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April 13, 2019

FROM: Rachel O Malley, Professor
Department of Environmental Studies

RE: Biological impacts of proposed bicycle/pedestrian path, Segment 7 Phase II, from Bay/California to Beach Street

Dear City of Santa Cruz Planning Commission and staff:

I am a biologist with 33 years of experience as a field researcher; I earned my BA in biology in 1986, and my PhD in Biology in 1997. My Ph.D. research was on wetland invertebrate ecology. As an assistant, associate and full professor at San Jose State University for 22 years, I have conducted research, published and taught courses in environmental restoration, graduate and undergraduate research methodologies, and environmental impact assessment, among other related subjects. During this time I have chaired over 40 Master of Science thesis committees, and I have conducted research and published academic journal papers on endangered plant and animal species in Santa Cruz County (please see Appendix A: Curriculum Vitae,).

At the request of the Sierra Club Conservation Committee, of which I am a member, I have reviewed the City of Santa Cruz response (City Response) to Sierra Club comments on the Recirculated Initial Study/Mitigated Negative Declaration (RIS/MND) for Phase II of the Rail/Trail Segment 7 Project (Project), as well as supporting documents. I have also conducted five site visits in August, January, March and April 2019; walked the site with the project engineer Nathan Ng; and reviewed public records regarding this site as well as scholarly literature. Based on this evidence and 33 years of field experience, my professional opinion is that **the proposed Project, as described in the RIS/MND, will cause significant impacts to biological resources that are not reduced to less than significant by the proposed mitigations**. An Environmental Impact Report is needed to adequately evaluate project alternatives to avoid significant impacts.

Page 1 of the City Response suggests that “no substantial evidence is provided” to indicate that "impacts to…special-status, riparian habitat and sensitive natural communities, wetlands, and wildlife movement) is provided. In addition to evidence already available elsewhere in the public record, I provide here further documentation of outstanding significant impacts to biological resources that will be caused by this project.

Specific examples follow here.

**Impacts on Neary lagoon ecosystem adjacent to Project site**

Page 2 of the City Response acknowledges that:

> *"It was decided early on, due to* ***potentially significant impacts*** *to Neary Lagoon, to shift the Segment 7 trail to the south side (ocean side) of the railroad tracks* (emphasis added).*"*

While I agree with the RIS/MND that the proposed bike and walking path along the railroad tracks between Bay Street and Beach Street would significantly impact Biological Resources in the adjacent Neary lagoon ecosystem, the RIS/MND has provided no substantial evidence to quantify the assertion that one side of the tracks would have less impact than the other. In my professional opinion, **aligning the path on the south (ocean) side of the tracks, a ~5-meter distance across horizontal ground-level ties,** will have **little to no mitigating effect on the significant impacts** of this path on vulnerable vertebrate, invertebrate and plant species using Neary lagoon. Whether sited on the north or south side of the tracks, the new lighting, noise, human activity and loss of upland and riparian habitat for wetland species the path will cause will result in significant impacts to the Neary lagoon ecosystem.

Neary lagoon is a biological hotspot, supporting over 220 bird species alone, regularly foraging, resting and nesting (see Appendix B, Figure 1), located in an unusually biodiverse region (See Appendix C). The RIS/MND describes many other sensitive vertebrates in the area, including "Sierran tree frog (*Pseudacris sierra*), California newt (*Taricha torosa*), arboreal salamander (*Aneides lugubris*), California slender salamander (*Batrachoseps attenuates*), California toad (*Anaxyrus boreas halophilus*), common red-sided garter snake (*Thamnophis sirtalis infernalis*), California legless lizard, western fence lizard (*Sceloporus occidentalis*), California alligator lizard (*Elgaria multicarinata multicarinata*), [and] dusky-footed woodrat (*Neotoma fuscipes*)." Among the other protected species, Western pond turtles (*Emys marmorata),* a species that is very sensitive to human disturbance,[1] is well-known to use Neary lagoon. A 2014 Neary lagoon biological assessment reported that*"…maintenance workers observed a female WPT attempting excavation along the gravel access road next to the WWTP* [wastewater treatment plant]." (Kittleson Environmental Consulting, See Appendix D). In addition to Hoary and Pallid bats, a total of fifteen migratory and resident bat species are found in Santa Cruz County (See Table 1). Bats are often missed in biological surveys because they must be censused using acoustic detectors. Review of City documents and academic literature yielded no acoustic bat survey data for Neary lagoon. Nonetheless, bats are usually associated with wetlands, due to the abundant insect life and roosting habitats (See Appendix E), and they

[1] Nyhof, P. E., & Trulio, L. (2015). Basking western pond turtle response to recreational trail use in urban california. Chelonian Conservation and Biology, 14(2), 182-184.

are very sensitive to light pollution that would be added through this Project (See Appendix F). Special status invertebrates, including monarch butterflies (*Danaus plexippus* L.) also use Neary lagoon and the Project site for foraging and resting habitats, including asters and willow (*Salix* spp) (See Figures 2 and 3).

The attached research paper (Appendix G) is one of many papers that document the effects of human activities on wetland bird species. Lighting travels hundreds of meters, affecting nocturnal species including owls, bats, mammals and night-flying insects. Noise and human activity can disrupt nesting and reduce fitness of sensitive species. Adjacent contiguous upland habitat provides critical buffers for higher quality habitats to protect them from edge effects. Eliminating this riparian corridor would cause edge effects to increase within the Neary lagoon ecosystem itself.

The proposed 5-meter shift to the "south side" of the tracks would not provide a sufficient buffer to reduce the recognized impacts on the Neary lagoon ecosystem to less-than-significant. In my professional opinion, proposed mitigations also do not adequately protect the ecosystem; the impacts of this project on the Neary lagoon ecosystem cannot be reduced to less-than significant in an alignment on either side of the tracks adjacent to Neary lagoon.

**Table 1. Bat Species Expected to Occur In the Santa Cruz County Region**

| | |
|---|---|
| **Family VESPERTILIONIDAE** (Plain-nosed or mouse-eared bats) | |
| *Myotis lucifugus* | Little brown myotis |
| *Myotis yumanensis* | Yuma myotis |
| *Myotis evotis* | Long-eared myotis |
| *Myotis thysanodes* | Fringed myotis |
| *Myotis volans* | Long-legged myotis |
| *Myotis californicus* | California myotis |
| *Myotis ciliolabrum* | W. small-footed myotis |
| *Lasionycteris noctivagans* | Silver-haired bat |
| *Parastrellus hesperus* | Canyon bat |
| *Eptesicus fuscus* | Big brown bat |
| *Lasiurus blossevillii* | Western red bat |
| *Lasiurus cinereus* | Hoary bat |
| *Corynorhinus townsendii* | Townsend's big-eared bat |
| *Antrozous pallidus* | Pallid bat |
| **Family MOLOSSIDAE** (Free-tailed bats) | |
| *Tadarida brasiliensis* | Mexican free-tailed bat |

(Reprinted from: Paul A. Heady III, Central Coast Bat Research Group. Report of Bat Survey Results for 3800 Portola Drive, Santa Cruz, CA. 02/28/15)

## **Impacts on biological resources in the Project site itself**

In addition to providing a buffer between Neary lagoon wetland habitats and the highly urbanized Bay Street corridor, the proposed project site itself currently contains protected riparian wetland which provides a wildlife corridor between the ocean ecosystem and the Santa Cruz mountains for larger mammals, including the Western Gray Fox (see Figure 4). The riparian corridor houses resident and migratory nesting birds (pers. obs), and the mature oak and willow canopy serves as nectar source for migratory birds and insects, as well as sequestering carbon from the atmosphere and cooling the local air and water. The riparian corridor additionally cleans the runoff from adjacent roads before it enters Neary lagoon or the Monterey Bay Sanctuary.

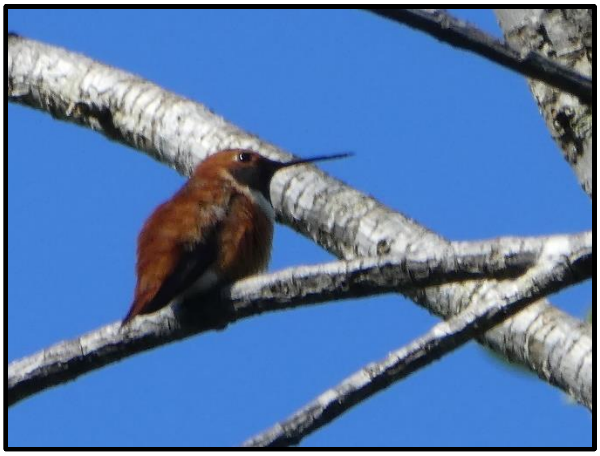

Figure 1. Rufous hummingbird (*Selasphorus rufus*) in Project site. Photo, J. Mio, March 2019. Rufous hummingbirds are uncommon migrants. Most recent available population data suggest that juveniles of this species are in decline.

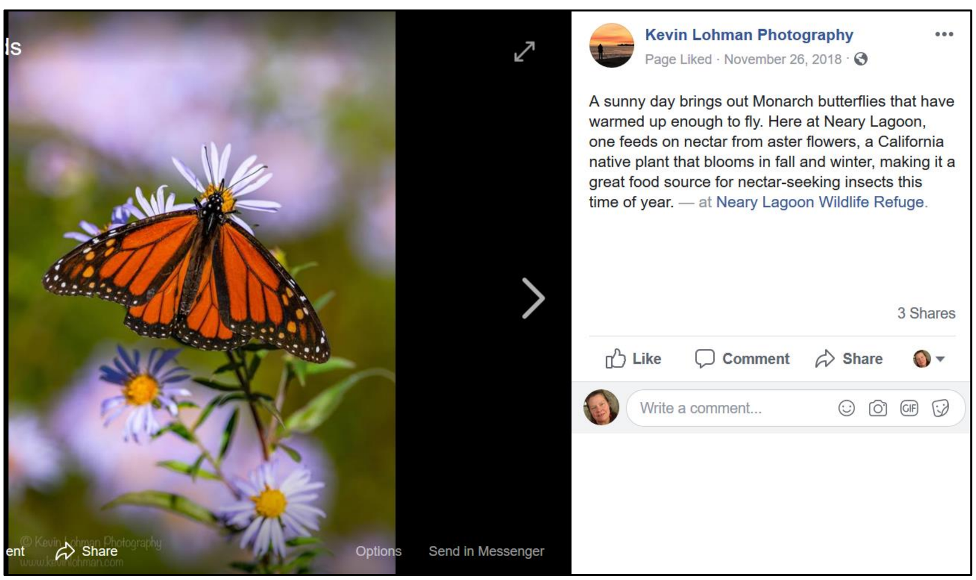


Figure 2. Monarch butterfly (*Danaus plexippus)* foraging at Neary lagoon. Photo, K. Lohman, November 2018. Western monarch populations are in catastrophic decline and at risk of extirpation locally.

The City Response continues:

> *"Furthermore, this area on the south side of the railroad contains a larger number of invasive plant species; is narrow and more sparsely vegetated; and may provide limited cover and accessibility for wildlife species…"*

This assertion is incorrect. The project site is a riparian forest dominated by a mix of mature and newly establishing coast live oaks (*Quercus agrifolia*) (see Figure 4) and willows (*Salix* spp) (see figure 5), with an understory that supports native species including the wetland indicator field horsetail (*Equisetum arvense*)(Figure 6), large stands of poison oak (*Toxicodendron vernix*)(Figure 7), and many other wildlife-supporting natives, in addition to English ivy (*Hedera helix*) (Figure 8) and other invasives. Most protected riparian corridors in California host invasive plant species, and yet they still serve as ecologically important habitats for sensitive species. Notably, with the loss of native willow and pine habitats, monarch butterflies have shifted to use English ivy (see Appendix H) among other nonnative winter nectar species. In fact, in one short (30 minute) survey, photos were obtained of a both a monarch butterfly and a rufous hummingbird (*Selasphorus rufus*) using vegetation in the project area. It is my professional opinion supported by field visits and photo documentation that replacement of this functioning riparian corridor with a paved pathway, vertical retaining walls and substantial human activity **will create a significant biological impact.**

Figure 3. Monarch foraging and resting in willow (*Salix* spp.) in project site. Photo, J. Mio, March 2019)

Page 2 of the City Response goes on to assert that:

> *"…the area on the south side of the railroad tracks provides low quality habitat to sensitive species because the area contains isolated*

*riparian vegetation that is physically separated from Neary Lagoon and the Regional Wastewater Treatment Facility by the railroad. ”*

From a biological perspective, the project site is contiguous to Neary lagoon. It is biologically incorrect to describe a flat railroad track with very infrequent train service as a barrier to sensitive winged species, including protected birds, bats and insects, or to the vegetation they disperse, such as oaks and willows. Similarly, frogs, lizards, snakes, woodrats, and smaller turtles will easily cross open railroad tracks, even with chain link fences running through. The project site serves as an important buffer from human activities on Bay Street for the Neary lagoon, and it provides refuge, rest, forage and nesting opportunities in its own right. The ecological value of this site is evident in the presence of nesting birds (pers obs), mature oaks and willows, wetland indicator species, foraging hummingbirds and monarchs, and running surface water. The presence of a topographic buffer in the form of a steep bank between the riparian corridor and the urbanized area further protects plants and animals that use it from human disturbance.

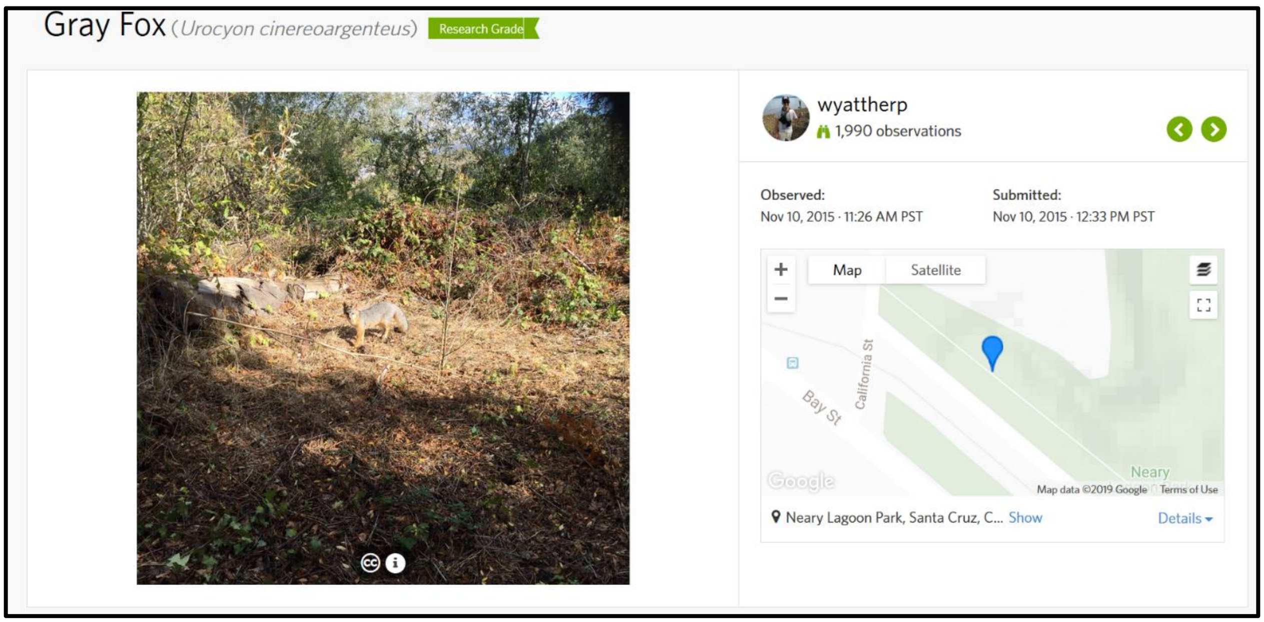


Figure 4.Research grade photo from iNaturalist record of native Gray fox (*Urocyon cinereoargenteus)* in proposed Project site in November 2015.

**<u>Relative value compared to other sites</u>**

In several parts of the City Response (pages 4, 5, 6) the assumption is made that the presence of a larger wetland adjacent to the project site reduces the significance of the loss of the 0.93 acres that would be lost, or that the presence elsewhere of higher quality habitat reduces the importance of monarch habitat that will be lost here. This reasoning is incorrect. The significance of loss of habitat must be evaluated based on its site-specific effects on the sensitive species. In the case of monarchs, for example, the species is currently catastrophically failing on the West coast of the US. Incremental loss of habitat is the primary reason. Incremental impacts to identified monarch habitat must be avoided. Similarly, over 90% of coastal wetlands and riparian corridors have already been lost. On April 2, 2019, the California Water Resources Board adopted a Statewide Wetland Definition and Procedures policy that supplements and reinforces section 404 of the Federal Clean Water Act, requiring no net loss of wetlands. The location of the affected habitat immediately adjacent to other important ecological resources, furthermore, increases rather than decreases the ecological value of this site and comprises part of the evidence that **loss of this riparian habitat will create a significant biological impact on wetland dependent species.** Edge and upland habitats located adjacent to higher value wetlands are well-known to provide more substantial ecosystem services than edge habitat islands isolated from intact ecosystems.

Figure 5. Coast live oak (*Quercus agrifolia*) canopy on south side of tracks, project site. Photo, R.E. O'Malley, March 2019) This ecosystem provides shelter, forage, and nesting sites for native and migratory birds and mammals. *Q. agrifolia* has also been documented as a high value species for carbon sequestration and storage. Proposed mitigation planting of individual immature trees would not reduce impacts on biological resources to less than significant.

Figure 6. One of several multistem willow thickets (*Salix* spp.) in Project site. Photo, R.E. O'Malley, March 2019. *Salix* spp. serve as late winter nectar source for sensitive species, including monarch butterflies, as well as year-round shelter, forage and nesting sites for hundreds of bird, mammal and invertebrate species. Proposed mitigation planting at Antonelli pond will not reduce significance of loss of this buffer at Neary lagoon.

Figure 7. Field horsetail (*Equisetum arvense*) is ubiquitous on the south side of the tracks in the proposed project site. Site. Photos, R.E. O'Malley, March 2019. This species is a wetland indicator. Direct impacts of the project on this riparian wetland would be significant.

Figure 8. Dense poison oak (*Toxicodendron diversilobum*) understory in the project site. Photo R.E. O'Malley, March 2019. This native species produces berries and provides cover and forage for sensitive species, including the Santa Cruz dusky–footed woodrat (*Neotoma fuscipes*).

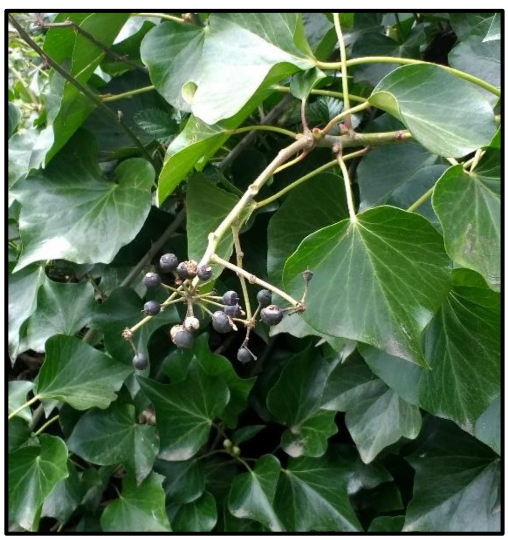

Figure 9. Fruiting English ivy (*Hedera helix*) in the Project site. Photo R.E. O'Malley, March 2019. Although English ivy is an invasive nonnative plant, presence of spring fruit is evidence that its flowers are available as a winter nectar source for sensitive species, including monarch butterflies.

**Proposed mitigations do not reduce impacts to less than significant**

I have reviewed the proposed mitigations in the RIS/MND, and in my professional opinion, biological impacts of the proposed project would remain significant even if these mitigations were adopted.

Bio-1, Bio-2, Bio-3, Bio-4 and Bio-5, Bio-6 and Bio-8 consist of preconstruction surveys of a subset of potentially affected species, silt fencing and worker training programs, all aimed to reduce construction impacts. These measures do not attempt to address biological impacts of the permanent loss of riparian wetland habitat.

Bio-8 goes on to require:

> *"The areas that undergo vegetative pruning and tree removal will be inspected immediately before construction, immediately after construction, and 1 year after construction to determine the amount of existing vegetative cover, cover that has been removed, and cover that resprouts. After 1 year, if these areas have not resprouted sufficiently to return the cover to the pre-project level, the City will replant the areas with the same native species to reestablish the cover to the pre-project condition."* RIS/MND

This mitigation is generally not feasible in the project area. The fundamental nature of the project is to eliminate existing riparian forest vegetation and contours of the habitat on-site, transforming topographically complex vegetated wetland habitat into a lighted horizontal path with a vertical retaining wall. The contour will eliminate amphibian, reptile, bird and bat habitat, impede movement, and create a surface that could lead to dangerous reptile and butterfly basking behavior while substantially increasing the quantity and speed of human traffic in the area. Riparian vegetation will be replaced with upland species including grasses and herbs. Wetland hydrology will be eliminated through construction of a storm drain. These proposed mitigations are inadequate to reduce Project impacts to less than significant.

Bio-7 in the RIS/MND proposes to replace lost willow trees at a 3-1 ratio, offsite. The City Response suggests these trees may be replaced at Antonelli pond. Planting willows at Antonelli pond is not adequate mitigation for loss of willows at this Project site. The City Response further lists 12 individual 1 to 3 stem willows as the only willows to be removed. The locations of these trees have not been identified in the document, but during the field visit with City staff in August 2018, several multistem *Salix* shrubs including the group pictured above were identified within the project site. The location of the tagged willows is not evident at the site.

The RIS/MND further acknowledges a loss of at least 42 total trees as part of the project. It asserts that the trees will be replaced per Coastal and City heritage tree project conditions. A contiguous grove of trees in a riparian corridor provide substantially more biological value than do isolated trees, and thus require greater mitigation to reduce impacts to less than significant. As part of the environmental review process, all trees to be removed should be identified publically and replanting locations must be specified. Furthermore, **no mitigation is proposed for loss of native scrub or riparian wetland understory habitat**.

As written, the proposed replanting mitigation and condition would **not reduce the impact of**

**loss of Biological Resources to less than significant.**

The City Response alludes to findings from the Monterey Bay Sanctuary Scenic Trail Network Master Plan Final EIR (MBBSSTN/MP/FEIR), a Program Environmental Impact Report (Program EIR) adopted November 7, 2013, however required mitigations from that document are not cited or incorporated by reference into the current RIS/MND to reduce impacts to onsite or offsite wetland ecosystems described here that will be damaged by the proposed Project.

The MBBSSTN/MP/FEIR finds that:

> "*Impact B-2 Implementation of the proposed MBSST Network project could result in impacts to riparian and other habitats considered sensitive by local, state, and/or federal agencies, including federally protected wetlands."* (section 4-4, page 67)"
>
> *"…Wetland habitats are varied and are generally associated with the drainages; however, there are several areas of fresh-water emergent wetland along the railroad corridor that are not likely mapped by the NWI. While these wetlands are likely an artifact of the construction of the railroad corridor, they are expected to fall under the jurisdiction of the CCC and RWQCB…"*
>
> "…*Impacts to these riparian and other sensitive habitats may include loss of habitat through construction of project features, such as trails and drainage crossings. Habitat degradation may also result from introduction of invasive species incidentally from construction equipment and through selection of invasive landscape plants, as well as through erosion of disturbed areas."*

The proposed mitigation for significant impacts on riparian wetland in the MBBSSTN/MP/FEIR reads as follows:

> *"Mitigation B-2(b) Wetland and Riparian Habitat Restoration. Impacts to jurisdictional wetland and riparian habitat shall be mitigated at a ratio of minimum 2:1 for each segment, and shall occur as close to the impacted habitat as possible. A Habitat Restoration Plan shall be developed by a biologist approved by the RTC and/or implementing entity in accordance with mitigation measure B-1(b) above and shall be implemented for no less than five years after construction of the segment, or until the RTC/implementing entity and/or the permitting authority (e.g., CDFW or USACE) has determined that restoration has been successful. All restoration/compensatory mitigation areas shall be permanently protected through a conservation easement or deed restriction."*

The program-level MBBSSTN/MP/FEIR did not analyze Segment 7 Phase II with sufficient detail to assess impacts of the Project on sensitive wetland habitat at Neary lagoon. In fact, Neary lagoon itself is not enumerated as a wetland in the MBBSSTN/MP/FEIR. The RIS/MND, a project-level document, identifies potential significant impacts of the Project on riparian wetlands, but proposed project-level mitigations do not incorporate required mitigations from the program FEIR, nor are proposed mitigations or project conditions sufficient to reduce impacts to less than significant, in my professional opinion.

**Alternative alignment would avoid significant impact**

Finally, the City Response asserts that "*the City considered several alternatives when developing the project.*"

The City Response first cites alternatives considered in the MBBSSTN/MP/FEIR. The two program-level alternatives analyzed in the MBBSSTN/MB/FEIR, however, do not consider alignments at the appropriate scale or specificity for this Project. The MBBSSTN/MP/FEIR Reduced Project Alternative offers no difference in alignment for Segment 7 (Phase II), and the On-Road Alignment takes a route closer to the coast, entirely bypassing Segment 7, phase II. It does not analyzing a fully separated alignment down Bay Street adjacent to La Barranca Park as part of the alternative at all (MBBSSTN/MP/FEIR Figure 6-1). Alternatives considered in the MBBSSTN/MB/FEIR thus provide no comparisons for this Project, and are inadequate for a tiered Project-level CEQA analysis.

The City Response goes on to assert that the following alternatives were considered and dismissed before environmental review:

> "*The City also considered an alternative route for the Project trail through La Barranca Park…*"
>
> *"The City also considered potential alternative alignments on existing roadways, including (1) an alternative alignment on Bay Street from the intersection of Bay Street/California Street to the intersection of Bay Street/West Cliff Drive and (2) an alternative alignment on California Street and Laurel Street from the intersection of California Street/Bay Street to the intersection of Laurel Street/Pacific Avenue. These alternative alignments were not pursued further because they would not meet the objective of maximizing safety of trail users. Furthermore, this alignment would have slopes that exceed 8.33 percent running slopes, which would result in the alignments not being compliant with the Americans with Disabilities Act (ADA). For these reasons, the Project is proposed next to the railroads tracks and not on roadways. Thus, these alternatives were not pursued further."*
>
> *"…Furthermore, during the design phase of the Project, the City considered a 16-foot wide trail at the request from City emergency services, members of the public, and trail support groups including Ecology Action and Bike Santa Cruz County. However, the City abandoned that design concept after considering the additional tree removals and impacts on La Barranca Park. The trail was ultimately reduced from 16-feet to 12-feet, in order to minimize costs and environmental impacts."*

None of the alternatives described above has been appropriately analyzed for environmental impacts in the RIS/MND or in any other CEQA document that I am aware of. In my professional opinion, and consistent with the MBBSSTN/MB/FEIR findings, an alternative alignment would successfully avoid significant impacts of this Project to Biological Resources. Reasons given for rejecting alternatives are not supported by adequate analysis or legal findings. Project-level changes in segments of the MBBSSTN have successfully moved other sections of the path on to city streets (in Segment 7, Phase I, for example). Before any decision is made on this Project, alternatives that consider environmentally superior alignments must be analyzed in an EIR for the benefit of the public and decisionmakers, and to protect the environment.

Sincerely,

Rachel E. O'Malley Ph.D.

APPENDIX A

Curriculum vitae for Rachel E.O'Malley

# CURRICULUM VITAE


## Rachel E. O'Malley

Department of Environmental Studies
San Jose State University, San Jose, CA 95192-0115
831-334-1066; Email: rachel.omalley@sjsu.edu


**Education**

**University of California, Santa Cruz, Biology, Ph.D.** December 1997, California 95064

Dissertation title: Evaluating wildlife conservation strategies for an agricultural wetland: dynamics of top-down versus bottom-up influences, omnivory and spatial scale

**Swarthmore College, Biology, B.A.** June 1986, Swarthmore, Pennsylvania 19081

**Relevant Appointments and Positions held**

2011-current **Professor,** Department of Environmental Studies, San Jose State University, California

- **Acting Department Chair** Fall 2014-Spring 2016
- **Department Graduate Program Coordinator** 2012-2014

2005- 2011 **Associate Professor**, Department of Environmental Studies, San Jose State University, California

- **Department Chair, Environmental Studies** 2005-2009
- **Founder, SJSU Sustainable Agriculture Garden**, 2005

1998- 2004 **Assistant Professor and Graduate Program Coordinator,** Environmental Studies, San Jose State University, California

- **Developer, Sustainable Agriculture Course and Laboratory**
- **Member, San Jose State Environmental Forum**

At SJSU, I have Chaired 45 (awarded) Master of Science thesis committees on biological conservation, environmental assessment, mitigation, restoration and sustainable agriculture. Some specific topics include:

**Sustainable agriculture**

- Avocado agroecology in demilitarized coastal Colombian communities
- Conserving pollinators and predators in central coast farm fields
- Culture of California central coast farmers
- Erosion control and runoff in California central coast farms
- Biological control of lepidopteran banana pests, Costa Rica
- Tree conservation in tropical pastures in Nicaragua
- Economics of sustainable cacao in Colombia, SA
- Opportunities and constraints for developing a campus teaching farm

**Conservation of rare plants, insects and small mammals of the Zayante sandhills**

- Santa Cruz wallflower (*Erysimum teretifolium*) and serpentine plants
- Mount Hermon June beetle (*Polyphylla barbata)*
- Zayante band-winged grasshopper (*Trimerotropis infantilis*)
- Santa Cruz kangaroo rat (*Dipodomys venustus venustus*)

**Urban sustainability in silicon valley**

- Environmental justice and impact assessment
- Trail use and invasive plant spread
- Restoration of urbanized riparian systems

| | |
|---|---|
| 1993-1997 | **Graduate Student Researcher,** Advisor: Dr. Dan Doak, Environmental Studies and Biology, UC Santa Cruz, CA |
| 1992 | **Research Assistant,** Law Offices of Norton Tooby, Oakland, CA |
| 1988-1991 | **Research Assistant, Graduate Student Researcher,** Advisor: Dr. Deborah Letourneau, UC Santa Cruz, CA |
| 1986-1987 | **Field and Laboratory Researcher/Consultant,** Agricultural Ministry, *Instituto Superior de Ciencias Agropecuarias*, *Universidad Nacional Autónoma de Nicaragua*, Matagalpa, Sebaco and Terrabona, Nicaragua |

**Selected Publications**


Melen, M.K., J.A. Herman, J. Lucas, R.E. O'Malley, I.M. Parker, A.M. Thom and J.B. Whittall. 2016. Reproductive success through high pollinator visitation rates despite self incompatibility in an endangered wallflower. American Journal of Botany 103(11):1979-1989.

