ Scott. 1994. Visual encounter surveys. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.), Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.

Scott NJ, BD Woodward. 1994. Surveys at breeding sites. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.

2.7.1.2 Dip net surveys

General description:

This monitoring technique estimates abundance of larval amphibians, primarily in shallow bodies of water such as wadeable streams and small ponds. Dip netting is preferable to seining in bodies of water with any appreciable amount of vegetation, as is found in many shallow aquatic habitats in SFAN. Observers walk the shore along or around a water body and at specified locations sweep a small net quickly through the water a specified number of times at a predetermined depth (*e.g.*, one sweep every 10 meters, immediately adjacent to the substrate). All animals caught are identified by species, and then immediately released to an area which is nearby but which will deter recapture of the same animal. Sampling locations along a transect may be stratified by habitat type, to ensure that observers are obtaining samples from habitats with a variety of depths, vegetation cover, and water velocities (for streams). In stream habitats with complex substrates, protocols may include displacing stream-bed cobbles immediately upstream of the sampling site before sweeping the net, in order to dislodge any animals sheltering between stones. For the smallest lentic habitats, those of about 1 meter in diameter or less, complete removal of all animals present may be possible, creating an absolute measure of abundance, rather than an abundance index, as would be derived from larger habitats. The net size and type is dependent on habitat type and target species, but generally a D-shaped net with a diameter of about 40 centimeters is appropriate for SFAN habitats and fauna. The fineness of the net should be consistent between sampling events and sampling locations. Several net sizes and net types should be tested during the pilot sampling period to determine the optimal equipment for SFAN habitats.

Sampling design considerations:

For sampling locations to be considered independent of one another they must be within separate bodies of water or separated by 10 meters or more of one another. Too frequent sampling may cause decreases in the number of animals caught, even without a true decrease in the abundance, due to dip-net wariness of repeatedly-caught animals. Sampling protocols should consider variations in weather, water temperature, and time of day, which will all impact the susceptibility of animals to be caught.

As with visual encounter surveys, some dip-net studies focus on recording attribute data such as sex, weight, or length for the animals observed. Workshop participants agreed that a SFAN long-term monitoring program should focus on efficiently sampling as many sites as possible, rather than gathering animal-specific attribute data, in order to best detect long term trends in distribution and relative abundance.

Assumptions:

- 1) All animals of each species are equally susceptible to being caught - not meeting this assumption is not always a problem since it can be corrected statistically with some models.
- 2) An equal amount of effort is expended during each capture event and at each location
- 3) If the same number of animals are present at a site between two sampling events, then for an equal amount of effort, the same number of animals will be caught

Reference:

Shaffer HB, RA Alford, BD Woodward, SJ Richards, RG Altig, C Gascon. 1994. Quantitative sampling of amphibian larvae. in: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.

2.7.1.3 Traps (turtles)

Turtles can generally be monitored by observing animals basking on woody debris and human-made structures in aquatic habitats. With binoculars experienced observers can often count individuals and identify species from a distance, taking care not to alarm the animals and cause them to retreat into the water. However, because some non-native turtles look very much like the Western pond turtle, it will be necessary to occasionally trap animals in order to obtain a positive species identification. 0.5-inch mesh double-throated hoop traps, baited with anchovies or sardines in oil, were used successfully at GOGA in 2002 to inventory native and non-native species in ponds and slow-moving streams. Depending on the size of the water body, 1 to 3 traps were used at each site. Animal attribute data collected will be limited to species and abundance in general, except in the rare instances when animals are trapped for species identification, when data on size, age and sex would be recorded.

References:

Fong D. 2002. Western pond turtle (*Clemmys marmorata*) inventory, Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area. 29 pp.

Holland DC. 1991. A synopsis of the ecology and status of the western pond turtle (*Clemmys marmorata*) in 1991. US Fish and Wildlife Service. 167 pp.

2.7.1.4 Artificial cover surveys

General description:

Terrestrial herpetofauna will be monitored with artificial cover surveys. For each sampling location, staff will place an array of 12-15 cover boards on the ground within a homogenous habitat. Cover boards can be plywood, usually between ½" and ¾" thick and can be arranged in transects or gridded arrays, depending on the shape of the habitat unit. Boards

within arrays should be placed 5 to 10 meters apart (no closer). Boards within an array may be spaced farther apart, but should be within a homogenous vegetation unit. Boards should be about 30 x 30 cm, up to 1.2 x 1.2 m; larger boards may be desirable for hotter environments or for tracking larger species. Thicker boards with larger dimensions are preferred for warm environments, in order to provide thermal shelter, but are more costly and more difficult to deploy. Before boards are deployed vegetation should be cleared from the ground so that the board rests on bare soil. Each board should be clearly labeled with contact information and a statement that the boards should not be disturbed, printed bumper stickers work well for this purpose. Boards may be “pre-aged” to conceal them better, but paint should not be used as it will change the thermal properties of the equipment. Plywood cover boards deteriorate with time; the monitoring protocol should include information about when and how to replace degraded equipment. Cover boards may be deployed in very steeply-sloped habitats, and may be lightly pinned down in one or more corners with stakes or large nails.

Observers commonly travel on a route to sample multiple locations stopping at each array, turning each board, and recording the number and type (species) of all animals observed present. Observers record one “hit” for each species observed per board. Abundance of animals observed will be recorded, but for this monitoring program these data will be of secondary consideration for tracking long-term trends, as they are highly variable. Observers should receive safety training regarding dangerous animals that may shelter under cover boards such as rattlesnakes, scorpions, and wasps.

Sampling design considerations:

Results from sampling with artificial cover arrays can vary greatly depending on the size and thickness of the cover boards used, the number of cover boards per array, and the season that the boards are checked. Furthermore, time of day can greatly influence how many animals are observed: after mid-morning animals may exit the shelter of the cover boards, or, as the day warms, observers may not be able to identify animals as they flip the boards, because the animals will flee too quickly. Fellers recommends a *two-animal rule*: observers start their route early if the weather is warm and reptiles are expected to be encountered. By the time the day has warmed up enough that the observers have been unable to identify two animals (due to their rapid escape) then sampling for the day is ended. Some experimentation may be necessary during a pilot period in order to determine the best board thickness and dimension, and to determine the best field protocols for SFAN habitats.

Some artificial cover studies have focused on recording attribute data such as sex, weight, or length for the animals observed. Workshop participants agreed that, while such information may be useful for short-term research, a SFAN long-term monitoring program should focus on efficiently sampling as many sites as possible, rather than gathering animal-specific attribute data, in order to best detect long term trends in distribution and relative abundance. Despite this focus, many species will be caught so infrequently as to make long-term trend analysis difficult or impossible.

Cover boards are generally dispersed among vegetation communities, with an effort to place each array within a typical and homogenous habitat patch. However, vegetation communities may shift dramatically during medium- to long-term monitoring studies. To compensate, the monitoring protocol for tracking animal populations with artificial cover will include a Standard Operating Procedure for periodically evaluating the vegetation community around each array, verifying that the community is still a homogenous habitat patch, and moving the cover boards to a new nearby location when necessary in order to follow vegetation communities. Furthermore, cover boards will not attract the same fraction of animals in different vegetation communities. For example, cover boards may attract a higher percentage of animals from the population in open grasslands where natural cover is rare, and a lower fraction of the population in woodlands where a great diversity of natural cover is available. Data should therefore only be compared between sample locations in similar habitats.

Finally, artificial cover may not be appropriate in areas where animals may disturb coverboards. For example, in some habitats tule elk may flip over and displace cover boards. This may be able to be mitigated by lightly pinning the boards to the ground. In other areas termites may destroy the boards relatively quickly, requiring frequent replacement of equipment. Also, Fellers has observed that catch rates decline if boards are flipped too frequently. Habitat quality under the boards may decline with heavy disturbance, or animals may become wary of frequent disturbance.

Calculating variability estimates during the pilot period may be difficult, especially as the boards may not be re-checked frequently. Although data from boards within an array are spatially correlated, within-array data may serve as a proxy for overall variability between sampling units. Additional information may be mined from exploring variability within sampling units.

Assumptions:

- 1) Any environmental factors which may change the susceptibility of animals to be observed under cover boards (*e.g.*, temperature, aridity) can be factored in to data analysis successfully to obtain a standard index
- 2) The value of the artificial habitat to fauna does not change over time or vary between sampling units

References:

- Fellers GM, CA Drost. 1994. Sampling with artificial cover. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Fellers GM, CA Drost, WR Heyer. 1994. Handling live amphibians. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Grant BW, AD Tucker, JE Lovich, AM Mills, PM Dixon, JW Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pp. 379-403 *in*: McCullough DR and Barrett RH, eds. Wildlife 2001: Populations. Elsevier Applied Science, New York, NY, USA.

