Relevance of Occupancy to Ecology and Conservation: Camera-trap Emphasis

Camera-traps and Occupancy: Brief History

- Initial uses were to obtain photos of secretive and rare species

- Subsequent use was to document presence of secretive/rare species
  - Related to occupancy questions
  - But occupancy approaches had not been developed

- Then used to estimate abundance of individually identifiable critters using capture-recapture approaches Karanth (1995)

Camera-traps and Occupancy: Brief History

- Initial camera-trap designs focused on abundance estimation, usually for big cats
- But these traps obtained many photos of other species, most of which were not individually identifiable, causing investigators to consider occupancy modeling for such data
- Much of interest in occupancy for CT data based on non-focal species

Camera-traps and Occupancy: Brief History

- CT studies for abundance estimation frequently use fairly dense deployment of CTs over areas that are not extensive

- So use of occupancy models for non-focal species in CT studies is not always ideal:
  - Sampling (e.g., CT placement) focused on other species
  - Smallish areas

Camera-traps and Occupancy: Brief History

- Some CT studies have been designed with occupancy in mind

- Some studies rely on sign or observation for most species but deploy CTs for rare/secretive species

- CT deployment at subset of sample units useful in false positive modeling

Classes of Ecological Questions: Single Species

- Geographic range.
- Habitat relationships and resource selection.
- Metapopulation dynamics.
- Large-scale monitoring.
- Conservation.
- Epidemiology.
- Paleobiology.

