Bat management in San Diego County

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Human activity shapes the landscape

- Anthropogenic activity is reshaping the landscape around the world
- Landscape modification has accelerated in the recent past

Human activity shapes the landscape

- Species respond differently to human activity
  - Some species adapt and thrive
  - Most appear to be detrimentally affected

Bats are adversely affected by human activity

- Worldwide, ~25% of bat species threatened by anthropogenic disturbance
- Bats are threatened by:
  - Poor quality habitat
  - Recreational activities
  - Land development
  - Roosts that occur on unprotected land

Elevated bat species diversity in California

- 41 bat species occur in the United States
  - 25 species occur in California
  - 22 species occur San Diego County
    - 16 are on conservation watchlists
- The human population in San Diego County is rapidly increasing

Bats provide important ecosystem services

- Insect population control (including agricultural pests)
- Pollination and dispersal
  - 33% of bat species are fruit or nectar-feeding
- Indicator species for cave biodiversity
  - Provide organic nutrients to cave ecosystems (guano)



Bats occupy vast areas of the landscape

- Roosts
  - Caves, rock crevices, old buildings, bridges, mines, trees
- Habitats
  - Deserts, woodlands, scrub, foothills, suburbs, cities, forests
  - Generally prefer warmer temperatures

How do we conserve bats affected by human land use?

- One-size fits all management is not always effective
- Conservation action should be more regionally coordinated
- Bats utilize different parts of the landscape

Management is more difficult for bats

- Management is difficult for elusive species such as bats
  - Unlikely to sample every species in every population across a region
  - How can management compensate for this?

San Diego County is a hotspot for North American bats

How can we strategize and prioritize areas across San Diego County for conservation?

Objectives

How much sampling is required to adequately sample bats, a cryptic group of species?

Objectives

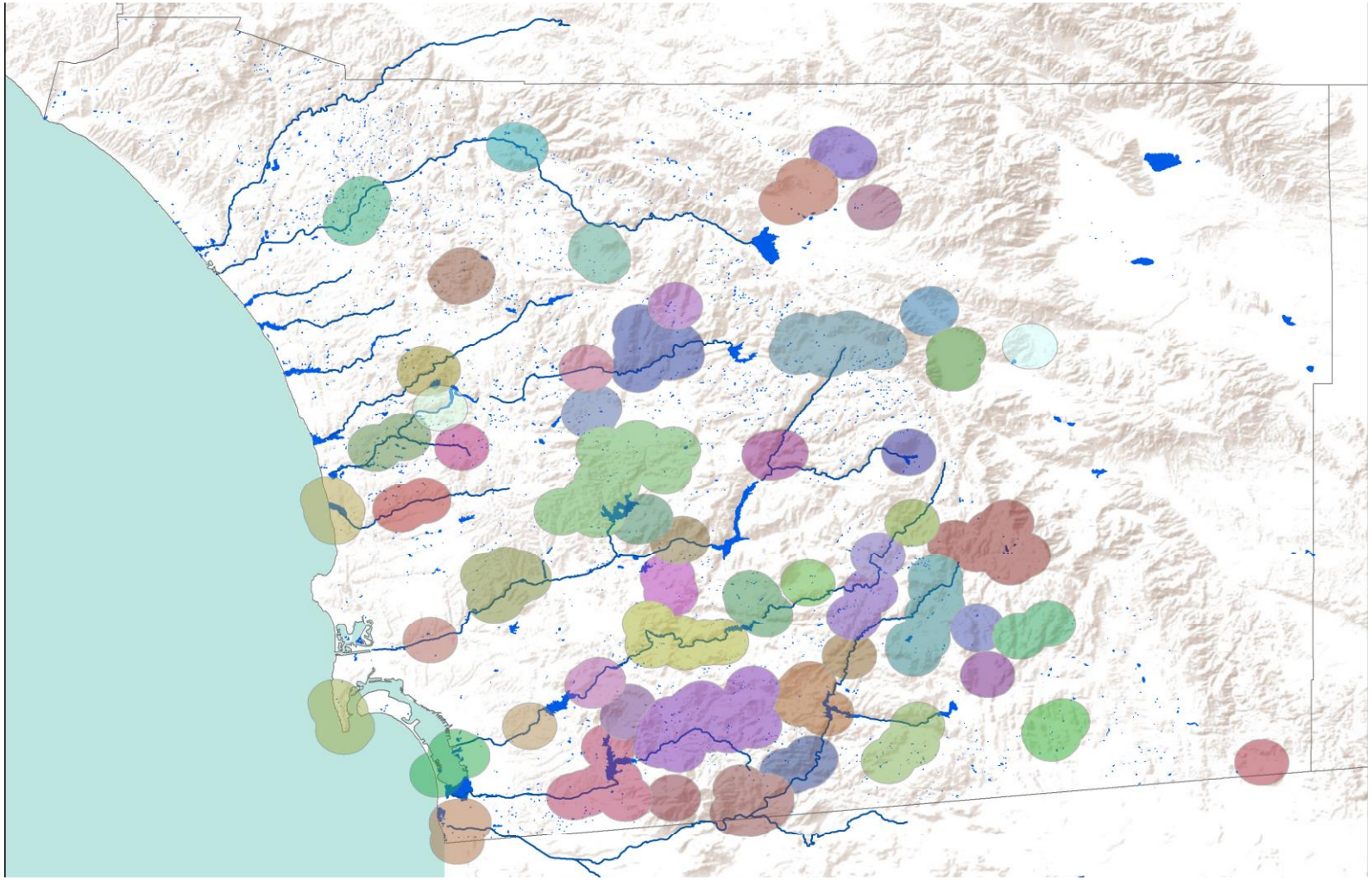
Are any threats that bats face disproportionately associated with species richness?

Objectives

How do we prioritize sampling sites based on species richness and the threats bats face?