2.7.2 Considered but rejected monitoring techniques

2.7.2.1 Pitfall traps

Pitfall traps are commonly used to conduct intensive studies of small vertebrate communities (*e.g.*, Fellers *et al.* 2004). For each sampling location, staff typically install a set of three or four 5-gallon plastic buckets buried so that the bucket rims are flush with the ground surface, and often supplement the traps with arrays of low fencing designed to direct animals into the buckets. However, workshop participants decided that pitfall traps are not an appropriate monitoring tool for this program for the following reasons:

- 1) Conducting monitoring with pitfall traps requires a substantial amount of staff time per sampling unit, generally a commitment of two people for an entire week per sampling event (*e.g.*, Monday open traps, Tuesday through Friday check traps daily, Friday close traps).
- 2) Pitfall traps may not be appropriate for long-term monitoring programs due to the large commitment required for installation and maintenance. Installation requires digging pits for the traps, and setting up drift fence arrays. These semi-permanent installations would not be appropriate in Wilderness areas. Long-term maintenance may require either removing traps or filling traps with dirt in-between any sampling events which are separated by months or years. Similarly, drift fence arrays need to be removed and reinstalled in-between sampling events.
- 3) Pitfall traps are not suitable for all locations: steeply-sloped sites and areas with subsurface cultural resources may not be suitable locations for pitfall trapping.
- 4) Pitfall traps can cause animal injury and mortality. Animals may be eaten by raccoons or trapped predators while in the traps, and animals may injure themselves while attempting to escape.
- 5) Pitfall traps may under-sample especially small or large animals: large animals commonly escape from the top of traps, small animals and snakes may escape from drain holes in traps.
- 6) Inventory work at EUON, JOMU, GOGA, and PORE (Fellers *et al.* 2004, Fellers and Pratt 2002) indicates that artificial cover objects (cover boards) may yield similar data, with less effort for installation, maintenance, and risk to animals.

2.7.2.2 Artificial basking habitat for turtles

Turtle habitat can be augmented with artificial basking habitat for the purposes of monitoring. Only a small percentage of animals within a population are basking at any one time - one Marin County study estimated 5% of the population was visible in the best of conditions - and because demand for basking structures may be higher than available basking space, increasing the amount of basking habitat may increase the percentage of

animals visible at any one time. Workshop participants rejected this technique for this long-term monitoring program. This program seeks to understand network-wide trends through observations at a high proportion of turtle habitat rather than tracking trends at a few sites; it is not desirable to have permanent or semi-permanent habitat augmentation at many sites.

2.7.2.3 Natural cover surveys for herpetofauna

Workshop participants also discussed the value of conducting searches for herpetofauna underneath natural cover objects, such as logs and stones. This technique is commonly used for faunal inventories. However, participants concluded that this method is undesirable for long-term monitoring because it lacks the consistency of analogous techniques such as monitoring under cover boards or conducting visual encounter surveys (see Fellers and Drost 1994).

2.7.2.4 Minnow traps

Minnow traps can be used to sample amphibian larvae, especially in deeper ponds where it is difficult to obtain a representative sample with dip nets. However, most aquatic habitats in SFAN parks are shallow and amenable to sampling with dip nets. Furthermore, in habitats with special status fauna species traps must be carefully placed and monitored by experienced personnel in order to avoid mortality. Study permits may be very difficult to obtain from regulatory agencies.

2.7.2.5 Call surveys

Sound recording and analysis equipment can be used to detect presence of calling amphibian species. This technique is useful for only a limited number of species in SFAN parks, particularly Pacific tree frog and bullfrog. Dip net and visual encounter surveys are more standard and tested techniques for monitoring these species, and also have the ability to target all life stages (eggs, juveniles, adults) (for further discussion of this technique see Canevaro *et al.* 1998; Scott and Woodward 1994)

2.8 Data analysis

2.8.1 Pilot studies

All of the proposed monitoring techniques have previously been used to study herpetofauna in SFAN parks. Data exist from these studies (see reference list) that will be invaluable for determining sampling locations, number of samples needed, stratification of samples, and monitoring regime. However, none of them have been employed in a long-term network-wide monitoring program. Therefore in order to formalize a permanent monitoring protocol, pilot studies must be conducted to obtain sample data. Pilot studies will answer questions such as:

- 1) What is the best equipment design?
- 2) How can sampling locations be located, as to be both representative and feasible?
- 3) What is the variability between strata?

- 4) What is the variability within strata (between sampling units)?
- 5) What is the variability between seasons?
- 6) What is the variability between years?
- 7) How can observer bias be minimized?
- 8) What is the detectability rate?
- 9) Which environmental covariates have the most impact on observations?
- 10) How much staff time will sampling require?

The pilot monitoring program should gather data at slightly finer spatial and temporal resolution than is anticipated to be necessary for the final monitoring program. Using the pilot data, SFAN Inventory and Monitoring program staff can evaluate the feasibility of the monitoring objectives proposed in this document, and reframe them if necessary.

2.8.2 Abundance indices

Workshop participants propose to monitor changes in observed abundance of animals and eggs to track several target species: California red-legged frog at PINN, Western pond turtle at GOGA and PORE, coast horned lizard at PINN. Trends in abundance will not be measured absolutely (*e.g.*, counting and tracking the total number of frogs at Bear Gulch Reservoir), but will be tracked through abundance indices.

Abundance indices assume that, for a given search or capture protocol in a consistent habitat with consistent environmental conditions, there is a constant relationship between the numbers of animals observed and the number of animals present. For example, when counting the number of basking turtles in a pond, it is assumed that some small number of animals are visible (perhaps 5%) while the rest of the population is not visible. When the same pond is revisited five years later, under similar weather, season, and time of day conditions, the proportion of observed to unobserved animals is assumed to be constant. If the number of observed animals increases by 50% then it is assumed that the entire population has grown by 50%. This assumption is generally problematic with cryptic fauna such as amphibians and reptiles, which may be very sensitive to conditions that observers may be unconscious of (*e.g.*, especially foggy morning conditions, unusually loud sounds, the recent presence of a predator). Because of this, workshop participants propose that monitoring programs designed to track indices of abundance be designed to detect only relatively large changes, as small changes may not represent true trends.

2.8.3 Percent area occupied

Because abundance indices usually require adoption of problematic assumptions, and because estimating true population abundances is exceedingly time consuming - generally limited to short-term and/or geographically limited studies - many amphibian and monitoring programs have adopted a "Percent Area Occupied" metric to track changes in populations over time. Percent area occupied defines and quantifies all potential habitat for a target species, then seeks to illuminate how occupancy of that site changes over time. Generally a habitat unit consists of a pond or a reach of stream. Observers visit the habitat unit and note if the target animal is observed or not observed. The number of animals observed may be estimated or recorded, but is not used for data analysis for this metric. This technique is typically conducted with double surveys (*e.g.*, one observer surveys a

pond and an hour later another observer returns to survey the same site in order to provide data for assessing observability). Presence/absence data are aggregated for many potential habitat sites to the landscape scale. It is assumed that a reduction in population health and/or abundance will result in a reduction in the number of habitat units occupied. The number of habitat units (*i.e.*, samples) required will depend on the occupancy rate. Monitoring programs tracking trends in animals with low occupancy rates will require high numbers of samples to detect trends, especially declines (for more on PAO see MacKenzie 2005; MacKenzie and Royle 2005).

2.8.4 Detectability

Detectability is closely related to - and often discussed interchangeably with - percent area occupied. Because amphibians and reptiles are generally cryptic, detection is rarely perfect. Given a trained observer, and a particular species and habitat type, there is some rate at which observers will see an animal if it is present. This rate is dependent on whether or not the animal is on the surface, its coloration, the time of day, the season, the cloud cover, and other factors. This rate can be estimated by repeat observations within a short time period (*e.g.*, 15 to 60 minutes apart). For example, an observer visits a site and sees an animal at 9 a.m., fails to see one at 10 a.m., and then sees an animal at 11 a.m.; the detection rate is 67%. The problem of imperfect detectability effects all of the monitoring protocols proposed in this document, whether an abundance index or percent area occupied is the metric tracked over time. Detectability curves should be explored during pilot sampling (*i.e.*, do the proposed techniques yield acceptable detectability metrics?). Detectability should be reassessed regularly over the life of the monitoring program, to confirm the assumption that detectability remains relatively constant over time, if adjusted for variables such as weather and habitat type (for more on detectability see MacKenzie *et al.* 2002; MacKenzie *et al.* 2003; MacKenzie *et al.* 2004)

3. Proposed Monitoring Targets

3.1 Pond-breeding amphibians

Monitoring Question 1a:

How are distribution and diversity of pond-breeding amphibians changing over time at GOGA and PORE?