Hill, Kirsten E. and R.E. O'Malley. 2010. A picky palate? The host plant selection of an endangered June beetle. Journal of Insect Conservation. DOI 10.1007/s10841-009-9257-7

Nieto, D.J., C. Shennan, W.H. Settle, R.E. O'Malley, S. Bros, and J.Y. Honda. 2006. How natural enemies and Cabbage Aphid (Brevicoryne brassicae L.) population dynamics affect Organic broccoli harvest. Environmental Entomology 35(1):94-101.

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Chu J. and R.E. O'Malley. 2002. Diet for an Endangered Insect: What Does the Zayante Band-Winged Grasshopper Eat? California Department of Fish and Game Publication.

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Doak, D.F, D. Bigger, E. Harding-Smith, M.A. Marvier, R.E. O'Malley, D. Thomson. 1998. The statistical inevitability of many stability-diversity relationships in community ecology. *American Naturalist* 151(3):264-276.

O'Malley, R.E. 1995. Insects in Flooded Rice. 26th Annual report to the California rice growers. California Rice Research Board.

Cohen, J.E. *et al.* (including O'Malley). 1993. Improving food webs. *Ecology* 74(1):252-258.

O'Malley, R.E. 1992. Indigenous cooperative blocks malathion spraying. Global Pesticide Campaigner 2(4):13.

O'Malley, R.E., M. Lacayo B, M. Lara S., D. Lopez H. 1987. Diagnóstico fitosanitario del cultívo de arroz. 35pp. Ministry of Agriculture. Matagalpa, Nicaragua.

APPENDIX B

E-bird listings for Neary lagoon, Santa Cruz, CA


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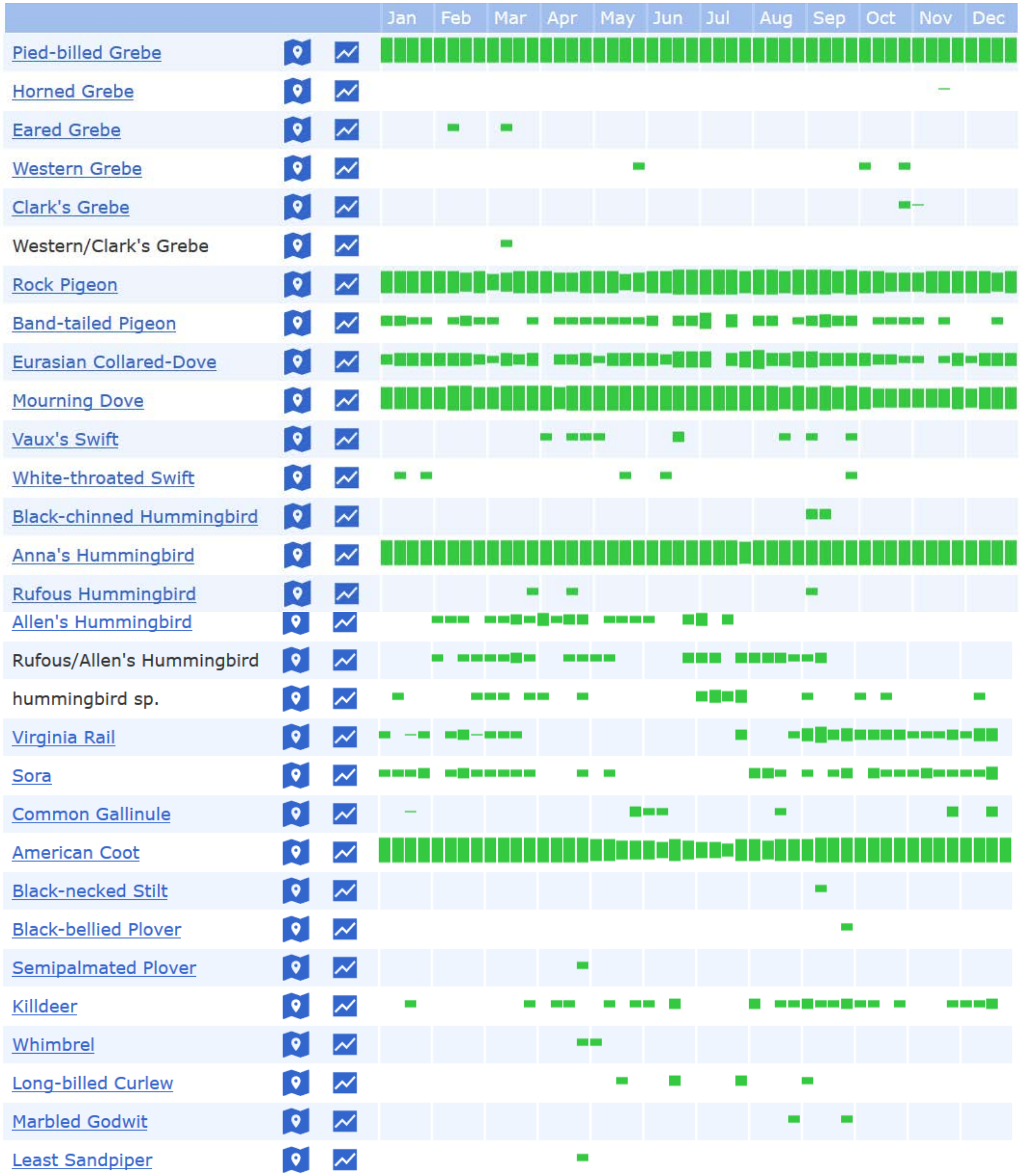


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| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| peep sp. | | | | | | | | | | | | |
| Short-billed Dowitcher | | | | | | | | | | | | |
| Short-billed/Long-billed Dowitcher | | | | | | | | | | | | |
| Wilson's Snipe | | | | | | | | | | | | |
| Red-necked Phalarope | | | | | | | | | | | | |
| Spotted Sandpiper | | | | | | | | | | | | |
| Wandering Tattler | | | | | | | | | | | | |
| Greater Yellowlegs | | | | | | | | | | | | |
| Willet | | | | | | | | | | | | |
| large shorebird sp. | | | | | | | | | | | | |
| Pigeon Guillemot | | | | | | | | | | | | |
| Bonaparte's Gull | | | | | | | | | | | | |
| Heermann's Gull | | | | | | | | | | | | |
| Mew Gull | | | | | | | | | | | | |
| Ring-billed Gull | | | | | | | | | | | | |
| Western Gull | | | | | | | | | | | | |
| California Gull | | | | | | | | | | | | |
| Herring Gull | | | | | | | | | | | | |
| Iceland Gull | | | | | | | | | | | | |
| Glaucous-winged Gull | | | | | | | | | | | | |
| Western x Glaucous-winged Gull (hybrid) | | | | | | | | | | | | |
| Herring x Glaucous-winged Gull (hybrid) | | | | | | | | | | | | |
| Larus sp. | | | | | | | | | | | | |
| gull sp. | | | | | | | | | | | | |
| Caspian Tern | | | | | | | | | | | | |
| Forster's Tern | | | | | | | | | | | | |
| Red-throated Loon | | | | | | | | | | | | |
| Pacific Loon | | | | | | | | | | | | |
| Common Loon | | | | | | | | | | | | |

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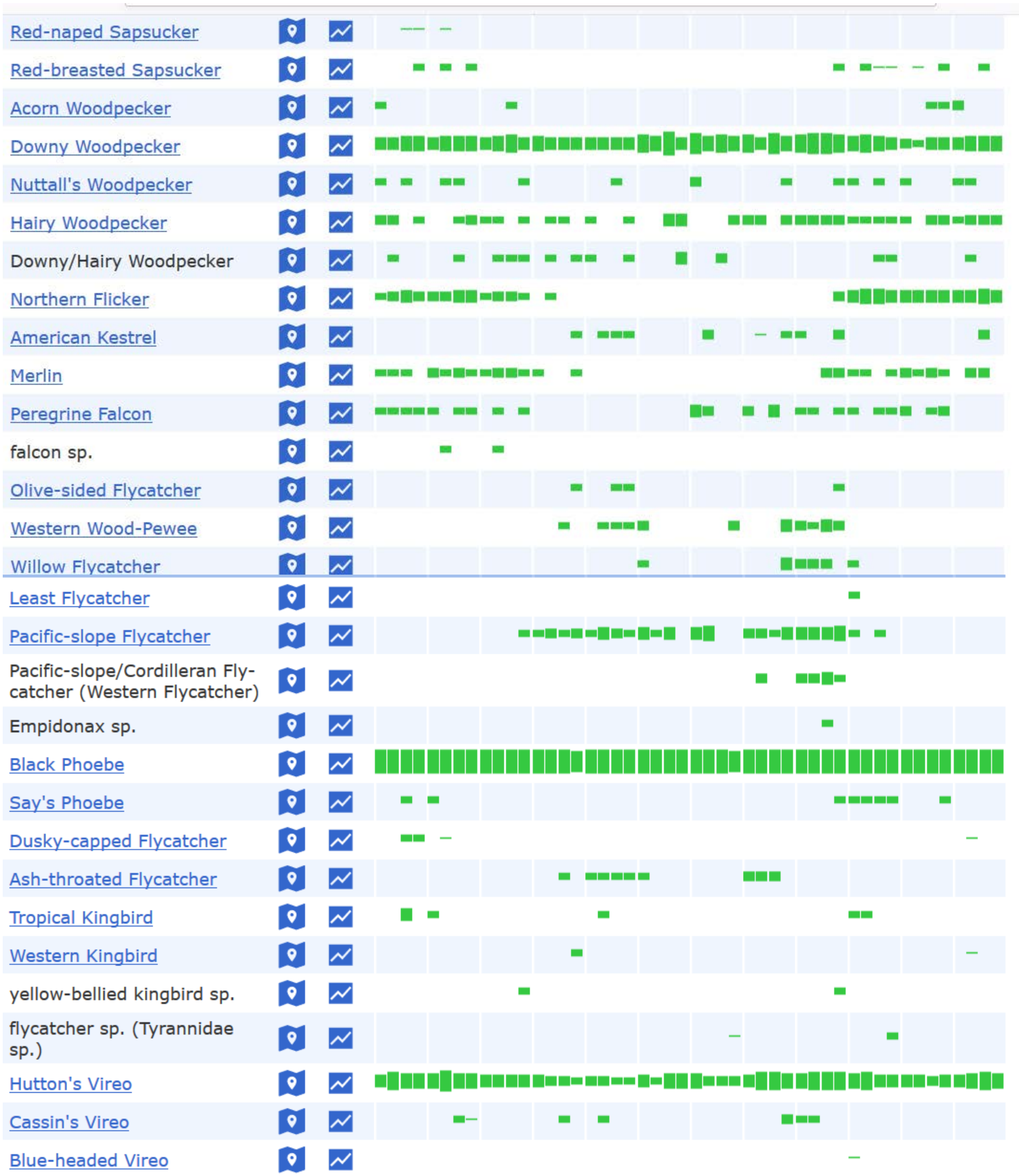


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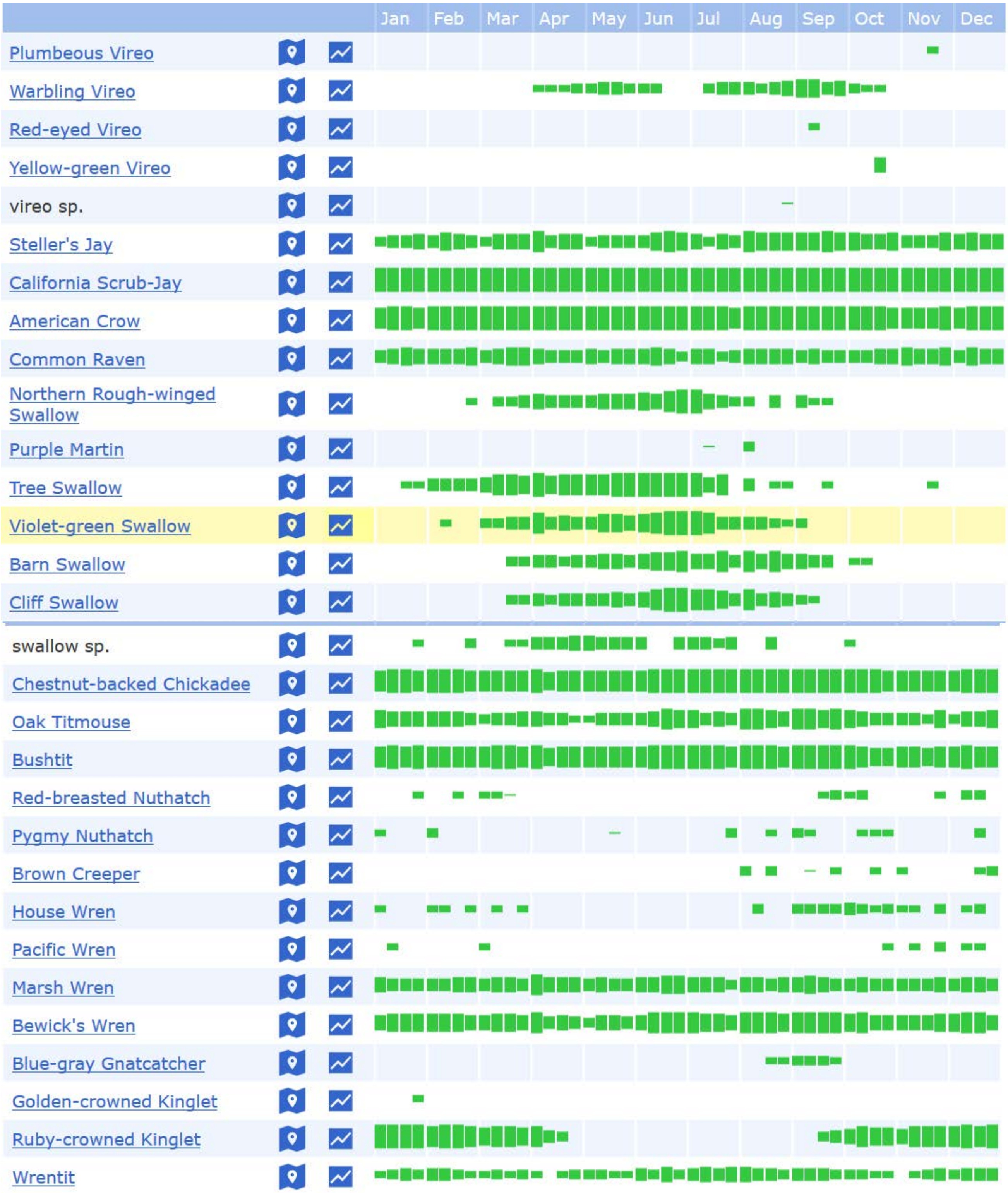


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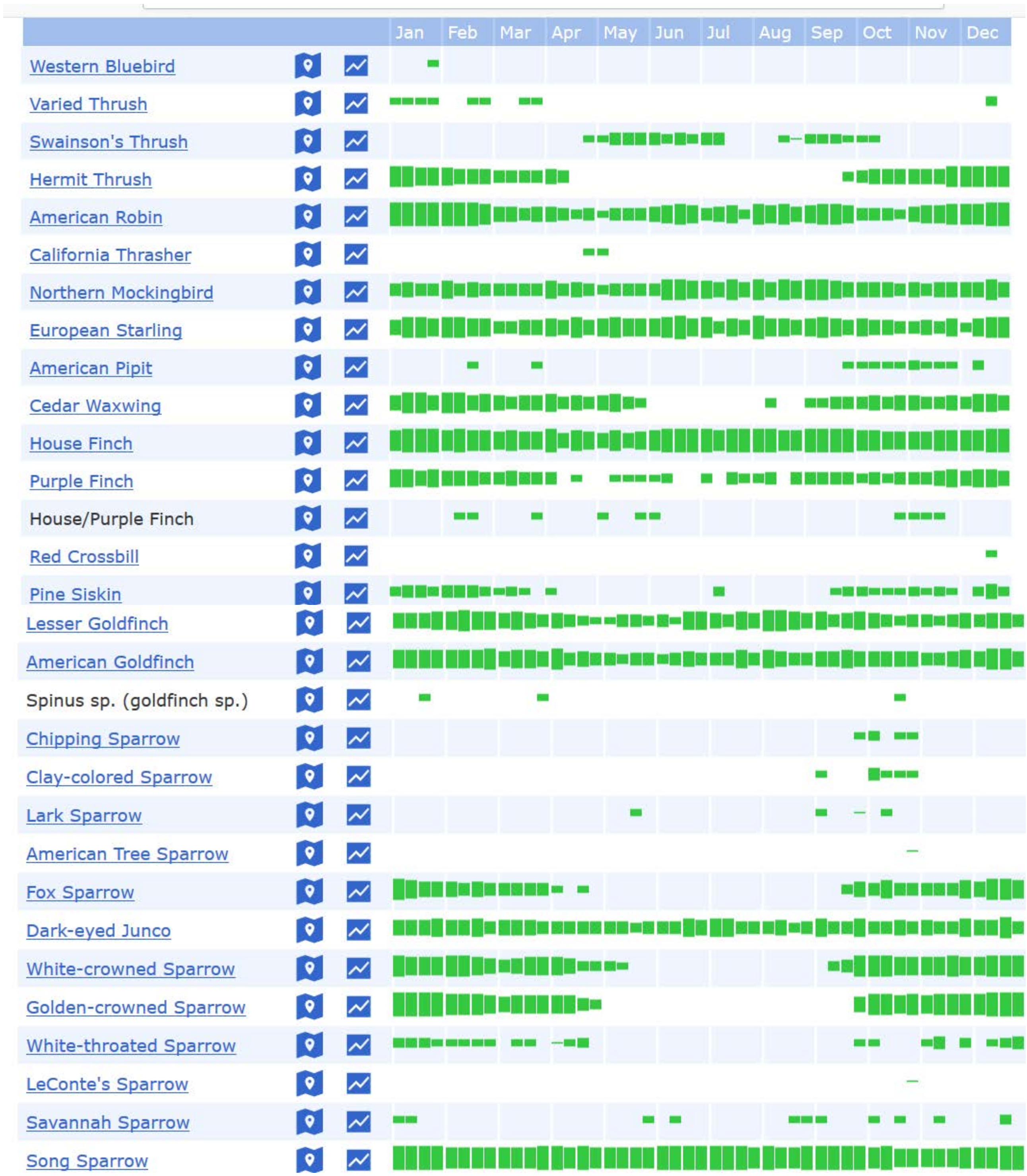

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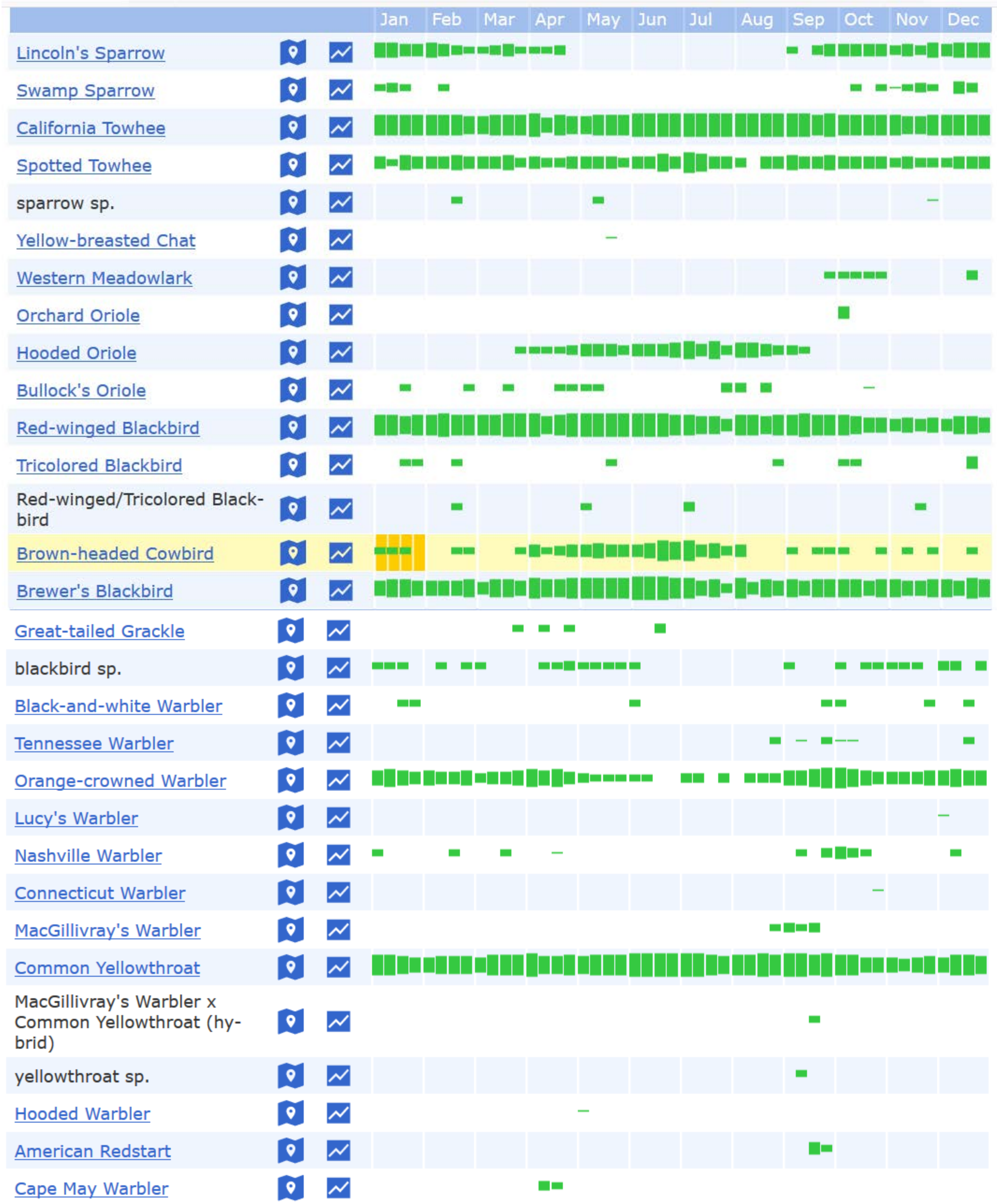


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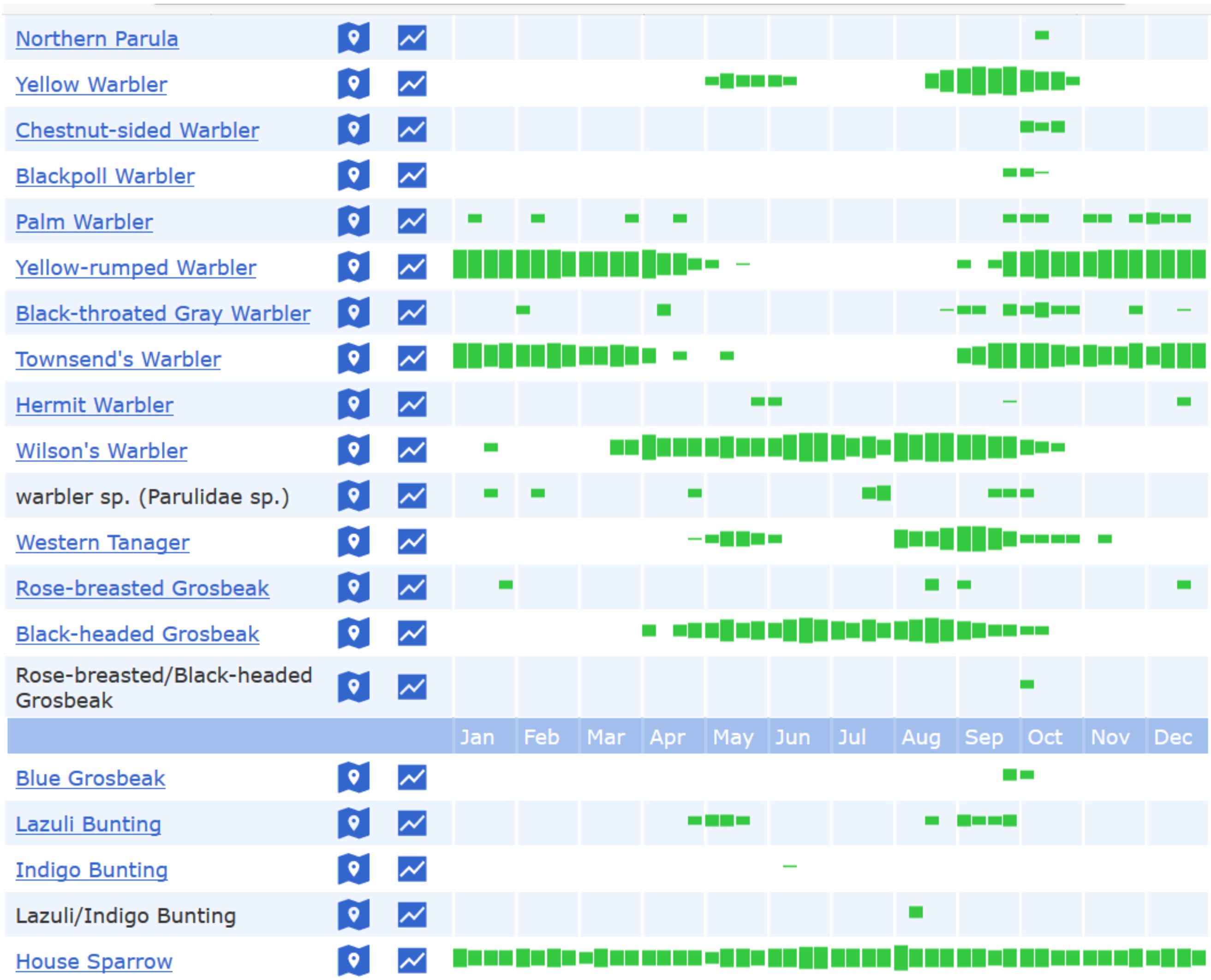
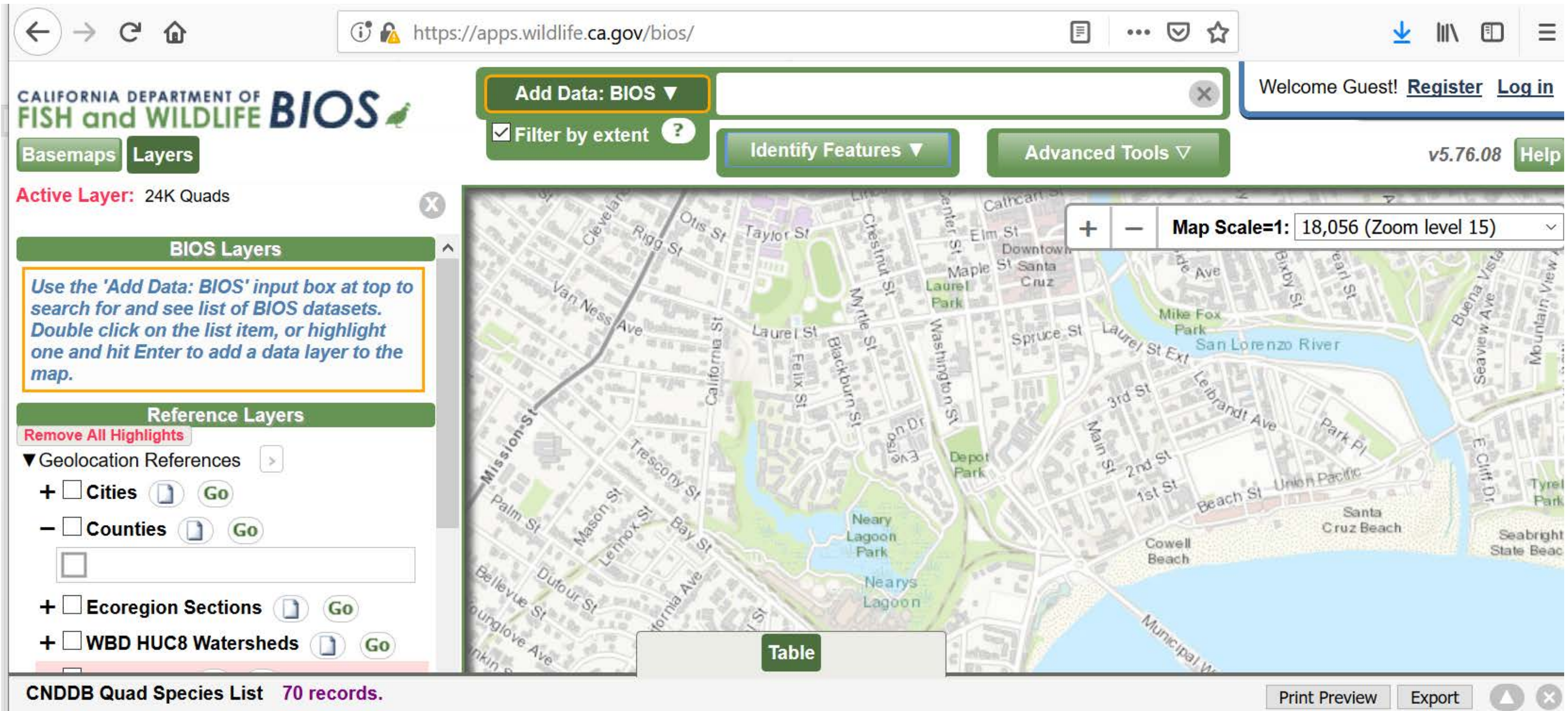

Northern Parula
Yellow Warbler
Chestnut-sided Warbler
Blackpoll Warbler
Palm Warbler
Yellow-rumped Warbler
Black-throated Gray Warbler
Townsend's Warbler
Hermit Warbler
Wilson's Warbler
warbler sp. (Parulidae sp.)
Western Tanager
Rose-breasted Grosbeak
Black-headed Grosbeak
Rose-breasted/Black-headed Grosbeak
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Blue Grosbeak
Lazuli Bunting
Indigo Bunting
Lazuli/Indigo Bunting
House Sparrow

