Adaptive management

The role of monitoring in scientific resource management

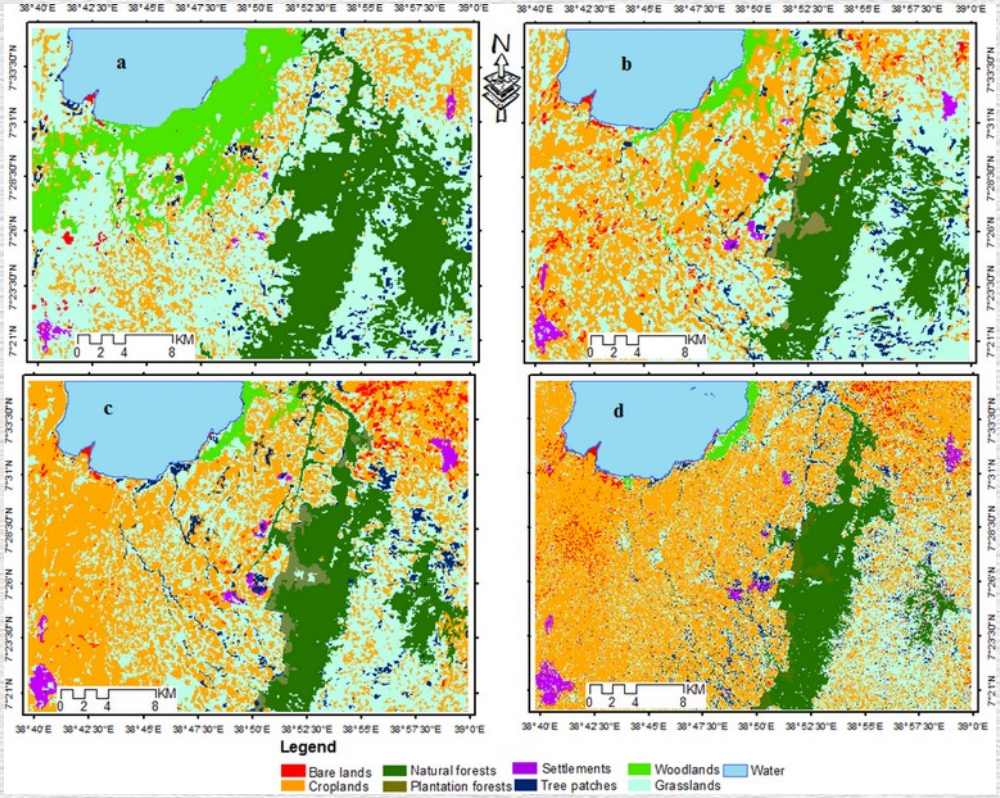
Surveillance monitoring

- Using general-purpose data collection in monitoring
  - Not tailored to a particular purpose
- May be adequate for general-purpose monitoring for change in state over time
  - Detecting unexplained increases or decreases in a species
  - Detecting changes in land cover
- This is generally done to monitor changes in state for a system, for which any change is potentially problematic
  - Endangered species, reduction in forest cover