Focal Species:

Selected native and non-native pond-breeding amphibians, primarily Pacific treefrog (*Pseudacris regilla*), California red-legged frog (*Rana draytonii*), rough-skinned newt (*Taricha granulosa*), California newt (*Taricha torosa*), and non-native bullfrog (*Rana catesbeiana*). Egg masses, larvae, young-of-the-year, adults.

Monitoring Objective:

Detect any 25% or greater change (between an initial 3-year baseline and any year monitored) in the number of ponds occupied by selected pond-breeding amphibians at GOGA and PORE.

Monitoring Locations:

Some percentage of all ponds within PORE and GOGA will be monitored. Potential monitoring locations will include seasonal, permanent, and floodplain ponds, as well as ponds surrounded by a variety of vegetation communities (*e.g.*, grassland/non-grassland, chaparral, woodland). The number of ponds needed for sampling will be based on data from a five-year pilot study. Site selection design to be determined: ponds to be monitored may be chosen randomly each year, or site selection may be based on a rotating panel design. In order to successfully detect trends with percent area occupied technique, many monitoring locations will be required.

Stratification of Monitoring Locations:

Ponds may be stratified by seasonal persistence and pond size, location within the watershed, surrounding vegetation community, presence of non-native species (*e.g.*, mosquito fish), and general species composition. Artificial ponds at PORE seem to function similarly to natural water bodies with respect to providing California red-legged frog habitat, and may not need to be considered as a separate stratum. Other stratification criteria may become evident during the pilot sampling program.

Monitoring Technique:

Dip-net surveys in small ponds for larvae. Observers typically walk the entire perimeter of each pond. Visual encounter surveys for adults. Egg mass counts, metamorph counts. During the pilot sampling period, one of these techniques may emerge as providing the best signal of amphibian population status.

Data Analysis:

Percent Area Occupied. Data analysis shall factor in covariates that may affect abundance such as weather, temperature.

Monitoring Regime:

Each pond will be visited three to four times per year for *each* targeted life stage (egg, larva, adult) during a five-year pilot study. After five years of data collection data will be analyzed for determination of permanent monitoring regime. During the pilot study, sites will be revisited for establishment of a detectability curve for *Rana draytonii* and *Pseudacris regilla* (see discussion of Percent Area Occupied, page 14). This will require visiting ponds three times per week by the same observer in order to determine detectability. During the inventory of California red-legged frog at PORE sites, Fellers at first visited sites one night per week, and then determined that visiting sites several nights in a row provided a better estimate of abundance.

Related Studies:

- Barry S, D Fong. 1999. Survey and habitat assessment for California red-legged frog, San Francisco gartersnake, and Western pond turtle at Milagra Canyon, Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area. NRBib#174456.
- Cook D. 1997. Tennessee Valley red-legged frog breeding survey report, Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area. NRBib#124727.
- Cook D. 1998. California red-legged frog and bullfrog tadpole trapping, egg mass, and frog surveys, Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area.
- Fellers GM, G Guscio. 2004. California red-legged frog surveys of Lower Redwood Creek, Golden Gate National Recreation Area.. US Geological Survey, Western Ecological Research Center. 73 pp.
- Fong D. 2000. Winter 1998-2000 frog breeding survey Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area. 33 pp. NRBib#160928.

Discussion:

- The technique described above has well-documented and extensively used protocols available (*e.g.*, Fellers and Freel 1995), but have not necessarily been designed for use with percent area occupied data analysis techniques.
- Workshop participants rejected using an abundance index for this target, and instead chose a percent of habitat occupied metric, due to the extremely high natural variability in larval abundance between years. Data can be analyzed for changes in abundance classes between years, but primary sampling design and data analysis will be based on a percent area occupied approach, requiring a large set of sampling sites.
- For each site observers will record: how many animals observed, how much time spent, how many observers.
- The percent area occupied approach is not feasible at PINN because there is only one habitat site (Bear Gulch Reservoir).
- Workshop participants chose a relatively sensitive threshold of 25% change detection because detected declines will loss of site occupancy, not just within-population declines.

- The sampling design will need to consider variability between species with respect to when egg masses, larvae, young of the year, and adults can be found in aquatic habitats. For example, rough-skinned newt adults migrate to streams earlier and stay longer into the summer than California newt adults.

3.1 Pond-breeding amphibians (continued)

Monitoring Question 1b:

How is abundance (as indicated by counts of egg masses and young-of-the-year) of pond-breeding California red-legged frog changing over time at PINN?

Focal Species:

California red-legged frog (*Rana draytonii*). Primarily egg masses, young-of-the-year.

Monitoring Objective:

Detect any 50% or greater change in abundance (index) in egg masses and young-of-the-year California red-legged frogs at Bear Gulch Reservoir at PINN.

Monitoring Location:

Bear Gulch Reservoir.

Stratification of Monitoring Locations:

None.

Monitoring Technique:

Young-of-the-year and egg mass counts by Visual Encounter Surveys from an inflatable boat at night (young-of-the-year) or day (egg mass).

Data Analysis:

Analysis of changes in abundance index of egg masses and young-of-the year.

Monitoring Regime:

Bear Gulch Reservoir will be surveyed for egg masses weekly in March and April, and for young-of-the-year amphibians every second week from mid-August to mid-October. The reservoir will be surveyed for egg masses weekly during the egg production season.

Related Studies:

Ely E. 1994. Report and findings 1994 amphibian surveys Pinnacles National Monument, California. National Park Service, Pinnacles National Monument. 7 pp. NRBib#103704.

Johnson PG. 2005. Riparian aquatic species inventory, Pinnacles National Monument 2001-2004. National Park Service, San Francisco Bay Area Inventory and Monitoring Network. 33 pp.

Discussion:

- PINN has an ongoing egg mass and metamorph monitoring program; detailed protocols have been established.
- The workgroup decided that monitoring California red-legged frog at Bear Gulch Reservoir only will serve as an indicator of park-wide trends for this species. Because of the focus on a single site, an excellent estimate of reproductive success from the reservoir can be obtained. Egg mass counts can be used to estimate a minimum number

of adult individuals fairly accurately. Metamorph counts will provide an indication of successful reproduction for the year.

- The uncalibrated index of abundance can be a better proxy of true abundance trends if sampled frequently within a single year. However, this remains a somewhat problematic measure, as it is unclear how the abundance index is related to true abundance.
- Because of differences in timing of egg laying and metamorph emergence, this monitoring program cannot track Pacific tree frog abundance successfully also, without substantial additional effort.

3.2 San Francisco gartersnake

Monitoring Question 2:

How is the San Francisco gartersnake (SFGS) population at Mori Point changing over time?

Focal Species:

San Francisco gartersnake (*Thamnophis sirtalis tetrataenia*).

Monitoring Objective:

Detect continuing presence of San Francisco gartersnake at Mori Point.

Monitoring Locations:

Mori Point. Any additional SFGS habitat that comes under GOGA management in the future.

Monitoring may focus on “bottleneck” habitats where animals are more spatially concentrated, such as at ponds, in order to increase the number of animals encountered.

Stratification of Monitoring Locations:

To be determined in consultation with US Fish and Wildlife Service (USFWS) personnel currently studying the population.

Monitoring Technique:

To be determined. Potentially Visual Encounter Survey (VES). Another possibility is deploying cover boards around ponds in SFGS habitat.

Data Analysis:

To be determined

Monitoring Regime:

To be determined.

Related Studies:

McGinness SM. 1986. Status of the San Francisco gartersnake *Thamnophis sirtalis tetrataenia* at Sharp Park Golf Course, Pacifica, California. Geomatrix Consultants, Inc., San Francisco California. 21 pp. NRBib#566200.

Steiner. 1991. The San Francisco gartersnake at Laguna Salada: a plan for management and enhancement. National Park Service, Golden Gate National Recreation Area. 18 pp.

also: ongoing USFWS-sponsored monitoring to determine effects of habitat enhancement actions on SFGS abundance.