(end

APPENDIX C

California Natural Diversity Database species listed for

Santa Cruz Coastal Quad 3612281




| Element_Type | Scientific_Name | Common_Name | Federal_Status | State_Status | CDFW_Status | CA_Rare_Plant_Rank |
|---|---|---|---|---|---|---|
| Animals – Amphibians | *Dicamptodon ensatus* | California giant salamander | None | None | SSC | - |
| Animals – Amphibians | *Aneides flavipunctatus niger* | Santa Cruz black salamander | None | None | SSC | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Animals – Amphibians | *Rana boylii* | foothill yellow-legged frog | None | Candidate Threatened | SSC | - |
| Animals – Amphibians | *Rana draytonii* | California red-legged frog | Threatened | None | SSC | - |
| Animals – Amphibians | *Taricha torosa* | Coast Range newt | None | None | SSC | - |
| Animals - Arachnids | *Meta dolloff* | Dolloff Cave spider | None | None | - | - |
| Animals - Arachnids | *Neochthonius imperialis* | Empire Cave pseudoscorpion | None | None | - | - |
| Animals - Arachnids | *Fissilicreagris imperialis* | Empire Cave pseudoscorpion | None | None | - | - |
| Animals – Birds | *Aquila chrysaetos* | golden eagle | None | None | FP ; WL | - |
| Animals – Birds | *Elanus leucurus* | white-tailed kite | None | None | FP | - |
| Animals – Birds | *Brachyramphus marmoratus* | marbled murrelet | Threatened | Endangered | - | - |
| Animals – Birds | *Cypseloides niger* | black swift | None | None | SSC | - |
| Animals – Birds | *Ardea herodias* | great blue heron | None | None | - | - |
| Animals – Birds | *Gymnogyps californianus* | California condor | Endangered | Endangered | FP | - |
| Animals – Birds | *Charadrius alexandrinus nivosus* | western snowy plover | Threatened | None | SSC | - |
| Animals – Birds | *Charadrius montanus* | mountain plover | None | None | SSC | - |
| Animals – Birds | *Spinus lawrencei* | Lawrence's goldfinch | None | None | - | - |
| Animals - Birds | *Riparia riparia* | bank swallow | None | Threatened | - | - |
| Animals - Birds | *Agelaius tricolor* | tricolored blackbird | None | Candidate Endangered | SSC | - |
| Animals - Birds | *Icteria virens* | yellow-breasted chat | None | None | SSC | - |
| Animals - Birds | *Lanius ludovicianus* | loggerhead shrike | None | None | SSC | - |
| Animals - Birds | *Pandion haliaetus* | osprey | None | None | WL | - |
| Animals - Birds | *Passerculus sandwichensis alaudinus* | Bryant's savannah sparrow | None | None | SSC | - |
| Animals - Birds | *Pelecanus occidentalis californicus* | California brown pelican | Delisted | Delisted | FP | - |
| Animals - Birds | *Coturnicops noveboracensis* | yellow rail | None | None | SSC | - |
| Animals - Birds | *Laterallus jamaicensis coturniculus* | California black rail | None | Threatened | FP | - |
| Animals - Birds | *Athene cunicularia* | burrowing owl | None | None | SSC | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Animals - Birds | *Contopus cooperi* | olive-sided flycatcher | None | None | SSC | - |
| Animals - Crustaceans | *Stygobromus mackenziei* | Mackenzie's Cave amphipod | None | None | - | - |
| Animals - Fish | *Gasterosteus aculeatus microcephalus* | resident threespine stickleback | None | None | - | - |
| Animals - Fish | *Eucyclogobius newberryi* | tidewater goby | Endangered | None | SSC | - |
| Animals - Fish | *Oncorhynchus kisutch pop. 2* | coho salmon - southern Oregon / northern California ESU | Threatened | Threatened | - | - |
| Animals - Fish | *Oncorhynchus kisutch pop. 4* | coho salmon - central California coast ESU | Endangered | Endangered | - | - |
| Animals - Fish | *Oncorhynchus mykiss irideus pop. 8* | steelhead - central California coast DPS | Threatened | None | - | - |
| Animals - Insects | *Bombus occidentalis* | western bumble bee | None | None | - | - |
| Animals - Insects | *Cicindela hirticollis gravida* | sandy beach tiger beetle | None | None | - | - |
| Animals - Insects | *Cicindela ohlone* | Ohlone tiger beetle | Endangered | None | - | - |
| Animals - Insects | *Lytta moesta* | moestan blister beetle | None | None | - | - |
| Animals - Insects | *Danaus plexippus pop. 1* | monarch - California overwintering population | None | None | - | - |
| Animals - Insects | *Polyphylla barbata* | Mount Hermon (=barbate) June beetle | Endangered | None | - | - |
| Animals - Insects | *Coelus globosus* | globose dune beetle | None | None | - | - |
| Animals - Mammals | *Dipodomys venustus venustus* | Santa Cruz kangaroo rat | None | None | - | - |
| Animals - Mammals | *Enhydra lutris nereis* | southern sea otter | Threatened | None | FP | - |
| Animals - Mammals | *Taxidea taxus* | American badger | None | None | SSC | - |
| Animals - Mammals | *Corynorhinus townsendii* | Townsend's big-eared bat | None | None | SSC | - |
| Animals - Mammals | *Lasiurus cinereus* | hoary bat | None | None | - | - |
| Animals - Mollusks | *Tryonia imitator* | mimic tryonia (=California brackishwater snail) | None | None | - | - |
| Animals - Mollusks | *Margaritifera falcata* | western pearlshell | None | None | - | - |
| Animals - Reptiles | *Emys marmorata* | western pond turtle | None | None | SSC | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Community - Aquatic | *North Central Coast Drainage Sacramento Sucker/Roach River* | North Central Coast Drainage Sacramento Sucker/Roach River | None | None | - | - | |
| Plants - Bryophytes | *Dacryophyllum falcifolium* | tear drop moss | None | None | - | 1B.3 | |
| Plants - Bryophytes | *Mielichhoferia elongata* | elongate copper moss | None | None | - | | 4.3 |
| Plants - Vascular | *Perideridia gairdneri ssp. gairdneri* | California Gairdner's yampah | None | None | - | | 4.2 |
| Plants - Vascular | *Holocarpha macradenia* | Santa Cruz tarplant | Threatened | Endangered | - | 1B.1 | |
| Plants - Vascular | *Monolopia gracilens* | woodland woollythreads | None | None | - | 1B.2 | |
| Plants - Vascular | *Pentachaeta bellidiflora* | white-rayed pentachaeta | Endangered | Endangered | - | 1B.1 | |
| Plants - Vascular | *Plagiobothrys diffusus* | San Francisco popcornflower | None | Endangered | - | 1B.1 | |
| Plants - Vascular | *Erysimum franciscanum* | San Francisco wallflower | None | None | - | | 4.2 |
| Plants - Vascular | *Arenaria paludicola* | marsh sandwort | Endangered | Endangered | - | 1B.1 | |
| Plants - Vascular | *Arctostaphylos andersonii* | Anderson's manzanita | None | None | - | 1B.2 | |
| Plants - Vascular | *Hosackia gracilis* | harlequin lotus | None | None | - | | 4.2 |
| Plants - Vascular | *Sidalcea malachroides* | maple-leaved checkerbloom | None | None | - | | 4.2 |
| Plants - Vascular | *Castilleja ambigua var. ambigua* | johnny-nip | None | None | - | | 4.2 |
| Plants - Vascular | *Collinsia multicolor* | San Francisco collinsia | None | None | - | 1B.2 | |
| Plants - Vascular | *Agrostis blasdalei* | Blasdale's bent grass | None | None | - | 1B.2 | |
| Plants - Vascular | *Leptosiphon grandiflorus* | large-flowered leptosiphon | None | None | - | | 4.2 |
| Plants - Vascular | *Chorizanthe robusta var. robusta* | robust spineflower | Endangered | None | - | 1B.1 | |
| Plants - Vascular | *Horkelia cuneata var. sericea* | Kellogg's horkelia | None | None | - | 1B.1 | |
| Plants - Vascular | *Horkelia marinensis* | Point Reyes horkelia | None | None | - | 1B.2 | |

APPENDIX D

Relevant data tables and photodocumentation of sensitive species at Neary lagoon. Excerpted from: Neary Lagoon Vegetation Management and Sediment Removal Project, City of Santa Cruz Santa Cruz, CA, Biological Assessment, April 2014, Prepared for: City of Santa Cruz Public Works Department Santa Cruz, CA 95060 by: Kittleson Environmental Consulting 3284 Malibu Drive, Santa Cruz, CA 95062

Table 1. Fish and Wildlife Species of Neary Lagoon

| | |
|---|---|
| Reptiles | |
| Western pond turtle | *(Emys marmorata)* |
| Red-eared slider | *(Trachemys scripta elegans)* |
| Southern alligator lizard | *(Elgaria multicarinata)* |
| Gopher snake | (*Pituophis catenifer catenifer)* |
| Western terrestrial garter snake | (*Thamnophis elegans)* Santa |
| Cruz aquatic garter snake | (*Thamnophis atratus atratus*) |
| Snapping turtle* | (*Chelydra serpentine)* |
| Amphibians | |
| Bullfrog | (*Rana catesbeiana)* |
| California slender salamander | (*Batrachoseps attenuates)* |
| Pacific treefrog | (*Hyla regilla)* |
| Fish | |
| Carp | (*Cyprinus carpio*). |
| Bluegill | (*Lepomis macrochirus)* |
| Green sunfish | (*Lepomis cyanellus),* |
| Largemouth bass | (*Lepomis macrochurus*) |
| Mosquitofish | (*Gambusia affinis*) |
| Threespine stickleback | (*Gasterosteus aculeatus*) |
| Brown bullhead | *(Ameiurus nebulosis)* |
| Prickly sculpin | (*Cottus asper*) |
| Rainbow trout** | (*Oncorhynchus mykiss*) |
| Sacramento sucker*** | (*Catostomus occidentalis*) |
| Large Invertebrates | |
| Louisiana swamp crayfish | (Procambarus clarkia) |

* *Single 160 mm turtle trapped on 6/3/2009.*

***Listed as present in Lagoon in 1992 Neary Lagoon Management Plan. One 140 mm rainbow trout/steelhead smolt was captured and relocated during KEC monitoring of railroad culvert slide gate installation, on 4/25/2014.*

*** *Listed in 1992 Neary Lagoon Management Plan.*

Table 2. Bird species observed at Neary Lagoon during 2005-2010 KEC field surveys

| | |
|---|---|
| Allen's Hummingbird | Lesser Goldfinch |
| Anna's Hummingbird | Lesser Yellowlegs |
| American Coot | Mallard |
| American Crow | Marsh Wren |
| American Goldfinch | Merlin |
| American Robin | Mourning Dove |
| Band-tailed Pigeon | Northern Flicker |
| Barn Swallow | Northern Rough-winged Swallow |
| Belted Kingfisher | Northern Mockingbird |
| Bewick's Wren | Northern Shoveler |
| Black Phoebe | Nuttall's Woodpecker |
| Black-crowned Night Heron | Orange-crowned Warbler |
| Black-headed Grosbeak | Osprey |
| Black Swift | Pacific-slope Flycatcher |
| Blue Grosbeak | Peregrine Falcon |
| Brewer's Blackbird | Pied-billed Grebe |
| Brown-headed Cowbird | Pintail |
| Bullock's Oriole | Purple Finch |
| Bushtit | Red-necked Phalarope |
| California Quail | Red-shouldered Hawk |
| California Thrasher | Red-tailed Hawk |
| California Towhee | Red-winged Blackbird |
| Canada Goose | Rock Pigeon |
| Cedar Waxwing | Rose-breasted Grosbeak |
| Chestnut-backed Chickadee | Ruby-crowned Kinglet |
| Cinnamon Teal | Ruddy Duck |
| Cliff Swallow | Rufous-sided Towhee |
| Common Moorhen | Say's Phoebe |
| Common Raven | Sharp-shinned Hawk |
| Common Yellowthroat | Song Sparrow |
| Cooper's Hawk | Sora |
| Double-crested Cormorant | Stellar's Jay |
| Downy Woodpecker | Spotted Sandpiper |
| European Starling | Spotted Towhee |
| Gadwall | Swainson's Thrush |
| Golden-crowned Sparrow | Tree Swallow |
| Great Blue Heron | Tricolored Blackbird |
| Great Egret | Turkey Vulture |
| Greater Yellowlegs | Violet-green Swallow |
| Greater White-fronted Goose | Virginia Rail (heard, not seen) |
| Green Heron | Warbling Vireo |
| Green-winged Teal | Western Scrub-Jay |
| Hermit Thrush | Western Wood-Pewee |
| Hooded Oriole | Wilson's Warbler |
| House Finch | White Pelican |
| House Sparrow | White-crowned Sparrow |
| Hutton's Vireo | Wood Duck |
| Kestrel | Wrentit |
| Killdeer | Yellow Warbler |
| Lawrence's Goldfinch | Yellow-rumped Warbler |

Table 3.Special Status bird species that may occur or are known to occur at Neary Lagoon

| | | |
|---|---|---|
| Brown Creeper (ssp. *phillipsi*) | proposed CSSC (nesting) | rare to uncommon non-breeding visitor |
| Cooper's Hawk | CSSC (nesting) | non-breeding visitor September to April |
| Double-crested Cormorant | CSSC (nesting) | non-breeding visitor; occurs all seasons |
| Merlin | CSSC (wintering) | non-breeding visitor September to early May |
| Northern Harrier | CSSC (nesting) | non-breeding visitor in fall and winter |
| Olive-sided Flycatcher | proposed CSSC (nesting) | spring and fall migrant |
| Osprey | CSSC (nesting) | non-breeding visitor; occurs all seasons |
| Peregrine Falcon | SE | non-breeding visitor, mostly fall and winter |
| Sharp-shinned Hawk | CSSC (nesting) | non-breeding visitor September to April |
| Summer Tanager | CSSC (nesting) | very rare fall migrant; does not nest in region |
| Swainson's Thrush | proposed CSSC (nesting) | fairly common nesting species, and migrant |
| Tricolored Blackbird | CSSC (nesting) | occasional non-breeding visitor |
| Vaux's Swift project area | CSSC (nesting) | spring and fall migrant; no nesting habitat in |
| White-tailed Kite | DFG Fully Protected | non-breeding visitor, mostly fall and winter |
| Willow Flycatcher | SE | rare spring and fall migrant |
| Yellow Warbler | CSSC (nesting) | uncommon nesting species; spring and fall migrant |
| Yellow-breasted Chat | CSSC (nesting) | rare spring and fall migrant |

*Source: CDFG California Bird Species of Special Concern 2006*

<u>Western Pond Turtle.</u> (excerpted)

Since 2002, a total of 10 individual adult western pond turtles have been observed, captured, marked and documented at Neary Lagoon Wildlife Refuge. During that same period, 20 red- eared sliders have been captured and documented. Of those twenty sliders, three have been removed from the wild by KEC, while the rest have been left at Neary Lagoon at the request of local residents that frequent the refuge.

Vegetation removal activities by Aquamog and the associated harvester vessel have been implicated in at least one turtle mortality since 2002. On 9/14/2004 Errol Griffin, a Santa Cruz City Department of Parks and Recreation employee, found a dead red-eared slider floating in main channel during Aquamog operations. The turtle was an unmarked, female with tissue damage on left side of head near mouth. It appeared bloated, possibly dead for a day at least. It was assumed to be hit by tule removal equipment.

No juvenile western pond turtles have been captured at Neary Lagoon during the trapping efforts that have been done since 2002, although photographs of a juvenile western pond turtle basking with an adult turtle was taken by local biologist Steve Gerow in June 2008. In those images, WPT #807 (136 mm CL) is clearly identifiable, and provides visual scale.

Upland breeding activities by WPT have not been observed by KEC or Biosearch Associates during our field investigations. Upland breeding activities were, however, anecdotally reported to investigators in 2005, with a report that maintenance workers observed a female WPT attempting excavation along the gravel access road next to the WWTP. That turtle was flushed back to open water and was not observed again.

Table 4. Summary of Western Pond Turtle Trapping Results 2002-2009

| SPECIES | Mark # | SEX | CL (MM) | CS (MM) | WEIGHT (GRAMS) | NOTES |
|---|---|---|---|---|---|---|
| WPT | 801 | M | | | | Captured in 2002 only No Photos |
| WPT | 802 | M | 185 | 59.5 | 793 774 | Captured 2002, 2005 & 2006 |
| WPT | 803 | F | 168 | 56 | 750 750 | Captured 2002, 2005 & 2006 |
| WPT | 804 | M | 155 | 50.5 | 545 547 | Captured 2002, 2005, 2006, 2007, 2008 and 2009 |
| WPT | 805 | M | 163 | 50.6 | 681 694 | Captured 2006 |
| WPT | 806 | M | 153 | 52.4 | 557 587 | Captured 2006 |
| WPT | 807 | F | 135.5 | 55 | 424 455 | Captured 2006, 2007, 2008 & 2009 |
| WPT | 808 | M | 164 | 57 | 720 | Captured 2008 Individual has 11 marginal scutes |
| WPT | 809 | M | 142 | 53 | 510 | Captured 2008 |
| WPT | 1601 | F | 164 | 56 | 450 | Captured 2008 & 2009 |

Notes: CL= carapace length, CH = carapace height

*Appendix B. 2005-2009 Neary Lagoon - Western Pond Turtle Photos*

## Male: #802

**#802**

Weight:
769 grams (8/23/05)
805 grams (10/11/05)
793 grams (8/21/2006)
774 grams (9/19/2006)

Carapace length: 185 mm
Carapace height: 59.5 mm

**#804**

Weight:
552 grams (8/27/2005)
548 grams (10/11/2005)
545 grams (8/21/2006)
547 grams (9/19/2006)
560 grams (9/12/2007)
595 grams (8/25/2008)

Carapace length: 155 mm
Carapace height: 51 mm

**#803**

Weight:
735 grams (9/7/2005)
730 grams (10/11/2005)
750 grams (8/21/2006)
776 grams (8/22/2006)
750 grams (9/19/2006)

Carapace length: 168 mm
Carapace height: 56 mm

## #805

Weight:
681 grams (8/21/2006)
694 grams (9/19/2006)

Carapace length: 163 mm Carapace height: 50.6 mm

#806

Weight:
557 grams (8/21/2006)
587 grams (9/19/2006)

Carapace length: 153 mm
Carapace height: 52.4 mm

**#807**

Weight:
424 grams (9/9/2006)
455 grams (9/19/2006)
480 grams (8/16/2007)
485 grams (9/11/2007)
450 grams (8/26/2008)
Carapace length: 136 mm
Carapace height: 55.0 mm

Juvenile WPT and female #807(6/7/2008) Juvenile photos by Steve Gerow

**#808**

Weight:
720 grams (8/24/2008)

Carapace length: 164 mm
Carapace height: 57.0 mm

## #809

Weight:
510 grams (8/24/2008) Carapace
length: 142 mm Carapace height:
53.0 mm

**#1601**

Weight:
610 grams (8/25/2008)

Carapace length: 164 mm
Carapace height: 56.0 mm

# APPENDIX E

# Bats and Wetlands

# Bats and Wetlands

Avery Howland, Alyssa Jones, Jessica Mailhot, Nate Tomlinson

## Executive Summary:

In the past decade there has been a severe decrease in North American bat populations (Batcon, 2016). This is largely attributed to a fungal infection known as White Nose Syndrome (*Pseudogymnoascus destructans*) (Belhert et al., 2009). In recent years there has been a large effort made towards increasing bat populations. Water availability has been shown to be crucial to bats (Yates and Muzika, 2006) as well as an abundant and reliable source of insects (Stahlschmidt et al., 2009). Although sources of water and insects have been shown to be important to bats, little is known about bats' specific relationship with wetlands. The goal of this project was to examine existing research and determine the correlation between bats and wetlands and how to apply that information to bat management in Vermont. Our objectives were to provide recommended monitoring methods in wetlands and applications of artificial and natural wetland restoration as bat habitat.

## Background:

Bats are an important part of many ecosystems around the world. Vermont is home to nine bat species, some residential and some migratory. The year-round resident species are the big brown bat (*Eptesicus fuscus*), the little brown bat (*Myotis lucifugus*), the Indiana bat (*Myotis sodalis*), the tri-colored bat (*Perimyotis subflavus*), the Northern long-eared bat (*Myotis septentrionalis*), and the Eastern small-footed bat (*Myotis leibii*). The migratory species are the hoary bat (*Lasiurus cinereus*), the silver-haired bat (*Lasionycteris noctivagans*), and the eastern red bat (*Lasiurus borealis*).

Although bats are small in size, the impacts they have on our ecosystem are vast, catching up to 1,200 insects in just one hour during peak feeding activity (Batcon, 2016). Unfortunately the North Eastern bat populations have been experiencing a sharp decline since 2006 when a fungal outbreak began to rapidly spread between colonies. This fungus, *Pseudogymnoascus destructans*, grows around the muzzles, ears and wing membranes of these bats. Because of its fuzzy white appearance on the bat's snout, it has been named White Nose Syndrome (WNS) (Belhert, 2009). WNS affects seven of the nine species of bats that inhabit the northeastern United States (Frick, 2010). Between 2007 when WNS had become more prevalent in the bat population and 2009, studies found that the North American bat populations had fallen by more than 75% as a direct result of this fungal infection (Blehert, 2009). Research done on the fungus shows that it grows on the sensitive areas of bats and effectively replaces hair follicles and sebaceous/sweat glands. As a result, this fungus erodes the epidermis of bat ears and wings (Blehert, 2009). WNS spreads and affects bats most during the winter months when they are in hibernation since the fungus thrives in cold damp areas (Frick, 2010). The disease tends to have greater impacts on residential species since they are roosting in cold damp hibernacula during the winter, whereas migratory bats spend the winter months in warmer climates (VTFWD).

In Vermont, the greatest decline in species populations has been the little brown bat and the northern long-eared bat (VTFWD), with the Indiana bat being at greatest risk across the entire United States (Yates, 2006). One step to help increase bat populations is to protect and preserve critical habitat for them. The continuing decline of several bat species linked with forests emphasizes the need for increased understanding of habitat relationships for North American bats (Yates, 2006). In recent years high quality habitats such as diverse inland wetlands have been impacted by or converted to agriculture (De Steven, 2011).

## Introduction:

Of the nine bat species found in Vermont, five have been in various degrees of decline over the past decade because of the spread of White Nose Syndrome and habitat loss (Batcon, 2016). Understanding these keystone species' relationship to wetland areas is crucial for effective conservation management. The ecosystems services provided by bats are extensive, especially for agriculture. They are a natural means of pest control, reducing the pressure for farms to apply harmful pesticides (Moran, 2015). While foraging for aquatic insects, they may also control disease vectors such as mosquitos. In general, wetlands are hotspots for diversity of both fauna and flora, and by managing wetlands for bats, many other species will be conserved in the process. In order to address this knowledge gap, we conducted a literature review that includes information about key healthy wetland characteristics, the preferences bats have for wetland characteristics, the potential for artificial wetlands to provide optimal habitat, and potential surveying methods and challenges. This information will help the Vermont Department of Fish and Wildlife effectively recover these important species in the state. In order to address this systematically, we investigated a series of subtopics including i) how to manage wetland restoration projects in a way that is beneficial for bats, ii) what wetland components are key for bats foraging and breeding, iii) which monitoring methods may be best suited for surveying in wetland areas, and iv) at what point after restoring a wetland do the conditions become suitable for bats.

## Methods/Approach:

We conducted a thorough and comprehensive literature review in order to meet our objectives. Each group member contributed equally to the research effort by exploring online literature databases.

## Findings:

### *Vermont's Wetlands*

The Vermont Wetlands Program defines a wetland as "areas of the state that are inundated by surface or groundwater with a frequency sufficient to support plants and animals that depend on saturated or seasonally saturated soil conditions for growth and reproduction" (Watershed Management Division, 2014). Parallel to the majority of the country, wetlands have been declining in Vermont over the past century. Currently about 4% of the land (230,000 acres) is classified as some category of wetland area, and it is estimated that 39% of the actual wetlands in the state have not yet been mapped (Watershed Management Division, 2014). While this may seem like a substantial percentage, more than 35% of the original wetlands in Vermont have been lost due primarily to residential, commercial, and industrial development (Watershed Management Division, 2014). This is not only a direct loss of wildlife habitat but also a loss of a wide range of ecosystem services. Some of these services include surface and groundwater protection, fish and wildlife habitat, and flood water storage (Watershed Management Division, 2014).

*Wetlands as Bat Habitat*

In the existing literature, we found several means of determining the suitability of wetlands as bat habitat. For example, one must examine the repopulation rates of certain birds, insects, and plants as suitable proxies. Wetlands provide critical breeding habitat for waterfowl and wetland-dependent songbirds (Wilson & Bayley, 2012). If a site is suitable for these songbirds, then they also tend to be suitable for bats because they utilize many of the same food sources. To assess the condition of a particular site, the index of biological integrity (IBI) can be used. IBI is a bioassessment tool that incorporates sites least impacted by human influence (Wilson & Bayley, 2012). In the IBI approach, scientists search for biological attributes that can predict underlying environmental stress. Environmental stress can be quantified by measuring physical and chemical stressors across a range of sites spanning the gradient of human influence (Wilson & Bayley, 2012).

After compiling all the data, it was found that the suitability of different biotic communities varied widely and that not all communities were sensitive to a gradient of environmental stress. They concluded that the wet meadow zone vegetation and wetland-dependent songbird communities are good indicators of environmental stress while emergent vegetation, open-water vegetation and waterbirds are fair to poor indicators of environmental stress (Wilson & Bayley, 2012). Wet meadow vegetation and wetland-dependent songbird IBIs were strong surrogates of each other, indicating that sampling one biotic community can reflect the health of other organisms of differing trophic levels (Wilson & Bayley, 2012).

There are a number of factors that contribute to bats' habitat preferences and what is considered to be a prime foraging area. One factor that affects habitat preference is a bat's wing morphology. Bats with low wing loads are more maneuverable and can use areas that are more enclosed with vegetation such as forest interiors; however, bats with high wing loads (i.e. larger bats) tend to prefer open areas, such as wetlands (Maslonek, 2010). The presence of water has been cited as being of great importance as a habitat resource for bat species (Yates, 2006). One study found that bats prefer still, calm waters as opposed to moving turbulent waters which seem to interfere with echolocation (Maslonek, 2010). Bat activity is also affected by the presence of roosting habitat. Wetlands in proximity to good roosting sites such as upland habitat had more bat activity than those isolated from prime roosting sites (Lookingbill, 2010). Pup mortality during the lactating season is directly related to how far the mother has to travel to forage, providing local areas of high prey abundance could increase pup survival (Stahlschmidt et al., 2009). Multiple studies have shown that another important factor is plentiful foraging habitat. Since most insects depend on water for at least one stage in their life cycle this makes a wetland prime habitat for multiple insect species to breed and live (Maslonek, 2010). Insectivorous bats will tend to live where food is most plentiful and therefore tend to use wetlands as foraging grounds (Menzel, 2005). One case study found that bats generally prefer wetlands compared to other habitat types; although species richness was not significantly different across habitat types, overall bat activity was (Figure 1; Sirami et al., 2013)

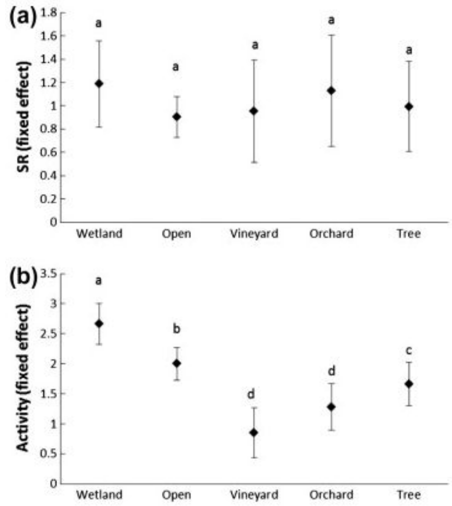



**Fig. 1**: This figure taken from the Sirami et al. shows that across habitat types, the diversity of bat populations is relatively the same. When looking at bat activity, however, there is predominantly more bat activity in a wetland habitat.

*How Artificial Wetlands Benefit Bats*

Artificial wetlands and other manmade bodies of water have been shown to be highly utilized by bat populations (Sirami et al., 2013; Stahlschmidt et al., 2012; Vindigni et al., 2009). In addition to artificial wetlands, bats have been found foraging around sewage treatment plants, agricultural retention ponds, helipads, and manmade ditches (Stahlschmidt et al., 2012; Vindigni et al., 2009). In some cases bats were actually observed foraging over helipads and ditches more than they were foraging over an adjacent natural wetland (Vindigni et al., 2009). It is believed that this was because the helipads and ditches were less cluttered, more easily accessible, and a reliable source of insects. Manmade ditches also act as corridors and provide connectivity across the landscape, allowing bats to access previously isolated areas (Vindigni et al,. 2009). In agricultural landscapes water retention ponds have been heavily utilized by bats. In a study by Stahlschmidt et al., data were collected on bat foraging time and insect abundance in an agricultural area that had several retention ponds. They found that 98.3% of the audio recordings they collected were over the retention ponds, and 76.9% of the 5,978 insects they collected were over the retention pond with 71% of these being emerged aquatic insects (Stahlschmidt et al., 2012).

*Survey Methods & Recommendations*

Many studies provide recommendations and insight into how to best cater bat surveying methods for wetland areas. When deciding how to structure the survey methods, it is important to apply knowledge about the bat's behavior to best collect data. Most research includes replicate audio recorders either in different habitat types or at different proximities to a wetland feature (Sirami et al. 2013, Stahlschmidt et al. 2012, Vindigni et al. 2009). Depending on the focus of the study either one of these formats or a hybrid between the two may be most appropriate. It was also noted that recorders should be at a variety of heights to capture activity that isn't just at one height above the ground, water or canopy (Sirami et al 2013). It is also important to be able to distinguish between the variety of calls made by bats, including echolocation, feeding buzzes and social calls. These all mark bat presence, but more information can be distilled from knowing exactly what types of behaviors are tied to wetlands, especially foraging (Mendes et al. 2014). Having sufficient background information about the behavior of the target species is ideal for drafting the most effective methods.

There are several factors to consider when formulating the surveying schedule. Research suggests that special attention should be made to the seasonal activity of the target species. Some studies have surveyed throughout the year in order to quantify and account for seasonal variation (Mendes et al. 2014), while others chose to survey in June through late July during the breeding season (Nummi et al. 2011). Because the ideal time to survey heavily depends on the life history characteristics and behaviors of the species as well as the local environmental factors for that population, it is crucial to do preliminary surveys to best inform the monitoring methods. In a study by Menzel et. al. they found greater number of bats over restored Carolina bays after completion of a restoration project. During this project there was less activity over the project sites, but upon completion they observed greater activity over restored areas than before restoration. It is important to consider that changes in bat activity may not be significant until completion of the project. In addition to seasonal variation, it is also important to note that weather plays a role in the daily activity and ability to record; Mendes et al. did not record on occasions of unfavorable weather (2014). Whether or not such data are excluded, the weather conditions should be recorded at each survey in order to explain possible variability afterwards.

<u>Discussion & Recommendations</u>:

The cost of restoring wetlands can vary based off of land value and the status of the wetland. This cost also includes the potential for urban development on the site. Easement costs need to offset nuisance costs for landowners to consider permitting use of their property for restoration. After taking into consideration site health, nuisance costs, and the per acreage costs, the total cost of restoring wetlands ranges from $170 - $6,100 (Hansen et al., 2015).

According to our research bats may benefit as much from artificial water bodies as they do from wetlands. If the body of water has some form of vegetation that provides cover and roosting sites it will attract local bats. This could provide a more financially feasible alternative to restoring or creating wetlands. Adding in local retention ponds in areas with potential to have roosting bats would increase local insect abundance and allow them to forage more efficiently.

To quantify if such wetland restoration measures actually bolster bat habitat, we recommend conducting field surveys catered for certain species and for wetland habitats. As mentioned above, the more information known about the species' life history and activity patterns, the more efficient the placement of the recorders can be. It's important to be aware of what time of year a species is most active in order to efficiently record. Some studies arranged their recorders at different proximities to open water and with replicates in a variety of habitats. These two strategies are of particular relevance to heterogeneous wetland landscapes. It's also important to account for potential background noise in the recordings, especially insects and amphibians which will likely be an issue in wetlands. Lastly, we believe it is best to monitor for bat presence in an area before and after restoration, although it is not necessary to monitor during the project itself. Post-restoration recording can begin the year directly following completion of the project because there is evidence that bats readily return to the area.