Examples of surveillance monitoring questions

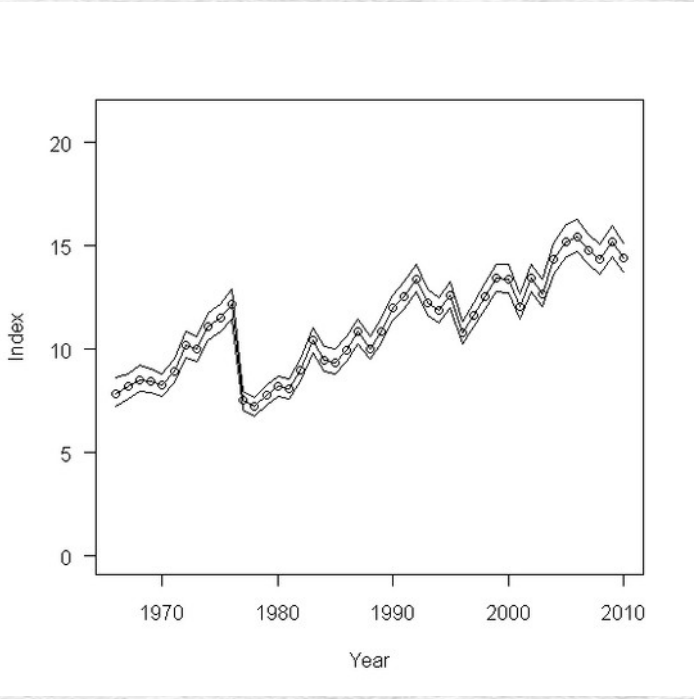
- Populations
  - How big are they?
  - Are they changing in size?
- Communities
  - Are species being lost (reduced species richness)?
  - Are the relative numbers changing (changing composition)?
- Ecosystems
  - Is there a change in energy flow through ecosystems?
  - Is there a change in nutrient cycling within ecosystems?
- Proxies for these
  - Is land cover changing?

Land cover change



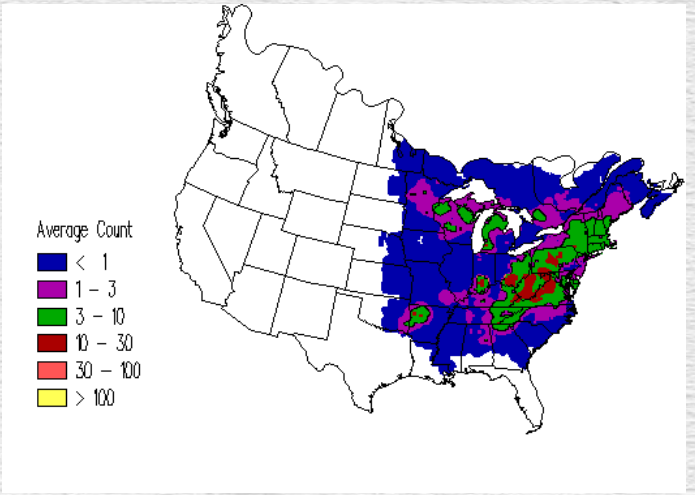
Development and loss of habitat in the Ethiopian Highlands, 1973-2012 (from Kindu et al. 2013)

Breeding Bird Survey

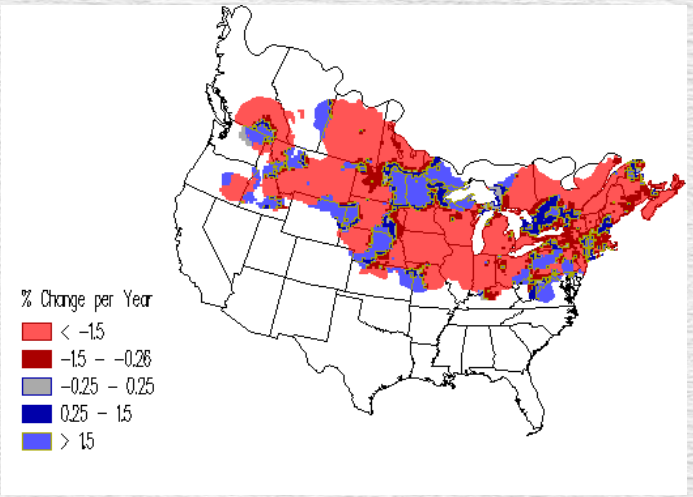


Carolina Wren numbers counted over time

Map of estimated abundance of Scarlet Tanager



Map of change in abundance of Scarlet Tanager



Limitations of surveillance monitoring

- General-purpose data sets can tell you if the measured quantities are changing over time
- But, they don’t tell you why they are changing
- May not detect the problem if you are measuring the wrong thing
- Example: over-fishing
  - Total catch may not decline if you switch from a depleted species to a non-depleted one
  - Size-selective fishing may cause the species to evolve to breed at a smaller size, which reduces productivity

There are often important unknowns

- We may not know the problems
  - Over-fishing plausibly *could* cause species to become smaller, but does it?
- We may know the problems, but not the best way to avoid them
  - How do we maximize effectiveness of controlled burning for habitat management?
  - How do we minimize sedimentation of streams and rivers from timber harvesting?
  - How do we prevent over-harvesting?
- In other words, how do we know if we're doing it right?