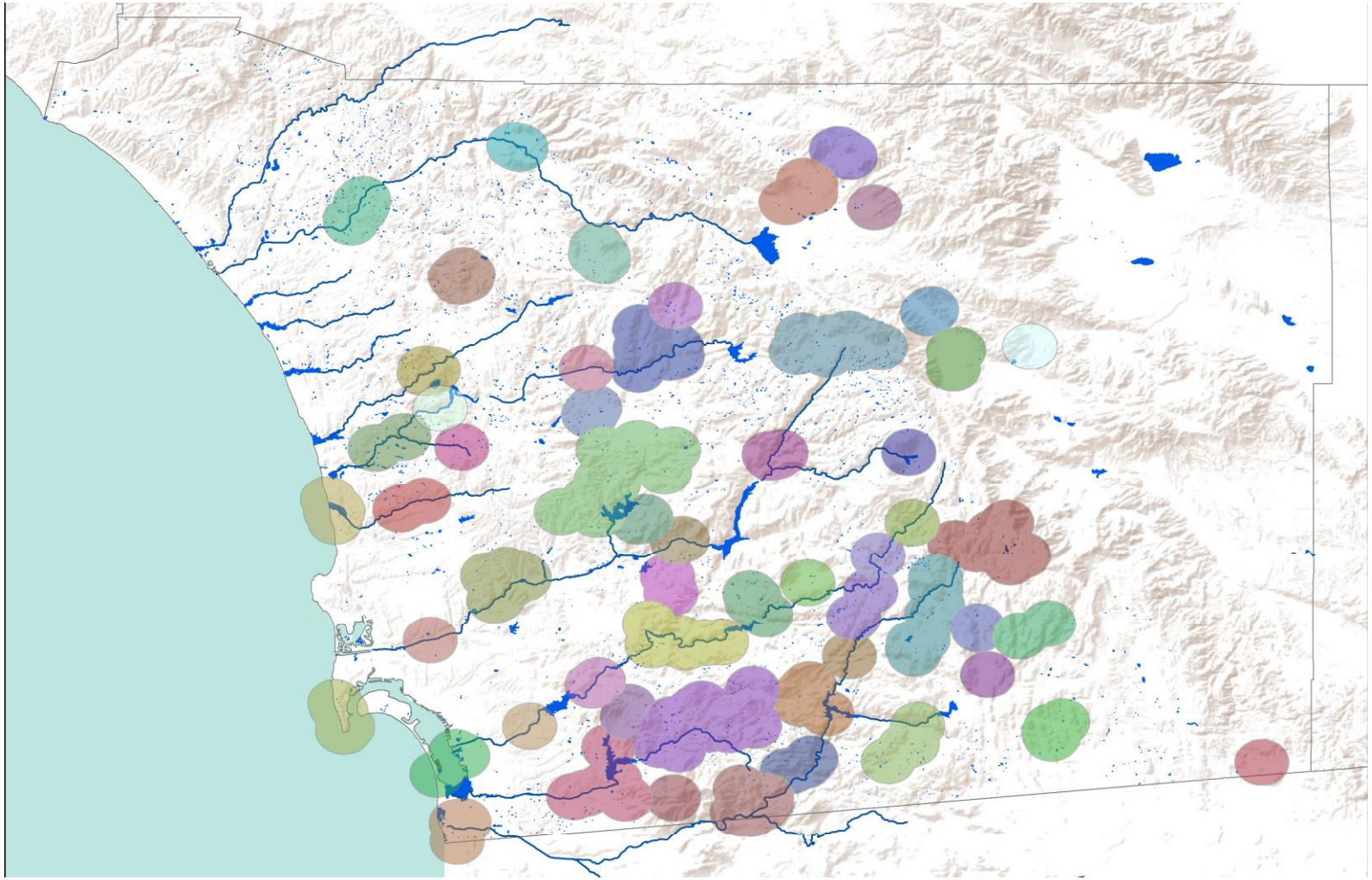
Sampling

- Occurred from 2002-2019
  - 156 sampling sites
  - Roosting + foraging sites
- Diverse habitat
  - Oak woodland
  - Forest
  - Coastal sage scrub
  - Desert



Sampling

- Data collection methods
  - ANABAT bat detector
  - Day roost surveys/exit counts
  - Night roost surveys
  - Mist netting
  - The unaided ear



All data treated as presence/absence

How much sampling is required to adequately sample bats, a cryptic group of species?

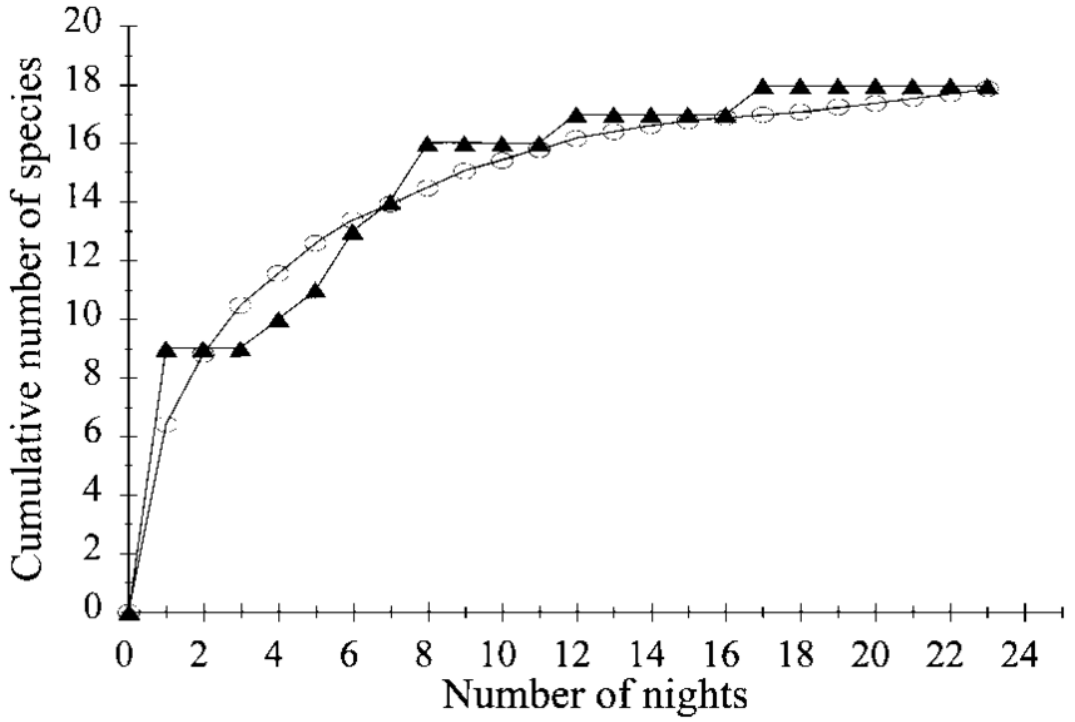
Quantifying richness of cryptic species

- Difficult to identify all bats in an area given limited sampling
- Survey effort was uneven
  - Sites ranged from 1 survey to over 30 surveys

- How can we extrapolate how many species occur in an area despite under sampling?
- How do we know when we have achieved adequate survey effort for a sampling site?