Although no data were found explicitly stating when wetland conditions become beneficial for bats post-restoration, Menzel et. al. discussed seeing a return of the bat population one year after restoration. In addition to this, no studies were found comparing artificial wetlands to naturally occurring ones. It's important to keep in mind that even though these findings aren't specifically about Vermont wetlands or bats species, it is still applicable information that can be utilized in managing for Vermont's bat populations.

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# APPENDIX F

Impacts of artificial lighting on bats: a review of challenges and solutions

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Review

# Impacts of artificial lighting on bats: a review of challenges and solutions

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ABSTRACT

Light pollution is a major emerging issue in biodiversity conservation, and has important implications for policy development and strategic planning. Although research is now addressing the negative impacts of anthropogenic noise on biota, less attention has been paid to the effects of light pollution. Changes in lighting technology have led to a diverse range of emerging low energy light types and a trend towards the increased use of white light. Light pollution affects ecological interactions across a range of taxa and has adverse effects on behaviours such as foraging, reproduction and communication. Almost a quarter of bat species globally are threatened and the key underlying threat to populations is pressure on resources from increasing human populations. Being nocturnal, bats are among the taxa most likely to be affected by light pollution. In this paper we provide an overview of the current trends in artificial lighting followed by a review of the current evidence of the impacts of lighting on bat behaviour, particularly foraging, commuting, emergence, roosting and hibernation. We discuss taxon-specific effects and potential cumulative ecosystem level impacts. We conclude by summarising some potential strategies to minimise the impacts of lighting on bats and identify key gaps in knowledge and priority areas for future research.


## Shedding light on the challenges – how important is light pollution?

Global increases in urbanisation (Grimm et al., 2008) and human development have led to a dramatic rise in both the extent and intensity of artificial lighting throughout the 20th and 21st centuries (Cinzano, 2000, 2003; Cinzano et al., 2001; Hölker et al., 2010a). Light pollution affects every inhabited continent; electric lighting has increased nocturnal sky brightness by 20% (Hendry, 1984). Worldwide, artificial lighting is increasing by around 6% per annum (Hölker et al., 2010b), and there was a 24% increase in light pollution in the UK between 1993 and 2000 (CPRE, 2003). Traditionally street lights consisted of sodium discharge lamps which generate light via electric discharges through a gas or vapour. The most common lights used were Low Pressure Sodium (LPS) and High Pressure Sodium (HPS). LPS lights are narrow spectrum, emitting an orange-based light with a correlated colour temperature (CCT) of 1807 Kelvin (K), and an absence of ultraviolet (UV) light. HPS are broad spectrum generating a pinkish light with a CCT of 2005–2108 K, with some light emitted in the UV spectrum. Trends in lighting technology have led to changes in the spectral content of artificial lighting (Davies et al., 2013a; Frank, 1988; Massey and Foltz, 2000) from predominantly orange sodium-based lighting in the 1960s and 1970s (Gaston et al., 2013) to broader wavelength lights such as high-brightness light-emitting diodes (LEDs). Today a variety of light types are used globally each with differing CCT and wavelengths (Table 1, Fig. 1). LEDs produce monochromatic radiation and their colour tone is defined by the dominant wavelength (Fig. 2), so LEDs can be a variety of CCTs from "warm white" similar to LPS to "blue white" similar to metal halogen. LEDs had a 31% growth in market share in 2010 (Steele, 2010) and are expected to represent 60% of the market share by 2020 (Peters, 2011).

## Ecological impacts of lighting

Global levels of light pollution are set to increase as human populations rise and become more urbanised. There has been increasing awareness of the ecological impacts of light pollution associated with urbanisation (Davies et al., 2013b; Gaston et al., 2012, 2013; Harder, 2002; Hölker et al., 2010a, 2010b; Longcore and Rich, 2004; Navara and Nelson, 2007; Smith, 2009). Light pollution affects ecological interactions across a range of taxa and negatively affects critical animal behaviours including foraging, reproduction and communication (for reviews see Gaston et al., 2013; Longcore

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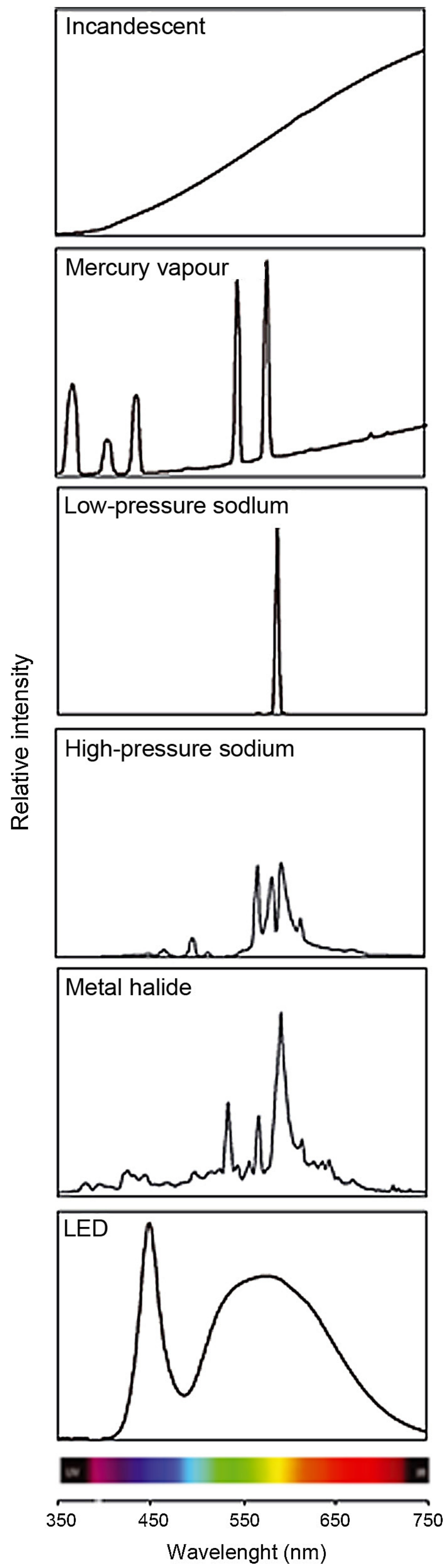


**Fig. 1.** Spectral composition of common street light types.
*Source*: Gaston et al. (2013).

and Rich, 2004; Rich and Longcore, 2006). Light pollution is now recognised as a key biodiversity threat and is an emerging issue in biodiversity conservation, with important implications for policy development and strategic planning (Hölker et al., 2010b). Being nocturnal bats are among those species most likely to be affected

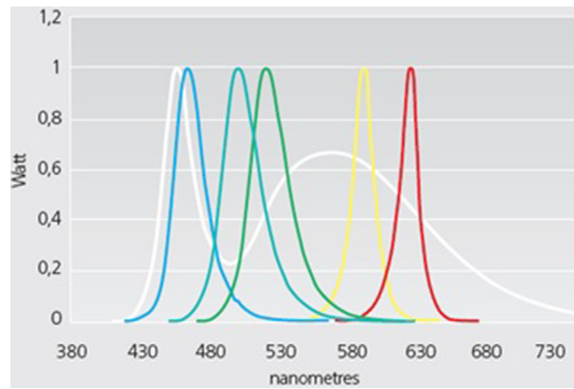


**Fig. 2.** Spectra of coloured and white LEDs.
*Source*: Anon (2005).

**Table 1**
Common light types and colour temperatures.

| Light type | Colour | Correlated colour temperature (K) |
|---|---|---|
| Low pressure sodium (LPS/SOX) | Yellow/orange | 1807 |
| High pressure sodium (HPS/SON) | Pinkish/off white | 2005–2108 |
| Compact fluorescent | Warm white | 2766–5193 |
| Metal halide (MH) | Blue-white | 2720–4160 |
| Light emitting diode (LED) | White/warm-white | 2800–7000 |

*Source*: Gaston et al. (2012).

by lighting, although artificial light can have an impact on a wide range of taxa and behaviours.

## Impacts of artificial lighting on bats

As the second most species-rich mammalian order in the world (Wilson and Reeder 2005) bats represent a significant contribution to global biodiversity (Altringham, 1996; Racey and Entwistle, 2003). Bats make effective bio-indicators, capturing the responses of a range of taxa and reflecting components of biological diversity such as species richness and biodiversity (Jones et al., 2009). Due to their high niche diversity bats are also effective ecological indicators reflecting responses over a range of trophic levels and highlighting effects of environmental degradation on specific ecological processes that are key to ecosystem functioning. Bats are potentially effective bio-indicators for conservation biologists measuring the human impact on the environment, including the impacts of light pollution as their relative abundance, species richness, and vulnerability to disturbance can be relatively easy to monitor over successive years (Fenton et al., 1992).

Bats are therefore critical to ecosystem functioning and should be included in conservation plans aimed at preserving the integrity of ecosystems (Kalka et al., 2008). Declining bat populations may compromise important ecosystem services, so understanding their conservation needs is vital (Williams-Guillén et al., 2008). Urbanisation and development affect bat habitats, either through direct loss or disturbance from light and noise pollution or human activities. Connectivity of habitat and foraging areas to roosts is fundamental to the survival of many bat populations (Verboom and Huitema, 1997). Linear landscape features such as hedgerows, river banks and canals are important for bats, often being used for foraging and commuting (Limpens and Kapteyn, 1991; Verboom et al., 1999; Park, 2015). Changes in habitat affect the quantity, quality and connectivity of foraging, drinking and roosting resources available to bats.

**Fig. 3.** Commuting route of *Rhinolophus hipposideros* in England illuminated with experimental HPS street lamps.
*Source*: Stone et al. (2009).

The natural light dark cycle (LDC) is a critical factor entraining the biological "circadian" rhythms of those organisms exposed to the daily fluctuation of sunlight (Aschoff, 1960, 1965, 1981). Daily patterns of activity and behaviour in bats are influenced by the LDC (Haeussler and Erkert, 1978). The timing of nightly emergence from roosts is influenced by the timing of sunset (Erkert, 1982), and foraging activity and behaviour is affected by moonlight (Morrison, 1978; Saldaña-Vázquez and Munguía-Rosas, 2013) and night length (Frafjord, 2013). Artificial lighting can have an impact upon a range of bat behaviours including foraging and commuting, emergence, roosting, breeding and hibernation. Artificial lighting can damage bat foraging habitat directly making an area unsuitable for foraging, or indirectly by severing commuting routes from roosts, through light spillage onto hedgerows and watercourses (Rasey, 2006).

## *Impacts on foraging and commuting behaviour*

### *Spatial avoidance and habitat fragmentation*

Light that spills onto bat commuting routes or flyways can cause avoidance behaviour for some species and fragment the network of commuting routes. Activity of *Rhinolophus hipposideros* and *Myotis* spp. was significantly reduced along commuting routes illuminated with HPS and LED street lights (Stone, 2011; Stone et al., 2009, 2012) (Fig. 3). *Rhinolophus hipposideros* and *Myotis* spp. avoided commuting routes illuminated with LEDs at light levels of 3.7 lux (Stone et al., 2012). In Canada and Sweden *Myotis* spp. were only recorded away from street lights (Furlonger et al., 1987; Rydell, 1992). Despite the presence of street lit areas within their home range, lit areas were never used by *Rhinolophus ferrumequinum* (Jones and Morton, 1992; Jones et al., 1995). Disruption of commuting routes can force bats to use alternative routes to reach their foraging grounds. The quantity and quality of alternative routes will vary on a site-by-site basis. Bats may be forced to use suboptimal routes that may cause them to fly further to reach their foraging grounds, resulting in increased energetic costs due to increased flight time. Alternative commuting routes may be suboptimal in terms of vegetation cover, resulting in increased predation risk or exposure to the elements (wind and rain) with the associated increased energetic costs. Where alternative routes are not available, bat colonies may be isolated from their foraging areas, potentially forcing them to abandon their roost. Such disturbance disrupts the ecological functionality of the landscape by creating barriers to effective animal movement.

### *Increased foraging opportunities*

Some bat species are attracted to lights because of the higher numbers of insects (particularly moths) attracted to street lights, especially lights emitting short wavelengths (Eisenbeis, 2006; van Langevelde et al., 2011). For such light-tolerant bat species artificial lights create an illuminated night niche that acts as an artificial feeding resource. Bats of the genera *Chalinolobus*, *Cormura*, *Cynomops*, *Diclidurus*, *Eumops*, *Eptesicus*, *Lasiurus*, *Mormopterus*, *Molossus*, *Myotis*, *Nyctalus*, *Nyctinomops*, *Pipistrellus*, *Tadarida*, *Saccopteryx* and *Vespertilio* have been recorded foraging at street lights (Avila-Flores and Fenton, 2005; Barak and Yom-Tov, 1989; Bartonička et al., 2008; Bell, 1980; Belwood and Fullard, 1984; Blake et al., 1994; Catto, 1993; de Jong and Ahlén, 1991; Fenton and Morris, 1976; Fullard, 2001; Furlonger et al., 1987; Geggie and Fenton, 1985; Haffner and Stutz, 1985/86; Hickey et al., 1996; Hickey and Fenton, 1990; Jung and Kalko, 2010; Kronwitter, 1988; Rydell, 1991, 1992, 2006; Rydell and Racey, 1995; Scanlon and Petit, 2008; Schnitzler et al., 1987; Shields and Bildstein, 1979). Higher densities of bats have been recorded in areas illuminated with Mercury Vapour Lamps (MVL) compared to unlit areas e.g. densities of *Pipistrellus* spp. were 10 times higher in lit versus dark areas in England (Rydell and Racey, 1995), and densities of *Eptesicus nilssoni* were 5–20 times higher in areas lit with MVL compared to dark areas in Sweden (Rydell, 1991). Activity levels of *Pipistrellus pipistrellus*, *P. pygmaeus* and *Nyctalus*/*Eptesicus* spp. were higher at white ceramic metal halide (MH) compared to LPS street lights (Stone et al., 2015). The highest levels of bat activity in lit areas have been recorded at white lights (Avila-Flores and Fenton, 2005; Blake et al., 1994; Rydell and Racey, 1995). This is reflected in the higher numbers of insects attracted to white MVL than HPS (Rydell, 1992). LPS (orange) lights do not appear to attract insects, with insect numbers as low as those recorded on unlit streets (Rydell, 1992). HPS lights attracted 57% fewer insects than white MVL in Germany (Eisenbeis, 2010). MVL lights are energy-inefficient and are now being phased out.

Fast-flying species adapted to forage in open areas, particularly bats of the genera *Eptesicus*, *Nyctalus* and *Pipistrellus*, may benefit from the increased foraging opportunities provided at lamps, which attract high densities of insects. However, while providing a feeding resource for some bats, artificial lights can potentially increase mortality risk due to collision with vehicles: juveniles may be at higher risk of predation due to their slower and less agile flight (Racey and Swift, 1985). Whether mortality risk increases in lit situations deserves further research.

### *Reduced foraging opportunities*

Illumination of foraging areas can potentially prevent or reduce foraging activity, causing bats to pass quickly through the lit area or avoid it completely (Polak et al., 2011). Lighting can disrupt the composition and abundance of insect prey (Davies et al., 2012). Acoustic tracking demonstrated that *Eptesicus bottae* failed to forage under lit conditions (Polak et al., 2011). Artificial illumination in foraging habitats can effectively cause a loss of foraging areas for some bat species. Experiments with both captive and free-flying bats showed reduced foraging success of frugivorous bats (*Carollia sowelli*) under lit conditions. Bats harvested fewer fruits, which could have negative impacts on seed dispersal (Lewanzik and Voigt, 2014). Currently there is a lack of empirical evidence on the impact of lighting on foraging success of insectivorous bat species.

## *Impacts on emergence, roosting and breeding*

### *Delayed emergence*

Disturbance by external lights during emergence can delay the timing and prolong the duration of emergence for some species.

Extending twilight caused delayed emergence in *Rhinolophus hipposideros* (McAney and Fairley, 1988) and light intensity was an important factor determining the onset of emergence. This species leaves exposed roost exits later than exits close to extensive vegetation (Duvergé et al., 2000). External lighting reduced the number of *Pipistrellus pygmaeus* emerging from roosts (Downs et al., 2003), and delayed emergence in *R. ferrumequinum*, *Myotis emarginatus* and *M. oxygnathus* (Boldogh et al., 2007). *Myotis myotis* failed to emerge from their roost under experimental illumination of their flight path (Decoursey and Decoursey, 1964). Lighting and noise during a music festival caused delayed emergence of *Myotis daubentonii* in England (Shirley et al., 2001). Delayed emergence caused by light disturbance will result in reduced foraging time and bats may be forced to compensate. Delayed emergence also increases the risk that bats will miss the peak in abundance of insects that occurs at dusk, thereby reducing the quality of foraging time (Rydell et al., 1996). Delayed emergence could therefore negatively affect the fitness of individuals and the roost as whole.

*Spatial avoidance or roost abandonment*

Long-term exposure to light during emergence may cause bats to use alternative exit/entrances if available and in the worst case scenario may cause bats to abandon the roost or become entombed. A maternity roost of 1000–1200 female *Myotis emarginatus* was abandoned after lighting spilled directly onto the entrance (Boldogh et al., 2007). Full illumination of roosts has been shown to cause sudden declines in bat numbers. Numbers of *Myotis lucifugus* and *Eptesicus fuscus* declined by between 53–89% and 41–96% respectively upon installation of incandescent lamps (40 and 60 watts), cool fluorescent lamps (40 watts) and spotlights (150 watts) inside nursery roosts ($n = 3$ *Myotis lucifugus* roosts; $n = 6$ *Eptesicus fuscus* roosts) (Laidlaw and Fenton, 1971).

Lighting that spills directly into a roost can cause roost abandonment or death and can have consequences for predation and connectivity. Bats may be forced to use alternative exits that may be suboptimal in terms of predation risk. Alternative exits may increase mortality risk due to their location in relation to the surrounding landscape e.g. bats may be forced to fly across roads once leaving the exit, or due to their situation e.g. located low to the ground or near a window sill enabling easy access for predators such as domestic cats (Ancillotto et al., 2013).

*Reduced reproductive success*

Internal and external lighting around a bat roost can have an impact on the fitness of the colony through reduced juvenile growth rates. Colonies of *Myotis emarginatus* and *Myotis oxygnathus* in buildings which were illuminated from the outside had lower juvenile growth rates than colonies in non-illuminated buildings (Boldogh et al., 2007). Reduced individual fitness can have implications for the long-term survival of a colony, making them more susceptible to other threats such as predation. Bats are long-lived and slow to reproduce, meaning they take time to recover from population declines.

*Impacts on hibernating bats*

Hibernation is an extended form of torpor (a period when a bat allows it body temperature to fall below its active homoeothermic level to conserve energy), and can occur on a seasonal basis in response to changes in temperature and food supply (Altringham, 1996). Hibernation is an integral component of the life history of both temperate and even some tropical bats (Altringham, 1996). The nature and extent of the impacts of lighting on hibernation will depend on many factors, including the thermoregulatory flexibility of the species in question, with more flexible species able to adapt to artificial stressors such as lighting, and therefore less likely to be affected negatively (Boyles et al., 2011). Overwinter survival of bats is largely dependent on their ability to find a hibernation site with suitable microclimatic conditions to allow efficient energy budgeting. Increased arousal from torpor caused by disturbance such as lighting can potentially cause energy losses, and may disrupt circadian rhythms, which may reduce overwinter survival.

*Spatial avoidance or roost abandonment*

The illumination of hibernation sites may cause spatial avoidance so that bats have to find alternative hibernation sites. There is currently no published evidence of the impacts of lighting on hibernating bats, but evidence from summer roosts (see above) suggests that bats would avoid roosting at illuminated hibernation sites. Further research is required to understand the conservation and energetic consequences of illuminating hibernation sites. If bats were deterred from using preferred hibernacula, this could have significant conservation consequences, potentially affecting overwinter survival.

*Increased arousal from hibernation*

It is possible that light disturbance within a hibernation site would cause bats to arouse from torpor. At present there is no empirical evidence that light stimulates arousal in hibernating bats. Laboratory studies found that bats do not arouse when exposed to slight variations in light (Speakman et al., 1991), although this study only tested the effect of the light emitted from a 14 watt head torch for a very brief time. This may not therefore be representative of the impacts of other light types on bat hibernation. If hibernating bats were disturbed regularly, this would result in significant energetic costs, perhaps reducing their overall fitness and ability to survive the winter and subsequent spring. In addition, artificial lighting may disrupt circadian rhythms during hibernation. In maritime Britain, hibernating bats are most likely to arouse close to dusk so they can exploit the peak in insect abundance (Hope and Jones, 2013; Park et al., 2000). As light can act as a zeitgeber to entrain circadian rhythms, it has the potential to disrupt them also.

## Species-specific effects

Responses to light pollution are species-specific (Rydell, 1991), and so care must be taken in making generalizations about potential impacts across bat species. Species-specific responses to light may be a function of flight morphology and echolocation: relatively fast-flying bats which typically forage in the open using long range echolocation pulses such as *Eptesicus*, *Nyctalus* and *Pipistrellus* species are attracted to street lights (Blake et al., 1994; Rydell, 1991, 1992), whereas slow-flying bats with echolocation adapted for cluttered environments appear to avoid street lights due to light-dependent predation risk (Furlonger et al., 1987; Rydell, 1992; Stone et al., 2009, 2012). Species that are light-averse often possess wing morphologies associated with higher extinction risk (Jones et al., 2003) and so may be of conservation priority. In addition there have been very few studies assessing the impacts of lighting on frugivorous and nectarivorous bats (although see Lewanzik and Voigt (2014)) and a diversity of responses are likely to occur.

## How big are the impacts: community and ecosystem effects?

To date there is no specific evidence of community or ecosystem level effects of artificial lighting on bats. However, evidence suggests that the effects of lighting on bats are likely to cascade to the community level. Lighting may alter the balance of communities through competitive exclusion of less tolerant species, as more light-tolerant species may out-compete them for aerial insect prey. A possible cause of the population decline in *Rhinolophus* *hipposideros* in Switzerland was competitive exclusion by *Pipistrellus pipistrellus*, which was able to take advantage of the increased foraging opportunities provided by street lights (Arlettaz et al., 2000). However as *R. hipposideros* avoids lit areas, this conclusion is perhaps unlikely.

Insects may be attracted away from dark areas creating a "vacuum effect" (Eisenbeis, 2006). This is supported by experiments with aquatic insects in Germany in which higher numbers of insects were recorded under HPS lamps away from waterways than at unlit waterways (Perkin et al., 2014). The "vacuum effect" may negatively affect bats by reducing prey availability for species that do not forage in lit areas. Artificial lighting may also act as a barrier for dispersing insects, disrupting movement and gene flow among populations, which could contribute to insect population declines (Fox, 2013).

Lighting also alters the community composition of the insect prey of bats. Higher abundances of predatory and scavenging ground-dwelling arthropods occur under HPS lights than at sites between lamps (Davies et al., 2012), including carabid beetles, which are eaten by gleaning bats such as *Myotis myotis* (Arlettaz, 1996). Macromoths exhibit species-specific differences in attraction to MH and HPS lamps (Somers-Yeates et al., 2013). As insects are important in ecosystem functioning (Fox, 2013), such changes in community composition can have cascading effects at higher tropic levels and consequential effects for ecosystem service provision.

The increased densities of insects at street lights may have ecosystem-level impacts. Moths attracted to street lights have increased mortality rates (Frank, 1988; Longcore and Rich, 2004) and larger moths are more attracted to lights than smaller moths (van Langevelde et al., 2011). This size-dependent mortality risk can have cascading effects for trophic interactions and ecosystem services. There is some evidence that artificial lighting may affect ecosystem service provision by reducing bat-mediated seed dispersal. Experiments with fruit bats (*Carollia sowelli*) in Costa Rica, recorded reduced harvesting success of wild *Piper* infructescences when plants were illuminated with HPS lights, suggesting a reduction in seed dispersal (Lewanzik and Voigt, 2014).

## Solutions and future challenges

### *Strategies to minimise effects*

#### *Avoidance*

The simplest and most effective way to minimise the effects of lighting on bats is to avoid illuminating the areas being used by bats. Where the area used by bats, such as foraging or commuting habitat, is already illuminated, lights can be switched off or removed, or light can be excluded using physical barriers such as hedgerows and walls. In many cases existing lamps are outdated, poorly installed and/or maintained, resulting in light trespass into unwanted areas. For example, 31% of UK street light columns had exceeded their lifespan by 2010 and were due for replacement (Anon., 2009). Trespass from existing lights can be reduced by simple maintenance such as altering the beam angle of the lamp, installation of hoods and reflectors to direct/restrict light to where it is needed, complete replacement with new directional lamps, or the construction of physical barriers (Gaston et al., 2012).

Where new developments are planned, it is possible to avoid illuminating areas used by light-averse bats through careful planning. Where possible, light exclusion zones (dark areas) should be created which are interconnected to allow such bats to move freely from their roosts along commuting routes to their foraging grounds without being subject to artificial illumination. In many cases however, it is not feasible to have light exclusion zones in all the parts of a site occupied by bats and removal of lights may not be practical or desirable from the human perspective.

#### *Variable lighting regimes*

In some cases the impacts of lighting on bats may be minimised by changing the duration and timing of lighting regimes, to suit both human and wildlife use of the site. Such strategies are termed variable lighting regimes (VLRs) and involve switching off or dimming lights for part or all of the night and could be an effective strategy to minimise effects on bats. The majority of UK local authorities and councils have commenced lighting reduction strategies and are adopting VLRs with Central Monitoring Systems (CMS) which allow for remote switching off/dimming lights when human activity is low e.g. between 00.30 and 05.30 am. Lights are being switched off between midnight and 05.00 am, using remote dimming technology, on several sections of the motorway network in England, resulting in 30% reductions of carbon and electricity consumption in each section and lower numbers of road traffic accidents after VLRs were installed (Highways Agency, 2011).

CMS technology can be used to switch lights off during periods of high bat activity, such as commuting or emergence to minimise impacts, though the peak times of bat activity may occur in the early evening when lighting is necessary because traffic and human activity levels are also high then. Lights can also be dimmed e.g. to 30% power, for periods of the night to reduce illumination and spill. CMS LED lamps have been installed along a canal used by bats in London as part of the Arcadia Project. The CMS allow bespoke dimming regimes to reduce the light levels to 1 lux at times of low human activity (Fure, 2012). The appropriate lighting regime for an area will be site-specific and dependent on the nature of public use and type and amount of bat activity.

Lights can also be fitted with movement sensors that switch lights on as people approach and switch them off after people pass. Movement sensors can reduce the overall lit time for the environment, allowing for longer periods of darkness than lamps that are lit all night, potentially reducing the impact on bats and insects. However, the effectiveness of VLRs is reliant upon a good understanding of the timing and nature of bat activity in an area. Currently the impacts of VLRs on bats, both in terms of dimming and timing of lighting, are not known and further research is required.

#### *Reducing the intensity of light*

Reducing light intensity will reduce the overall amount and spread of illumination (Gaston et al., 2012). For some bat and insect species this may be sufficient to minimise disturbance or the magnitude of any negative impacts and disruption to circadian rhythms. However, some species may require very low light levels to have little/no impact on behaviour and circadian rhythms. Stone et al. (2012) tested the effect of LED lights on bats along commuting routes at three light intensities: mean 3.6 lux, mean 6.6 lux, and mean 49.8 lux. Activity of *Rhinolophus hipposideros* and *Myotis* spp. was reduced at all light intensities, even at 3.6 lux. Average light levels recorded along preferred commuting routes of *Rhinolophus hipposideros* under natural unlit conditions were 0.04 lux across eight sites (Stone, 2011). When mitigating the impacts of lighting for such species, very low lux levels may not be suitable for human requirements. In such cases reducing intensity may not be appropriate and alternative strategies, such as dark corridors or physical barriers, may be preferable. Currently there is a lack of evidence regarding the light intensities below which there are no/reduced impacts on bats, and responses are likely to vary between species and behaviours. A "light threshold" below which there is little impact on bats may not exist for those species that may be light averse regardless of light intensity e.g. possibly *Rhinolophus hipposideros*.

Light intensity can be reduced by dimming lights (e.g. using CMS technology), changing the light source (e.g. new technologies such as ceramic MH often have a lower wattage compared to old lamp types such as HPS) or creating physical barriers such as walls, or hedgerows to reduce the total amount of light reaching an area. HPS lights have been fitted with louvres to reduce light spill on the Grand Canal in Dublin, reducing light intensity on the river, allowing bats to fly in darkness (Fure, 2012). However, there is a trade-off between reduced intensity and the pattern of light distribution. Some older light types such as HPS, produce a heterogeneous light environment whereby light intensity declines steeply away from the light source. However, some new technologies such as LEDs produce a uniform light distribution resulting in a loss of dark refuges between the lamps (Gaston et al., 2012). In such cases it may be preferable to increase the spacing between the units to create dark refuges to facilitate the movement of light-averse bats.

*Changing the light type*

Light technology is developing rapidly and there is a general trend towards white light due to the increased colour rendering and perceived brightness for the human eye compared to HPS or LPS lights (Knight, 2010; Lockwood, 2011). Emerging light types increasing in popularity include white LED, warm-white LED, and MH. Warm white (600 nm) LED street lights are being tested in the Netherlands for their potential to reduce negative impacts on bats (Fure, 2012). There is increasing concern that the shift to broad spectrum lighting could alter the balance of species interactions (Davies et al., 2013a). Few studies have compared the effects of impacts of different light types on bats across species and behaviours, although there was no difference in the nature and magnitude of the effect of LED and HPS lights on commuting *Rhinolophus hipposideros* (Stone et al., 2012). Lights emitting blue, green or UV wavelengths, such as MH or mercury light sources, attract large numbers of insects and increase insect mortality (Bruce-White and Shardlow, 2011; Frank, 2006; Somers-Yeates et al., 2013). Some LED lamps attract fewer insects than MH and MV (Eisenbeis and Eick, 2011). Different light types are likely to have different effects on bats, and these effects will be species- and behaviour-specific. Choice of light type, and hence its spectral distribution will inevitably be a compromise between wildlife and public requirements. However, potential negative impacts on light-averse bats and insects can be minimised by avoiding short wavelength "blue" lights (Falchi et al., 2011).

*Are we in the dark: setting priorities and key questions?*

The effects of lighting on bat hibernation are currently not known. Given the importance of hibernation for the survival of many temperate species, this is an area that requires urgent attention. Key questions include the impacts of lighting on arousal and overwinter survival.

A key topic requiring further research is the fitness costs of artificial lighting on bats. This is critical in understanding the long-term implications for bat populations. We need to better understand how lighting affects critical population parameters such as sex ratios, dispersal, productivity and survival to understand and predict population level effects. Important questions include: what are the fitness costs of lighting on individual bats and across species? What are the population level effects of lighting on bats?