The goal: take a scientific approach

- Scientifically study the management practice
- Experiments are the most reliable methods
  - Hypothesize a cause/effect relationship
  - Design a (manipulative) experiment to test it
  - Conduct the experiment
  - Use the results to evaluate the hypothesis
- We would like to have this kind of scientific evidence that what we do is effective, sustainable, non-destructive
- But, this is easier said than done

Problem with experiments

- Scale - many of our management problems are large scale, not amenable to experiment
  - Global climate change – how do you do a manipulative experiment with the atmosphere?
  - Small-scale experiments may be feasible, but may not predict large-scale effects
- It may not be ethically, politically possible to do the work
  - Overfishing: shut down commercial fishing, and randomly assign regions to different levels of harvest – select the level that prevents collapse
  - Habitat management: light experimental fires in wet season and dry season, and see which results in the best post-fire recovery of plants, while burning the fewest houses

Adaptive management

- One possible solution – recognize that management practices themselves are manipulations
- Why not manage in a way in which the outcomes yield better scientific understanding?
- This approach is called adaptive management
  - Designing management so that outcomes yield scientifically reliable data
  - Monitoring the outcomes to generate the data
  - Making changes in management practices based on the findings, if needed

How is this different?

- Scientifically reliable data has to be designed
  - Treatment vs. control is best
  - Before vs. after is possible, but with limitations
- The right data has to be collected
- What constitutes the right data? Depends on the (known) unknowns

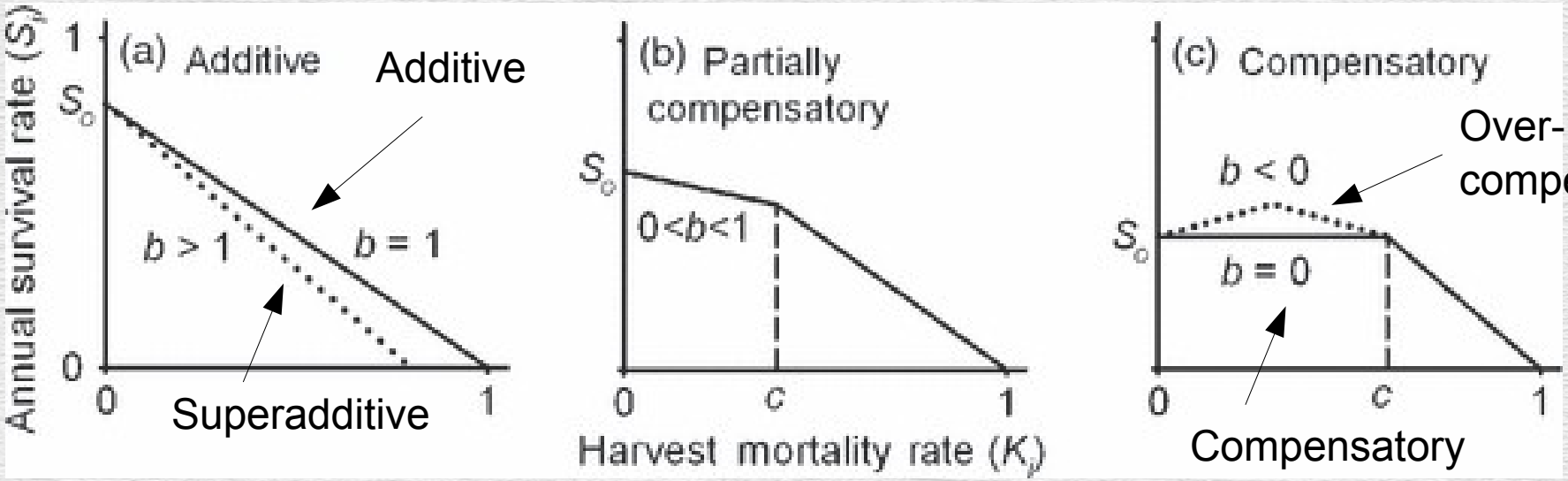
Not easy...example of population change of a harvested species