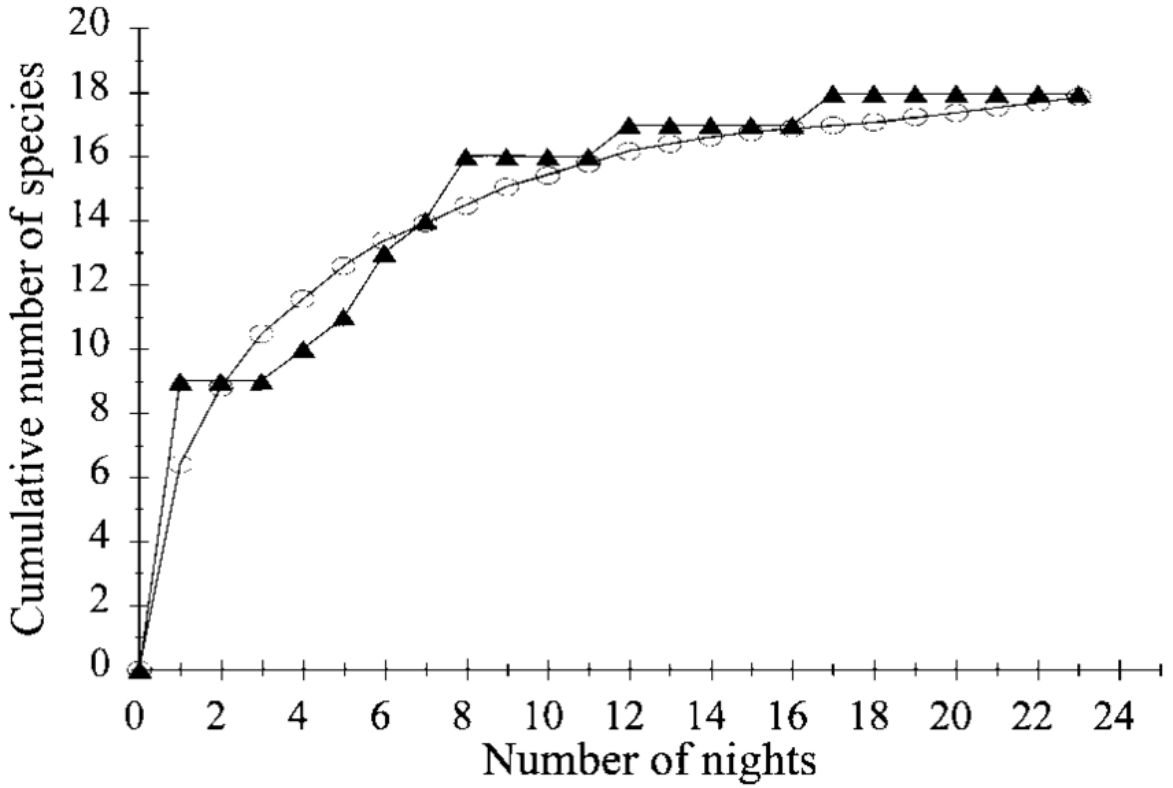
Species accumulation curves

- Give the expected number of observed species as a function of sampling effort
- When the slope of the curve reaches 0, an area is fully sampled



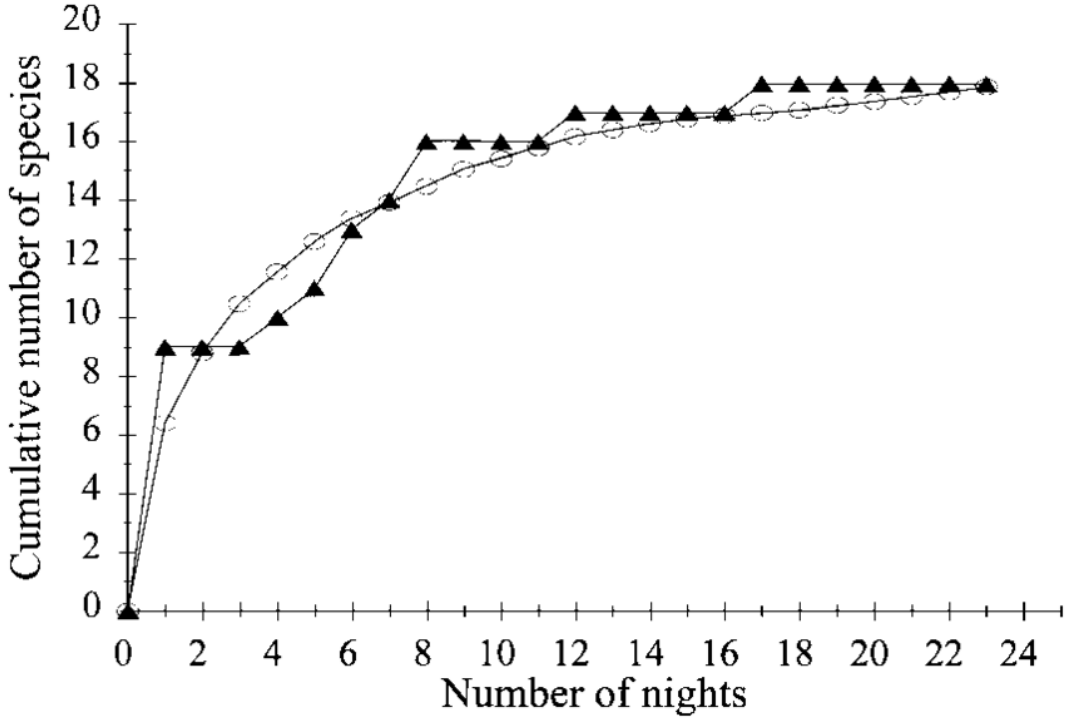
Species accumulation curves

- For curves that flatten, generally, after how many surveys do they flatten?