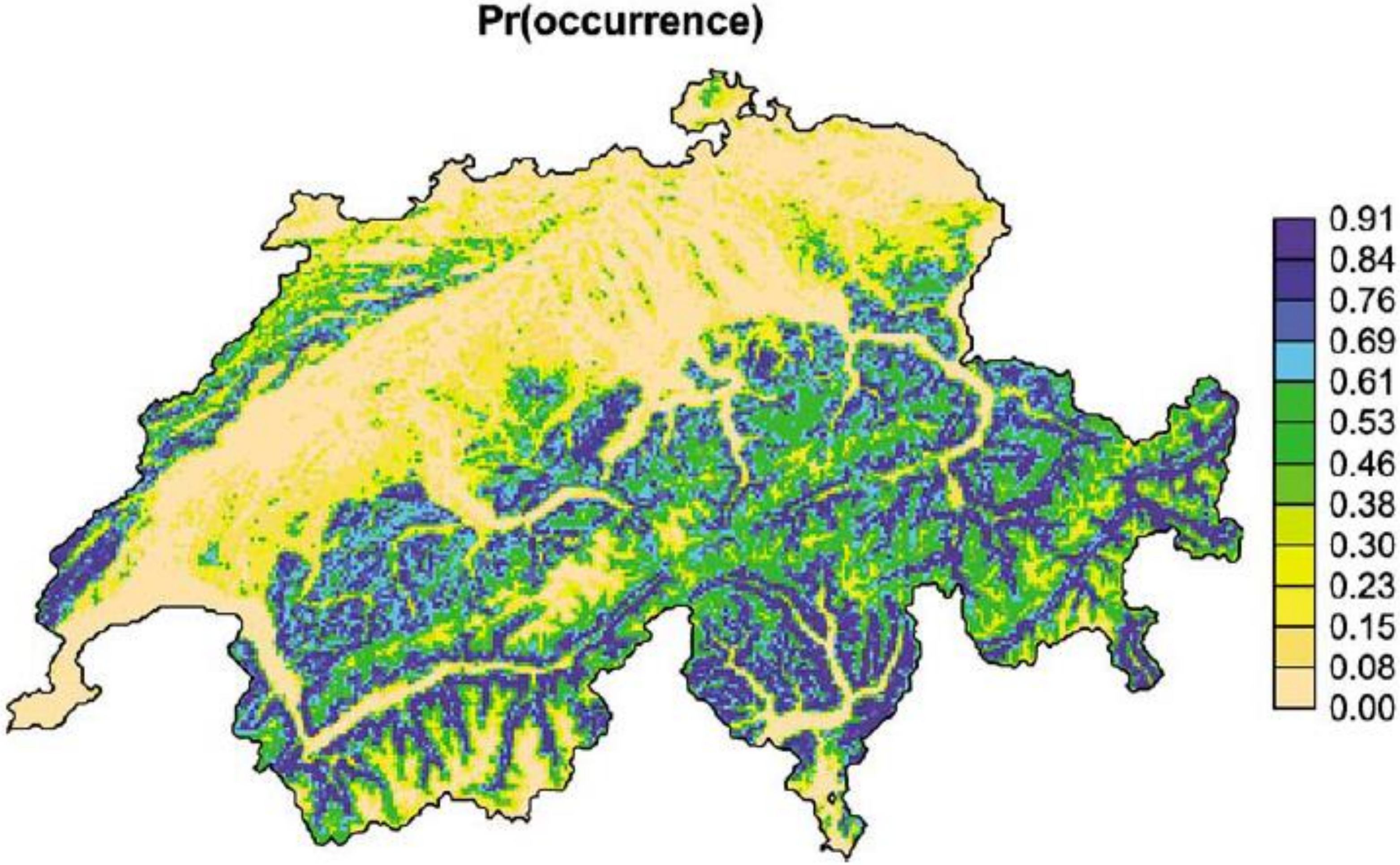
Geographic Range

- Ecology: the study of the distribution and abundance of organisms (Elton 1927; Andrewartha and Birch 1954).
- Range:
  - the primary element of the distributional component of ecology (Brown et al 1996).
  - the basic unit of biogeography (MacArthur 1972).
  - lots of recent attention with interest in macroecology (Brown and Maurer 1989, Brown 1995, Rosenzweig 1995, Gaston and Blackburn 2000).

Geographic Range: Definitions/Approaches

- Extent of occurrence:
  - Line enclosing "minimal" area containing all individuals of a species.
  - Dependent on scale and how jagged boundary may be.
- Area of occupancy
  - Superimpose grid over area containing all animals.
  - Range is set of occupied cells.
  - Dependent on scale and grid size.
- "Extent" may include central unoccupied grid cells; "Area" does not.
- Both approaches are based on occupancy and exhibit problems in the face of nondetection.

Geographic range: willow tit in Switzerland



Geographic Range: Ecological Hypotheses and Relationships

- Range size vs.
  - abundance/density
  - body size
  - dispersal capability
  - latitude
  - elevation
- Range shape
- Position within range vs.
  - abundance/density
  - probabilities of extinction/colonization
  - temporal variation in occupancy dynamics
- Range dynamics