- Can think of population dynamics as a balance between...
  - Additions = births, immigration
  - Subtractions = deaths, emigration
- Harvesting wild populations causes deaths
- Can you just monitor amount of harvest?

Problem: additive vs. compensatory mortality

- In the absence of harvest, deaths still occur due to old age, disease, predation, starvation, and accidents
- Several of these are “density dependent” = increase in severity as the population density goes up (which?)
- Reduced density due to harvest *decreases* the severity of natural sources of mortality
- The question is, are you just harvesting animals that would have died anyway (compensatory mortality), or are you adding to the mortality that would have occurred (additive)?

Five possible effects of harvest mortality on survival probability



Additive = each harvested animal's death is in addition to natural mortality (S_0)

Superadditive = harvesting causes additional natural mortality (e.g. if social structure is disrupted)

Partially compensatory = little or no effect of harvest below a threshold harvest rate (c), additive above

Compensatory = no reduction in survival due to harvest below c (only take the **doomed surplus**)

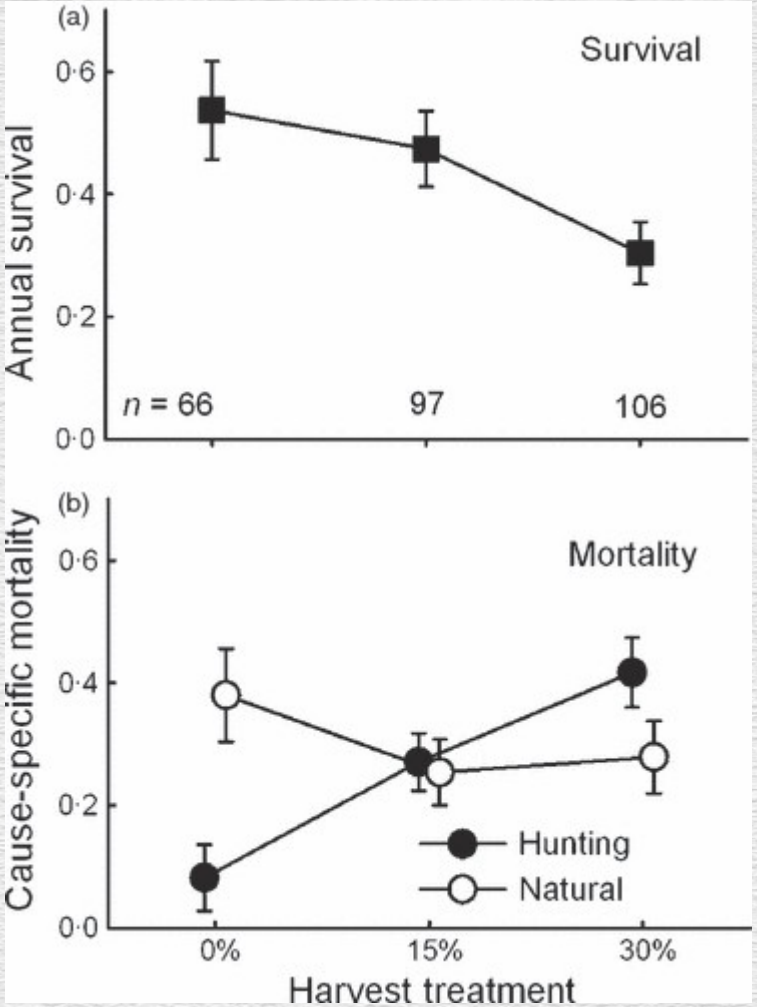
Over-compensation = harvest increases natural survival due to reduction in competition below c

What would the harvest rate tell you?