Discussion:

- In the approved 1985 USFWS San Francisco Gartersnake Recovery Plan (USFWS 1985), recovery goals are specified in terms of *abundance* of snakes at each habitat site. Therefore, any monitoring plan for SFGS at Mori Point should attempt to track the abundance of animals at the site.

- The SFGS population that uses Mori Point habitat also inhabits adjacent lands, including a municipal golf course. Any long-term monitoring program for SFGS at Mori Point should incorporate the entire potential habitat, not just the lands administered by GOGA.
- Although artificial cover may be a technique to successfully monitor SFGS, concentration of animals under readily visible equipment may attract poachers. Also, there would be concerns about permanently or semi-permanently augmenting essential habitat of a federally-endangered species.
- The USFWS is currently monitoring the effects of restoration activities on SFGS abundance at Mori Point; they are not conducting long-term monitoring. However, the techniques developed for the current programs may be adaptable for detecting long-term trends.
- Although USFWS is comfortable permitting current researchers to trap and mark snakes, the NPS may not be able to get permits for this activity for long-term monitoring. Furthermore, the USFWS may not permit handling of snakes by less-specialized personnel. Therefore, VES may be a more appropriate technique for tracking snakes.

3.3 Stream-inhabiting amphibians and reptiles

General Discussion:

- This target was considered a higher priority than Monitoring Target 4 (terrestrial amphibians and reptiles) because workshop participants are concerned that aquatic systems are generally more at risk from anthropogenic stressors than terrestrial systems.
- Tracking stream-inhabiting salamanders at GOGA and PORE (Monitoring Question 3a) was considered to be a much lower priority than tracking stream amphibians at PINN (Monitoring Question 3b), primarily due to a high focus on stream health at GOGA and PORE by the SFAN Stream Fishes Monitoring Program.
- EUON was not included in Monitoring Target 3 because it has no lotic habitat. Similarly, JOMU was not considered for this Monitoring Target because it has only very limited stream habitat. Workshop participants also noted that JOMU streams are surveyed for the Stream Fishes Monitoring Program; the only vertebrates detected in JOMU streams to-date are stickleback fish.

Monitoring Question 3a:

How are the distribution and diversity of aquatic salamanders changing over time at GOGA and PORE?

Focal Species:

Primary monitoring target is California giant salamander (*Dicamptodon ensatus*). Secondary monitoring targets include rough-skinned newt (*Taricha granulosa*), California newt (*Taricha torosa*). Egg masses, larvae, adults.

Monitoring Objective:

Detect any 25% or greater habitat contraction for any aquatic salamander species at GOGA and PORE between any two sampling events.

Monitoring Locations:

All potential aquatic salamander habitat, primarily perennial low- and mid-order streams.

Stratification of Monitoring Locations:

No stratification. Streams will be subdivided into monitoring units (*e.g.*, 500-meter reaches), all streams reaches will be visited. Ideally, monitoring unit endpoints will be defined by prominent and permanent geomorphic features.

Monitoring Technique:

Egg mass counts. Dip-net surveys. Visual encounter surveys.

Data Analysis:

Primary analysis: percent area occupied (streams segmented into stream reaches). No detectability curve will be developed for this monitoring effort. Secondary analysis: index of relative abundance by stream reach.

Monitoring Regime:

One-half of all streams will be visited each year, so that all streams will be visited within a two-year period.

Related Studies:

Fong D, JA Howell. 2005. Distribution and abundance of California giant salamander (*Dicamptodon ensatus*) and signal crayfish (*Pacifastacus leniusculus*) in the upper Redwood Creek watershed, Marin County, California. National Park Service, Golden Gate National Recreation Area. 64 pp.

Wood L. 2004. Tennessee Valley seep and stream amphibian surveys, Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area. NRBib#568485.

Discussion:

- Fong and Howell have conducted baseline *Dicamptodon* surveys for a subset of streams within GOGA (Fong and Howell 2005); detailed protocols can be drawn from this study.
- Stream-inhabiting salamanders at GOGA and PORE cannot be monitored easily in conjunction with other monitoring programs. A dedicated monitoring effort would be required in order to track trends in these populations.
- Another stream amphibian, foothill yellow-legged frog (*Rana boylei*) was considered for monitoring in stream habitats, but rejected by the workshop participants for two reasons: 1) the frog is very uncommon, and species-specific surveys would likely yield very few encounters, making trends difficult to track, and 2) the species is found in lower-order streams (generally, in comparison with *Dicamptodon* and *Taricha* species), and if present may be detected by Stream Fish Monitoring efforts in these habitats.
- Seasonal timing for surveys may not be critical: larvae of *Dicamptodon*, the primary focus of this monitoring effort, mature over two years and are visible in the water year-round. Floating view boxes or glass-bottomed buckets may assist with detecting animals swimming below the water surface. Gary Fellers has used view boxes to better observe swimming animals.
- Surveying a sub-sample of creek reaches would not be cost-effective. Rather than expending effort in selecting and traveling to designated “sample” reaches, effort should be directed to surveying entire creeks.

Monitoring Question 3b:

How are the distribution and diversity of stream-inhabiting herpetofauna changing over time at PINN?

Monitoring Targets:

Western toad (*Bufo boreas*), Pacific treefrog (*Pseudacris regilla*), California red-legged frog (*Rana draytonii*), foothill yellow-legged frog (*Rana boylei*) (if successfully re-established at PINN), Western spadefoot (*Spea hammondi*). Incidental observations of *Emys marmorata*. Any unexpected native herpetofauna, or non-native vertebrates or invertebrates encountered. Egg masses, larvae, adults.

Monitoring Objective:

Detect any 25% or greater habitat contraction for any native aquatic herpetofauna species at PINN between any two years. Detect any 25% or greater habitat expansion of any non-native stream-inhabiting vertebrate or invertebrate species between any two years.

Monitoring Locations:

All lotic habitat with perennial or intermittent flow.

Stratification of Monitoring Locations:

Potentially stratify streams by *Bufo* habitat (lower-gradient streams) vs. non-*Bufo* habitat to determine appropriate seasonal timing for surveys. Potentially stratify by perennial/intermittent stream reaches. Streams are already subdivided into sampling units by stream reach.

Monitoring Technique:

Dip-net surveys for amphibian larvae and other aquatic animals. Visual encounter surveys for amphibian egg masses, amphibian adults, and other taxa.

Data Analysis:

Primary analysis: percent area occupied by stream reach. A detectability curve will be developed for higher-priority monitoring targets (e.g., *Rana draytonii*), and will be reported by reach. Secondary analysis: index of relative abundance by stream reach.

Monitoring Regime:

Each site will be surveyed once per year. Additional surveys may be required in some reaches in order to observe egg masses for all target species.

Related Studies:

Ely E. 1994. Report and findings 1994 amphibian surveys Pinnacles National Monument, California. National Park Service, Pinnacles National Monument. 7 pp. NRBib#103704.

Johnson PG. 2005. Riparian aquatic species inventory, Pinnacles National Monument 2001-2004. National Park Service, San Francisco Bay Area Inventory and Monitoring Network. 33 pp.

Also: PINN has additional well-documented existing protocols and datasets.

Discussion:

- Monitoring targets will consist of any native aquatic vertebrates, expected or unexpected, including all frogs, toads, salamanders, snakes, turtles, and fish. Monitoring targets will also include all non-native vertebrates and invertebrates observed.
- Timing for the surveys will be primarily determined by detectability of *Rana draytonii*, *Bufo boreas*, and *Pseudacris regilla*. These species will have different seasonal periods of maximum detectability - generally when egg masses are present. Surveys may be conducted twice per season: one early season survey to focus on *Bufo boreas* and *Rana* detection, one later season survey to focus on *Pseudacris regilla* detection.

3.4 Terrestrial amphibians and reptiles

Monitoring Question 4a:

How are the distribution, abundance, and diversity of selected terrestrial amphibians and reptiles changing over time at GOGA, PINN, and PORE?

Monitoring Targets:

Terrestrial amphibian and reptile species that utilize artificial cover, including slender salamanders (*Batrachoceps* spp.), Ensatina (*Ensatina eschscholtzii*), newts (*Taricha* spp.), snakes, and lizards. Fraction of these populations that is susceptible to detection with artificial cover techniques: adults, juveniles.

Monitoring Objective:

Detect a 25% change (between an initial 3-year baseline and any single year monitored) in the number of cover board transects occupied by the five most commonly detected amphibian and reptile species at PINN, GOGA, and PORE.

Monitoring Locations:

Throughout GOGA, PINN, and PORE lands.

