

POPULATION VIABILITY ANALYSIS BAY CHECKERSPOT BUTTERFLY

Introduction

Let's step back for a moment and think about general lessons from our analysis of northern spotted owl population dynamics.

1. Even with the huge effort that has been expended it is difficult to be sure that current forest management plans are sufficient to ensure persistence.
2. Long-lived animals are buffered from immediate extinction because of the long life span, but that also means that our understanding of the population dynamics is very limited.
3. Understanding *something* about population dynamics is critical to making intelligent management choices.
 - (a) Focus management efforts on policies that will increase juvenile survivorship and fledging success.
 - (b) Protection of unoccupied, suitable habitat is critical to population persistence.
 - (c) Population/metapopulation is the appropriate unit of management.

This overview of the northern spotted owl has also introduced you to one of the most detailed population viability analyses available for *any* species, plant or animal. In fact, most population viability analyses have focused on “charismatic megavertebrates,”¹ e.g., the grizzly bear, the northern spotted owl, and the red-cockaded woodpecker.

The focus on these species is often justified by arguing that they are “umbrella species,” whose protection will enhance the protection of many other species less immediately attractive to the general public. There are, however, several reasons protecting “umbrella species” may fail to protect other species of concern:

¹If you want another acronym, I suppose we could call them CMVs. And yes, I know that CMV more commonly refers to cytomegalovirus, but there are only so many acronyms you can make. Some are sure to be duplicates.

- Protection of large expanses of habitat will not necessarily ensure that all plant or animal species in that area will persist. Successional change or the invasion of exotics may lead to exclusion of other components of the community without endangering the charismatic megavertebrates that were the original target. Plants and invertebrates (and small mammals and small cold-blooded vertebrates for that matter) may require management even within a large ecosystem that is being protected for use of a charismatic megavertebrate.
- Many plant and invertebrate species are found in highly localized populations in the absence of any association with these species, e.g., Texas wild rice (*Zizania texana*), caliente farewell-to-spring (*Clarkia tembloriensis* subsp. *calientensis*).
Bay checkerspot *Euphydryas editha bayensis* is restricted to serpentine outcrops in the San Francisco Bay area, which lost all its large vertebrates by the turn of the century.
- Plants and invertebrates (and small mammals and small cold-blooded vertebrates for that matter) share few of the life-history characteristics that put large vertebrates at risk of extinction. They can exist in much smaller areas than large vertebrates, e.g., urban and suburban corridors. Techniques for management of charismatic megavertebrates may or may not apply to them.
- Areas that are important for protection of diversity in one group of organisms are not necessarily the same as those that are important for protection of diversity in another group, unless very large areas are protected. We'll discuss the problem of identifying "hotspots" later in the course.

Biology of the Bay Checkerspot Butterfly

Paul Ehrlich began long-term studies of the biology and demography of the Bay Checkerspot Butterfly (*Euphydryas editha bayensis*) shortly after he arrived at Stanford University in 1960 as a newly appointed assistant professor. In the five decades since, he and his associates have monitored population sizes annually and done detailed analyses of larval food plant specialization, adult nectar feeding preferences, and studied many other aspects of the basic ecological relationships in this species and its relatives. There may be more information about the population size fluctuations of this butterfly than for any other invertebrate.²

The Bay Checkerspot Butterfly is currently listed as a threatened species by the U.S. Fish and Wildlife Service. It used to be found in two, largely separate, metapopulations

²This discussion is drawn largely from [2].

that are about 50 miles apart — one highly fragmented one in San Mateo County, another more or less intact in Santa Clara County, California. The largest part of the metapopulation in San Mateo County, subpopulations on the Jasper Ridge Biological Preserve of Stanford University, went extinct in 1997. A small population remains on a separate serpentine outcrop about 4 miles to the north. The butterfly is restricted to patches of native grassland that support its native host plants (*Plantago erecta* and *Castilleja purpurascens*³) and adult nectar sources (including *Lomatium*, *Lasthenia*, *Layia*, and others). With only one exception, the patches supporting native grassland are outcrops of serpentine soil.⁴

Basic life-history⁵

- Univoltine — one generation per year.
- Adults fly from late February to early May.
- Females lay masses of up to 200 eggs at the bases of the larval host plants — *Plantago* is the primary host plant, *Orthocarpus* is used as a secondary host when *Plantago* senescences before the larvae diapause.
- Diapause extends through the summer drought. It is broken by late summer rains when the larvae begin feeding.

Population dynamics

- Population size of reproductive adults largely regulated by larval mortality in preceding spring.
- Larval mortality largely controlled by timing of rainfall, adult emergence, and senescence of food plants
 - Spring rainfall delays senescence of food plants, decreases mortality
 - Warm temperatures increase rate of larval development
 - Microtopographic influences on soil moisture (host plant senescence) and temperature (larval development, adult emergence) have large effect on larval survival rates — larvae that hatch from eggs laid on cool slopes by females that emerge early from warm slopes are most likely to survive

³Formerly known as *Orthocarpus purpurascens*.