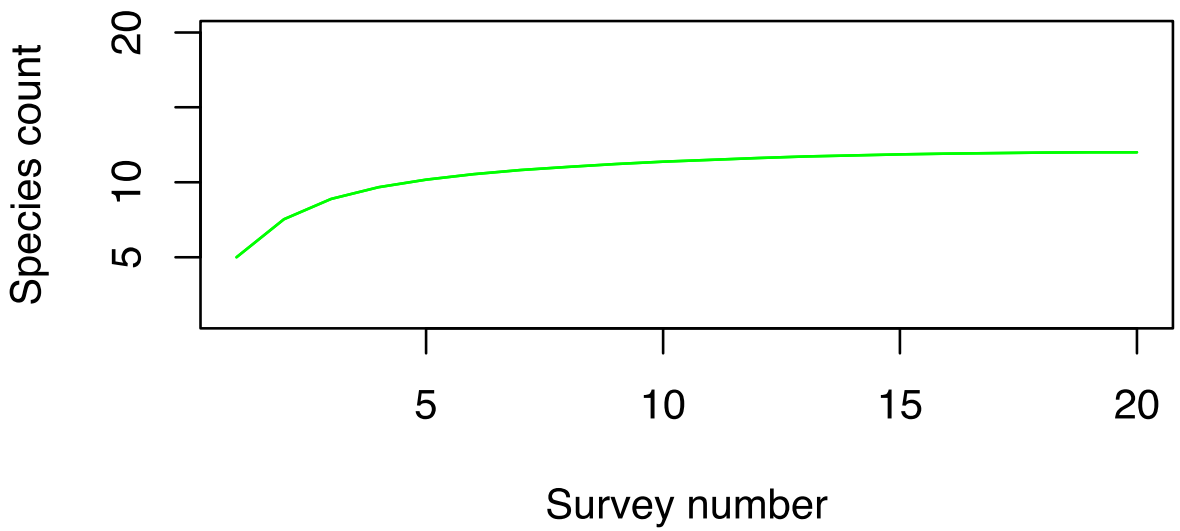
Uneven sampling

- How can we identify undersampled sites?
- How many species actually occur at each site?

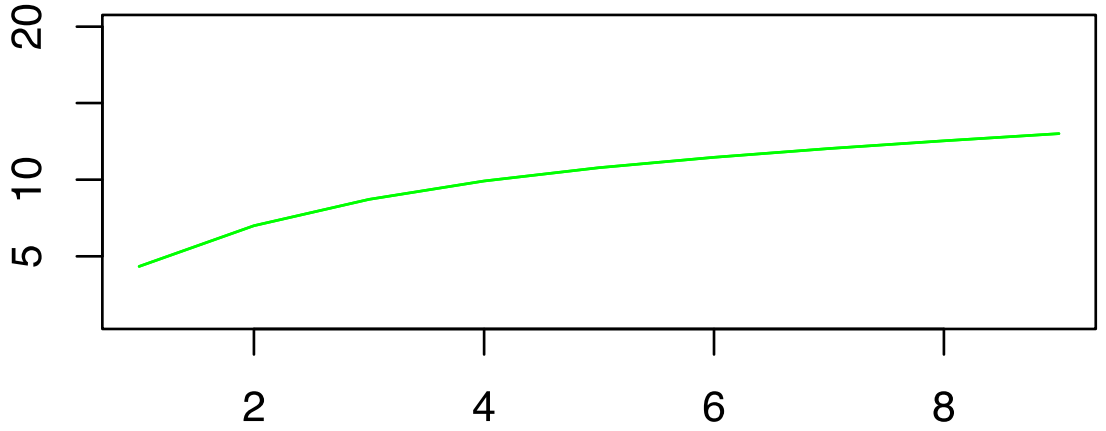


If 90% of the species that are predicted to occur at a site were sampled, the site was considered fully sampled, and retained for further analysis