Stratification of Monitoring Locations:

Sampling locations will be well-dispersed among broad-scale vegetation community types (*e.g.*, Douglas fir forest, chaparral, urbanized areas). Sampling locations will ideally be centered in large homogeneous habitat patches, rather than nearby or within ecological transition zones. Sampling locations will be randomly selected with constraints that assure adequate representation of vegetation communities and good dispersion. Vegetation communities to be sampled may be chosen by areas suspected of having high herpetofauna abundances; communities will of necessity be chosen as those areas where cover boards may be successfully employed (*e.g.*, this technique cannot be adapted for use in dune habitats).

Monitoring Technique:

Artificial cover. Arrays of twelve to fifteen coverboards each.

Data Analysis:

Percent area occupied. Sampling unit will be each artificial cover *array*.

Monitoring Regime:

Each array will be visited three times per year during a five-year pilot study: once in spring, winter, and fall seasons. After the pilot period, data will be examined to determine final monitoring regime appropriate to address the monitoring question.

Related Study:

Fellers GM, D Pratt. 2002. Terrestrial vertebrate inventory, Point Reyes National Seashore 1998-2001. US Geological Survey, Western Ecological Research Center. 78 pp.

Discussion:

- The decision to track the five most commonly detected species is based on previous inventory data (Fellers and Pratt 2002). Pilot sampling may suggest that the program should only track the most commonly-observed three or four species (*i.e.*, these may be the only species observed frequently enough to ascertain long-term trends).
- Cover board monitoring will incidentally provide presence/non-detect data for rare species, even if these species are not observed frequently enough to determine trends.

Monitoring Question 4b:

Are common terrestrial amphibians and reptiles continuing to be detectable at EUON and JOMU?

Monitoring Targets:

Terrestrial amphibian and reptile species that utilize artificial cover, including California slender salamander (*Batrachocephalus attenuatus*), Ensatina (*Ensatina eschscholtzii*), newts (*Taricha* spp.), snakes, and lizards. Fraction of these populations that is susceptible to detection with artificial cover techniques: adults, juveniles.

Monitoring Objective:

Detect continuing presence (based on initial inventories) of the five most commonly detected amphibian and reptile species at JOMU and EUON.

Monitoring Locations:

Throughout EUON and JOMU lands.

Stratification of Monitoring Locations:

Sampling locations will be well-dispersed among broad-scale vegetation community types, and centered in large homogeneous habitat patches. Sampling locations will be randomly selected with constraints that assure adequate representation of vegetation communities and good dispersion.

Monitoring Technique:

Artificial cover. Arrays of twelve to fifteen coverboards each.

Data Analysis:

Percent area occupied. Sampling unit will be each artificial cover array.

Monitoring Regime:

Each array will be visited three times per year during a five-year pilot study: once in spring, winter, and fall seasons. After the pilot period, data will be examined to determine final monitoring regime appropriate to address the monitoring question.

Related Study:

Fellers GM, L Long, G Guscio, D Pratt. 2004. Inventory of terrestrial vertebrates at John Muir National Historic Site and Eugene O'Neill National Historic Site. US Geological Survey, Western Ecological Research Center. 16 pp.

3.5 Turtles

Monitoring Question 5

How are the abundance, distribution, and diversity of pond turtles changing over time at GOGA and PORE?

Monitoring Targets:

Western pond turtle (*Emys marmorata*). Non-native turtles such as common slider (*Trachemys scripta*).

Monitoring Objective 5a:

Detect a 25% change (between an initial 3-year baseline and any single year monitored) in number of ponds occupied by native turtles at PORE and GOGA.

Monitoring Objective 5b:

Detect a 50% increase (between an initial 3-year baseline and any single year monitored) in number of ponds occupied by non-native turtles at PORE and GOGA.

Monitoring Locations:

Ponds within GOGA and PORE with potential turtle habitat. Lagunitas Creek.

Stratification of Monitoring Locations:

Monitoring locations will not be stratified before surveys; all potential turtle habitat will be monitored, including most ponds and Lagunitas Creek. The protocol focuses on “all potential turtle habitat” rather than currently occupied turtle habitat, because the monitoring program should be sensitive to both extensions and contractions of occupied turtle habitat.

Monitoring Technique:

Visual encounter surveys. Observers will identify all turtles to species and estimate abundance.

Traps. If visual encounter survey observers are unable to identify turtle species, then animals will be trapped for identification.

Data Analysis:

Percent area occupied. Monitoring bias will be estimated by conducting repeat detectability surveys.

Monitoring Regime:

Rotating panel design of all potential turtle habitat. Some percentage of the sites will be designated as *Permanent*; these will be monitored every year. Additional monitoring will be conducted at a randomly selected sample of the remaining sites. Robert Fisher’s Arroyo Toad monitoring protocol may provide guidance on establishing the specific rotating panel design. For each selected site, observers will conduct three repeat surveys during spring to early-summer (some turtles spend winters on land). The repeat surveys will help to account for variation due to temperature, cloud cover, and other environmental variables. Devon Reece,

currently working with the USFWS developed guidelines for adjusting turtle monitoring data for variable weather conditions.

Related Study:

Fong D. 2002. Western pond turtle (*Clemmys marmorata*) inventory, Golden Gate National Recreation Area. National Park Service, Golden Gate National Recreation Area. 29 pp.

Discussion:

- Although turtles will not be formally tracked at PINN, due to low densities, turtles observed in Chalone Creek during stream herpetofauna surveys will be recorded to document continuing presence.
- Turtles have been observed frequently at PORE in Lagunitas Creek (between White House Pool and Green Bridge, also Giacomini Pond and Martinelli).
- Currently non-native red-eared sliders are present at most turtle-occupied habitat at GOGA; non-native turtles are extremely rare at PORE.

3.6 Coast horned lizard

Monitoring Question 6

How are distribution and abundance of coast horned lizard, native harvester ant, and the non-native Argentine ant changing over time at PINN?

Monitoring Targets:

Coast horned lizard (*Phrynosoma coronatum*), harvester ant (*Pogonomyrmex*) and Argentine ant (*Linepithema humile*).

Monitoring Objective:

Detect a 25% change (between an initial 3-year baseline and any single year monitored) in the number of sites occupied by coast horned lizards, harvester ants, and Argentine ants.

Monitoring Locations:

Selected sites known to currently support coast horned lizard populations.

Stratification of Monitoring Locations:

Sites will be stratified by distance from water, distance from human developments, and vegetation type. These factors are implicated in determining the spread of Argentine ants.

Monitoring Technique:

Visual encounter surveys for all species. Slow walking transects for coast horned lizards. Natural cover surveys for harvester ant and Argentine ant.

Data Analysis:

Percent area occupied. Spatial boundaries of habitat occupied by Coast horned lizard, harvester ant, and Argentine ant.

Monitoring Regime:

During an initial five-year pilot study, each sampling site will be visited five times from mid-March through mid-June. In addition, to establish a detectability curve, survey frequency will be tripled during the first year. After five years of data collection, data will be analyzed for determination of a permanent monitoring regime.

Discussion:

- Coast horned lizard, a California species of special concern, is disappearing in many places throughout its range due to Argentine ant invasions.
- PINN has tested an existing protocol for monitoring these three species, written by David Morafka. Andrew Suarez at University of California Berkeley is assisting PINN staff with Argentine ant inventory and management.

4. Considerations Common to All Targets

4.1 Staff qualifications and training

In order to avoid biased data due to discrepancies between observers, staff must be consistently trained. Training should seek to standardize observations in different weather conditions, in different habitats, and, perhaps most difficult, between years. Training should also ensure that all observers identify animals correctly. Careful training is necessary at the beginning of every field season, and recalibration is needed mid-season as well. Some protocols suggested in this document will require staff with more experience. For example, monitoring pond-breeding animals requires observers with an experienced search image, knowledge of how animals use their habitat, and an ability to identify eggs and larvae. Some protocols may be accomplished by staff with less experience, for example monitoring terrestrial animals under cover boards. These monitoring programs may be adaptable for implementation by dedicated volunteer groups.

4.2 Vouchers and tissue samples

Workshop participants discussed the need to verify the identity of animals observed within SFAN parks, in order to assure future researchers and managers that identifications are correct. This should happen via several techniques: vouchers, tissue samples, and photography. Vouchers of all species tracked, except for extremely imperiled species such as San Francisco gartersnake, should be collected periodically and sent to specimen storage facilities. Alternatively or additionally tissue samples, such as toe clips or scales, can be collected for genetic analysis. Voucher and tissue collections can have unforeseen benefits, such as retroactively determining when pathogens arrived at network parks. Regular photography of observed animals is essential; photographs should focus on species-distinguishing features, as many species are difficult to differentiate. Final protocols for the monitoring program should include detailed species verification procedures such as: voucher collection schedule, procedures for collection of incidental mortality vouchers, voucher documentation and storage procedures, photography guidelines, and photograph archive procedures.