⁴Serpentine soil is derived from rock high in heavy metals and having an unusual calcium/magnesium ratio. It is toxic to most plants, including nearly all introduced grasses and forbs. In fact, serpentine grasslands are almost the only remaining native grasslands in this part of California.

⁵N.B.: Central California has a Mediterranean climate — Most of the roughly 20" of rain it receives comes between late October and early April.

- Severe droughts, e.g., 1975–1977, cause severe population declines, even local extinctions.
 - * Three subpopulations at Jasper Ridge Biological Preserve, smallest went extinct, but was re-established a few years later, presumably by colonists from one of the other Jasper Ridge populations. Now that all populations at Jasper Ridge are extinct, the USFWS continues to include the serpentine grasslands there in its critical habitat designation in the hope that migrants from remaining population units will re-establish it.
 - * In Santa Clara County all populations except one went extinct during the 1975–1977 drought.
- Local population dynamics can be *extremely* local — two subpopulations at Jasper Ridge separated by less than 500m showed opposite changes in population in 6 out of the 25 years from 1960–1985.
- Increased nitrogen deposition associated with air pollution is increasing the fertility of serpentine soils, which are naturally low in N, and allowing exotic grasses to invade. As the exotic grasses invade they exclude the food plants and nectar sources on which the bay checkerspot depends. In the large metapopulation south of San Jose removal of cattle from grasslands harboring the butterfly led to a dramatic *decrease* in butterfly population size. Grazing leads to a net export of N as cattle are removed for slaughter. Thus, moderate grazing enhances the viability of an endangered butterfly [4].

Metapopulation Dynamics

The sensitivity of local populations to year-to-year differences in rainfall combined with the enormous variation in timing and amount of rainfall this area receives suggests that they are highly susceptible to extinction, as does the observation of several local extinctions and re-colonizations in the past 30 years. The best explanation for the persistence of many of the small, isolated populations is that they form part of an extended metapopulation linked by recurrent extinctions and recolonizations. It is interesting to wonder whether these metapopulation dynamics have always been characteristic of the species or if they date only from the introduction of non-native grasses and the reduction of native grasslands to their current patchwork (ca. 1800).

In the Morgan Hill population (Santa Clara County; Figure 1), one population is far larger than any of the remaining ones. It apparently acts as a reservoir from which smaller patches are recolonized. Interestingly, butterflies were found on eight small patches of native

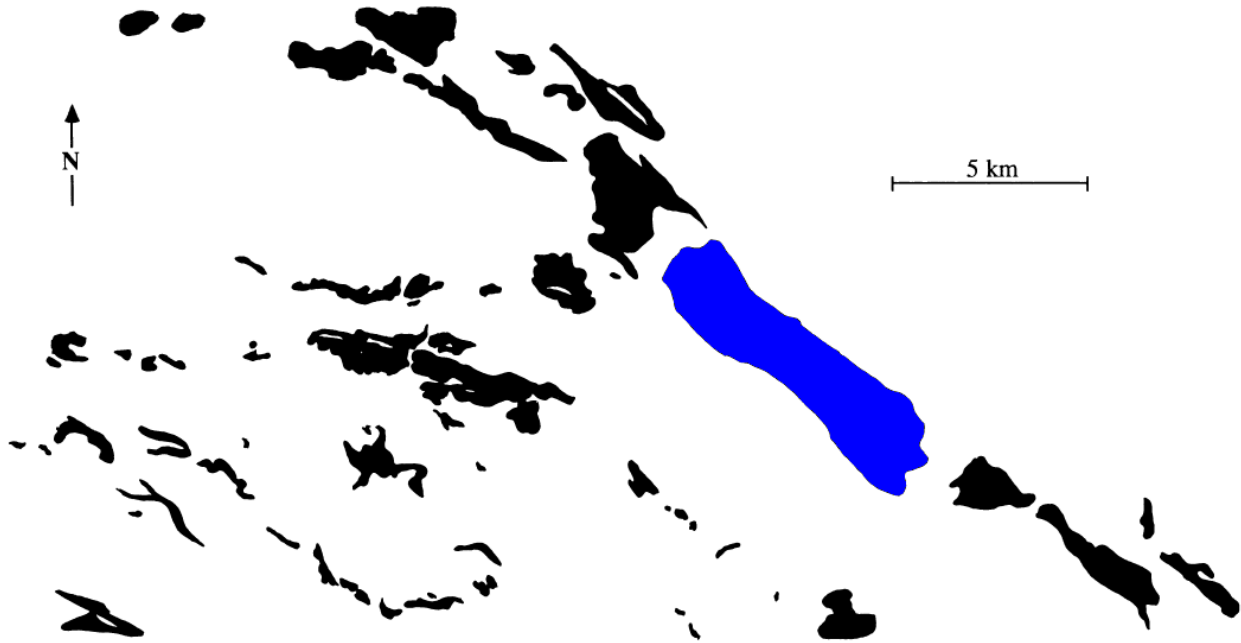


Figure 1: Serpentine outcrops in part of Santa Clara County, California. The blue one is (I think) the outcrop at the Morgan Hill reservoir (modified from [2])

grassland within 5 km of this apparent source, but none were found on more distant patches that appear to be suitable habitat. Immigration rate estimates were derived from a model assuming that

- all satellite populations went extinct during the 1975–1977 drought
- colonists re-establishing populations came from the reservoir population

This analysis suggested that satellite populations were unlikely to be maintained beyond a radius of 7 km, because catastrophic extinction occurs at a higher rate than re-colonization beyond this distance.