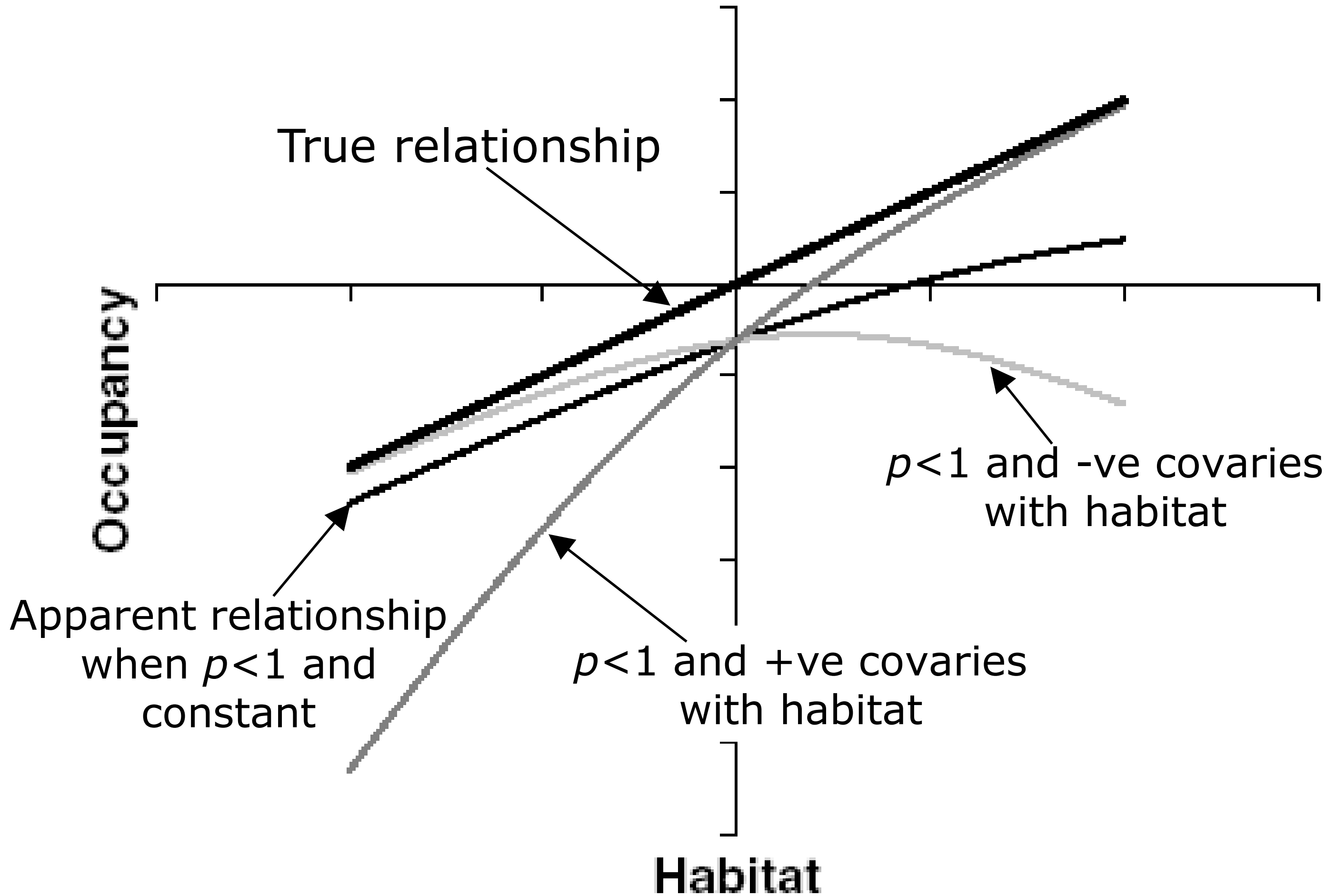
Habitat Relationships and Resource Selection

- Model occupancy as function of habitat covariates.
- Predict species occurrence from habitat data (Scott et al. 2002).
- Resource selection and relative use of different types of resource units (Manly et al. 2002).
- Detection probabilities are important, especially when they are also related to habitat covariates and resource units.

Habitat Relationships and Resource Selection

- Resource selection functions (RSF) are relative measures of use.
- Resource selection probability functions (RSPF) are absolute measures of use.
  - essentially standardized RSF's
- Occupancy models are RSPF's corrected for imperfect detection.

Habitat Relationships and Resource Selection



Habitat Relationships and Resource Selection

Example: Mahoenui Giant Weta

- Naïve logistic regression:

$$\text{logit}\left(\psi_i\right) = -0.50 + 0.90 \times Browse_i$$

- From occupancy modelling

$$\text{logit}\left(\psi_i\right) = 0.02 + 1.17 \times Browse_i$$

Metapopulation Dynamics: Single Season Occupancy Data

- Incidence functions used to estimate probabilities of patch extinction and colonization, assuming a stationary Markov process and relationships between:
  - Extinction and patch size
  - Colonization and patch isolation
- Even when relationships exist, this pattern-based estimation yields biased estimates when detection probabilities <1.

Metapopulation Dynamics: Multiple Season Occupancy Data

- Used for direct estimation of probabilities of local extinction and colonization.
- When detection probabilities <1:
  - Estimated Pr(extinction): positive bias.
  - Estimated Pr(colonization): bias can be positive or negative.