5. Recommendations for Next Steps

This document lays out priority “vital sign” targets for a SFAN amphibian and reptile monitoring program, based on the experience and judgment of workshop participants (Appendix A). However, in order to transform this priority list into a detailed monitoring protocol will require considerable effort (Oakley *et al.* 2003). The first steps toward that goal may consist of:

- For each of the six monitoring targets, sketch a short proposal for a pilot study. Determine where sampling should occur, how often sampling should occur, how long the pilot program should last, what type of equipment should be used, how data should be analyzed, and what primary questions will be answered by the end of the pilot.
- Concurrently with completing pilot proposals, create a graphical and/or narrative ecological model for each of the monitoring targets. The purpose of the model will be to communicate current knowledge, illuminate data gaps, inform decisions about protocols, and demonstrate how addressing the proposed monitoring questions will lead to greater understanding of the target organisms and the ecology of SFAN parks.
- For each proposal draft a projected budget.
- Summarize the results for consideration and prioritization by the SFAN board of directors, technical steering committee, and Inventory and Monitoring Program coordinator.
- For the highest-priority monitoring targets, refine the proposed pilot studies and implement.

6. SFAN Amphibian and Reptile Reading List

6.1 Ecology, conservation, investigative techniques

- Beebee TJC, RA Griffiths. 2005. The amphibian decline crisis: a watershed in conservation biology? *Biological Conservation*. 125:3 pp 271-285.
- Campbell HW, SP Christman. 1982. Field techniques for herpetofaunal community analysis. *in*: NJ Scott (ed.), *Herpetological Communities*. US Fish and Wildlife Service Wildlife Resources Report. pp. 193-200.
- Canevaro L, D Fong, D Cook. 1998. Amphibian calling and breeding survey manual. National Park Service, Golden Gate National Recreation Area. NRBib#7805.
- Crump ML, NJ Scott. 1994. Visual encounter surveys. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.), Corn PS, RB Bury. 1990. Sampling methods for terrestrial amphibians and reptiles. *in*: AC Carey and LF Ruggiero (eds.), *Wildlife-Habitat Relationships: Sampling Procedures for Pacific Northwest Vertebrates*. US Department of Agriculture, General Technical Report PNW-GTR-256. pp. 1-28.
- Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Donnelly MA, C Guyer, JE Juterbock, RA Alford. 1994. Techniques for marking amphibians. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington DC. 364 pp.
- Fellers GM. 2006. Identification of selected larval amphibians. US Geological Survey, Western Ecological Research Center. Unpublished. 3 pp.
- Fellers GM, C Corben. A technique for detecting eyeshine of amphibians and reptiles. US Geological Survey, Western Ecological Research Center. Unpublished. NRBib#160584.
- Fellers GM, CA Drost. 1994. Sampling with artificial cover. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington DC. 364 pp.
- Fellers GM, CA Drost, WR Heyer. 1994. Handling live amphibians. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington DC. 364 pp.
- Fellers GM, KL Freel. 1995. A standardized protocol for surveying aquatic amphibians. US Geological Survey, Western Ecological Research Center, Technical Report NPS/WRUS/NRTR-95-01. 117 pp.
- Fellers GM, DO Leonard, WR Bury. 1997. Design of amphibian surveys; sampling amphibians in lentic habitats: methods and approaches for the Pacific Northwest. *Northwest Fauna* 4. NRBib#160833.
- Grant EHC, RE Jung, JD Nichols, and JE Hines. 2005. Double-observer approach to estimating egg mass abundance of vernal pool breeding amphibians. *Wetland Ecology and Management* 13: 305-320.
- Grant BW, AD Tucker, JE Lovich, AM Mills, PM Dixon, JW Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pp. 379-403 *in*: McCullough DR and Barrett RH, eds. *Wildlife 2001: Populations*. Elsevier Applied Science, New York, NY, USA.
- Hall RJ, CA Langtimm. 2001. The US. national amphibian research and monitoring initiative and the role of protected areas. *National Park Service, George Wright Forum*. 18:2 pp 14-25.
- Hoffman RL, TJ Tyler, GM Larson, MJ Adams, W Wente, and S Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes. US Geological Survey, Forest and Rangeland Ecosystem Science Center. 90 pp.
- Holland DC. 1991. A synopsis of the ecology and status of the western pond turtle (*Clemmys marmorata*) in 1991. US Fish and Wildlife Service. 167 pp.

- Jacobs JF, WR Heyer. 1994. Collecting tissue for biochemical analysis. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Mackenzie DI. 2005. Managers' monitoring manual: estimate of percent area occupied. US Geological Survey, Patuxent Wildlife Research Center. 3 pp. Available at: <http://www.pwrc.usgs.gov/monmanual/approaches/pao.htm>
- MacKenzie DI, JD Nichols, GB Lachman, S Droege, JA Royle, CA Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83: 2248-2255.
- MacKenzie DI, JD Nichols, JE Hines, MG Knutson, AB Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* 84: 2200-2207.
- MacKenzie DI, LA Bailey, JD Nichols. 2004. Investigating species co-occurrence patterns when species are detected imperfectly. *Journal of Animal Ecology* 73: 546-555.
- MacKenzie DI, JA Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. *Journal of Applied Ecology* 42: 1105-1114.
- Ministry of Environment, Lands and Parks, British Columbia, Canada. 1998. Inventory methods for pond-breeding amphibians and painted turtle. Published digitally at <http://www.for.gov.bc.ca/ric>
- Ministry of Environment, Lands and Parks, British Columbia, Canada. 1998. Inventory methods for plethodontid salamanders. Published digitally at <http://www.for.gov.bc.ca/ric>
- Reynolds RP, RJ Cromnie, RW McDiarmid. 1994. Voucher specimens. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Scott NJ, BD Woodward. 1994. Surveys at breeding sites. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Shaffer HB, RA Alford, BD Woodward, SJ Richards, RG Altig, C Gascon. 1994. Quantitative sampling of amphibian larvae. *in*: WR Heyer, MA Donnelly, RW McDiarmid, LC Heyek, MS Foster (eds.). 1994 Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Smithsonian Institution Press, Washington DC. 364 pp.
- Stebbins RC. 2003. Western reptiles and amphibians, third edition. Houghton Mifflin, New York. 533 pp.
- US Fish and Wildlife Service. 1997. Guidance on site assessment and field surveys for California red-legged frogs (*Rana aurora draytonii*). United States Fish and Wildlife Service. 8 pp.
- US Fish and Wildlife Service. 1985. Recovery plan for the San Francisco gartersnake *Thamnophis sirtalis tetrataenia*. United States Fish and Wildlife Service, Endangered Species Program, Portland OR.
- US Fish and Wildlife Service. 1985. Recovery plan for the California red-legged frog *Rana aurora draytonii*. United States Fish and Wildlife Service, Endangered Species Program, Portland OR.
- US Geological Survey. 2003. Amphibian research and monitoring initiative (ARMI) in the Pacific Northwest. Available at: fresc.usgs.gov/products/fs/fs-020-03.pdf

6.2 Herpetofauna inventory and research conducted at SFAN parks

- Barry S. 1979. Investigation on the occurrence of the San Francisco gartersnake on Sweeny Ridge, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. NRBib#67112.
- Barry S, D Fong. 1999. Survey and habitat assessment for California red-legged frog, San Francisco gartersnake, and Western pond turtle at Milagra Canyon, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. NRBib#174456.