Species accumulation curves



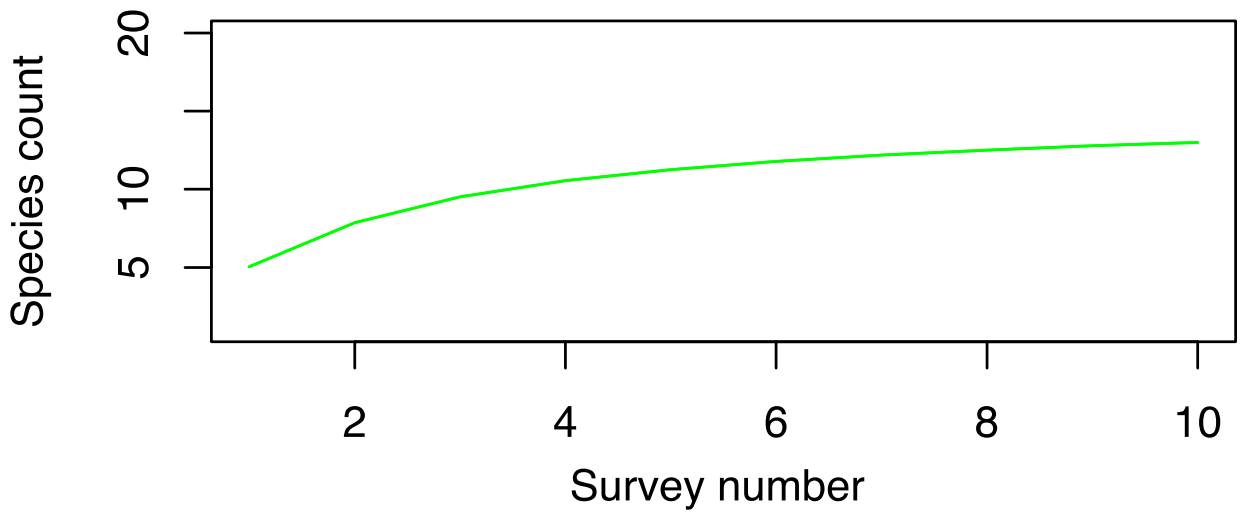
Ramona Grasslands



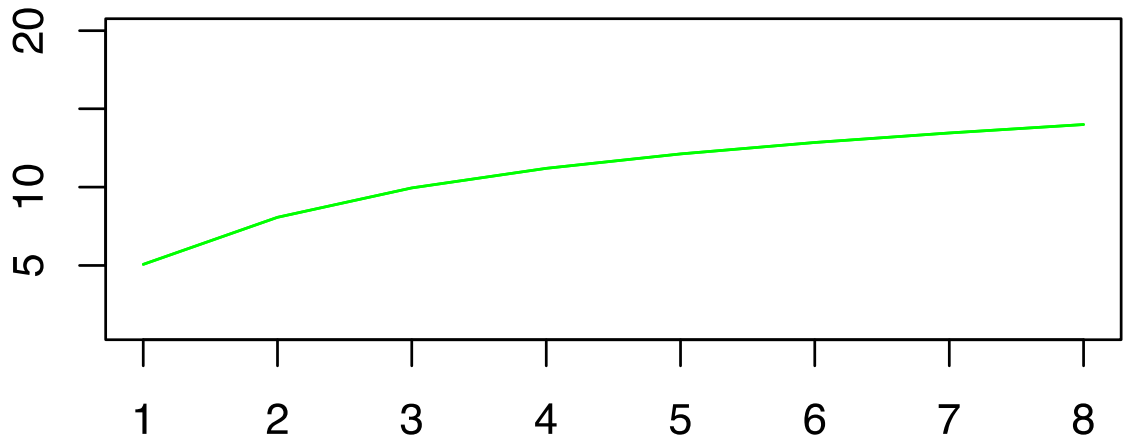
Long Potrero

Sampling site	#Surveys	#Species observed	#Species present (Chao)	%Sampled
Ramona Grasslands	20	12	12	100
Long Potrero	9	13	17	76

Species accumulation curves



Laguna Ranch



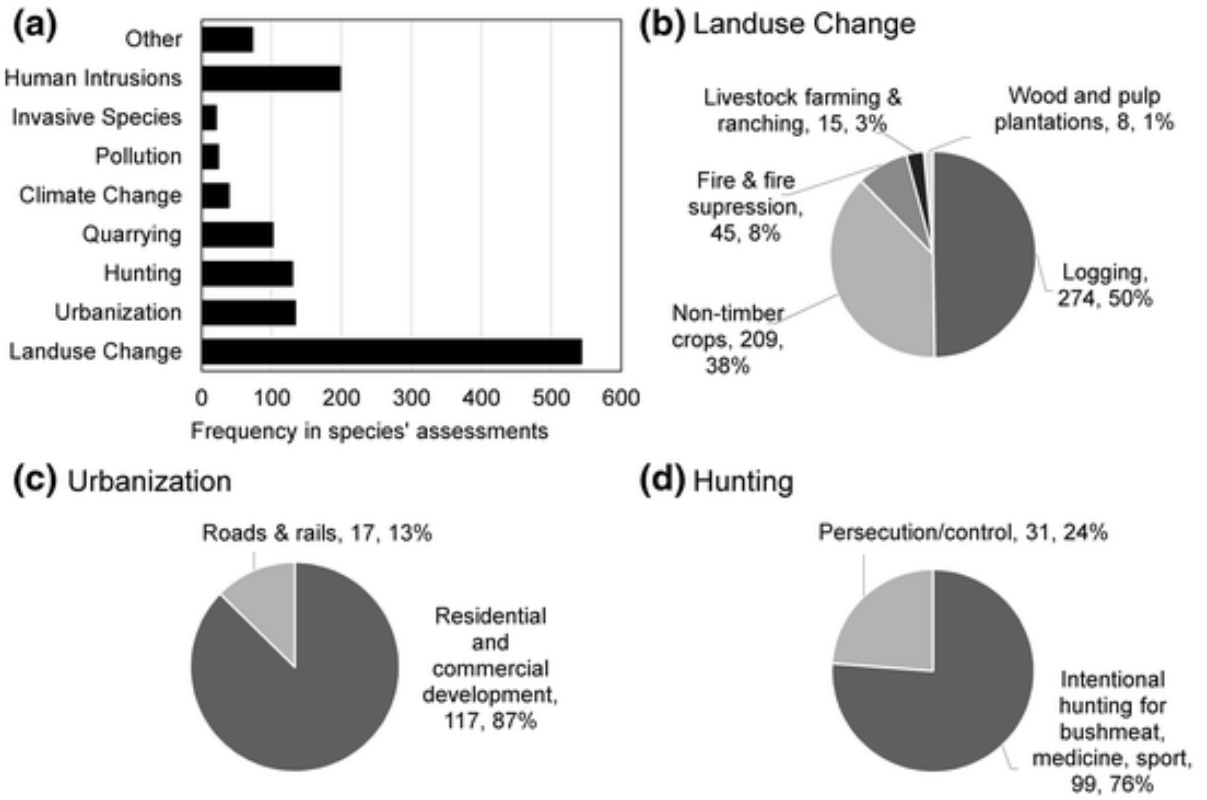
San Felipe II

Sampling site	#Surveys	#Species observed	#Species present (Chao)	%Sampled
Laguna Ranch	10	9	10	90
San Felipe II	8	14	18	78

Are any threats that bats face disproportionately associated with species richness?

Threats to bat biodiversity

- Threats to bats are numerous and well-documented
- Threats are predominantly linked to human activity



Frequency of threats listed in the IUCN assessments of bat species. **a** Distribution of major threats across assessments. Land use changes, urbanization. and hunting are aggregations of IUCN listed threats given in **b**–**d**. Frequency of threat and percentage contribution are given (Voight and Kingston 2015)

How can we rank threats in order of potential effects on bats at localized spatial scales?

Threats to bat biodiversity

- A cohesive management plan for bats is needed
- Threats to foraging areas
- Threats to roosting habitat

Foraging threats

- Artificial lights
- Pesticide use
- Recreational activity
- Urbanization
- Poor quality habitat
- Lack of open water

Roosting threats

- Human visitation (public)
- Human visitation (maintenance)
- Roost structure
- Roost on unconserved land
- Roost unknown to land owner
- Cave modification