To date most research has assessed the impacts of lighting on specific behaviours such as commuting and roosting. Future research should aim to elucidate the impacts of artificial lighting across trophic levels. Such answers require a multidisciplinary approach to assess the ecosystem level impacts of lighting, using bats as indicators of wider ecosystem health and functioning.

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# APPENDIX G

## Wintering Waterfowl Avoidance and Tolerance of Recreational Trail Use

# Wintering Waterfowl Avoidance and Tolerance of Recreational Trail Use

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**Abstract.—**An experimental approach was used to investigate wintering waterfowl responses to introduced trail use at foraging sites with and without recreational trails in California, USA. Waterfowl were exposed to trail use in the form of two researchers walking levees adjacent to ponded habitat, and the number of waterfowl by species were compared before and after experimental walks in 40-m bands starting at the levee and extending 200 m into the ponds. The researchers recorded distances to the nearest individuals, responses of focal animals, and numbers of recreational trail users. The most numerous species were Ruddy Duck (*Oxyura jamaicensis*), Northern Shoveler (*Anas clypeata*), and scaup spp. (*Aythya affinis* and *A. marila*). Recreational trail use rates at trail sites averaged 1 to 82 people/hr. The greatest difference in numbers of birds before vs. after experimental walks occurred in the two 40-m bands closest to the levee at non-trail sites (0-40 m [$t = 4.558$, $P = 0.0001$], 40-80 m [$t = 3.775$, $P = 0.001$]) and trail sites (0-40 m [$t = 3.049$, $P = 0.005$], 40-80 m [$t = 1.808$, $P = 0.082$]). The relationship between the ratio of before- to after-walk waterfowl numbers vs. date since the start of the winter season ($r^2 = 0.315$, $P = 0.102$) and the total number of birds vs. the number of recreational trail users ($r^2 = 0.041$, $P = 0.847$) did not indicate increasing tolerance to trail use for waterfowl overall. However, species varied in their tolerances. Ruddy Duck numbers declined with increasing numbers of recreational trail users ($rho = -0.481$, $P = 0.017$), while Northern Shoveler numbers increased ($rho = 0.456$, $P = 0.025$). Distances (using the 95th percentile) that individual birds were recorded from researchers during experimental walks varied from approximately 170-200 m at both non-trail and trail sites. *Received 24 October 2016, accepted 17 December 2016.*

**Key words.—**avoidance, ducks, habituation, human disturbance, Pacific flyway, San Francisco Bay, tolerance, trail, waterfowl, wintering.

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As outdoor recreation increases in popularity, so does concern about the impact of public access on wildlife (Burton *et al.* 2002; Steven *et al.* 2011). This issue is of growing concern internationally (Burton *et al.* 2002; Cardoni *et al.* 2008), especially with respect to migratory birds. Migratory waterfowl at their overwintering sites are vulnerable to disturbance if their wetland habitats are within or adjacent to recreational areas (Navedo and Herrera 2012). Local impacts of human disturbance in estuarine areas along migratory flyways can threaten the waterfowl populations using these areas (Burton *et al.* 2002; Navedo and Herrera 2012). Geese (Madsen 1995; Béchet *et al.* 2004; McLeod *et al.* 2013) and ducks (Klein 1993; Mori *et al.* 2001; Pease *et al.* 2005; McLeod *et al.* 2013) will avoid human approach. Researchers have characterized some responses of wintering waterfowl to trail use, such as percent of waterfowl fleeing (Navedo and Herrera 2012), behavioral responses (Klein 1993; Pease *et al.* 2005), and distances at which some species respond to disturbance (Pease *et al.* 2005; Burton *et al.* 2012; McLeod *et al.* 2013). Trail walkers can be highly disruptive to waterfowl (Klein *et al.* 1995; Pease *et al.* 2005; McLeod *et al.* 2013), as can recreational uses that occur at higher speed, such as jogging and bicycling (McLeod *et al.* 2013). Although there is variation in waterfowl response by species to different recreational uses, McLeod *et al.* (2013) suggested that using the response of wildlife to even a single walker is an effective way to determine buffer distances for a range of other non-motorized recreational disturbances, such as joggers and bicyclists.

An important management question is whether waterfowl can develop tolerances to regular trail use (Fox and Madsen 1997), but this topic has been little studied (Weston *et al.* 2012). Frid and Dill (2002) provide a framework describing how animals view people as predators and respond accordingly. Due to their relatively large size (Blumstein

2006) and the fact that they are hunted (Fox and Madsen 1997), waterfowl are expected to react strongly to trail users when recreationists are introduced into areas without trails, such as when a new trail is opened. However, when exposed to repeated, non-threatening disturbance stimuli, such as regular recreational trail use, animals may habituate and cease treating these stimuli as threats (Stankowich and Blumstein 2005; Ellenberg *et al.* 2009).

We used an experimental approach to investigate wintering waterfowl responses to introduced trail use at foraging sites with and without recreational trails. Experimental approaches that compare treatment and non-treatment conditions before and after disturbance can be used to control for confounding factors and more clearly identify causal relationships (Tarr *et al.* 2010). We tested whether and to what extent the overall waterfowl community, common species (Pease *et al.* 2005; Blumstein 2006), and individuals (Ellenberg *et al.* 2009) showed avoidance or tolerance of both newly introduced and regular trail use over the winter season. Our overall goal was to provide managers with useful information for protecting waterfowl and for justifying management to the public.

## METHODS

### Study Area

We conducted this study in California, USA, at the south end of the San Francisco Bay at ponds owned and managed for wildlife (Fig. 1). These ponds, part of a complex of ponds previously used for salt-production, have been actively managed by public agencies since 2005 to enhance their quality for wildlife (Athearn *et al.* 2012). The ponds selected for study were documented as important to migratory waterfowl, providing a valuable stopover location for thousands of foraging and roosting waterfowl along the Pacific flyway (Takekawa *et al.* 2001; Athearn *et al.* 2012). Data collected by Athearn *et al.* (2012) from 2006-2009 showed that waterfowl numbers in the complex in which the study ponds were located peaked at approximately 100,000 birds each year. During the study period, all ponds were managed as mesohaline ponds (< 30 ppt), which supported a wide diversity of invertebrate taxa (Brand *et al.* 2014). In addition to the ponds, significant foraging habitat existed for waterfowl in the San Francisco Bay itself (Takekawa *et al.* 2001).

### Data Collection

We collected data on waterfowl numbers, behavior by species, and behavior of individuals at five pond sites adjacent to levees with public trails (trail sites) and at seven pond sites adjacent to levees with no public trails (non-trail sites) (Fig. 1). The ponds with trail sites were A11, A16, A3W, A2E and Charleston Slough (CHSL); the ponds without trail sites were A1, A9, A10, A11, A3W, and AB1 (Fig. 1). Ponds used in the study ranged in size from 52.6 to 230.7 ha. Motorized recreation was not permitted on the trails, but maintenance and research vehicles traveled both non-trail and trail levees at irregular intervals. Levees were approximately 2 to 4 m in height. Ponds had no emergent aquatic vegetation, and vegetation on the levees was relatively short (< 1 m), providing birds unobstructed, long-distance views of the levee tops. The part of the levee we walked at each site began at the corner of the pond, where two levees intersected, and was a total of approximately 600-900 m in length.

Data at each site were collected over six consecutive months during one fall/winter season between October and March 2006-2011 to provide a total of six samples at each site. However, data for October at three ponds (one in 2006 and two in 2010) and at one pond each in February 2009, March 2009, and November 2010 were not collected. Non-trail and trail sites were not paired or sampled on the same day due logistical constraints. Two sites, a non-trail and a trail site, were located at the same pond (A11), but were far enough apart (1.6 km) so as not to impact each other. The monthly samples from the non-trail and trail sites at another pond (A3W) were collected in different years, first when there was no public trail (2008-2009) and later after a public trail was opened (2010-2011). One pond, Charleston Slough, had greater tidal fluctuation than the others, and we collected data at that pond when water levels in the pond were high enough to attract numerous waterfowl and individuals were present within the data collection area.

We collected data in the morning between 08:00 and 11:00 hr to minimize time of day as an influence on bird behavior. At this time of day, recreational trail users were typically present; waterfowl were always present when we conducted our observations. Observations at each site were made at least 20 days apart. During the hunting season, hunting was permitted at certain ponds 3 days a week. We sought ponds where hunting was not permitted to minimize the effects of hunting as a factor in our study and, thereby, focus on disturbance from trail use. However, hunting was permitted at three ponds we studied, two with trail sites (A2E and A3W) and two with non-trail sites (AB1 and A3W). To minimize the effects of hunting as a factor at these sites, we collected data 2 days after hunt days, as Dooley *et al.* (2010) found that waterfowl numbers recover to pre-hunt levels 2 days after hunting has occurred.

We placed poles in the ponds at each study site to establish 40-m wide “distance bands” into the ponds, measured from the non-trail or trail levee that we used for experimental walks by researchers. In total, there

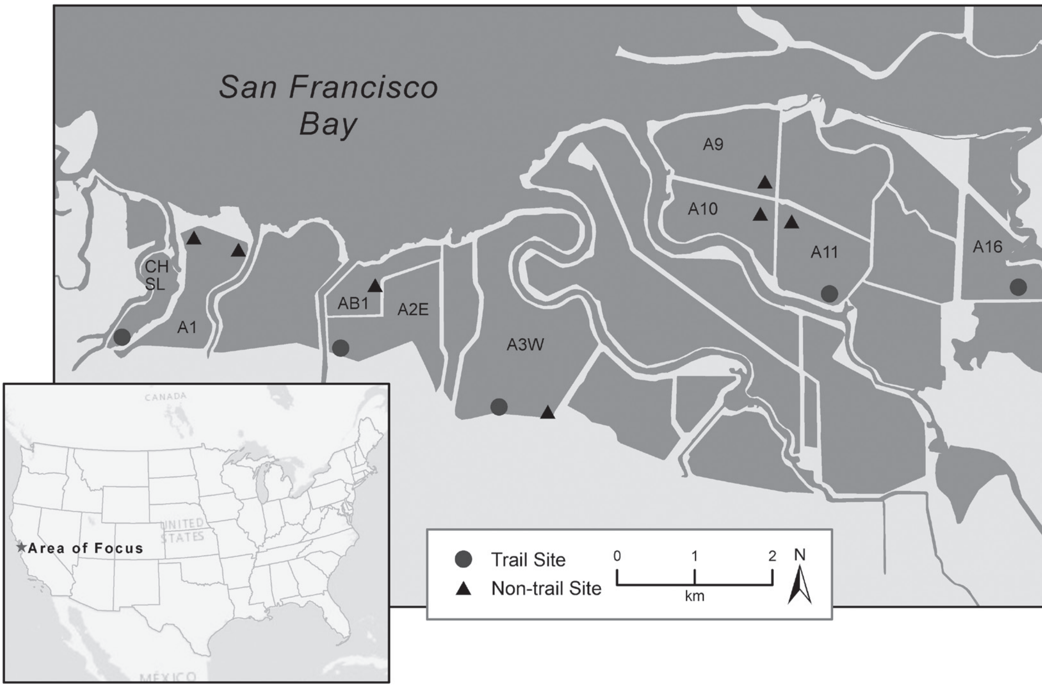



**Figure 1. Study area showing data collection sites at non-trail (triangles) and trail (dots) sites at ponds in San Francisco Bay, California, USA, 2006-2011. The ponds with trail sites were A11, A16, A3W, A2E and Charleston Slough (CHSL); the ponds without trail sites were A1, A9, A10, A11, A3W, and AB1.**

were five bands at these distances from each levee: 0-40 m, 40-80 m, 80-120 m, 120-160 m, and 160-200 m. These widths allowed us to readily count all or most of the individuals by species within a band, and they provided an adequate distance into the ponds from the levees to characterize the graduated influence of recreational disturbance on waterfowl (Pease *et al.* 2005).

On each site visit, we conducted an experimental walk consisting of two researchers who walked by waterfowl foraging habitat. A third researcher collected data on individual bird responses to the two researchers walking the levee. Before each experimental walk, we counted birds by species within each 40-m distance band using a Nikon Spotter XL or Leica 16-47 x 60 scope. We counted the birds in an area located 300-350 m from the scope, delineated by distance band poles. These counts provided the "before-walk" data and also characterized the "background conditions" at each site, unaffected by our experimental walks. Starting at the scope, approximately 300-350 m from the area where birds were initially counted, two researchers walked the levee, passed by the area originally counted and then returned to the starting point. We then counted the birds in the area of each distance band originally counted to provide "after-walk" data. The duration of experimental walks was relatively constant, averaging 24 min (Range = 16-37 min).

We counted the total number of recreational trail users at trail sites (not including researchers conducting experimental walks) and recorded their activities. At non-trail sites, the researchers were the only trail user disturbance to which the birds were exposed, and at trail sites researchers added to the existing level of trail use. Recreational trail users may or may not have been present before our experimental walks at trail sites, and, at lesser-used trail sites, there may have been cases of no recreational trail users before we took our experimental walks. While variation in recreational trail use may have resulted in different before-walk bird numbers at the different trail sites, our goal was to assess the response of birds to our experimental walks across a range of trail use conditions. That said, we statistically tested whether bird numbers before walks differed among trail sites.

During each experimental walk, the two researchers who walked the levee stopped in the vicinity of three to six predetermined locations and, using a Bushnell Elite 1500-7 x 26 Rangefinder (accurate to ± 1 m), measured the distances to individual birds (identified to species) nearest the walkers within 200 m, the edge of the furthest distance band. These results provided the distances individuals stayed from active trails. During experimental walks, we also recorded the response behavior of focal birds by randomly selecting an individual ≥ 300 m from the scope before each experimental walk in one of the two distance bands closest to the levee; we recorded the behavior of the focal bird before the walk and then the response behavior as the researchers approached. Behaviors recorded included: relaxed (sleeping, floating, preening), swimming (general swimming, not including swimming away from the levee), foraging (feeding on surface or diving), flying, and swimming away from the levee.

We used several metrics to provide detailed information. We assessed the responses of the waterfowl community (all birds counted) and the most numerous species to trail use by comparing the ratio of the number of birds before to after experimental walks by researchers. To test for habituation at trail sites, we compared the number of recreational trail users each observation day to the numbers of all birds and to numbers of the most numerous species before experimental walks (background conditions). We also compared the number of days elapsed in the season to the ratio of before-walk to after-walk numbers for all birds and by most numerous species to determine whether birds changed their response to trail use over time. We assessed the species composition of the most numerous species before experimental walks at non-trail and trail sites to provide a view of bird responses to existing trail use conditions. Metrics for individual birds included the distance individuals stayed from researchers during our experimental walks as well as changes in individual behavior in response to approaching researchers.

### Data Analyses

Statistical analyses were conducted with SYSTAT (SYSTAT Software, Inc. 2009). To compare non-trail to trail sites directly, we used ANOVA for each distance band separately and all bands added together with trail type (non-trail vs. trail) and hunt season (hunt vs. no hunt season) as factors and the ratio of before-walk to after-walk bird numbers as the dependent variable. Data were transformed (log [x + 1] transformation) to meet test assumptions. We compared distance bands separately to determine waterfowl community and species responses at specific distances from the levee. Although we sought to exclude hunting as a factor at our sites, we initially included hunt season in our analyses to assess whether hunting in the region may have influenced the results. If we found hunting not to be a factor, then we excluded it from other before- vs. after-walk analyses. We then analyzed non-trail and trail sites separately, using paired t-tests to compare bird numbers before and after walks (log [x + 1] transformation) for each distance band separately. We used a Mann-Whitney U test (due to small sample sizes) to determine if the number of birds before our experimental walks in the bands closest to the levee differed among the five trail sites.

Two tests for habituation were conducted using data from trail sites for the distance bands closest to the trail levee where bird response was strongest. For these tests, we used regression (log [x +1] transformation) or Spearman Rank tests (when normality assumptions could not be met) to examine the relationship between: 1) number of days elapsed from the start of the winter season vs. the ratio of before- to after-walk bird numbers for all birds and by most numerous species; and 2) numbers of recreational trail users vs. numbers of birds, using before-walk data, for all birds and by species.

For distance bands closest to the levee at non-trail and trail sites, we determined the species composition of the most numerous species, using before-walk data, by dividing the number of birds per species by the sum of the number of birds for the most numerous species. To evaluate changes in focal animal behavior in response to researchers during experimental walks, we compared the percent of individuals exhibiting specific behaviors before vs. during experimental walks at both trail types. These species composition and focal animal behavior comparisons were qualitative.

Distances, as determined using a range finder, that individuals of various species stayed from the levee during experimental walks at non-trail vs. trail sites during hunt and non-hunt seasons were compared using ANOVA (log [x + 1] transformed) or Mann-Whitney *U* tests, when test assumptions were not met. Hunt season was included in this analysis to determine potential species-specific effects from hunting in the region. To estimate buffer distances from active trails, we used the mean + 1 SE and 95th percentile distances, the latter standard being a precautionary buffer distance for determining human-wildlife buffers for conservation purposes (Weston *et al.* 2012).

## RESULTS

We collected data during 66 experimental walks by researchers, 38 walks at the seven non-trail sites and 28 walks at the five trail sites. Of the 15 different taxa recorded, the six most numerous were Ruddy Duck (*Oxyura jamaicensis*), Northern Shoveler (*Anas clypeata*), scaup spp. (*Aythya affinis* and *A. marila*), Canvasback (*Aythya valisineria*), Bufflehead (*Bucephala albeola*), and American Wigeon (*Anas americana*). These six species comprised 67% of all the birds counted before experimental walks. Average human trail use at each of the trail sites was: A11 = 1/hr (Range = 0-3/hr), A16 = 3.5/hr (Range = 0-9/hr), A3W = 7/hr (Range = 4-8/hr), A2E = 10/hr (Range = 9-11/hr), and CHSL= 82/hr (Range = 38-88/hr). Overall, 61% of the recreational trail users we counted were walkers, 20% were joggers, and 19% were bicyclists. Sites differed in the level of each of these primary use types; depending on the site, between 0% and 69% of users were walkers and between 31% and 100% of users were joggers and bicyclists. Despite the range in recreational trail use rates and uses by site, the total number of birds before experimental walks did not differ by site ($U$= 2.184, df = 4, $P$ = 0.702).

### Waterfowl Community Responses

Including hunt season as a factor, non-trail and trail sites did not differ with respect to the ratio of before- to after-walk waterfowl numbers ($F_{1,66}$ = 2.011, $P$ = 0.161). Hunt season was not a significant factor ($F_{1,66}$ = 0.406, $P$ = 0.526) nor was there an interaction between hunt season and trail site type ($F_{1,66}$ = 0.026, $P$ = 0.872). Removing hunt season and comparing non-trail to trail sites showed no statistical differences for all bands combined or by band, except potentially for band 2 (Table 1). However, there were much larger drops in bird numbers before vs. after walks, especially in the two closest distance bands, at non-trail sites compared to trail sites (Table 1; Fig. 2).

Examining non-trail and trail sites separately, we found there were greater numbers of birds before compared to after experimental walks up to 160 m from the levee at non-trail sites (0-40 m [$t$ = 4.558, $P$ = 0.0001], 40-80 m [$t$ = 3.775, $P$ = 0.001], 80-120 m [$t$ = 3.170, $P$ = 0.003], 120-160 m [$t$ = 2.583, $P$ = 0.014], 160-200 m [$t$ = -0.364, $P$ = 0.718]; Fig. 2) and approximately 80 m from the levee walked by researchers at trail sites (0-40 m [$t$ = 3.049, $P$ = 0.005], 40-80 m [$t$ = 1.808, $P$ = 0.082], 80-120 m [$t$ = 1.099, $P$ = 0.281], 120-160 m [$t$ = 0.681, $P$ = 0.502], 160-200 m [$t$ = -0.305, $P$ = 0.782]; Fig. 2). The strongest response at both non-trail and trail sites was in the two distance bands closest to levees we walked. We found approximately five times the number of birds in each band before walks at non-trail sites compared to trail sites (Fig. 2). However, this difference was driven by three non-trail sites (A9, A10 and A11), which had very high bird numbers compared to the other sites. At trail sites in the two closest distance bands combined, there was no relationship between the ratio of before- to after-walk bird numbers vs. date since the start of the winter season (Table 2). Nor was there a relationship between the total number of birds before walks and the number of recreational trail users (Table 2).

### Species Responses

Qualitative comparisons of the percent composition of the six most numerous species in the 80 m closest to the levee, where the response of birds was the strongest, showed Ruddy Ducks and scaup spp. were approximately twice as numerous at non-trail as at trail sites. Northern Shovelers, Canvasbacks, and American Wigeons, on the other hand, were approximately two to four times as numerous at trail sites compared to non-trail sites (Fig. 3). At trail sites in the 80 m closest to the levee, the ratio of birds before to after walks did not change significantly over the season for Ruddy Ducks, scaup spp. or Northern Shovelers (Table 2). Comparing bird numbers before experimental walks to numbers of trail users showed Ruddy Duck numbers declined as recreational trail use increased, as did scaup spp. numbers, while Northern Shoveler numbers increased with increasing recreational trail use (Table 2). Canvasbacks, Buffleheads, and American Wigeons were seen too infrequently at trail sites to assess these relationships.

**Table 1. Means (± SE) for the ratio of the total numbers of birds before to after experimental walks with statistical results comparing non-trail and trail sites.**

| | Ratio of Before/After-Walk Bird Numbers (df = 64) | | | |
|---|---|---|---|---|
| Distance Bands | Non-trail | Trail | $t$-value | $P$-value |
| 0-40 m | 6.78 ± 1.99 | 3.20 ± 0.70 | 1.263 | 0.211 |
| 40-80 m | 4.54 ± 0.99 | 1.70 ± 0.24 | 1.915 | 0.060 |
| 80-120 m | 2.74 ± 0.50 | 1.75 ± 0.29 | 1.305 | 0.197 |
| 120-160 m | 3.49 ± 0.91 | 2.20 ± 0.74 | 1.339 | 0.185 |
| 160-200 m | 1.90 ± 0.54 | 1.88 ± 0.84 | -0.048 | 0.982 |
| All Bands | 2.22 ± 0.36 | 2.99 ± 1.78 | 1.500 | 0.139 |

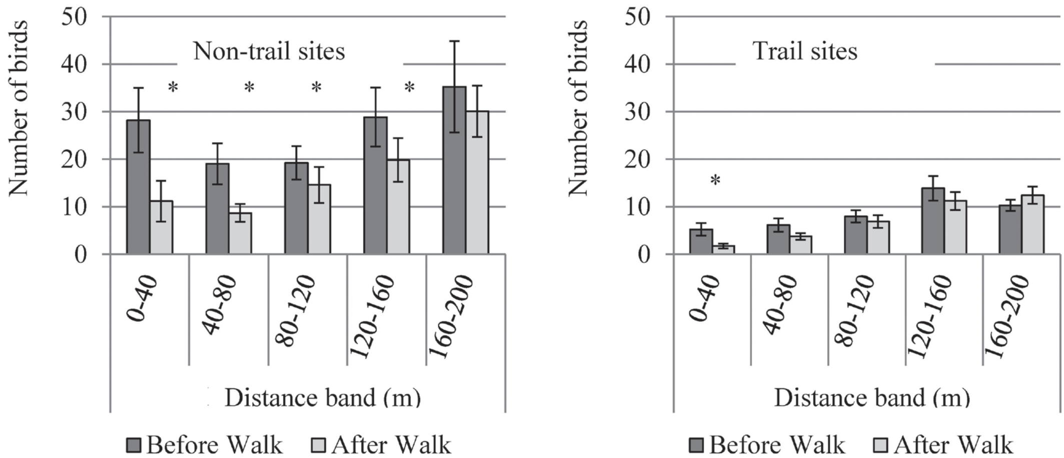



**Figure 2. Total number of birds ($\bar{x}$ ± SE) before and after experimental walks by researchers by distance band (data not transformed) at non-trail (df = 37) and trail sites (df = 27) (* indicates a significant result at P < 0.05).**

Individual Responses

We recorded behaviors of 82 individuals or same-species groups during our experimental walks, 24 at non-trail and 58 at trail sites. Relaxed (sleeping, floating, preening), swimming (not including swimming away from the levee), and foraging behaviors (feeding on surface or diving) dominated the activities of individuals before the experimental walks at non-trail and trail sites (Table 3). Our qualitative comparisons showed the majority of individuals, 79.3% at non-trail sites and 63.8% at trail sites, changed their behavior to swimming away as researchers walking the levee approached. Approximately four times as many individuals flew in response to approaching researchers at non-trail sites compared to trail sites; and during experimental walks, 4.2% of individuals at non-trail sites exhibited relaxed, foraging or general swimming activities vs. 32.0% at trail sites (Table 3).

Distances that individuals were recorded (using a range finder) from researchers during our experimental walks varied by species (Fig. 4). Ruddy Ducks were seen closer to researchers walking at trail sites compared to non-trail sites ($F_{1, 202}$ = 4.242, $P$ = 0.041; Fig. 4); hunt season was not a factor in the results ($F_{1, 202}$ = 0.707, $P$ = 0.401; Fig. 4), and there was no interaction between these factors ($F_{1, 202}$ = 0.791, $P$ = 0.375). Northern Shovelers were also found closer to trail than non-trail sites ($U$ = 447.00, df = 1, $P$ = 0.011), but during the hunting season were farther from non-trail sites ($U$ = 13.5, df = 1, $P$ = 0.004) and, potentially, from trail sites ($U$ = 60.0, df = 1, $P$ = 0.055) than in the non-hunting season (Fig. 4). There was no difference in

**Table 2. Results of two tests of habituation at trail sites for the three most numerous species and the waterfowl community (total number of birds) in the 80 m closest to the levee: Number of days elapsed since the start of the season vs. the ratio of before-walk to after-walk bird numbers (df = 26) to test change in bird response over the season, and Recreational trail user number/hr vs. before-walk bird number (df = 22) to test the relationship of bird numbers to varying levels of recreational trail use. Spearman's *rho*-values reported for each species; $r^2$ -value reported for the total number of birds (* indicates a significant result at $P$ < 0.05).**

| | Days vs. Before/After Ratio | | Trail User/hr vs. Bird Numbers | |
|---|---|---|---|---|
| Species | *rho- or* $r^2$-value | *P*-value | *rho- or* $r^2$-value | *P*-value |
| Ruddy Duck | -0.327 | 0.090 | -0.481 | 0.017* |
| Scaup spp. | 0.237 | 0.222 | -0.436 | 0.033* |
| Northern Shoveler | 0.049 | 0.804 | 0.456 | 0.025* |
| Total Number of Birds | 0.315 | 0.102 | 0.041 | 0.847 |

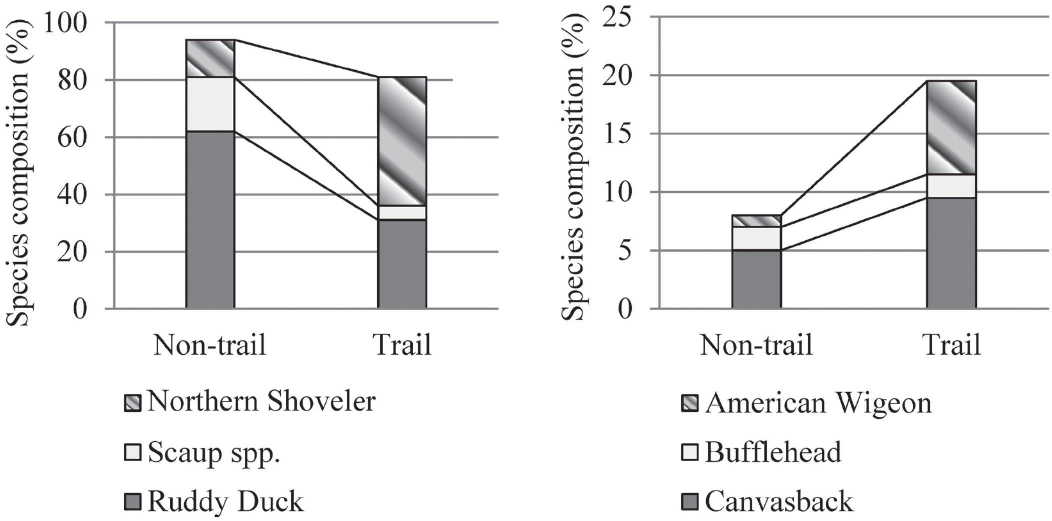



**Figure 3. Percent of birds for the six most numerous species within 80 m of the levee at non-trail and trail sites before experimental walks by researchers.**

distances between non-trail and trail sites for scaup spp. ($F_{1, 52}$ = 1.472, $P$ = 0.231) or Canvasbacks ($U$ = 242.00, df = 1, $P$ = 0.112) or for either species due to hunting season (scaup spp.: $F_{1, 52}$ = 2.110, $P$ = 0.152; Canvasbacks: $U$ = 197.00, df = 1, $P$ = 0.395; Fig. 4). There were too few observations to statistically analyze Bufflehead and American Wigeon distances.

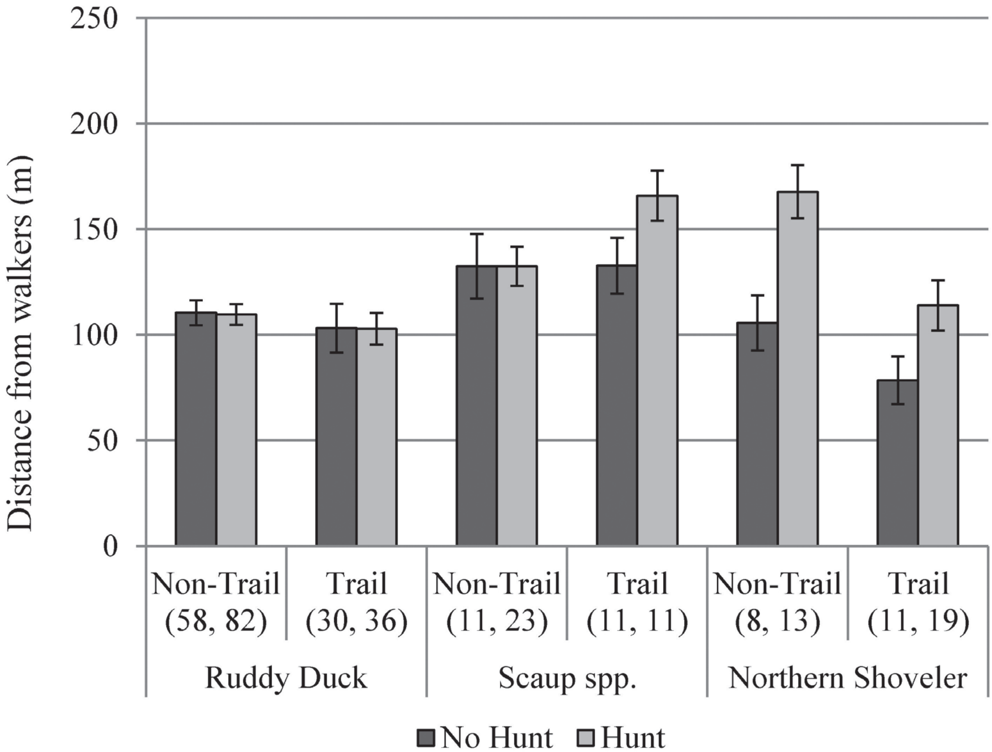
Using the mean + 1 SE standard, buffer distances for Ruddy Ducks were 113.8 m and 109.5 m from non-trail and trail sites, respectively. Northern Shovelers were most sensitive to walkers at non-trail sites during the hunting season and stayed 180.3 m from researchers walking the levee. The distances from walkers for individuals of the other four common species either did not differ by type of site or the difference could not be tested. Therefore, combining non-trail and trail site data for these species provided these buffer distances (mean + 1 SE): scaup spp. = 146.4 m, Canvasback = 145.5 m, Bufflehead = 142.8 m, and American Wigeon = 141.3 m. Based on the 95th percentile of distances, individuals of all species were 200 m or more from researchers during our walks at non-trail sites, and at trail sites the distance was 200 m or more for all species, except Northern Shovelers (185 m) and American Wigeon (170 m).