- If mortality is additive, it tells you how much additional mortality is occurring
- If mortality is superadditive, it under-estimates the amount of reduction in survival
- If mortality is compensatory, partially compensatory, or overcompensatory it depends on whether you are above or below threshold

Experimental test for willow ptarmigan

- Sandercock et al. (2011) experimentally tested which of these models best fit survival data for willow ptarmigan
- Three radio-marked populations established, one at each of three levels of harvest
- Survival over three years was measured
- Found that partially compensatory model fit the data best
- Don't know if this is universal, but it's probably common



Implications...

- Simply monitoring the population size, or the amount of harvest, will not tell you how you are affecting the population
- For most species, the way that hunting mortality affects the population won't be known
- But, if you monitor both hunting mortality and non-hunting mortality, it's possible to tell
- Once known, it's possible to set bag limits at levels that avoid large amounts of additive mortality

Example: mitigation projects

- Several Federal laws require permits from federal regulators for any developments that might affect water quality, wetlands, or sensitive species
- If a project is found to have potential impacts, the regulators can allow the project in exchange for “mitigation”, such as...
  - Restoration of other degraded sites, or creation of new habitat, to replace the lost acreage
  - Donation of land for conservation purposes
- This is a cost to developers, who are trying to maximize profits

Monitoring mitigation projects

- There are two levels of monitoring that should be done:
  - Compliance monitoring = confirming that restoration projects complete the work required under the permit
  - Effectiveness = monitoring over time to determine whether the restoration project continues to function
- Studies of compliance show a lack of monitoring in ~90% of permits
- Follow-up monitoring of mitigation projects is very rare
- When studied, only abut 21% of mitigation wetlands have equivalent function to natural wetlands

Example: San Dieguito River coastal wetlands restoration

- San Dieguito River Park's estuary selected as mitigation for wetlands loss at the San Onofre Nuclear Generation Station (SONGS)
- So. Cal. Edison funded the project
- Started in 2006, completed in 2011, cost of $90mil
- Included:
  - Opening the mouth of the river to tidal flushing
  - Dredging of channel, removal of sediment
  - Creation of wetland habitat (both tidal and non-tidal)

https://vimeo.com/165399650

Post-construction recovery

- At the end of construction, the site still had to recover
  - Lots of bare ground
  - Lacking in aquatic plants
  - Natural re-colonization hadn’t occurred yet
  - Planted areas still needed to grow and fill in
- How do you know when recovery has occurred?

Monitoring recovery

- Need reference sites – relatively undisturbed, naturally tidally influenced, located in So Cal that provide the target conditions
  - Tijuana River estuary
  - Mugu Lagoon
  - Carpinteria salt marsh
- Once the restoration site has the same properties as the reference site, recovery is complete
  - Quantitative criteria for recovery (e.g. within 4 years of construction, total densities and abundance of fish, macro-invertebrates, and birds shall be similar to reference wetlands)
  - Monitored to determine whether these criteria had been met

And what if recovery doesn't occur?

- Monitoring is detailed enough that the problems should be identifiable
  - Water quality?
  - Lack of plant recovery?
  - Problems with hydrology?
  - Invasive exotics?
- Requirement that all criteria satisfied within 10 years
- If not met after 12 years, additional work require to fix the problems detected

Monitoring for change after recovery is complete

- Manage to maintain the open mouth
- Surveillance monitoring of vegetation and animal populations to ensure that conditions don’t degrade over time
- Intervene as needed to maintain conditions