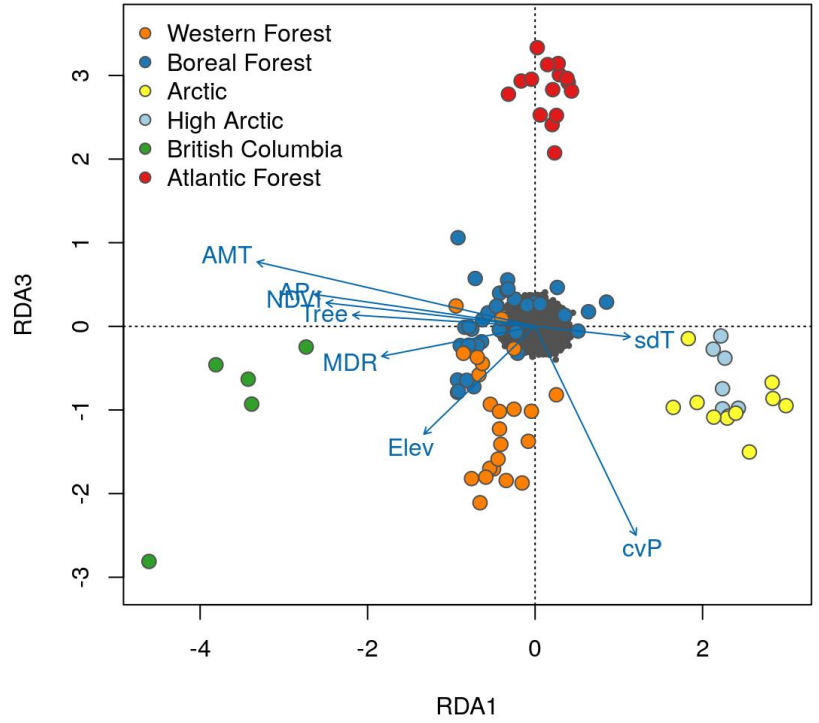
Which sampling metrics influence species richness the most?

- Variability in sampling probably affects species detection
  - Sampling effort
  - Survey time period

- Which sampling variables affect species detection the most?

Redundancy analysis (RDA)

- Identifies the variables that influence presence/absence of bat species
- Which threats are associated with species richness?
- Which sampling metrics are associated with richness?



RDA variables: threats to bats

- Input
  - Values for each threat
  - Sampling metrics
    - Sampling effort: how many surveys were done for each site?
    - Time period: did the surveys occur from 2000-2009 or from 2010-2020?

- Species most affected by a specific metric will align more closely to its axis

How do we prioritize sampling sites based on species richness and the threats bats face?

Prioritizing sampling areas in San Diego County

- We will know which sites have been adequately sampled (and should be included in the dataset)
  - And which sites require further sampling
- We will know how different variables affect the presence/absence of species

- How do we use this information to best identify areas of high management need?

Scoring of sampling sites: threats

- Threat scores
- Based on landscape threats and the potential for human disturbance
- Scored from 1 to 3 (from least to most severe)

Scoring of sampling sites: richness

- Conservation status + species richness = species score
  - 1 point for every species detected
  - 1 additional point for each species listed as a CDFW Species of Special Concern

Prioritizing sampling areas in San Diego County

- How we will rank each sampling site
  - Highest priority areas: high species scores with high threat scores
  - Lowest priority areas: low species scores with low threat scores
  - Only sites that were adequately sampled (90% of species sampled according to species accumulation curves) will be included

Conservation categories

- Each sampling site will be placed in 1 of 4 quadrants on a scatterplot based on its score
- The median of species score will divide quadrants vertically
- The median of foraging threat scores will divide quadrants horizontally
- Four categories based on conservation priority:
  - 1: high species score, high threat score
  - 2: high species score, low threat score
  - 3: low species score, high threat score
  - 4: low species score, low threat score

Scoring for a fictional sampling site

A

Species present:
Pallid bat[SSC]
Yuma myotis
Hoary bat
Pocketed free-tailed bat[SSC]
Mexican free-tailed bat

Richness score:
1
1
1
1
1

Conservation status score:
1
0
0
1
0

Species score:
1 + 1 = 2
1 + 0 = 1
1 + 0 = 1
1 + 1 = 2
1 + 0 = 1
Total = 7

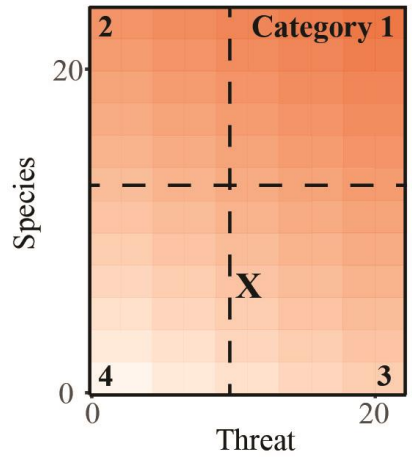
B

Foraging threat score (8):
Lack of open water (3)
Urbanization (2)
Poor quality habitat (3)

Roosting threat score (6):
Human visitation: public (2)
Roost structure (3)
Cave modification (1)