## DISCUSSION

This study examined how wintering waterfowl responded to trail users at sites without trails and at sites with regularly used trails. We predicted a strong response by waterfowl exposed to walkers where trails did not exist, as animals not regularly exposed to human disturbance are expected to respond

**Table 3. Percent of individuals exhibiting specific behaviors before experimental walks and in response to approaching researchers walking levees at non-trail and trail sites.**

| | Non-trail Sites | | Trail Sites | |
|---|---|---|---|---|
| Behavior | Before | Response | Before | Response |
| Relaxed | 16.7 | 0.8 | 29.3 | 8.4 |
| Foraging | 58.4 | 2.4 | 51.7 | 12.4 |
| Swimming | 25.0 | 1.0 | 15.5 | 11.2 |
| Swimming Away | 0.0 | 79.3 | 0.0 | 68.3 |
| Flying | 0.0 | 16.7 | 3.5 | 4.2 |



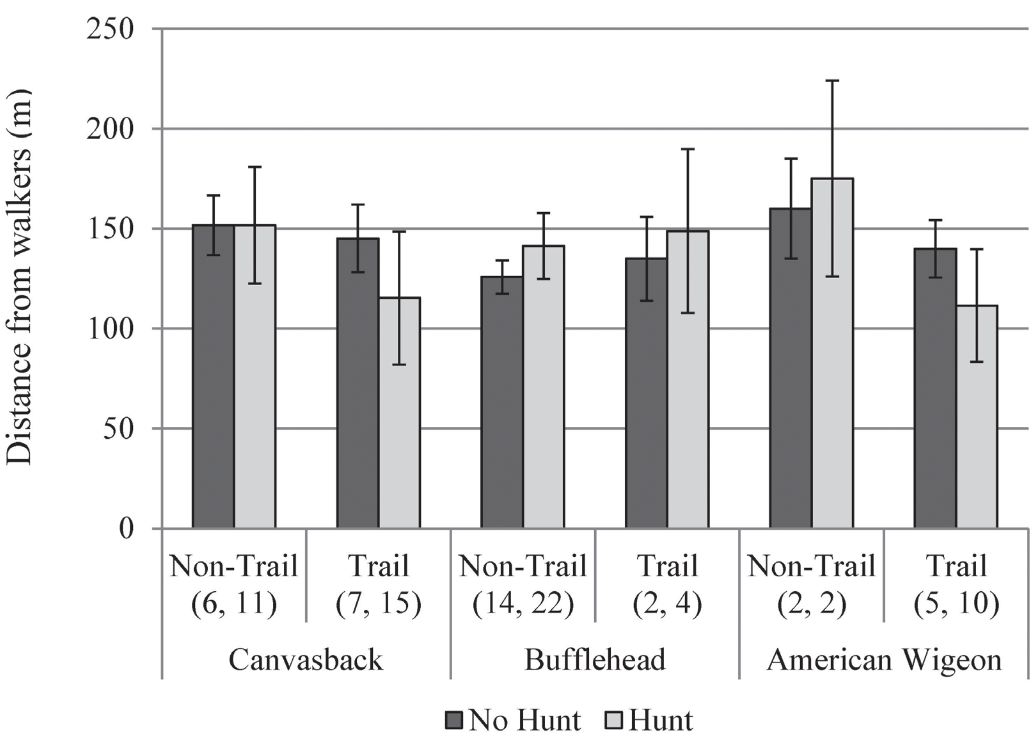




**Figure 4. Distance ($\bar{x}$ ± SE) of individuals of the six most numerous species from researchers during experimental walks at non-trail sites and trail sites during non-hunting and hunting seasons. Sample sizes for each mean in parentheses.**

to people as they would to predators (Frid and Dill 2002; Stankowich and Blumstein 2005). And, indeed, at non-trail sites we found far fewer birds after our experimental walks compared to before walks at distances up to 160 m from the levees we walked. In response to approaching researchers at non-trail sites, 96% of birds changed their behavior from relaxed, foraging or general swimming to flying or swimming away.

Birds regularly exposed to non-threatening disturbances, such as recreational trail use, may habituate to the disturbance stimuli to avoid wasting energy on unnecessary movement and to continue to take advantage of resources in the vicinity of the disturbance (Stankowich and Blumstein 2005). Habituation requires that animals show increasing tolerance to the stimuli (Ellenberg *et al.* 2009). However, waterfowl did not show increasing tolerance to trail use over the season, which would be expected if birds became habituated to walkers over time. And, instead of showing increasing tolerance with greater numbers of recreational trail users, both Ruddy Duck and scaup spp. numbers decreased as trail use increased. Northern Shoveler numbers, however, increased with increasing numbers of recreational trail users, suggesting habituation for this species.

Habituation can occur when animals are exposed multiple times to regular, non-threatening stimuli (Ellenberg *et al.* 2009). Waterfowl at our sites may not typically become tolerant to trail use as average stopover durations for migratory waterfowl have been estimated at approximately 1 month (O'Neal *et al.* 2012) to 2 months (Hagy *et al.* 2014). Such stopover durations would allow only a relatively short time for repeated exposure to trail users. In addition, wintering waterfowl at stopover sites can forage widely from their winter roosts (Johnson *et al.* 2014) and thus may not frequent sites adjacent to trails. In the San Francisco Bay, much additional habitat is available to waterfowl away from trails (Takekawa *et al.* 2001).

However, there were several indications of tolerance to trail use. The reduction in waterfowl numbers before compared to after experimental walks was less and extended a shorter distance at trail sites than non-trail sites. And, many more birds at trail sites showed relaxed, foraging or general swimming behaviors in response to approaching walkers than at non-trail sites. Species-specific tolerance of human disturbance may be a factor in these results. Such species differences seem to be shown by Northern Shovelers and American Wigeons, which were more numerous at trail vs. non-trail sites. Northern Shovelers demonstrated other signs of their ability to adapt to trail use including their increasing tolerance as numbers of recreational trail users increased. Ruddy Ducks and scaup spp., on the other hand, showed general intolerance of trail use. Although they studied different waterfowl species, Burton *et al.* (2002) also found varying levels of species-specific tolerances to footpaths.

Individual differences in behavior also seemed to play a role in our findings. For example, despite the general avoidance of trail users shown by Ruddy Ducks, some individuals remained after our experimental walks and were found closer than any other species to the researchers walking the levees at both trail types. It may be that "shyer" birds left in response to our experimental walks, and the birds remaining were the "bolder", more tolerant birds (Webb and Blumstein 2005; Ellenberg *et al.* 2009; Evans *et al.* 2010). While some individuals may have stayed due to temperament (Ellenberg *et al.* 2009), it is important to note that birds may remain at disturbance sites for many other reasons, such as lack of other habitat or poor health (Beale and Monaghan 2004).

Flight initiation distance (the distance at which animals begin escape behaviors in response to a disturbance) and minimum approach distance (the distance at which humans should be separated from wildlife) (Livezey *et al.* 2016) are often used to determine buffer distances between humans and wildlife (Blumstein 2006; Livezey *et al.* 2016). Livezey *et al.* (2016) reported mean minimum approach distances for non-nesting Anseriformes as 71.0 m in response to pedestrians and 111.6 m for bicyclists. McLeod *et al.* (2013) recorded flight initiation distances for a number of Anatidae species in Australia. Australian Shelducks (*Tadorna tadornoides*) showed the most sensitive reaction, with birds initiating a response up to 222 m (mean + 1 SE) from multiple walkers who started an average of 300.6 m from the birds. Our results provided distances waterfowl stayed from active trails, a measure of the amount of habitat unavailable to birds during trail use. Using the mean + 1 SE distance as a buffer size, we found buffer distances of approximately 110-180 m, depending on the species. However, the 95th percentile of distances indicated that at least 200 m is a more precautionary buffer for most waterfowl under the conditions we studied them. This estimate of avoidance distance was similar to the flight initiation distances found by McLeod *et al.* (2013) for Australian Shelducks. Since we did not measure distances to individuals beyond 200 m, studies able to detect individuals at a longer range may show greater avoidance distances. Based on a 200-m impact distance, a trail encircling a pond of 16 ha or smaller would make the pond unavailable as foraging habitat for most waterfowl while walkers pass by. While this impact may not last long after each disturbance event, especially for birds that stop feeding rather than leave in response to walkers (Marsden 2000), regular impacts could affect significant periods of the day.

Trails are a known source of disturbance to wildlife (Thompson 2015; Livezey *et al.* 2016), and migratory waterfowl around the world may use winter habitat adjacent to trails or other non-lethal recreational uses (Steven *et al.* 2011). Waterfowl using small or patchy habitats are especially sensitive to human disturbance (Navedo and Herrera 2012). Our findings indicate that trail use, whether at new or existing trails, can reduce the number of birds adjacent to trails, change their behavior, and reduce the habitat area available to birds—all impacts that can decrease the carrying capacity for waterfowl at wintering sites (Knapton *et al.* 2000; Burton *et al.* 2002). Our data indicate that managers should consider putting new trails approximately 200 m from wintering waterfowl foraging habitat to reduce or avoid immediate impacts to waterfowl. Whether recreational trail use rates were at the low end (1 person/hr) or the high end (82 people/hr) of our trail use observations, we found significant impacts on waterfowl behavior and habitat use. Given this, to maximize public use and minimize waterfowl impacts, managers could concentrate trails in popular public-access areas and eliminate low use trails or shut them temporarily during the winter migratory season.

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# APPENDIX H

## The Monarch project's Conservation and management Guidelines for preserving the monarch butterfly migration and monarch overwintering habitat in California: A guide for land managers and community activists.

# THE MONARCH PROJECT'S

## *CONSERVATION AND MANAGEMENT GUIDELINES*

## *FOR PRESERVING THE MONARCH BUTTERFLY MIGRATION AND MONARCH OVERWINTERING HABITAT IN CALIFORNIA*

A GUIDE FOR LAND MANAGERS AND COMMUNITY ACTIVISTS

January 1993


by:

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Walter Sakai, Professor of Biology, Santa Monica College
Katrin B. Snow, Director, The Monarch Project of the Xerces Society
Stewart Weiss, Staff Biologist, Center For Conservation Biology, Stanford University

*The authors dedicate these Guidelines*
*to the citizens of Pacific Grove,*
*who with determination and creativity are successfully leading*
*a campaign to restore and preserve the world-famous*
*monarch butterfly habitat in Butterfly Town, U.S.A.*

*And to*

*Dedicated citizens throughout California*
*who lobby public officials and educate children,*
*testify at hearings, and love monarchs.*

*Without you all, these habitats could not be saved.*
*Thank you for your inspiration.*

The Monarch Project's Conservation and Management Guidelines for Preserving the Monarch Butterfly Migration and Monarch Overwintering Habitat in California are a project of the Xerces Society. The Guidelines are made possible with funding from:

**THE ARCO FOUNDATION**

**and**

**THE PACKARD FOUNDATION**

# TABLE OF CONTENTS

## *LIST OF CONSULTING INDIVIDUALS AND ORGANIZATIONS*

The following representatives were participants in the Esalen Monarch Habitat Management Symposium which generated the Guidelines, and have provided consultation and review in the development of the Guidelines:

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# *EXECUTIVE SUMMARY*

## *THE MONARCH MIGRATION: A SPECTACULAR AND ENDANGERED PHENOMENON*

The North American Monarch butterfly (*Danaus plexippus* L.) is unique among insects for its long-distance seasonal migration, rivaling bird and mammal migrations in predictability and distance. Each autumn, Monarchs fly from throughout the United States and as far north as southern Canada to overwintering sites in California or central Mexico. California is the only state in the United States that regularly supports these spectacular, large aggregations of overwintering Monarch butterflies.

The Monarchs remain in their overwintering sites from about October through February, then depart in the spring, flying north and east to search for the milkweed plants (*Asclepias* spp.) on which they lay their eggs (see fig. 1). Through spring and summer, Monarchs produce four or five successive, short-lived generations, building up a large population. The last generation of butterflies that emerge in the fall are the new migrants who will make the journey to the overwintering habitats.

The North American Monarch population is separated into an eastern and western migration (see fig. 2). The eastern Monarch population migrates to Mexico. Monarch butterflies overwintering in California migrate from summer breeding areas west of the Rocky Mountain Range. In 1983, the International Union for Conservation of Nature and Natural Resources (IUCN) classified the migration and overwintering behavior of the Monarch butterfly as a "Threatened Phenomenon." The California legislature in 1987 passed Assembly Bill #1671 to recognize the Monarch's migration and winter aggregation as a natural resource and to encourage the protection of its winter habitat. A year after its passage, California voters approved a bond issues allocation $2,000,000 to purchase critical overwintering habitat.

The overwintering forests are the Achilles' Heel of the Monarch migration. Although the Monarch butterfly is unlikely to become an endangered species since it persists in its tropical range, the vast numbers of Monarchs in North America, along with its migration and overwintering phenomenon, could be destroyed by the end of the century if extensive overwintering habitats in Mexico and California are not successfully protected (see Appendix L for a summary of legal precedents supporting Monarch conservation). California is particularly important to the preservation of the Monarch migration in North America. The Monarch migration east of the Rocky Mountains is perilously threatened and likely to be destroyed by continual pressure on dwindling forest resources in Mexico (Brower and Malcolm, 1991). Thus, California may become the sole North American steward of the Monarch migration. Working in collaboration, dedicated and creative land managers, local citizens, politicians, and biologists, can protect this world-famous and beloved butterfly and its migration in a harmonious balance with human use of California's coastal forests.

# *THE GOAL OF MONARCH CONSERVATION*

The primary goal of Monarch conservation in California is to establish and maintain stable Monarch overwintering colonies that can survive indefinitely. Only a few of the many groves along the California coast have the necessary stand density, age, and configuration to support overwintering butterflies. Multiple sites and suitable habitats must be preserved and managed to persist through daily, seasonal, and occasionally catastrophic disturbances that seriously threaten California Monarch overwintering habitats. These disturbances include aggressive development, poor or neglectful management, tree aging and disease, and overuse by visitors.

Overwintering butterflies are generally founds in stands of Eucalyptus or Monterey pine that offer shelter from strong gusty winds, freezing temperatures, and prolonged exposure to direct sun (Leong, 1990; Leong, et al., 1991). The indiscriminate removal of one or more trees within or bordering overwintering habitat may adversely affect the sunlight and wind exposure for the roosting butterflies. The effects of such activities may make a suitable habitat unsuitable for overwintering butterflies, especially during storms. In addition, a grove of trees is a dynamic and ever changing system. It is conceivable that a winter grove, if left to the normal process of maturity, may become unsuitable for mass winter aggregation. Older groves (such as those in Pacific Grove) have taller trees that often lack lower branches, a product of natural thinning. The lack of natural understory foliage may increase wind movement through the grove and consequently increase the air's dryness. Scientists have shown that noncluster groves are characterized by more light and wind and less moisture in the air than overwintering groves (Leong et al., 1991).

Monarch conservation has succeeded best where citizens, local environmental groups, politicians, land managers, and biologists have joined forces to accomplish the multiple goals of conservation and land us on California's coastlands. The purpose of The Monarch Project Guidelines for Monarch Overwintering Habitat Management is to help land managers assess Monarch overwintering habitats in their jurisdiction and maintain colony stability over the long term. The Guidelines propose a conservation strategy for Monarch habitat in California. They describe what is currently known about Monarch biology, overwintering, and the environmental correlates of suitable Monarch overwintering habitats. They then offer management recommendations for shepherding these habitats into the next century.

# *A PROPOSED CONSERVATION STRATEGY FOR MONARCH OVERWINTERING HABITATS*

Until recently, Monarch conservation was based largely on anecdotal information. As political pressure has mounted on the lucrative coastal real estate where the habitats are located, Monarch conservation has increasingly been plagued with fractious debates about the importance of individual trees, the size of habitats and their proximity to urban development, and the existence or non-existence of "microclimate" – in short, nearly every aspect of Monarch biology has been debated before elected officials who must sort through the conflict to arrive at a political decision regarding property use.

Because of the lack of solid, quantitative information on which policymakers can base their decisions, these conflicts have frequently been resolved to the detriment of Monarchs. The recommendations for designing and managing Monarch reserves, Section II of the Guidelines, are predicated on the assumption that land managers and policymakers will be committed to generation quantitative scientific information on which to base conservation and development decisions that affect Monarch habitat. In cases of development, this can be generated through the environmental impact report. In other cases, and when management funds are restricted, land managers can devise simple, inexpensive monitoring techniques which can provide helpful data for management.

A broad conservation strategy for the western Monarch migration can be modeled on a conservation strategy for endangered species articulated by Dr. Dennis D. Murphy, Director of the Stanford University Center for Conservation Biology, and Barry Noon, Director, Redwood Sciences Lab, U.S. Forest Service. The following five rules of thumb (Murphy and Noon, 1992) can be useful in establishing conservation priorities that are designed to preserve the Monarch butterfly migration in western North America over the long-term future. These rules of thumb were employed by the Jack Ward Thomas Commission in devising its strategy for the long-term preservation of the threatened Northern Spotted Owl.

***Rules of thumb for Reserve Design***

1) Species that are well distributed across their ranges are less prone to extinction than species confined to small portions of their ranges.
2) Large blocks of habitat with many animals are superior to small blocks of habitat with smaller populations.
3) Blocks of habitat that are close together are better than blocks located far apart.
4) Contiguous blocks of habitat are better than habitat that is fragmented.
5) Habitats in a less disturbed landscape are more desirable than habitats in more disturbed landscapes.

Applying these rules to Monarch conservation, an effective Monarch conservation strategy should:

- Maintain the interrelationships between Monarch habitats by protecting a network of overwintering habitats in any given locale;
- Preserve a range of Monarch habitats along the length of the California coast that exhibit diverse vegetation and include varying population sizes and tenure;
- Protect all significant populations (either singly or in a metacolony); and
- Provide for effective long-term management

## ***THE THREE MOST IMPORTANT RECOMMENDATIONS***

Habitat management through grove modification (i.e. tree plantings or removal or plantings) is not an exact science. In most instances when Monarch overwintering habitat has been destroyed, the loss could have been prevented by these three recommendations:

**Recommendation 1: Consult with a qualified Monarch biologist before making any decision that would alter a habitat, and follow his or her advice.**

**Recommendation 2: Gather baseline data on each protected habitat.** Baseline data allows before and after comparisons to evaluate the effects of grove modification. See pages 16-19 for a discussion of recommended baseline studies.

**Recommendation 3: Implement a low-key monitoring program**. This information will help identify habitat disturbances and generate practical information to guide management decisions.

The following section, Reserve Design and Management, contains further recommendations for how to apply the knowledge scientists have gained about Monarch habitats, and how to solve practical problems.

# MILKWEEDS

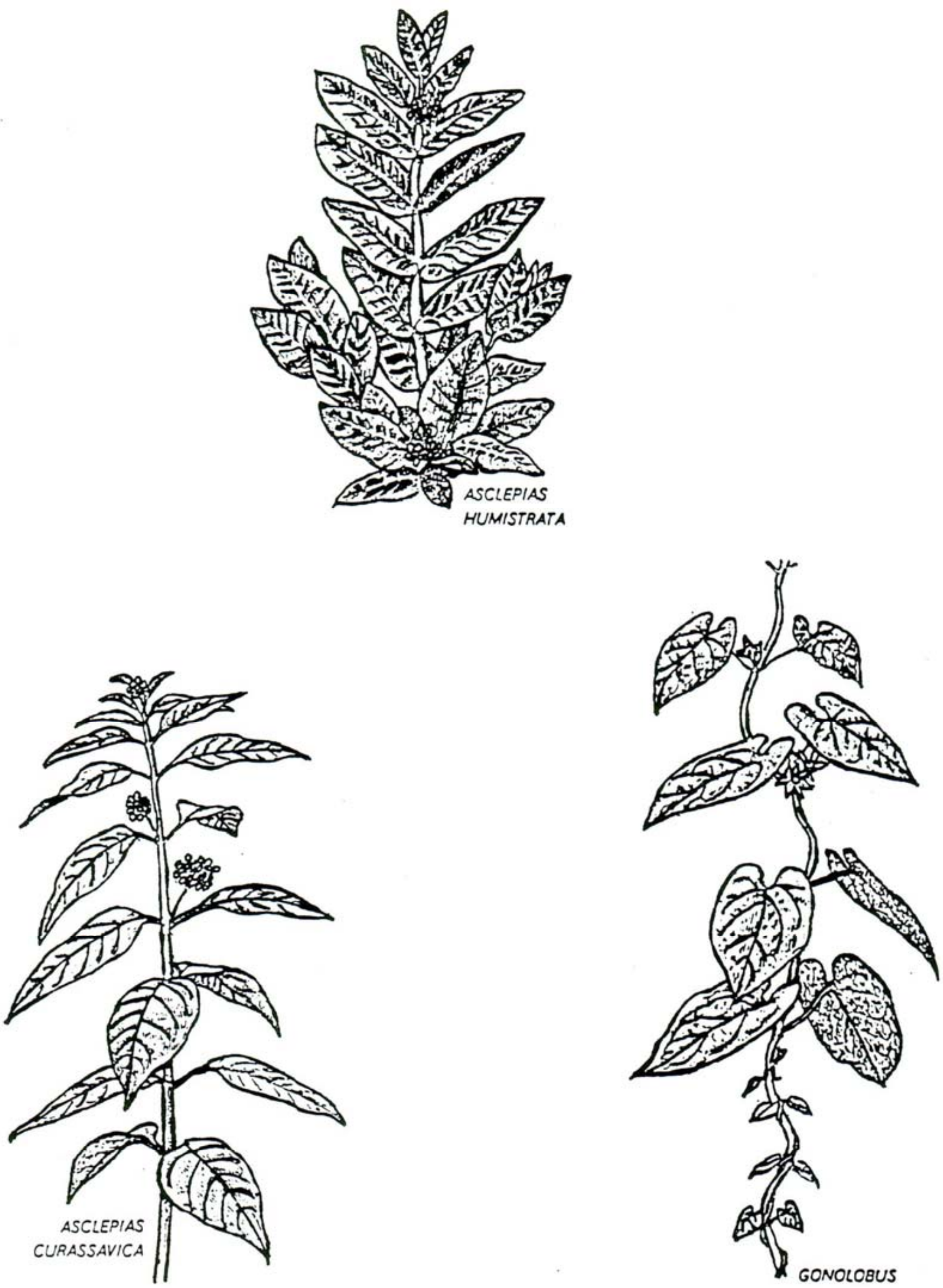
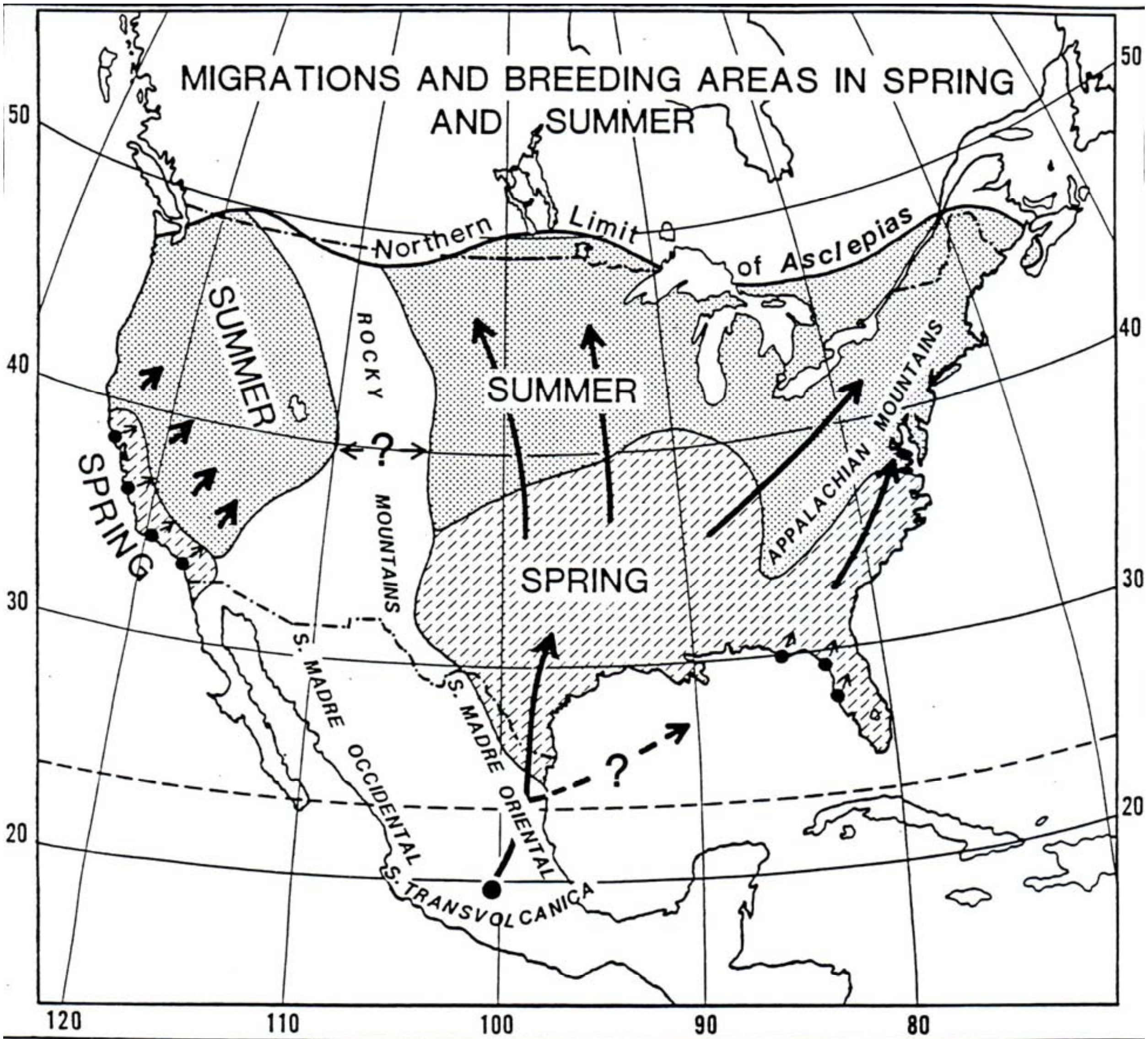
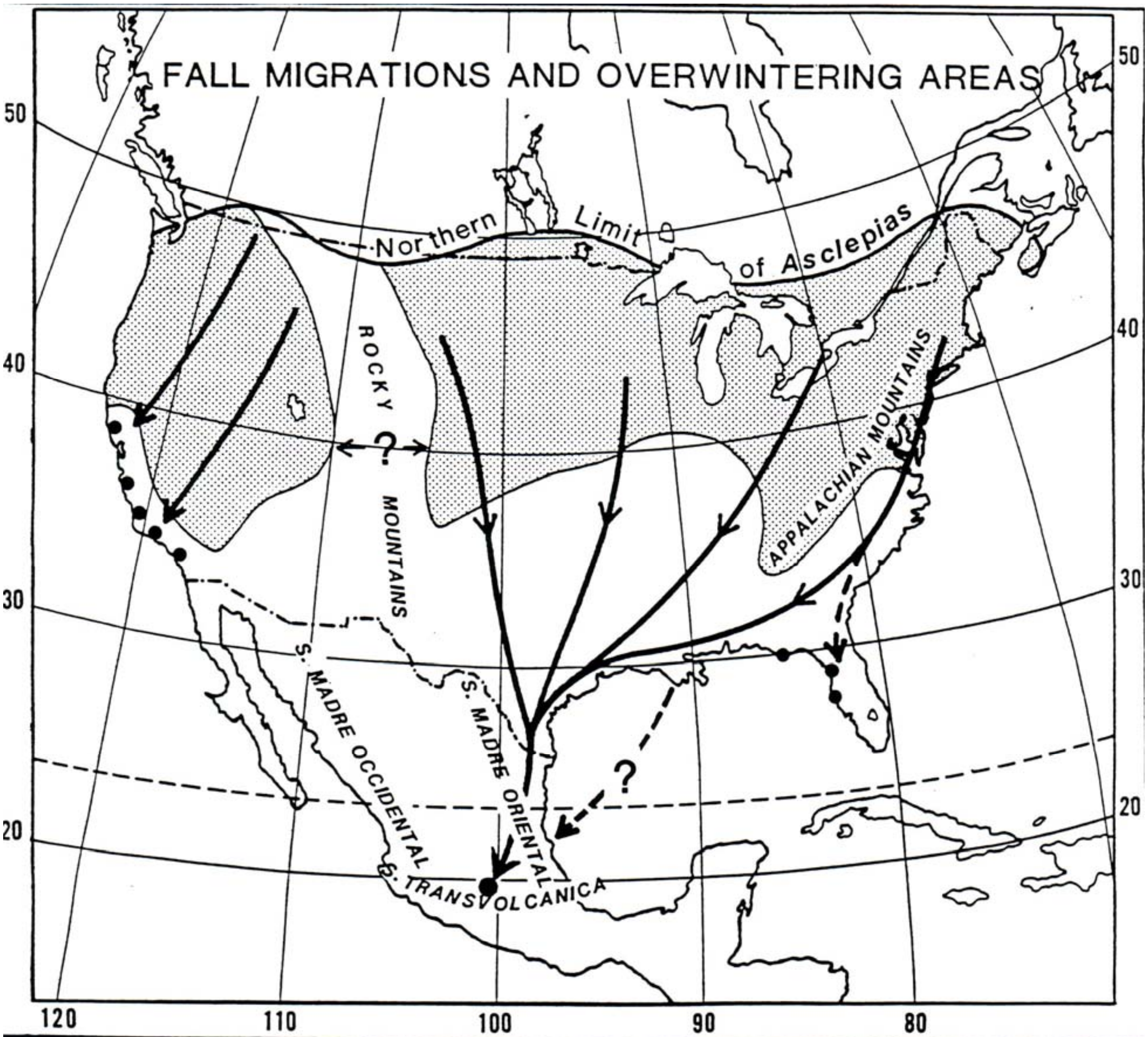



Figure 1



MIGRATIONS AND BREEDING AREAS IN SPRING AND SUMMER
Northern Limit of Asclepias
SUMMER
SPRING
ROCKY MOUNTAINS
APPALACHIAN MOUNTAINS
S. MADRE OCCIDENTAL
S. MADRE ORIENTAL
S. TRANSVOLCANICA
50
40
30
20
120
110
100
90
80


Figure 2



FALL MIGRATIONS AND OVERWINTERING AREAS
Northern Limit of Asclepias
ROCKY
MOUNTAINS
APPALACHIAN MOUNTAINS
S. MADRE OCCIDENTAL
S. MADRE ORIENTAL
S. TRANSVOLCANICA
?
?
50
40
30
20
120
110
100
90
80


Figure 3

# *SECTION ONE*

# *THE BIOLOGY OF MONARCH OVERWINTERING HABITATS*

## *SPECIFIC ELEMENTS COMPRISING THE MONARCH OVERWINTERING HABITAT IN CALIFORNIA*

Monarchs use well-sheltered areas as overwintering sites. The specific trees on which the butterflies aggregate are sheltered by adjacent trees, topographical features, and ground vegetation growing under the canopy or around the edge of the grove. All of this vegetation comprises the Monarch overwintering habitat. It is a common mistake, and one that has led to the destruction of many Monarch habitats, to assume that Monarch overwintering habitat includes only the trees on which the butterflies aggregate.