- Banta BH. 1966. An annotated check list of the recent amphibians and reptiles inhabiting the city and county of San Francisco, California. *The Wasmann Journal of Biology*. 24:2 pp 223-237. NRBib#8876.
- Banta BH. 1967. An annotated check list of the recent amphibians and reptiles of the **Pinnacles National Monument** and Bear Valley, San Benito and Monterey Counties, California, with some ecological observations. Department of Science, University College, Michigan State University. 26 pp.
- Cook D. 1997. Tennessee Valley red-legged frog breeding survey report, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. NRBib#124727.
- Cook D. 1998. California red-legged frog and bullfrog tadpole trapping, egg mass, and frog surveys, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area.
- Domingo C. 1999. Characterization of chemicals in amphibian breeding sites, **Point Reyes National Seashore**. National Park Service, Point Reyes National Seashore.
- Ely E. 1993. Report and findings California red-legged frog survey, Lobos Creek, San Francisco **Presidio**. National Park Service, Golden Gate National Recreation Area. 2 pp. NRBib#103705.
- Ely E. 1994. Report and findings 1994 amphibian surveys **Pinnacles National Monument**, California. National Park Service, Pinnacles National Monument. 7 pp. NRBib#103704.
- Fellers GM. 1993. Checklist of amphibians and reptiles, **Point Reyes National Seashore**. US Geological Survey, Western Ecological Research Center. 2 pp. NRBib#549356.
- Fellers GM. 1994. An assessment of the status of amphibians in the vicinity of California National Parks. US Geological Survey, Western Ecological Research Center. 13 pp.
- Fellers GM, G Guscio. 2004. California red-legged frog surveys of Lower Redwood Creek, **Golden Gate National Recreation Area**. US Geological Survey, Western Ecological Research Center. 73 pp.
- Fellers GM, L Long, G Guscio, D Pratt. 2004. Inventory of terrestrial vertebrates at **John Muir National Historic Site** and **Eugene O'Neill National Historic Site**. US Geological Survey, Western Ecological Research Center. 16 pp.
- Fellers GM, D Pratt. 2002. Terrestrial vertebrate inventory, **Point Reyes National Seashore** 1998-2001. US Geological Survey, Western Ecological Research Center. 78 pp.
- Fesnock AL, PG Johnson. 2002. Reestablishing California red-legged frogs to their historical range within Pinnacles **National Monument**. Wildlife Society, paper presented at Western Section Meeting, March 7-9, 2002, Visalia, CA.
- Fesnock AL, PG Johnson. 2005. Checklist of the amphibians and reptiles of **Pinnacles National Monument**. 1 page. NRBib#59023
- Fong D. 2000. Tennessee and Oakwood Valley introduced aquatic animal management plan, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. 6 pp.
- Fong D. 2000. Winter 1998-2000 frog breeding survey **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. 33 pp. NRBib#160928.
- Fong D. 2002. Western pond turtle (*Clemmys marmorata*) inventory, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. 29 pp.
- Fong D, JA Howell. 2005. Distribution and abundance of California giant salamander (*Dicamptodon ensatus*) and signal crayfish (*Pacifastacus leniusculus*) in the upper Redwood Creek watershed, Marin County, California. National Park Service, Golden Gate National Recreation Area. 64 pp.
- Howell JA. 1991. Coastal scrub and prairie wildlife inventory, **Golden Gate National Recreation Area**, California. Proceedings of the Symposium on Biodiversity of Northwestern California October 28-30 1991. Santa Rosa, CA. 7 pp. NRBib#24792.
- Howell JA, M Semenoff-Irving. 1997. California wildlife: wildlife habitat relationships and ecological monitoring in the **Golden Gate National Recreation Area**. US Geological Survey, Western Ecological Research Center. 7 pp. NRBib#20170.

- Johnson PG. 2005. Riparian aquatic species inventory, **Pinnacles National Monument** 2001-2004. National Park Service, San Francisco Bay Area Inventory and Monitoring Network. 33 pp.
- Jones & Stokes. 1997. Natural resource inventory and vegetation management options, **Presidio** of San Francisco, appendix L: wildlife inventory. National Park Service, Golden Gate National Recreation Area. 54 pp. NRBib#97614.
- McGinness SM. 1986. Status of the San Francisco gartersnake *Thamnophis sirtalis tetraena* at Sharp Park Golf Course, Pacifica, California. Geomatrix Consultants, Inc., San Francisco California. 21 pp. NRBib#566200.
- Morafka DJ, BH Banta. 1972. The herpetozoogeography of the Gabilan Range, San Benito and Monterey Counties, California. The Wasmann Journal of Biology. Vol. 30 pp. 197-240.
- Morafka DJ, BH Banta. 1973. The distribution and microhabitat of *Xantusia vigilis* in the **Pinnacles National Monument**, San Benito and Monterey Counties, California. Journal of Herpetology. Vol. 7 pp. 97-108. NRBib#33075.
- Morafka DJ, BH Banta. 1976. Ecological relationships of the recent herpetofauna of **Pinnacles National Monument**, San Benito and Monterey Counties, California. The Wasmann Journal of Biology. 34:2 pp. 304-324.
- Semenoff-Irving M, JA Howell. 2002. Pilot inventory of terrestrial vertebrates, **Golden Gate National Recreation Area**, California, 1990-1997. US Geological Survey, Western Ecological Research Center. Open-file Report. 119 pp. NRBib#551859.
- Steiner. 1991. The San Francisco gartersnake at Laguna Salada: a plan for management and enhancement. National Park Service, Golden Gate National Recreation Area. 18 pp.
- Wauer R. 1958. A general report on the vertebrates of **Pinnacles National Monument**. National Park Service, Pinnacles National Monument. 47 pp.
- Wood L. 2004. Tennessee Valley seep and stream amphibian surveys, **Golden Gate National Recreation Area**. National Park Service, Golden Gate National Recreation Area. NRBib#568485.

6.3 Relevant NPS inventory and monitoring program guidance and protocols

- Bailey LL, EHC Grant, SD Mattfeldt. 2006. **North Capitol Region** Parks amphibian monitoring protocol. US Geological Survey, Patuxent Wildlife Research Center. 59 pp.
- Busteed G, S Riley. 2004. Breeding aquatic amphibian monitoring (stream survey) for the Mediterranean Coast Network, **Santa Monica Mountains National Recreation Area**. National Park Service, Mediterranean Coast Network. 42 pp.
- Dodd CK. 2003. Monitoring amphibians in **Great Smoky Mountains National Park**. US Geological Survey, Florida Integrated Science Center. Circular 1258. 118 pp.
- Fancy SG. 2000. Guidance for the design of sampling schemes for inventory and monitoring of biological resources in national parks. National Park Service, National Inventory and Monitoring Program. 10 pp.
- Oakley KL, LP Thomas, SG Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin. 31:4 pp. 1000-1003.

Appendix A: Workshop Participants

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Marcus Koenen, Inventory and Monitoring Coordinator, San Francisco Bay Area Network of Parks

Norm Scott, Ecologist, USGS (retired)

Appendix B: Amphibians and Reptiles of the San Francisco Bay Area Network National Parks

| EUON | GOGA | JOMU | PINN | PORE |

Class Amphibia, 14 species

Order Caudata - Salamanders, 8 species

California tiger salamander ②	<i>Ambystoma californiense</i>	✕ ^d	✕ ^d	✕ ^d	❖ ^h	
Arboreal salamander	<i>Aneides lugubris</i>	✓ ^d	✓ ^d	✓ ^e	✓ ^{a, g, j}	✓ ^{c, f}
Black salamander	<i>Aneides flavipunctatus</i>		○ ^d			
California slender salamander	<i>Batrachoseps attenuatus</i>	✓ ^e	✓ ^d	✓ ^e	✕ ^{a, j}	✓ ^{c, f}
Gabilan slender salamander	<i>Batrachoseps gabilanensis</i>				✓ ^g	
California giant salamander	<i>Dicamptodon ensatus</i>		✓ ^d			✓ ^{c, f}
Ensatina	<i>Ensatina eschscholtzii</i>	✓ ^d	✓ ^d	✓ ^e	✓ ^{a, g}	✓ ^{c, f}
Rough-skinned newt	<i>Taricha granulosa</i>	❖ ^d	✓ ^d	❖ ^d		✓ ^{c, f}
California newt	<i>Taricha torosa</i>	❖ ^d	✓ ^d	✓ ^e	❖ ^h	✓ ^c

Order Anura - Frogs and Toads, 6 species

Western toad	<i>Bufo boreas</i>	❖ ^d	✓ ^d	❖ ^d	✓ ^{a, b, g, i, j}	✓ ^c
Pacific treefrog	<i>Pseudacris</i> (= <i>Hyla</i>) <i>regilla</i>	✓ ^d	✓ ^d	✓ ^e	✓ ^{a, g, i, j}	✓ ^{c, f}
California red-legged frog ②	<i>Rana draytonii</i>	✕ ^d	✓ ^d	✕ ^d	✓ ^{a, b, g, i, j}	✓ ^{c, f}
Foothill yellow-legged frog ③	<i>Rana boylei</i>	✕ ^d	❖ ^d	❖ ^d	○ ^{b, i, j, h}	❖ ^d
Western spadefoot	<i>Spea hammondi</i>	✕ ^d		✕ ^d	✓ ^{a, g, i, j}	
Bullfrog ④	<i>Rana catesbeiana</i>	✕ ^d	✓ ^d	✕ ^d	○ ^h	✓ ^c