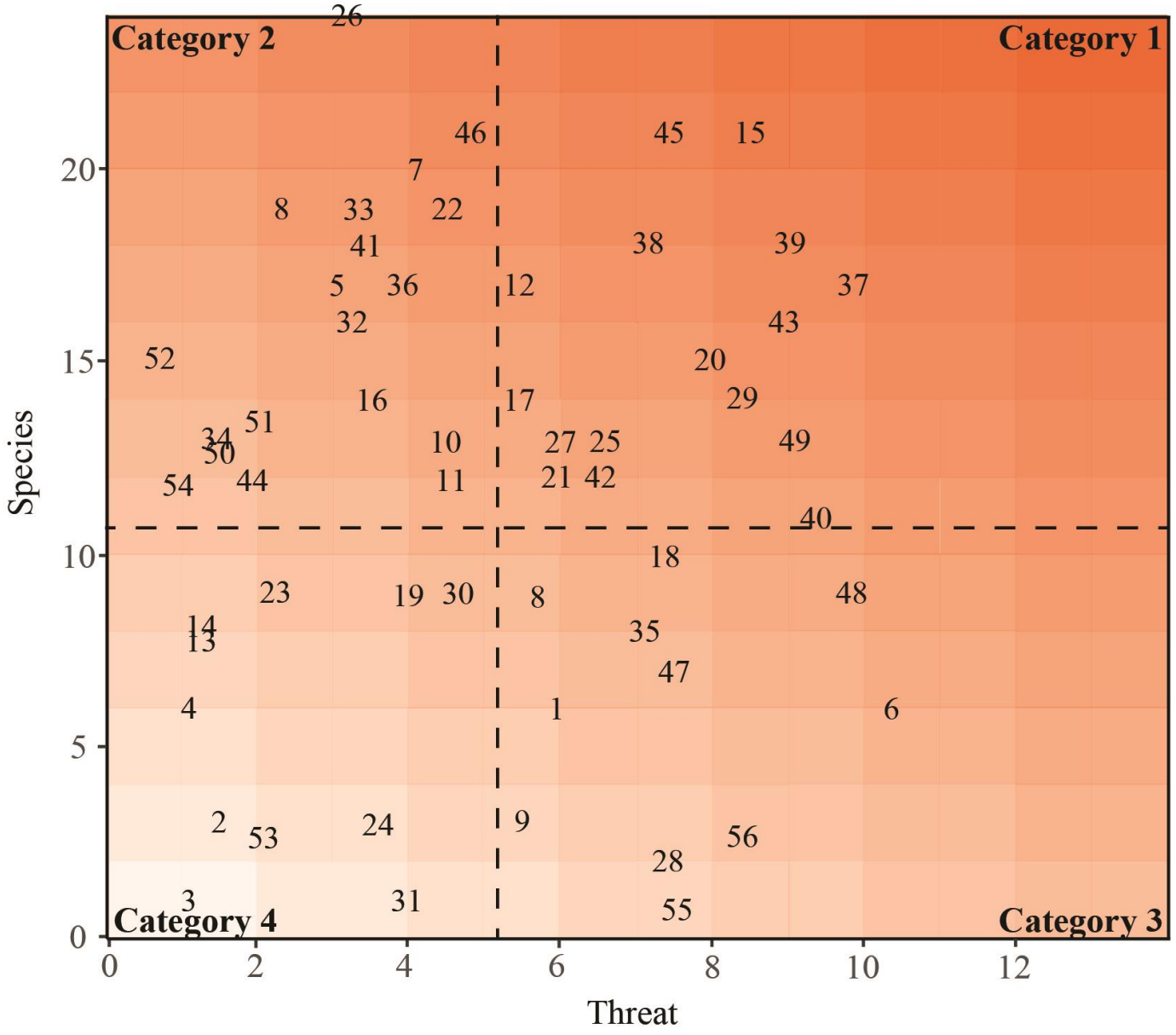
Threat score:
Foraging (8) + Roosting (6) = 14

C



Conservation category:
Species score (7)
Foraging threat score (8)
Category 3

Conservation categories



Townsend's big-eared and pallid bat

- Pallid bat (*Antrozous pallidus*) and Townsend's big-eared bat (*Corynorhinus townsendi*) are of elevated concern in the county
  - Both are CDFW Species of Special Concern
  - Both species are roost-limited
  - Hypothesized to be sensitive to urbanization

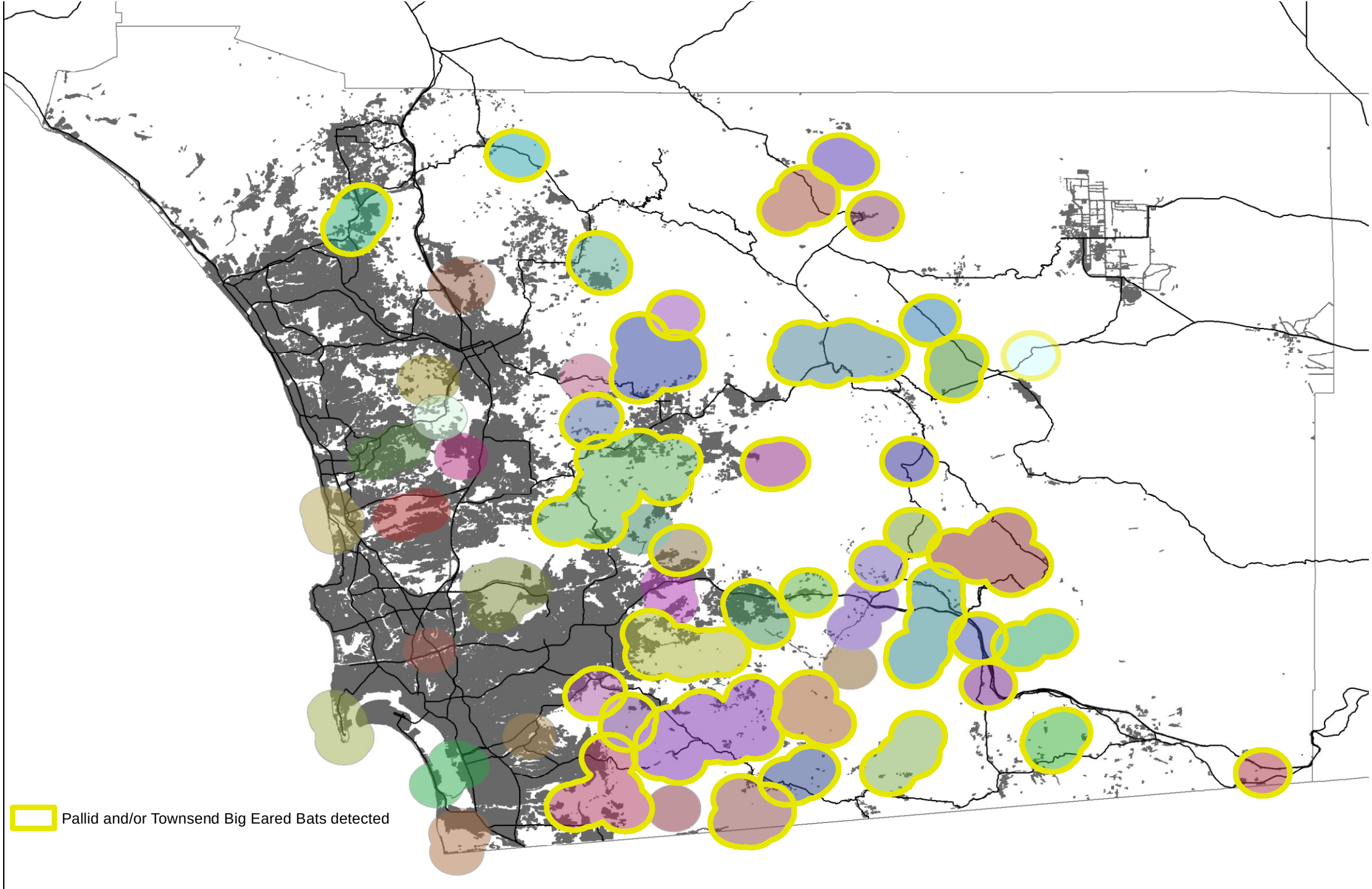
Townsend's big-eared and pallid bat

- At least one of these species observed in over 50% of sampling sites
- When these species are absent from a site, is their absence associated with high urbanization?
  - Two-sample t-test assuming unequal variance

Townsend's big-eared and pallid bat

- At least one of these species observed in over 50% of sampling sites
- When these species are absent from a site, is their absence associated with high urbanization?