A decade of research in Mexico and several years of research in California has provided insights into what makes a successful wintering habitat. The forests and groves that support Monarch overwintering habitats are characterized by a very specific range of climatic variables. Together, these variables make up the "microclimatic envelope." Research shows that overwintering habitats have lower wind velocity, lower light and solar radiation intensities, and higher vapor pressure deficits than non-wintering groves (Leong et al., 1991; Weiss et al., 1991). Environmental parameters associated with suitable Monarch overwintering habitats do not vary between overwintering sites composed of different tree species (Leong et al., 1991; Frey et al., 1992). In California, overwintering tree species include Monterey Pine (*Pinus radiata* D. Don), Monterey cypress (*Cupressus macrocarpa* Hartw. Ex Gord.), the introduced Australian Eucalyptus species (*Eucalyptus globulus* Labill. and *Eucalyptus camaldulensis*), and others.

Despite the vast difference in elevation and latitude between the overwintering sites in California and those in Mexico, the California groves provide a microclimate remarkably similar to that in Mexico (Brower, 1985). Monarchs single out the same forests, even the same trees, every year. In both Mexico and California there are intact areas of forest that appear to have characteristics similar to Monarch habitats, but that do not support Monarch overwintering habitat. This suggests that suitable habitat for the butterflies is extremely limited by natural as well as human constraints (Brower, 1985; Brower and Malcolm, 1989).

Microclimate is determined by the same features that determine regional climate (latitude, altitude, and proximity to large bodies of water), but it is further modified by the local features of an overwintering grove. These features are the physical, or abiotic, aspects of the grove (direct and indirect sunlight, temperature, wind, and humidity) and the living, or biotic factors. (The biotic factors are principally the species composition and structural arrangement of trees, understory, and edge vegetation.) For the most part, the features that determine microclimate act to buffer or reduce the variability of temperature, humidity and sunlight within the overwintering grove.

The forest suitable for Monarch overwintering provide the butterflies with both shade and a minimal exposure to direct sunlight, buffered temperatures, high humidity, low vapor pressure deficit, and protection from wind and severe weather conditions. Overwintering habitats have extensive canopy cover with some gaps to allow direct sunlight into the grove. They typically have a developed understory which may include saplings or mid-level canopy as well as ground-level vegetation in some sites. Leafy, ragged, edge vegetation often surrounds the grove. Nearby nectar and water resources are frequently present and are probably critical.

Microclimatic data on California Monarch habitats were derived from research conducted at Montana de Oro State Park, Pismo State Beach, and Los Osos by Drs. Kingston Leong and Dennis Frey, Cal Poly, San Luis Obispo; in Santa Barbara County by Dr. Lincoln P. Brower, Dr. William Calvert, and Stuart B. Weiss under the auspices of the Stanford Center for Conservation

Biology; and at Natural Bridges State Beach and Moran Lake in Santa Cruz County by Elizabeth Bell and John Dayton, University of California at Santa Cruz. Data on microclimate at Natural Bridges in the mid-1960s and during 1991 were provided by Robert Brownlee. Population and tagging studies have been conducted by Walter Sakai, Santa Monica College. Overwintering and population studies have been done by Dayton & Bell. See Appendix K for the addresses of these authors.

This research has led to the identification of specific environmental parameters associated with successful Monarch overwintering. Table 1, page 3, is a list of environmental factors associated with habitat suitability, and therefore colony stability.

The suitability of a particular overwintering site is in large part determined by the options it presents to the Monarchs. (After all, the Monarchs make the final decision about where they want to be.) A suitable habitat must provide, for example, a choice between sun and shade, and protection from wind as the winds shift direction over the course of the season. Research strongly indicates that the distribution of Monarch clusters within grove is associated either with areas having favorable conditions, or with avoidance of adverse conditions (Leong, 1990). Monarchs need heterogeneous habitats, that is, habitats that provide a variety of conditions so they can shift their roosting location in response to the highly varied climatic conditions outside the grove.

Understanding, maintaining, and enhancing the habitat heterogeneity is probably the most important aspect of designing and managing a stable, thriving Monarch habitat reserve. The vegetational and forest canopy structure are measures of Monarch habitat heterogeneity and suitability that managers can both quantify and manipulate. Indeed, the management of forest structure is the only feasible means of modifying microclimatic conditions such as wind, exposure to sun, and relative humidity within a forest stand.

Quantification of key elements of forest stand structure, and the correlation of these elements with microclimatic variables such as light, temperature, wind, and humidity are valuable steps in the development of effective conservation and management plans for the Monarch butterfly (Weiss et al., 1991). Baseline studies of the microclimatic and biotic parameters, combined with a low-key monitoring program, can illuminate what creates habitat stability or contributes to habitat disturbance. When an environmental impact is required, funding is typically provided for these studies by the developer. In other cases, land managers can assess their needs and request aid from Monarch scientists in choosing studies that best provide needed information within the management budget. See pp. 14-17 for recommended studies that can aid long term management.

The following is a brief discussion of individual parameters characterizing overwintering groves.

## *TABLE 1: ENVIRONMENTAL FACTORS ASSOCIATED WITH HABITAT SUITABILITY*

| | |
|---|---|
| A. Microclimatic Conditions | Temperature<br>Wind Velocity<br>Wind direction, into and through the grove<br>Indirect sunlight<br>Direct sun exposure<br>Humidity<br>Vapor Pressure Deficit<br>Sunlight Direction |
| B. Topography | Exposure<br>Presence of fresh, clean water |
| C. Biotic Conditions | Size of Forest Patch<br>Structure, or arrangement, or vegetation<br>Species composition of vegetation<br>Movement of butterflies within grove<br>Population estimates<br>Orientation of butterflies on trees<br>Predation<br>Human disturbances<br>Nectar sources |

### *THE OVERSTORY CANOPY: COVER AND INSULATION*

The canopy is the uppermost spreading layer of branches of the forest. Forest canopy structure is a primary determinant of microclimatic conditions within forest stands (Weis et al., 1991; Calvert and Brower, 1982). Forests with extensive canopy cover are more humid and retain moisture better than open forests. Temperatures within these forests are significantly warmer at night and cooler during the day than in adjacent clearings or open canopy forests. An extensive canopy insulates the butterflies from wind that can dislodge them. Since Monarchs don't roost in the uppermost branches, the canopy shields the interior of the overwintering habitat from direct sunlight and makes excessive Monarch movement less necessary and less likely (Frey et al., 1992). Monarchs also are not found in fully-closed canopies that allow no sunlight to penetrate to the forest floor, since this would trap grounded Monarchs and make them more vulnerable to mouse, bird, and wasp predation (Sakai, in review). (see References, page 41 for publications describing the characteristics and role of the forest canopy.)

Nor do Monarchs thrive in excessively open canopies. Monarchs maintain a balance between expending and conserving their energy to fulfill two needs. They must conserve sufficient stored fat reserves to last through the winter and power their spring reproduction and remigration. And they must able to use stored fat as an energy source to power flight so they can escape predators and excessively cold ground temperatures, and obtain water and nectar when needed (Master et al.,1988; Chaplin and Wells, 1982). An excessively open canopy makes it more than likely that Monarchs will be (a) dislodged from their clusters by wind, (b) subject to greater predation from wasps, birds, and mice, (c) forced to expend valuable fat stores to fuel movement back to clusters, and (d) subject to overheating by exposure to direct sunlight, which causes them to use up fat reserves at a higher rate. (One theory is that they expend valuable fat reserves by taking flight to cool down.)

### *THE EDGE BARRIER AND UNDERSTORY: SUSTENANCE AND SHELTER*

Many Monarch habitats are characterized by a raggedy edge of bushy trees or plants that create sheltered pockets within the edge of the grove. Some, not all, have understory plants, bushes, or grasses. A well-structured edge barrier and understory plants help regulate the microclimates by retaining heat at night, keeping the grove cooler during the day (Calvert and Brower, 1986), and reducing ground level air movement. They may also provide nectar sources. Monarchs use low-lying vegetation within and near overwintering habitat to crawl up when trapped on the ground by low temperature. Where visitors to Monarch overwintering sires are numerous, low vegetation limits visitor access and can help grounded Monarchs avoid being trampled to death.

Non-cluster trees, the edge barrier, and understory are too frequently underrated in the creation of a successful overwintering habitat. Edge barriers and understory should include a diverse collection of plants which have varying heights, so that the plant cover reinforces the protection provided by larger trees. Thus, as the large trees age and their lower branches become barren, the bushier edge and understory will still provide shelter and protection from winds.

### *TEMPERATURE*

Cold temperatures serve Monarch colonies by keeping the butterflies inactive, so they conserve their stores of fat. In sites that become too warm, Monarch become increasingly active, cease clustering, become reproductive and leave to see nectar, using up fat stores (Masters et al., 1988). Monarchs seek a narrow range of microclimatic conditions that are cool enough for them to remain inactive, but not so cold they can't survive.

Thinning or removal of trees has a direct effect on forest temperature. As one would expect, a more open forest is colder at night and warmer during the day. Thinning of critical windbreak trees, and sometimes even of critical individual branches can have devastating effects on Monarch habitats (see Appendix E).

Temperature plays a key role in butterfly mortality, and not only because it can directly cause their death. Temperature limits the ability of grounded butterflies to fly or crawl to safety and a long stretch of cold can put the butterflies at risk for dehydration. In California, dehydration and being stranded on the ground are greater mortality risks than freezing. (see "Environmental Correlates of Butterfly Mortality," page 6.)

The lowest temperature at which Monarch can fly is about 57 degrees Fahrenheit. The lowest temperature at which they can crawl is 34 degrees Fahrenheit. Ambient temperatures vary greatly from October through February, and so habitats that are more heterogeneous are more likely to provide a range of microclimatic conditions within the grove, contributing to suitability.

### *SUNLIGHT*

The relationship of sunlight to the thermoregulatory needs of overwintering Monarchs is dynamic and changes as the ambient temperatures change during the winter. In the fall, when air temperatures are relatively warm, Monarchs generally avoid roosting in direct sunlight. By roosting in shady areas of the overwintering habitat, Monarchs can remain inactive during the midday heat, thereby conserving their fat reserves for the coming winter.

During the mid-winter's cold, when sunlight is at its lowest intensity, the butterflies roost in areas of the grove that receive direct sunlight for brief periods of time (Frey et al., 1992). Monarchs need sunlight on cold days to raise their body temperature in order fly in search of nectar or water, to relocate their clusters, or to regain their positions in the clusters if they are dislodged from the trees. Thus, a certain amount of sunlight penetration into a grove is essential to the survival of overwintering Monarchs during mid-winter.

Researchers believe the exact location of Monarch clusters on a particular branch has to do with their need to thermoregulate (Masters et al., 1988). Since the exact way the forest intercepts the sun is habitat-specific, the precise location of Monarch clusters is also habitat-specific. It is a mistake to assume that, in general, increasing the direct sunlight would enhance a Monarch grove. Habitats must be assessed individually when making management decisions.

### *HUMIDITY AND WATER*

Humid air reduces water loss in roosting Monarchs, thus reducing their need to fly out in search of water. Many of the aggregation sites that support butterflies throughout the entire overwintering season in California are associated with coastal stream canyons that act as drainage basins for both rainwater and pools of cool moist air (Weiss et al., 1991; Calvert and Murphy, 1990). Understory and other vegetation, by increasing the surface area available for condensation and by adding moisture to the air through transpiration, help increase the water content of the air. If the air is not humid enough to provide condensed moisture on trees and plant leaves, the butterflies will be forced to fly out to obtain it from a nearby stream or lawn.

### *WIND VELOCITY*

Wind is a strong factor in habitat suitability, and influential in the butterflies' choice of cluster locations and movements around the grove. Wind velocities associated with trees supporting butterfly clusters are often low. As the wind changes, the butterflies shift their cluster locations to avoid areas or trees exposed to gusts (Leong, 1990).

Windbreak trees are critical to all Monarch habitats, and may include groups of trees in which Monarchs never cluster, but which provide protection for the clustering areas. Because windbreak trees are so important, local ordinances protecting "Monarch trees" can frequently by ineffectual in that the trees providing wind protection are ignored in the process. If sufficient habitat is not protected, including trees the Monarchs are never seen clustering on, the site could as easily be destroyed as if the center of the grove were removed.

The overwintering site at the Pismo State Beach campground is a good example of the dilemma that arises when critical windbreak trees occur outside the immediate habitat area. On the opposite side of Highway 1 from the Pismo colony is a row of trees growing along the railroad tracks. These trees are not part of the protected park area, but they are essential windbreak for that Monarch habitat. The total Monarch habitat at any one site thus may not correspond to the land ownership or political boundaries, and protection of any one site may require the cooperation of several property owners.

### *NECTAR SOURCES*

Nectar is the sugar source that the Monarchs use to make body fat, and nectar resources are an important element in most Monarch overwintering habitats. (see Appendix H for a list of common nectar sources.)

Physiological changes associated with sexual dormancy in Monarchs cause them to build up body fat before overwintering. Fat reserves are crucial to overwintering survival because Monarchs must fast for several months during the winter when nectar sources are absent or scarce. During their winter fast, Monarchs utilize about 50% of their body fat (Dayton and Bell, 1985; Brower, 1985). If butterflies do not have enough fat to last through this fasting period they may either starve to death or lack the energy to make the spring remigration and die en route.

Declining fat reserves are important in motivating Monarchs to leave the overwintering site in search of nectar. As winter progresses and nectar sources are less available, low fat stores are harder to replenish. The presence of onsite nectar sources in the later part of the season (January through March) can stabilize the colony by supplementing their fat reserves and reducing the need for the Monarchs to fly out in search of nectar (Dayton and Bell, 1985).

Nectar sources must be located close to the colony (within ¼ mile) in order to be useful in stabilizing the overwintering colony. Nectar sources located within the habitat contribute most to colony stability.

## *ENVIRONMENTAL CORRELATES OF BUTTERFLY MORTALITY*

In California, mortality of Monarchs in their overwintering habitats is generally low. Winter storms tend to be the major cause of mortality, especially when they occur in conjunction with low temperatures (Dayton and Bell, 1985). Predation by birds, mice and ground-dwelling invertebrates also contributes to butterfly mortality in overwintering habitats (Tuskes and Brower, 1978; Sakai, in review).

Most butterfly mortality occurs when Monarchs are dislodged from the trees and stranded on the ground when temperatures are below the Monarch's flight threshold. The combined effects of sun exposure, temperature, wind, precipitation, and predators determine whether the butterflies will get back to the clusters.

During cold weather, the butterflies can elevate their body temperatures enough to fly back up to the trees by basking in the sun or by shivering. If Monarchs are too cold to fly, they may climb to safety upon any understory vegetation that is present. The probability of survival is much lower for butterflies on the ground, especially if there is little understory vegetation, if pavement underlies the overwintering colony, or if it receives a lot of visitors. This underscores the importance of wind protection from overwintering habitats, the presence of some light gaps within the forest canopy and the preservation of understory vegetation when it is present.

## *RANKING SITES TO DEVELOP CONSERVATION PRIORITIES*

Ranking Monarch habitats is done essentially for political reasons rather than biological ones. Monarch conservationists rank habitats in order to allocate scarce research and acquisition funds and develop conservation priorities. Political and practical considerations dictate that conservation priorities must seek to preserve some percentage of the whole. But Monarchs have already lost a substantial number of habitats along the California coastline (see Appendix E). With the diminished number of habitats remaining, each potential new loss poses an increasingly greater risk to Monarch migration.

There are no quantitative data to show the minimum number of overwintering habitats needed to sustain the migration, but it is clear by the way that Monarch populations dwindled in key overwintering areas such as Pacific Grove[1] that aggressive coastal development and the attendant loss of Monarch habitats can diminish the migratory phenomenon in coastal areas.

Habitat rank is largely a subjective judgement providing a framework for conservation strategy and cannot substitute in environmental impact reports or management plans for scientific analysis of individual sites. Environmental impact reports that aim to assess the potential effects of intrusion into a Monarch grove by development must include appropriate population studies and quantitative microclimatic and forest canopy studies. These will provide a scientific means of arriving at the political decisions required to mitigate the development.

Habitat rank is achieved by weighing the characteristics of a site to determine its quality and its regional and statewide importance. Except, perhaps, for colony size, no single characteristic weighs substantially heavier in deciding rank than others. Monarch habitats are ranked by assessing the following essential characteristics in relation to other protected habitats in the same region and statewide. A discussion of some of the complexities involved in determining habitat rank follows this list:

*Essential characteristics*:

- Colony Size
- Average tenure (the length of time the butterflies stay during the winter, averaged over several years)
- Proximity to equivalent alternative habitats

[1] See Recommendation 72 for how Pacific Grove is protecting its Monarch overwintering habitat and how others can help.

> Function of the site with regard to its role in perpetuating the migration phenomenon (role of the site in the larger metacolony)
> Uniqueness of the site with regard to location, vegetative composition, etc.

*The following secondary characteristics are also important*:
> Microclimatic suitability
> Availability of resources: nectar, water, understory
> Size of forest
> Potential for funding and implementing management or manipulation
> Likelihood of public support for necessary maintenance and management

## *MONARCH HABITAT STATUS*

Monarch scientists categorize overwintering habitats according to the length of time the butterflies remain at the site. Two types of Monarch roosting habitats are generally distinguished: <u>autumnal roost sites</u> and <u>overwintering habitats</u>. Along the coast of California, autumnal sites vastly outnumber the overwintering habitats.

(1) Autumnal roost sites generally host relatively small populations of Monarchs (hundreds to low thousands) during the fall, usually September though mid-November. Autumnal sites are often associated with fall-blooming nectar sources, especially English Ivy (*Hedera helix*). These sites may serve an important role as feeding habitats for Monarchs that are replenishing their fat reserves for the coming winter. The butterflies roost at these sites for a few weeks, but abandon them by mid-November, as the <u>overwintering habitats</u> are reaching their peak populations. Butterflies rarely re-occupy these habitats during the remainder of the winter.

(2) Monarchs inhabit overwintering habitats throughout the fall and winter, and they remain in most through the end of February, when mating and spring re-migration occur. A very small number of these overwintering habitats sustain Monarch colonies through about mid-December, when they apparently move on to other overwintering habitats for the coldest part of the winter. The number of Monarchs in overwintering habitats is highly variable and may depend on many factors, such as geographic location and site-specific attributes of the microclimatic conditions of the habitat. Some of these habitats support Monarch colonies comprised of more than 200,000 butterflies (Dayton and Bell, 1984). Overwintering habitats also typically have nectar sources, especially blue gum Eucalyptus and native willows (*Salix* spp.), which bloom during the latter part of the winter. Most of the research on overwintering Monarchs in California has been conducted in these habitats. Several prime overwintering habitats are on land owned by the California Department of Parks and Recreation.

## *THE BIOLOGICAL SIGNIFICANCE OF AUTUMNAL VERSUS OVERWINTERING HABITATS: THE METACOLONY CONCEPT*

The significance of any given Monarch overwintering site depends upon a host of interrelated variables, and one of these is its interdependence with other surrounding Monarch sites. Recent research in southern California (Sakai, in prep.) suggests that individual overwintering sites do not support overwintering populations in isolation from other nearby

Monarch habitats; instead, groups of Monarch habitats act to support a "metacolony" of butterflies that move between these sites,

It is tempting to use the tenure of the site as the most significant determinant in ranking a Monarch habitat for conservation. And on this basis autumnal sites seem to be less worthy of protection, since they are not used as an overwintering site for the entire winter and since the colonies that inhabit them are typically smaller than overwintering sites. But autumnal and overwintering habitats each serve different functions and are each important for maintaining local Monarch populations. Because the level of inter-colony movement, particularly in southern California, suggests that a metapopulation of Monarchs depends on several sites in one areas, sites cannot be ranked strictly according to how long the butterflies use them. The ranking of Monarch habitat should consider colony size in combination with tenure, and should evaluate the level of inter-colony movement between local habitats. In many cases, the most effective conservation choices will reserve a network of habitats rather than individual sites.

Marking and tagging studies indicate that Monarchs move between nearby overwintering habitats (inter-colony movements) when conditions are favorable for flight. Some inter-colony movement is a response to the onset of winter. It is also possible that, early in the season, autumnal sites may provide better conditions for butterflies than do overwintering sites, particularly if they are providing nectar. Monarchs then leave autumnal sites in late fall or mid-winter to seek the more favorable microclimatic conditions of overwintering sites. In the northern part of the Monarch's overwintering range in California, inter-colony movement largely ceases by the end of November and Monarchs display relatively high fidelity to overwintering sites during most of the winter. In contrast, inter-colony movement appears to occur throughout the overwintering season in southern California.

Researchers have found that some sites serve as important nectaring bivouacs. They may support an autumnal colony during the fall flowering period or an overwintering site through the entire season. During the favorable conditions, these sites have a constant flow of butterflies in and out of the site as the butterflies refuel.

Preserving a network of habitats supports the metacolony of butterflies in the areas. Ranking the entire area's Monarch habitats can aid in deciding which should remain in a protected network. Protecting a number of colonies in an area is a practical guard against natural disaster, as well. Natural events such as chaparral fires in southern California and violent wind storms in central California can destroy even a large site. Other nearby sites must be available for the surviving butterflies to spend the winter.

## *THE IMPORTANCE OF EUCALYPTUS AS MONARCH OVERWINTERING HABITAT*

Overwintering Monarchs have become highly dependent on the presence of Eucalyptus trees. Most Monarch overwintering habitats in California are located in mature groves of Eucalyptus, and almost all large overwintering colonies (more than 30,000 butterflies) occur in this type of habitat. It is thought that most of the original Monarch overwintering habitats comprised of native tree species have been destroyed or irrevocably altered by humans over the past several hundred years. The historical native habitats no longer exist, nor can they be recreated. Removal of the sites unusable, and could cause the virtual collapse of the western North American migratory Monarch population.

Eucalyptus groves are abundant along the California coastline, but only some of them have microclimatic conditions suitable for Monarch overwintering. In addition to providing shelter for Monarch colonies, blue gum Eucalyptus serves as a source of nectar during the winter, providing the butterflies a way to replace lost lipids at a time when their lipid content is likely to be depleted and when native plants do not bloom. The presence of winter-blooming Eucalyptus contributes significantly to colony stability.

Conflict between Monarch habitat conservation and Eucalyptus removal for native revegetation arises when the tree removal occurs in proximity to a Monarch overwintering habitat. Since the entire grove of trees serves as Monarch habitat, even selective tree removal around the margins of groves may have adverse effects on the habitat. At a time when current political and development pressures imperil Monarch habitats statewide, the butterflies cannot afford to lose these prime Eucalyptus habitats to a political battle between native and non-native species. Some native plant advocates assert the Monarchs will go elsewhere if their Eucalyptus habitats are destroyed. But the decline of Monarch populations in areas where Eucalyptus groves were developed suggests otherwise.

This issue is especially critical on state park lands, where the California Department of Parks and Recreation under the Public Resources Code is undertaking to remove Eucalyptus and other non-natives and replace them with native vegetation. Native habitat revegetation should not be accomplished at the expense of the unique coastal Monarch overwintering habitats. Eucalyptus groves should be understood as “major vegetation” within the definition of the Coastal Act and the removal of Eucalyptus trees from a Monarch habitat should be understood as “development” under the Act. The Monarch Project, Monarch scientists, and Monarch conservationists support the goals of native revegetation, but not where they compromise the integrity of overwintering habitats.

Although native nectar plants will not serve to replace the nectar available from Eucalyptus trees, they can enhance a non-native grove with native flora. Native willows (*Salix* spp.) are virtually the only native plant that provide mid-winter nectar, but there are a number of fall blooming and spring blooming natives (see Appendix H).

Statewide Monarch habitat conservation strategies should target habitats composed of several different tree species in order to broaden the diversity of protected habitats and reduce the vulnerability of Monarchs to Eucalyptus insect pests. Preservation of Monarch habitats located in Monterey pine and cypress is particularly important.

## *COLONY STABILITY DEPENDS ON HABITAT SUITABILITY*

A varying forest age, structure and the plant species composition are prime contributors to habitat suitability and colony stability. In fact, heterogeneity is probably the single most important factor in the long term survival of Monarch overwintering habitats. The structure created by the trees, topography, and vegetation surrounding the overwintering habitat determine how suitable it is. A heterogeneous habitat and varied county-wide reserve designs which include nectar and water sources and other several Monarch colonies are key to sustaining Monarch populations. Monarch conservation has tended to focus on trees, but all the evidence points to the need for a broader approach that preserves the ecological system in which the trees must thrive.

Based on the information in these Guidelines about the specific elements that comprise Monarch habitats, optimal Monarch habitats provide:

> Suitable microclimatic conditions in a variety of mild to extreme weather conditions.
> Adequate wind protection
> A rich diversity of vegetation, providing dense and light areas, warm and cool areas, and dryer areas
> On-site nectar sources
> On-site water sources (particularly in the south, where humidity is lower)
> Protection from human disturbances, including adjacent land use and tourist impact

Butterflies shift locations in the grove in an effort to maintain the correct balance among various physiological needs, including conservation (and/or replenishment) of fat stores, and maintenance of body temperature within certain other words, Monarch may be choosing the cluster location based on how the site factors in that location compare with site factors in other locations in the grove. Their movement around the grove seems to be affected by the configuration of trees in each chosen site. Whether a colony persists over the long term may have less to do with a single factor than with the habitat heterogeneity of the grove overall.

Reserves should be designed and managed to provide suitable habitat through the chance catastrophic occurrences of a 50-year time-frame as well as the more benign annual winter storms. Long term habitat suitability and colony stability will also depend on minimizing disturbances and intrusions into the grove. Section Two of these Guidelines offers practical recommendations for how to design reserves and minimize disturbances in the grove.

## *TABLE 2: PRACTICAL QUESTIONS TO ASK IN ASSESSING YOUR MONARCH HABITAT*

Based on data summarized above, here is a list of practical questions to ask in assessing the health of a Monarch habitat. Land managers can design a study and monitoring program to address these questions and build a base of applicable information about the habitat.

> Is the canopy too open? Too closed?
> Is there too much sunlight? Too little?
> Is there some direct sunlight in the winter and sufficient shade in the fall?
> Does the understory dill in bare areas sufficiently to provide extra wind protection and increase humidity?
> Is the habitat too warm overall? Too cold? Too dry? Too windy?
> Does the vegetation provide refuge from storms? Do Monarchs tend to seek shelter in other habitats during storms, or get knocked from the trees in large numbers?
> Does the grove contain a mix of vegetation heights and thicknesses, and a variety of sunny and shady conditions through the winter months? Or it is fairly uniform?
> Is there a water source?
> Are there fall and winter nectar sources within or near the grove?

# *SECTION TWO*

# *GUIDELINES AND RECOMMENDATIONS*

# RESERVE DESIGN & RESERVE MANAGEMENT

## *LONG-TERM MONARCH HABITAT PRESERVATION REQUIRES ACTIVE MANAGEMENT*

It was once possible to go by the old adage that the best management for a Monarch overwintering habitat is benign neglect: leave the sites alone and they will survive. Over many decades, as forests climaxed and became unsuitable for Monarchs, butterflies probably moved to new locations. Today there are Monarch habitats in Eucalyptus groves only 30 years old, so we know Monarchs continue to colonize new areas.

But benign neglect will not help Monarch habitats survive into the next century. With the rapid development of the California coastline, few forests remain for Monarchs to colonize. The dramatic loss of trees in urban areas shrinks potential habitat. Many Monarch habitats have already been lost and development chips away at the remaining sites. Moreover, the removal of Eucalyptus (the most widely used overwintering species) and its replacement with native vegetation is a primary goal of the California Department of Parks and Recreation and the California Native Plant Society. Monarch conservationists cannot count on a continued supply of these weedy, fast-growing forests to replace those lost to development.

It used to be that for a Monarch habitat to be “protected”, it only need be legally barred from development. Now, as even “protected” habitats are stricken by disease or degraded due to tree senescence, tourism and poor management, owners and managers of Monarch habitat must view their role in a new light. They must work actively to preserve and sustain existing Monarch overwintering habitats. To ensure that Monarch habitats thrive, land managers must be active, developing programs for tourism control, tree planting, and tree trimming or removal when necessary.

The following information offers suggestions for developing baseline data on any Monarch overwintering habitat, for designing a Monarch reserve, and for solving common management problems or correcting habitat deterioration in Monarch reserves. Some material is equally applicable for both design and management, and land managers working with an existing design may benefit from some of the suggestions in the design section. Appendices listing helpful resources and individuals are cited throughout the text.

## *DESIGNING A MONARCH RESERVE OR RESERVE SYSTEM*

A reserve can be a single Monarch overwintering habitat, or a system that includes a network of autumnal and overwintering habitats that Monarchs can move among throughout a winter season. Monarch conservationists seek to protect a variety of habitats along the coast, with a diversity of vegetation. Diversity shields the migration phenomenon from the sudden loss of an entire area or tree species due to natural disaster or disease, and contributes to heterogeneity within a habitat, which scientists believe is a key element in its long-term survival.

**Recommendation 4 (recommendations 1-3 are on page 9): County and city governments should protect as many sites within one locality as possible, using wide buffer zones and making conservative initial decisions**. Local governments establishing Monarch reserves should make conservative decisions, establish monitoring programs, and adjust the reserve design slowly over time as the data show appropriate means to do so. Use wide buffer zones with little active management at first, unless the habitat is noticeably degraded and in danger of disappearing.

**Recommendation 5: Design reserves or reserve systems with three basic goals in mind:** 1) Conservation planning should address the systematic threats to Monarch Populations: habitat destruction, predation, and disturbances caused by humans. The habitat location must be secure, and legally protected from daily threats such as wood-gathering, fire-building, or motorized traffic before an appropriate reserve system can be designed and an active management plan adopted.