Class Reptilia, 35 species and subspecies

Order Testudinada - Turtles, 7 species

Loggerhead ②	<i>Caretta caretta</i>		❖ ^d			❖ ^d
Green turtle ②	<i>Chelonia mydas</i>		❖ ^d			✓ ^c
Pacific pond turtle ③	<i>Emys</i> (= <i>Actinemys</i> , <i>Clemmys</i>) <i>marmorata</i>	✕ ^d	✓ ^d	✕ ^d	✓ ^{a, b, g, i, j}	✓ ^c
Leatherback ①	<i>Dermochelys coriacea</i>		❖ ^d			✓ ^c
Olive ridley ②	<i>Lepidochelys olivacea</i>		❖ ^d			✓ ^c
Snapping turtle ④	<i>Chelydra serpentina</i>	✕ ^d	❖ ^d	✕ ^d	✕ ^d	✓ ^d
Common slider ④	<i>Trachemys scripta</i>	✕ ^d	✓ ^d	✕ ^d	✕ ^d	✓ ^d

Order Squamata - Lizards and Snakes, 28 species and subspecies

Suborder Sauria - Lizards, 10 species

California legless lizard	<i>Anniella pulchra</i>	❖ ^d		❖ ^d	✓ ^{a, g}	
Western whiptail	<i>Aspidoscelis</i> (= <i>Cnemidophorus</i>) <i>tigris</i>	✕ ^d		✕ ^d	✓ ^{a, g, i, j}	
Gilbert's skink	<i>Plestiodon</i> (= <i>Eumeces</i>) <i>gilberti</i>	❖ ^d		❖ ^d	✓ ^{a, g, j}	
Western skink	<i>Plestiodon</i> (= <i>Eumeces</i>) <i>skiltonianus</i>	✓ ^e	✓ ^d	✓ ^e	✕ ^d	✓ ^{c, f}
Northern alligator lizard	<i>Elgaria</i> (= <i>Gerrhonotus</i>) <i>coerulea</i>	❖ ^d	✓ ^d	✓ ^e		✓ ^{c, f}
Southern alligator lizard	<i>Elgaria</i> (= <i>Gerrhonotus</i>) <i>multicarinata</i>	❖ ^d	✓ ^d	❖ ^d	✓ ^{a, g, i, j}	✓ ^c
Coast horned lizard ③	<i>Phrynosoma coronatum</i>	✕ ^d		✕ ^d	✓ ^{a, g, j}	
Western fence lizard	<i>Sceloporus occidentalis</i>	✓ ^e	✓ ^d	✓ ^e	✓ ^{a, g, j}	✓ ^{c, f}
Side-blotched lizard	<i>Uta stansburiana</i>				✓ ^{a, g, j}	
Desert night lizard	<i>Xantusia vigilis</i>				✓ ^{a, g, j}	

		EUON	GOGA	JOMU	PINN	PORE
Suborder Serpentes - Snakes, 18 species and subspecies						
Glossy snake	<i>Arizona elegans</i>				❖ ^d	
Rubber boa	<i>Charina bottae</i>	❖ ^d	✓ ^d	❖ ^d	✗ ^h	✓ ^{c, f}
Racer	<i>Coluber constrictor</i>	❖ ^d	✓ ^d	❖ ^d	❖ ^h	✓ ^c
Sharp-tailed snake	<i>Contia tenuis</i>	✓ ^e	✓ ^d	✓ ^e	✓ ^{a, g}	❖ ^c
Western rattlesnake	<i>Crotalus oreganus</i>	✓ ^e	✓ ^d	❖ ^d	✓ ^{a, g, j}	✓ ^c
Ring-necked snake	<i>Diadophis punctatus</i>	✓ ^e	✓ ^d	❖ ^d	✓ ^{a, g, j}	❖ ^c
Night snake	<i>Hypsiglena torquata</i>	✗ ^d		✗ ^d	✓ ^{a, g, j}	
Common kingsnake	<i>Lampropeltis getula</i>	✓ ^e	✓ ^d	✓ ^e	✓ ^{a, g, i, j}	✓ ^c
San Joaquin coachwhip ①	<i>Masticophis flagellum ruddocki</i>	❖ ^d		❖ ^d	✓ ^{a, g, j}	
California whipsnake	<i>Masticophis lateralis</i>	❖ ^d	✗ ^d	❖ ^d	✓ ^{a, g, j}	✗ ^c
Gopher snake	<i>Pituophis catenifer</i>	❖ ^d	✓ ^d	❖ ^d	✓ ^{a, g, j}	✓ ^{c, f}
Long-nosed snake	<i>Rhinocheilus lecontei</i>	✗ ^d		✗ ^d	✓ ^{a, g, j}	
Western black-headed snake	<i>Tantilla planiceps</i>				✓ ^{a, g}	
Aquatic gartersnake	<i>Thamnophis atratus</i>	❖ ^d	✓ ^d	❖ ^d	✓ ^{b, g}	✓ ^c
Terrestrial gartersnake	<i>Thamnophis elegans</i>	❖ ^d	✓ ^d	❖ ^d	✓ ^h	✓ ^{c, f}
Two-striped gartersnake	<i>Thamnophis hammondi</i>				❖ ^h	
Common gartersnake	<i>Thamnophis sirtalis</i>	❖ ^d	✓ ^d	❖ ^d	✓ ^{a, b, g, i, j}	✓ ^{c, f}
San Francisco gartersnake ①	<i>Thamnophis sirtalis tetrataenia</i>		✓ ^d			

Explanation of Symbols

✓	Known to be present
✗	Not likely to occur
❖	May occur in the park, but no confirmed observation
○	Assumed to be extirpated
	Out of range (Stebbins 2003)
⊗	Non-native
①	Federally endangered
②	Federally threatened
③	California state species of concern

a)	Banta BH and DJ Morafka. 1967. An annotated checklist of the recent amphibians and reptiles of Pinnacles National Monument and Bear Gulch Reservoir.
b)	Ely E. 1994. Report and findings: 1994 surveys Pinnacles National Monument.
c)	Fellers GM. 2003. Checklist of amphibians and reptiles Point Reyes National Seashore. NRBib#549356
d)	Fellers GM. 2005. Personal communication.
e)	Fellers GM, L Long, G Guscio, and D Pratt. 2004. Inventory of terrestrial vertebrates at John Muir National Historic Site and Eugene O'Neill National Historic Site.
f)	Fellers GM and D. Pratt. 2002. Terrestrial vertebrate inventory Point Reyes National Seashore. NRBib#561929
g)	Fesnock AL and PG Johnson. 2005. Checklist of the amphibians and reptiles of Pinnacles National Monument. NRBib#59023
h)	Johnson PG. 2005. Personal communication.
i)	Johnson PG. 2005. Riparian aquatic species inventory Pinnacles National Monument.
j)	Wauer R. 1958. A general report on the vertebrates of Pinnacles National Monument.

Appendix C:

Summary of Proposed Monitoring Targets and Monitoring Questions

Monitoring Target 1: Pond-breeding amphibians

How are distribution and diversity of pond-breeding amphibians changing over time at GOGA and PORE?

How is abundance (as indicated by an index of egg masses and young-of-the-year) of pond-breeding California red-legged frog changing over time at PINN?

Monitoring Target 2: San Francisco gartersnake

How is the San Francisco gartersnake population at Mori Point changing over time?

Monitoring Target 3: Stream-inhabiting amphibians and reptiles

How are the distribution and diversity of aquatic salamanders changing over time at GOGA and PORE?

How are the distribution and diversity of stream-inhabiting herpetofauna changing over time at PINN?

Monitoring Target 4: Terrestrial amphibians and reptiles

How are the distribution, abundance, and diversity of selected terrestrial amphibians and reptiles changing over time at GOGA, PINN, and PORE?

Are common terrestrial amphibians and reptiles continuing to be detectable at EUON and JOMU?

Monitoring Target 5: Western pond turtle

How are the abundance, distribution, and diversity of turtles (with a focus on Western pond turtle populations, but including observations of all turtles) changing over time at GOGA and PORE?

Monitoring Target 6: Coast horned lizard

How are distribution and abundance of coast horned lizard, harvester ant, and the non-native Argentine ant changing over time at PINN?