Yes ($P < 0.05$)


Pallid and/or Townsend Big Eared Bats detected

Roosting threat mitigation strategies

- Human visitation (public)
  - Installation of bat gates at cave and tunnel entrance areas.
- Human visitation (maintenance)
  - Communication of roost locations with groups that might require cave access
- Roost structure
  - Modify to make fire-proof and away from the public; accommodate day and night roosting bats

Roosting threat mitigation strategies

- Roost on unconserved land
  - Construction of an artificial roost on conserved land
- Roost unknown to land owner
  - Educate staff to reduce or eliminate disturbance to roosting bats
- Cave modification
  - Protect cave entrance areas from modification when roosting bats are present.

Foraging threat mitigation strategies

- Artificial lights
  - Removal of artificial lights from areas inhabited by bats
- Urbanization
  - Conserve lands in lesser-developed areas or enact mitigation measures such as development of riparian habitat
- Pesticide use
  - In-depth study of the effects of insect control (and the chemicals used) on bats, and explicit testing of the hypothesis that pesticide use lowers food availability and quality

Foraging threat mitigation strategies

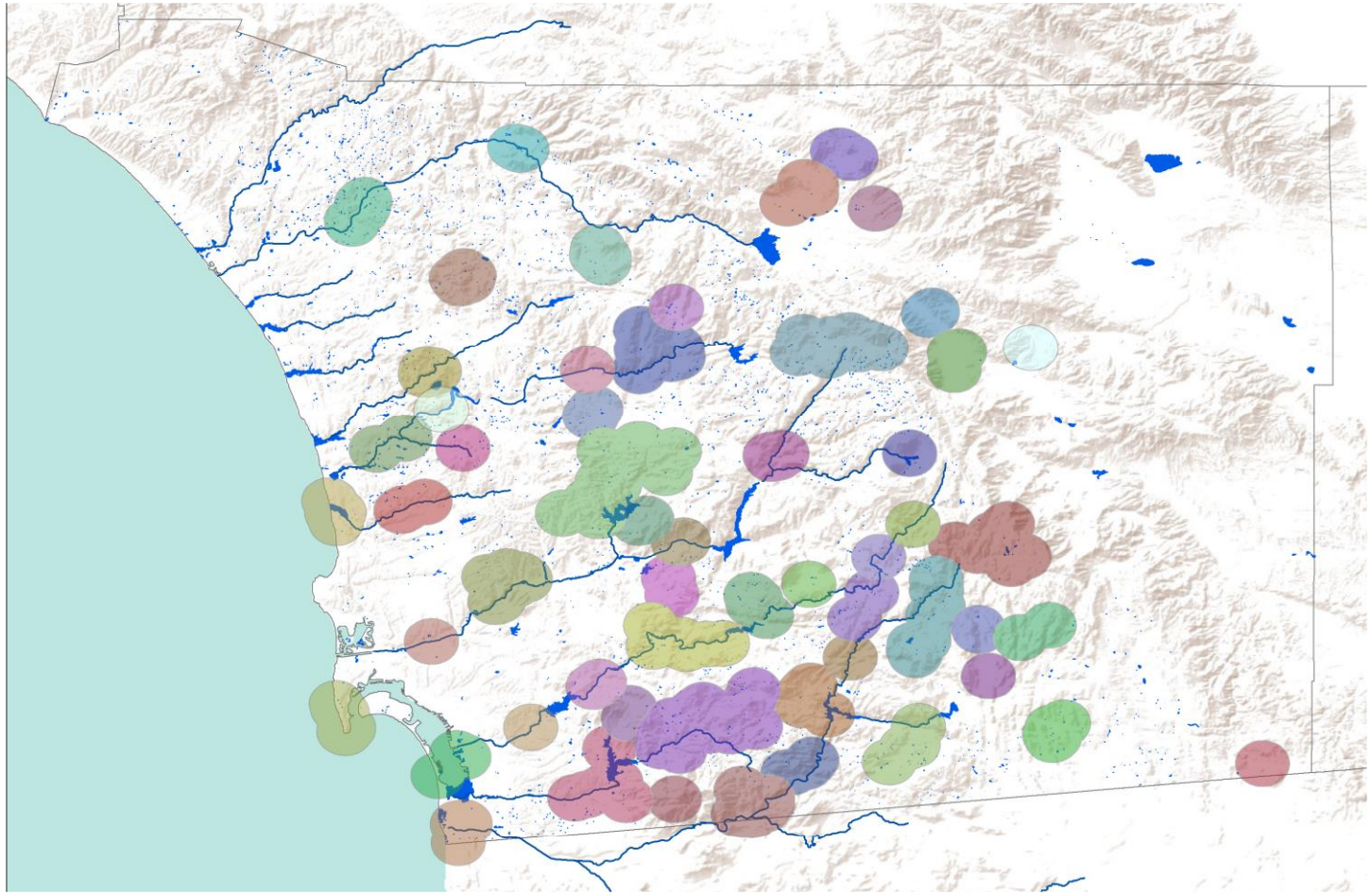
- Poor quality habitat
  - Elimination of exotic plants, restoration of native vegetation
- Lack of open water
  - Construction of a permanent water source where it is lacking

Prioritization of conservation needs

- Complex conservation issues require a more regional approach, where the most pressing conservation needs might vary across geographic space
- Must quantify which threats require the most urgent conservation action across sampling sites
- Management can choose how to take specific action based on feasibility, as determined at the local level

Future directions

- Address gaps in sampling
- Address under sampled sites
  - Need reliable estimates of how many (and which) species occur at sites
- Provide a cohesive report for conservation of the San Diego County bat community



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Acknowledgments

- Kevin Burns, SDSU
- Emily Perkins, USGS
- Carlton Rochester, USGS