Stepping-stone migration among satellite populations contributes relatively little to population persistence because

- Migration *from* satellite populations diminishes their population size, increasing their susceptibility to extinction.

- *Number* of migrants from satellite populations is much smaller (generally) than number of migrants from reservoir population.
- Appears to be an example of “source-sink” population dynamics. Peripheral populations are a demographic sink, but may not contribute to long-term persistence of the species.⁶

Local Extinction

In 1997 the Jasper Ridge population of the bay checkerspot declined to extinction [1]. The discovery of the large population near Morgan Hill in the mid-1980’s made Ehrlich, Murphy, and colleagues believe that they could learn more from watching the Jasper Ridge population decline to extinction than by intervening to prevent its extinction.

In a similar vein, populations of a different subspecies of *Euphydryas editha* underwent a drastic change in the central Sierra Nevada [3]. Clearcutting of the forest in part of Sequoia National Forest in 1967 created artificial meadows that were excellent habitat, and the butterflies switched to a different food plant that was very abundant there, *Collinsia torreyi*.

- Populations in clear-cut areas behaved as source populations.
 - They produced an excess of offspring every year, and some of that excess resulted in migrants to nearby native populations on rock outcrops.
 - Population sizes on outcrops were larger the closer those populations were to clearcut populations.
 - Individual breeding success was poor in outcrop populations.
- During a severe drought in 1992, plants of *C. torreyi* did not survive, but the host plants used by checkerspots in outcrop populations persisted.
- Clear-cut populations of checkerspot declined to extinction, while outcrop populations persisted.

⁶We’ll come back to this in discussing the management recommendations Murphy et al. make.

Conclusions

- Local topography and microclimate have a dramatic impact on population dynamics, but the year-to-year variation in regional climate has a far larger impact.
- Habitat “quality” plays a role in patch occupancy, but patch distance from a large, persistent reservoir population plays a larger role.
 - *Key conservation goal*: protect the habitat areas that supports the reservoir populations in Santa Clara and San Mateo Counties.
- Protection of habitat patches > 7 km from reservoir population may not be necessary, but protection of patches < 7 km is, even though those colonies may be subject to relatively frequent local extinctions. Protection of small, relatively low quality patches close to the reservoir population may be more important than protection of larger, higher quality patches further away.⁷
- Even with three decades of research behind it, much remains to be done for an accurate, predictive model of population dynamics⁸ is available.
 - Successful parameterization of key factors affecting population persistence, but no estimates of variances — particularly difficult when year-to-year variation may be an order of magnitude or more
 - Factors other than topography affect resource availability, but they are poorly understood
 - Metapopulation dynamics are critical, but factors promoting successful colonization and the characteristics of effective dispersal corridors have not been established
- Focusing on genetic or local demographic factors in efforts to preserve populations with high local densities is often a misallocation of effort. Instead
 - Focus on identifying habitat features and resources that determine occupancy.
 - Distinguish between temporarily empty habitat and unsuitable habitat.

⁷Is this assertion actually defensible? There is no evidence that satellite populations contribute to persistence of the reservoir population. If the satellite populations go extinct frequently, should we really be concerned about them? Are they any more than a sink?

⁸Which we supposedly need *before* we can do a population viability analysis.

- Find out why suitable habitat is unoccupied. (Recall that in a true metapopulation model, unoccupied but suitable habitat may be critical to long term persistence of a population.)
- Do we really need a detailed, numerically accurate, predictive model of population dynamics in order to make reasonable conclusions about management right now?

References

- [1] E McGarrah. Much-studied butterfly winks out on {Stanford} preserve. *Science*, 275:479–480, 1997.
- [2] D D Murphy, K E Freas, and S B Weiss. An environment-metapopulation approach to population viability analysis for a threatened invertebrate. *Conservation Biology*, 4:41–51, 1990.
- [3] C D Thomas, M C Singer, and D A Boughton. Catastrophic extinction of population sources in a butterfly metapopulation. *American Naturalist*, 148:957–975, 1996.
- [4] S B Weiss. Cars, cows, and checkerspot butterflies: nitrogen deposition and management of nutrient-poor grasslands for a threatened species. *Conservation Biology*, 13:1476–1486, 1999.

Creative Commons License

These notes are licensed under the Creative Commons Attribution-NonCommercial-ShareAlike License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-sa/3.0/> or send a letter to Creative Commons, 559 Nathan Abbott Way, Stanford, California 94305, USA.