2) Reserve systems should cushion against catastrophic random events and regional climate change. Fire, disease, or massive erosion may threaten the persistence of otherwise stable populations. Regional climate change prompts Monarchs to move substantially throughout a large geographic area. Land managers can identify the metapopulation dynamics for their area, and design a reserve system that secures the ability of Monarchs to move between several habitats to insulate the population against the sudden loss of one.

3) Reserve systems should address the predictable environmental perturbations such as drought. A multi-age stand of trees, including some drought-resistant vegetation would enhance the long-term survival of the grove. (A classic model for reserve systems would also address demographic stochastity or deleterious genetic effects, but population in Monarch habitats are sufficiently large that these problems do not plague them.)

A competent baseline study can provide the information to accomplish these goals. Baseline data gathered onsite will reveal the strengths and weaknesses of the habitat and highlight the warning signs that indicate habitat degradation. A practical course of research can produce data useful in deciding where and how to modify the reserve over time; how to repair or enhance the grove in response to disturbances such as vandalism or downed trees; and how to plan for tree senescence.

**Recommendation 6: Develop baseline data to quantify the characteristics of the habitat. Use the study to test the reserve design:** The top priority is to establish minimum standards for the long-term survival of prime Monarch overwintering habitats. Baseline studies provide critical information for developing these standards. This information is also useful to politicians who must balance Monarch habitat preservation with development. Land managers will be able to apply the data to immediate practical decisions. They will not have to wait for the completion of lengthy studies.

Studies should be designed and implemented by a Monarch biologist, who can recommend what information should have top priority and how extensive each investigation should be. At least one full overwintering season is necessary to characterize the biology and dynamics of Monarch overwintering. The authors recommend an ongoing follow-up monitoring program, to be designed in consultation with the Monarch biologist.

The following studies are outlines for a competent database quantifying the microclimatic envelope in Monarch overwintering habitats. These studies examine population biology and the biotic and abiotic components of the Monarch habitat. A description of their practical application is included.

***TABLE 3***

***Suggested Studies of the Abiotic Habitat***

Record temperature, humidity, wind speed and direction, and rainfall inside the Monarch habitat. This can be done by setting up a weather station at the site.

Make temperature and humidity recordings at different heights from the ground up to the canopy, and at regular intervals inside and outside the Monarch habitat.

Measure and map direct and indirect light inside and adjacent to the Monarch habitat at regular intervals.

To gauge the broader influences on Monarch populations, onsite monitoring should include monitoring the variables that affect summertime reproduction

***The Practical Application of These Studies***

Monitoring temperatures inside and outside the grove will give an indication of the suitability of the grove and the expected butterfly behavior. Behavior that could not be expected based on ambient temperatures may be attributable to problems at the site, such as a lack of vegetation.

Establishing baseline measurements will allow land managers to begin characterizing the habitat, comparing the parameters of their study site with those at optimal sites, and analyzing potential problems.

Weather information is helpful. Research at Natural Bridges has shown rain affects the overall Monarch population throughout the state. Wide variations from the population expected at the study site may be attributable to site factors.

***TABLE 4***

***Suggested Studies of Biotic Habitat***

Use hemispherical photography with digital image analysis to quantify the forest canopy structure and the amount of direct and indirect sunlight.

Mark out a survey grid over the Monarch habitat. Catalogue tree and understory species, and measure densities, diameters at breast height, and basal areas of the trees.

Estimate age of the vegetation within the forest.

Map tree and understory distributions. The distribution, abundance and structure of understory species can be determined with standard botanical quadrant methods in relation to the survey grid coordinates.

Compare heights, distributions and sizes of Monarch clusters in relation to forest canopy and understory structure in the Monarch habitat survey grid and adjacent non-Monarch habitat survey grids.

***The Practical Application of These Studies***

Forest canopy structure is one of the few pertinent environmental measures of Monarch habitat suitability that managers can both quantify and manipulate. Indeed, management of forest structure with standard silvicultural techniques is the only logistically feasible means of modifying insulation, wind, and relative humidity within a forest stand.

Hemispherical photographs of the forest canopy can be digitized in a computer program, allowing researchers to “edit” trees, thus to assess impacts of tree removal on light conditions. By establishing the range of canopy structure that is correlated with Monarch butterfly aggregations, and correlating that with other site factors, a hemispherical photography study can help predict effects of changes in the canopy (thus presumably on habitat suitability) caused by tree growth, senescence, and human disturbance (Weiss et. Al., 1991).

***TABLE 5***

| ***Suggested Studies of the Monarch Population Biology*** |
|---|
| Design a mark-release-recapture study to test explicit hypotheses related to specific environmental phenomena at the site that may bear on population persistence. Mark-release-recapture is a process of marking a specific number of butterflies and estimating the population size from the proportion of marked butterflies there are in each subsequent recapture.<br><br>Map the locations of clusters. Map the movement around the site through the overwintering season. Correlate this information with data on the microclimate. Studies should examine not just where the butterflies are at any given moment, but what is available to them during different conditions as the season passes.<br><br>Institute a tagging program to examine immigration to, and immigration from, the overwintering habitat.<br><br>Take small samples of overwintering butterflies for analyses of size, age, reproductive status, stored fat content, host plant origin, geographical origin, and capability of defense against predators. The multiple information that can be gathered from each butterfly includes: wing condition, wing size, sex, lean weight, percent of lipid, sexual condition, frequency mated, and defensive chemicals content. |
| ***The Practical Application of These Studies*** |
| Population size is an indication of whether the overwintering habitat is suitable and stable. But counting butterflies is relatively useless. Land managers who monitor their sites for changes in population need to have some idea whether an increase or decrease has to do with large issues beyond the control of management, or with small manipulations.<br><br>Overwintering is characterized by arrival and departure phases separated by a stable overwintering phase. Adult nectar feeding, clustering movement and reproductive behaviors will vary according to these phases and abiotic conditions. Mapping will help researchers examine the reasons for butterfly movement.<br><br>Tagging butterflies can indicate intercolony movement and aid in describing metacolony dynamics.<br><br>Fat and water content are indications of the health of overwintering butterflies. This and the other information gathered from the butterflies themselves can help determine the success and dynamics of Monarch overwintering at the study site, including the need for nectar, reasons for mortality, and the potential migration route of butterflies at the site. |

**Recommendation 7: Using information gleaned from baseline studies, establish an appropriate habitat area, with heterogeneous vegetation and sufficient buffer.** Monarch habitat includes trees the butterflies cluster on and vegetation that provides the appropriate microclimate and protection from wind, rain, and storms. Monarch habitat is not just butterfly trees, but Monarch butterflies have what scientists call high fidelity, that is, they return predictably to the same groves. Some autumnal sites have high fidelity and some don't. Design the reserve to protect a stable network of autumnal and overwintering habitats.

A buffer will be partially determined by the direction and velocity of prevailing winds, and the proximity of disturbances that could affect the habitat. Monarch habitats vary greatly in size, and a buffer should be established with the help of a Monarch biologist.

**Recommendation 8: Ensure the habitat is legally protected.** Habitats may be protected in several ways. They may be owned by the state, a local government entity, or a land trust, any of which can be dedicated to protecting the area as a Monarch butterfly overwintering habitat. While most public agencies now managing Monarch habitats make a good faith effort to protect them, public ownership does not guarantee the habitat will survive. Monarchs have to compete for survival with other resources and with revenue-generating activities on some park lands. Park management plans should explicitly protect Monarch butterfly habitat and should provide for ongoing monitoring and active management.

Monarch habitats may also be protected legally with a conservation easement. (see Appendices C, D.) Conservation easements are a tool used frequently by land trusts to preserve property while the original landowner retains the title and some rights to the land. Easements can provide tax benefits to a landowner, and are a flexible and useful tool for preserving habitats over the long term. They may be donated by a landowner, or required as a condition of a development permit.

**Recommendation 9: Establish a trail system.** A designated trail system is essential to protect the overwintering trees, and prevent soil compaction and erosion. It also protects understory vegetation and ground cover, and prevents people from trampling on Monarchs. Trails can be designed to allow easy access and viewing.

A single access and return trail can be marked into the butterfly area with a viewing arena near the center of the overwintering tree area. The route of the trail should be chosen in consultation with a Monarch biologist to minimize damage to existing vegetation and limit possible exposure to wind.

The trail system will work well in conjunction with the five recommendations which follow, since these recommendations will encourage people to keep to the designated trails.

**Recommendation 10: Mulch all paths to be used in trail system.** A heavy wood-chip mulch can be used on areas intended for use in the designated trail system. The chips can be spread manually using snow shovels and rakes with rigid metal tines. Avoid using trucks or tractors to dump the chips, since these vehicles add to soil compaction and damage the grove.

**Recommendation 11: Plant ground cover or mulch designated areas which are not used as trails**. This will to relieve any existing compaction and prevent further compaction. If soil compaction is a problem, bark mulch can also be spread manually in areas that will not be used as paths. Avoid sawdusts that would deplete nitrogen from the soil.

**Recommendation 12: Construct a fence around the perimeter of the reserve.** Managing the entry points into the reserve interior will help control foot traffic and encourage people to keep to the designated trail system. Signs posted at each entry can inform people about the unique qualities of the reserve, and ask them to stay on the designated trails. Fences can be unobtrusive and designed to blend with the natural environment.

**Recommendation 13: Construct a boardwalk and viewing platform in the Monarch overwintering habitat.** A boardwalk and viewing platform for visitors will protect the forest floor f the whole butterfly viewing area. The viewing platform could contain benches and interpretive signs. Wet weather is common during the Monarch winter visit, and a boardwalk will enhance visitor comfort when the soil is wet and muddy.

Monarch groves cannot sustain unrestricted human use without becoming seriously degraded. The best and only hope that Monarch reserves will survive is if the most important areas are well-protected. The choice is between completely unrestricted use on the one hand, and the very survival of the overwintering groves on the other.

**Recommendation 14: Design tourist information boards or signs.** Interpretive signing in the overwintering habitat can increase the public level of environmental awareness and sensitivity toward local species and will encourage the public's respect for trails and boardwalks. See Appendix J for suggested language for the signs.

**Recommendation 15: Institute more restrictive measures if necessary.** The preceding recommendations are the least intrusive possible, and, if they are reinforced by a program of community education and honored by reserve visitors, should aid greatly in protecting the grove. If they are insufficient to control visitor use, progressively more restrictive measures have been applied in state parks facing the same conflict between resource preservation and multiple-use. These include: 1) eyebolt-and-cable path guides, as used at Point Lobos State Reserve; 2) wood beam fences, such as those recently installed at Pescadero Point in Del Monte Forest; and 3) docent supervision.

## *MANAGING A MONARCH RESERVE*

Monarch science can describe the microclimatic conditions in optimal groves but does not currently describe in quantitative terms the precise minimum conditions Monarchs need. Monarch habitat management questions can only be answered site by site. The few rules that apply broadly to all habitats (i.e. don't remove vegetation from a Monarch habitat) are not useful in solving specific management problems. Monarch scientists recognize that tree hazards, winter storm blowdowns, and other management problems can require altering a Monarch habitat. But land managers should never alter Monarch habitats without consulting with a Monarch biologist. And the best way to reach decisions about altering a grove is to conduct a baseline study: the information generated can guide management decisions and serve to measure changes and plan mitigations. The following recommendations are broad guidelines land managers, in consultation with Monarch biologists, may find useful in preparing a management plan for a Monarch reserve.

**Recommendation 16: Conduct baseline studies; use the suggested studies in Recommendation 6.** The first step in managing a Monarch grove is the same as the first step in designing one: do a baseline study and follow-up with an ongoing monitoring program. The information is critical for determining the health of the grove and assessing its needs.

**Recommendation 17: Conduct an ongoing monitoring program for microclimatic and population information.** Once a weather station has been installed, information can be transcribed by interns or other interested citizens. If your park has a docent system, or collaborates with a local university, it may not be difficult ton continue gathering the basic temperature and humidity information year-to-year, and the information will be extremely useful for tracking changes in the grove.

Tagging is another program that has often relied on students and volunteers. Mark-release-recapture requires trained people, so may be more difficult to conduct in an ongoing fashion. It does, however, provide important information on butterfly population, and should be incorporated into long-term monitoring programs in a manner feasible for the managing agency.

**Recommendation 18: Consult a Monarch biologist before limbing or cutting any trees or other vegetation in a Monarch habitat.** Monarch habitats are destroyed and degraded every year by managers who remove even a small number of trees. See Appendix E, "A Butterfly's Hit List," for examples. The authors recognize the importance of removing hazardous trees from forests. But not every dead tree is a hazardous tree, and land managers must be committed enough to maintaining the Monarch overwintering habitat that they remove vegetation only when necessary and that they simultaneously seek to maintain and enhance the overwintering habitat.

**Recommendation 19: When replanting a Monarch habitat, use a tree species compatible with those already present, even if it's non-native.** If the habitat is in Eucalyptus, let it stay Eucalyptus. Monarch scientists don't know how to replace one species with another and sustain the habitat. It is not worth losing a Monarch habitat to gain one grove of native trees.

**Recommendation 20: Identify and encourage the planting of nectar sources in and near the Monarch grove.** Include both fall and winter nectar sources in the reserve design. Add nectar to marginal Monarch colonies as a possible way to improve them. Fall nectar will attract the butterflies, and winter nectar will sustain them through lean periods and may aid their survival through extreme weather.

To be useful to the butterflies, nectar sources should be located inside the colony or within one-quarter mile. Monarchs may actually use nectar sources as much as a mile or two away, but that causes them to burn needed energy. Nectar sources onsite with increase the colony's stability.

**Recommendation 21: Remove factors that negatively alter the internal temperature and humidity in the grove.** These may add heat to the habitat: a new paved path or road; materials stored under Monarch clusters that can collect heat and radiate it upward into the clusters (black culverts stored on the forest floor at Moran Lake had a noticeable detrimental impact on the Monarch clusters above the culverts); a wider opening to the south that allows more direct sunlight to penetrate the grove.

**Recommendation 22: Reduce and discourage soil compaction and erosion.** Soil compaction adversely affects the health of trees by stressing tree roots and preventing water and nutrients from penetrating the soil. Erosion is also a problem in some habitats where foot, bicycle or motorcycle traffic has worn down the understory or soil.

Although aerating the soil is a common treatment for soil compaction, aerating in some habitats – where trees are old or roots are close to the surface, for example – could damage the root systems of trees and promote weeds. In this case, avoid any disturbance to the root systems. See Recommendations 9-13 for ways to avoid and reduce soil compaction.

**Recommendation 23: Develop a program for the identification and treatment of hazardous trees.** Dead trees which could be classified as hazardous, posing a risk to the public, are a standard concern to land managers. This report does not attempt to develop a hazard tree policy since it is outside the scope of the project. However, a policy should be in place as part of a park's long term management program. The authors recommend that hazardous trees be removed or limbed by tree experts without driving heavy equipment into Monarch groves and that hazardous trees be removed or limbed between March and September, when the butterflies are not clustering. The authors of this report assume no responsibility associated with hazardous trees in Monarch groves.

**Recommendation 24: When hazardous trees must be removed or limbed, consult with a Monarch biologist on the potential effects to the Monarch habitat and implement mitigations.** Park managers have used constructed wind barriers to mitigate the impacts of tree removal. Planting new trees or vegetation may also be necessary. If the unavoidable removal of vegetation has degraded the habitat, institute a simultaneous and immediate program to enhance the habitat.

**Recommendation 25: Allow downed trees and standing dead trees which are not hazardous to remain standing for wildlife use.** In some Monarch habitats, other wildlife, such as cavity nesting birds, use standing dead trees. When a hazardous tree is taken down, a determination can be made on a tree-by-tree basis whether or not to leave it on the site as habitat for other wildlife.

**Recommendation 26: Thicken the vegetation around existing roads and do not use roads to create open space in Monarch groves.** The most stable and largest Monarch overwintering habitats in California are not over roads. There is ample evidence that roads can degrade a habitat and increase butterfly morality (see Appendix E). Butterflies knocked from clusters onto a road are more likely to drown, be crushed by traffic, or freeze to death than butterflies knocked onto a natural understory.

A road, even a winding road, is a significantly different form of canopy opening than a stream source or a clearing. It adds heat to the microclimate and takes out a wide swath of trees, leaving a clear sky overhead rather than a substantially closed canopy. Roads allow more wind penetration and can create wind tunnels, whereas prime Monarch habitats tend to be found in nearly windless areas.

**Recommendation 27: Make monarchs the priority in the Monarch conservation area.** Monarch conservation zones in national or stat parks can be established, within which park rangers manage the flora differently than in zones where they manage for native plants. Such a policy would explicitly define Monarchs as the resource to be protected, and flora would be managed with the ultimate goal of sustaining the Monarch overwintering habitat through the long term future.

**Recommendation 28: If prescribed burns are scheduled to occur near Monarch habitats, ensure that they don't disturb the clusters.** Two Monarch habitats in Marin County are next to prescribed burn sites for the Golden Gate National Recreation Area. This situation may exist for Monarch habitats in other areas of the state. A problem arises if burning occurs when the butterflies are clustered in the groves and the prevailing winds carry the smoke in their direction. Since the optimal burning months in Marin are October and November, there is a potential conflict.

The best option is to burn before the Monarchs arrive. Local Monarch conservationists should work with park rangers to incorporate into burn regulations the policy that burning be done before the butterflies arrive, and if that is impossible, that it be done on a day when the prevailing winds won't send smoke into clusters.

**Recommendation 29: Do not use controlled burning to encourage natural regeneration within the grove.** Controlled burning and accidental fires have played an important role in natural regeneration in some forests. Controlled burning, however, also presents a potential threat to the Monarch habitat, and the authors recommend against it. Eucalyptus groves grow like weeds and need no extra encouragement, and Monarch groves of other species can be replanted manually if they are thinning out.

**Recommendation 30: Incorporate the following policies into a fire management plan for the reserve.** The following measures will aid in controlling the fuel load and providing adequate safeguards against the introduction of fire from outside the park. This is a not a complete fire plan, but includes information pertinent to the concerns of Monarch habitat management.

> Understory levels should be managed to prevent a localized buildup of dead plant materials. Only the excess dead materials and plant rubbish should be removed; live understory plants and grasses are valuable to the Monarch habitat and should be left alone.
> Over many years the build-up of live brush should be monitored. A Monarch biologist and the appropriate fire inspection staff should work together to advise managers about the removal of live brush build-up. Attention should be given to the understory requirements for Monarch habitat.
> Most open areas can be mulched to inhibit the growth of weed species.
> No vegetation other than grasses should be mowed.
> No chemicals such as Roundup should be used anywhere in the Monarch reserve.
> Fire breaks and other provisions should be developed by the managing agency and reviewed by a Monarch biologist.

**Recommendation 31: Adopt the following list of restricted activities to preserve the natural character and health of Monarch reserves:**

> Ban motor vehicles in the reserve.
> Allow pedestrians and bicycles only on a designated trail system.

> Ban spraying or other application of biocides (pesticides, herbicides, or insecticides). The area should be managed as a natural biotic community complete with a normal complement of insects.

> Ban fires.

**Recommendation 32: Seek the advice of a Monarch consultant regarding the replacement of an exotic understory with a native understory.** The Monarchs require vegetation for its nectar or as protective cover, and this can be provided equally by native or exotic species. Because Monarch habitats are so delicately balanced and because so many have been destroyed in recent years, it is essential to make Monarch habitat preservation the first priority and native vegetation the second.

However, recognizing that it is a goal of the California Department of Parks and Recreation to encourage native species, it may be possible to encourage native understory in Monarch habitats in a way that does not threaten the habitat. These plans should be developed only in consultation with a Monarch biologist, and should follow a baseline research program that examines the vegetational structure in the grove.

**Recommendation 33: Management practices on autumnal and overwintering habitats can be essentially the same.** Management practices will differ between colonies simply because there will be different problems to solve, not because they are autumnal or overwintering.

**Recommendation 34: Maintain the configuration of the vegetation.** In general, vegetation in Monarch habitats appears either as a semi-circle around an opening, a full circle, an oval, or an S-shape. Permanent overwintering sites are usually S-shaped or oval. The oval allows better sun exposure at both morning and afternoon, so when the Monarchs seek more sun exposure in winter the habitat can provide it. The S-shape allows better wind protection as well as exposure to both morning and afternoon sun. The sometimes ragged edges of a grove can be an important thermal blanket, and provide sheltered pockets for butterfly clusters. Pruning or limbing trees can alter the shape of the grove and may substantially disturb the habitat.

## *WORKING WITH THE LOCAL LAND TRUST*

Land Trusts have tremendous resources for Monarch conservation, from expertise in land preservation and the ability to purchase or negotiate fee title or easement to volunteer networks that can monitor developments. A land trust is a non-profit corporation whose purpose is to protect land, usually some specific type of land or land in some specific area. There are not 800 land trusts across the country. The oldest one is 100 years old. They may be run by volunteers or have a paid staff. The basic goal of protecting land in a trust is to take the property off the market where it is a commodity that can be bought, sold, and developed. Instead the land trust holds those rights for perpetuity.

Land trusts negotiate purchases for themselves, or they can buy for government agencies. Since they are non-profit, land trusts do not have to pay full market value and can work out various types of tax benefits for landowners, some quite sizeable.

**Recommendation 35: Get land trusts involved in Monarch habitat preservation negotiations.** A local land trust can receive a conservation easement that is dedicated as a condition of a development permit. It can negotiate an easement or purchase of a Monarch habitat with a landowner who does not want to develop but wants to see the habitat protected in perpetuity. And it can help the state negotiate the purchases of Monarch habitat that are now being done with funds from Proposition 70.

**Recommendation 36: Write conservation easements to protect other values on the property in addition to the Monarchs.** Once a land trust obtains a conservation easement, the challenge is to ensure the habitat remains protected. Despite their good intentions, people can disturb or destroy Monarch habitats by activities like pruning trees, mowing understory or burning leaves. Some vegetation may need to be removed to prevent fire or tree hazards and will probably be allowed by the terms of the easement, but a Monarch biologist should be consulted so that removal of vegetation does not disturb the habitat. Certainly, no vegetation should be removed simply for cosmetic purposes.

It would be useful to write Monarch conservation easements for long-term protection of both the Monarch habitat for as long as the butterflies remain, and the other natural and scenic values of the land as well. It may happen occasionally that the butterflies will leave a site for a year or longer, and unless there has been a specific violation of the conservation easement which would trigger litigation, the property owner should not be held responsible for unexplained changes in butterfly behavior.

**Recommendation 37: Train land trust volunteers in Monarch conservation.** Land trusts have a corps of eager volunteers who are dedicated to protecting land in its natural state. Land trusts who become involved in Monarch conservation can find any of a number of projects for local volunteers, including: tagging butterflies; monitoring development projects; making regular visits to inspect protected sites; or testifying in favor of local Monarch preservation land use goals or ordinances.

## *PREPARING AN ENVIRONMENTAL IMPACT REPORT ON MONARCH HABITATS*

The public process, and Monarch habitat preservation, has suffered from amateur treatment of Monarch habitats for environmental impact reports (EIRs). Having been an avid student of the butterflies does not qualify one to evaluate the potential effects of a development on a Monarch butterfly habitat.

In every other category of analysis, lead agencies insist that consultants be credible scientists in their areas of expertise. The authors urge state and local agencies to hold to no lower standard for Monarch science.

**Recommendation 38: Lead agencies should require that Monarch biologists demonstrate their scientific competence to perform studies of Monarch butterfly habitats for environmental impact reports.** The agency should evaluate the expertise of a potential Monarch biologist based on whether they have:

> Completed an advanced degree in biology with research experience on Monarch overwintering biology; or

> Designed and conducted a quantitative research program o aspects of Monarch biology and overwintering; or

> Published on Monarch butterflies in juried scientific journals.

**Recommendation 39: Get the Monarch survey information for your jurisdiction and map it on local resource maps.** Legislation approved in 1987 mandated a survey of all Monarch overwintering habitats in California. That list and maps are available to local planning departments, land trusts, and others involved in Monarch habitat preservation from the Natural Diversity Database, maintained by the California Department of Fish and Game. Call 916-324-3812 for information on how to order copies.

**Recommendation 40: If the lead agency is unsure whether Monarch habitat is on the property, have a Monarch scientist do a site visit.** The consulting firm can employ a biologist to do an initial site visit and determine whether there is a concern about Monarch habitat. Because Monarchs are present only in the winter months, the determination should be made enough in advance to authorize the biologist to begin a study at the start of the overwintering season.

**Recommendation 41: When preparing an environmental impact report, conduct the Monarch habitat study for one full overwintering season.** One full overwintering season is the absolute minimum acceptable length of time to study a Monarch habitat for the purposes of preparing an environmental impact report. An overwintering season runs from October 1 through February 28. (As is the case for all other sensitive species, site visits should be made when the species are expected to be present.) Monarchs shift throughout the grove during the overwintering season in response to climatic conditions. It is not possible to assess adequately the impacts of a proposed development on a Monarch habitat if the consultant has not been able to delineate the habitat based on the locations of the Monarch clusters throughout the entire season.

If the political process delays the beginning of the Monarch study past October 1, the lead agency should authorize the continuation of the study through the initial months of the following winter, so that the study covers one full overwintering season. An insufficient study sets up the lead agency for lengthy appeals and litigation.

**Recommendation 42: Conduct the mark-release-recapture, microclimatic studies and mapping of clusters as outlined in recommendation 5 to determine the habitat boundary and mitigations that will protect the Monarch habitat from the impacts of the development.** Counting butterflies and surveying the site visually are not sufficient to assess the impacts of development on a Monarch grove, and will only produce anecdotal information that can be too easily manipulated by people on all sides of a development conflict. Monarch surveys should be based on standard, quantitative science.

All environmental impact reports should examine not just where the butterflies are at any given moment, but what is available to them as the season passes. EIRs should examine how the proposed change is going to affect vegetational structure and how it could affect microclimatic parameters. Neither an increase nor a decrease in current conditions should be done without assessing the effects on the butterfly clusters.

**Recommendation 43: Include, as a condition of the development permit. that a conservation easement be donated to preserve the habitat in perpetuity.** A conservation easement is the minimum requirement for protecting Monarch habitat in conjunction with development. Monarch habitats can and do survive near developments. They do not have to be mutually exclusive, although in certain cases they are. A conservation easement, donated to a local lad trust or other appropriate agency, is the only guarantee that the Monarch habitat will remain protected, and any developer whose permit is approved should be required to ensure that Monarch habitat on the property will survive. An easement will also provide the legal structure for monitoring changes and managing the habitat.

**Recommendation 44: Make mitigations specific, with a plan for how they will be implemented and who will do the follow-through. Mitigations must read "shall" and "always."** Mitigations can and have included the following:

> Protecting the entire habitat area with a conservation easement.
> Providing a monitoring fund to ensure mitigations are implemented and to monitor changes in the grove.
> Planting trees as the perimeter of disturbed areas, along roadways, or to reinforce wind protection.
> Planting other understory or windbreak vegetation.
> Planting nectar sources, or other landscaping in and near the development which would benefit the Monarch butterflies.
> Banning or limiting wood burning fireplaces.
> Banning construction that could damage the habitat during months when the Monarch butterflies are present.
> Requiring that construction be done with methods that preserve the natural vegetation. For example, certain areas may be designated off-limits to large machinery, or certain vegetation may be marked that cannot be cut to allow passage of large machinery. Storage of woodpiles

and equipment, and parking space may be confined to specific areas outside the drip line of the grove.

- > Restricting paving close to the Monarch habitat.
- > Restricting the width of access roads. Further road improvements may be significantly restricted.
- > Restricting management in the grove to what is minimally necessary for fire safety, and to protect homes and people.

It is possible that changes to the draft EIR recommended by other consultants could significantly change the project's potential impact on Monarch habitat. The Monarch scientist may want to revise his or her comments if the final plan significantly changes, for example, the location of buildings in relation to roosting sites.

**Recommendation 45: Institute a monitoring program as part of mitigation and require a fund to implement it.** Public Resources Code 21081.6 which was passed in 1988 as AB3180 requires monitoring of projects. This monitoring is not required to be part of an EIR, but it is required to be adopted at the time the agency acts on the project. Monitoring should be conducted by a Monarch biologist and should include:

- > A simple weather station that can remain in place to measure temperature and humidity.
- > A two-year mark-release-recapture program to provide basic information about whether and how the development has affected the Monarch habitat.
- > Other monitoring that may address specific threats the development poses, as the Monarch consultant advises.
- > A length of time long enough to mitigate the impact. If construction will last five years, the monitoring program should last seven.

These goals are enforceable, and can be quantified so compliance will be easily measurable. Planting of new vegetation can be conditioned on the results of the monitoring program.

Monitoring funds can be raised through home sales or room taxes. Data gathered in the monitoring program should be compiled to compare with other areas where development coexists with Monarch habitat, so that land managers and local governments can benefit from knowledge gleaned by other projects.

**Recommendation 46: When mitigations protect one habitat out of several on the same property, the best habitat should be protected.** Mitigations should never allow the destruction of a more stable, more functional habitat in favor of preserving a less stable, less functional one. Protecting a habitat somewhere else is not an acceptable mitigation, but on occasion a single property will include several habitats. The EIR should examine the interrelationships between them, preserving the most important areas for Monarch overwintering.

**Recommendation 47: Do not attempt to create a new Monarch habitat to mitigate the loss of an existing Monarch habitat.** It is scientifically insupportable to attempt to mitigate the loss of a Monarch habitat by creating a new one elsewhere. Monarch scientists do not know how to create Monarch habitats with any guarantee that it will be successful. Moreover, there would be a 20 to 50-year gap between the time the trees were planted, and the time one discovered whether they developed into a suitable Monarch overwintering habitat or not.

Because the migration is so perilously dependent on the existing Monarch overwintering sites, Monarch conservationists cannot countenance the loss of a stable, well populated Monarch habitat on the off-chance that a new be could be created. The western Monarch migration simply cannot afford to lose more prime habitats.

## *CREATING NEW MONARCH HABITATS*

Research suggests that someday it may be possible to create new Monarch habitats. Currently, however, Monarch scientists do not know how to do it successfully. Furthermore, research now is directed at establishing the minimum standards for preserving Monarch habitats, not at creating them.

Historical records do not show where Monarchs used to winter before the widespread and successful introduction of Eucalyptus species along the California coast. Monarch scientists lack data on how may sites there were, how big they were, and on their latitudinal extent along the coastline. Monarch scientists cannot recreate the forests that may have harbored Monarch clusters at the turn of the century. Nor is it possible to aim for whatever might have been the historical distribution of Monarchs. These questions are interesting from an historical point of view but researching them contributes little to reducing the immediate political and ecological threats facing Monarch habitats.

**Recommendation 48: Launch an experimental habitat creation project.** As a first step toward knowing how to create Monarch habitats, it would be helpful to attempt to re-create habitats where Monarchs once used to cluster but now do not. Monarch conservationists would enthusiastically support the creation of new habitats as experiments. Lighthouse Field in Santa Cruz would be an excellent location for an experimental re-creation of a Monarch habitat.