Metapopulation Dynamics: Interesting Ecological Hypotheses

- Commonly assumed relationships can be modeled and tested.
  - Pr(extinction) vs. patch size (patch isolation).
  - Pr(colonization) vs. patch isolation (connectivity, distance from source populations, matrix habitat, etc.).
- Inferences about "extinction thresholds" and "minimum viable metapopulations".
  - Pr(extinction) = *f*(proportion of habitat that is suitable)
- Asymptotics.
  - Equilibrium occupancy:

$$\psi_{eq} = \frac{\gamma}{\gamma + \varepsilon}$$

Large-scale Monitoring

- Basic ideas:
  - Abundance estimation can be too expensive of funds and effort to use in geographically extensive monitoring.
  - Occupancy estimation is usually less expensive and well-suited for extensive surveys.
  - Territorial species with sample unit = territory size: occupancy ≈ abundance (many caveats).
- Example programs:
  - Amphibian monitoring (USGS ARMI program).
  - Spotted owls.
  - Marbled murrelets.
  - Mid-sized carnivores.
  - Insects (NZ weta).

Conservation

- Criteria for “threatened” and “endangered” listing.
  - Degree of fragmentation or isolation.
  - Range size.
  - Rate of change in range size and occupancy.
- Extinction threshold
  - probability of extinction as function of proportion of habitat that is suitable.

Epidemiology

- Spatial modelling
  - Replicates within an area are individuals checked for disease.
- Model geographic disease spread
  - Discrete approximation of diffusion model.
  - Colonization at t+1= f(disease state of neighbouring locations at t).
- Different scale
  - If disease detection for an individual is not perfect, then treat individuals as patches and estimate disease prevalence and dynamics with replicate tests for individuals.

Paleobiology

- Assessing the range of extinct species at certain points in geologic time.
- Often interested in changes in range through time.
- Sometimes changes in community pool is of interest.

Classes of Ecological Questions: Multiple Species

- 2-species:
  - 1 season: independence vs. contagion vs. segregation (species interactions).
  - multiple seasons: do extinction or colonization of species 1 depend on presence of species 2?
- Multiple species:
  - Species interactions.
  - Nested subsets.
  - Local extinction/colonization dynamics, *f*(stuff).

2-Species, 1-Season: Tests for Independence

- Species presence-absence data.
- Simple case with 2 species and s sites
- No replication, species 1 and 2, 4 possible detection histories (e.g., Forbes 1907):

12	10
02	00

- Use data to test for independence vs. aggregation or segregation.
- Problems occur when 0 can reflect nondetection.

Multiple Species

- Species interactions: single season
  - Based on species co-occurrence or incidence matrices (e.g., species presence-absence on archipelagos).
  - “Assembly Rules”: *a posteriori* stories developed for processes underlying observed patterns (e.g., Diamond 1975).
  - Null models developed for such matrices to investigate the possibility of generation by different underlying processes (e.g., Simberloff, Connor).
  - Despite lots of statistical attention devoted to discrimination among competing process models, virtually no attention to statistical methods for dealing with nondetection.

Species Co-occurrence Matrix

Species

Sites

	1	2	3	4	5	…	k
1	1	0	0	1	0	.	1
2	1	1	0	0	1	.	0
3	0	1	1	1	0	.	0
4	1	0	0	0	1	.	1
5	1	1	0	1	0	.	0
…	.	.	.	.	.	.	.
s	1	0	0	1	1	.	0

Multiple Species, Multiple Seasons

- Species interactions: multiple seasons
  - Potential to estimate local probabilities of extinction and colonization.
  - Model Pr(extinction) and Pr(colonization) as functions of presence or absence of other species.
  - Should lead to much stronger inferences than those based on pattern (species incidence matrices).

Multiple Species

- Nested subsets
  - Example: on islands of an archipelago, species found on more distant islands represent a nonrandom sample (nested subset) of species on islands closer to source/mainland.
  - Can be viewed as a spatial Markov process similar to stepping stone models of population genetics.
  - Nondetection presents problems.
- Single season
  - Model occupancy of more distant location as function of occupancy state of less distant location.
- Multiple seasons
  - Model Pr(colonization) for more distant location as function of occupancy state of less distant location.

Multiple Species

- Borrow information across species.
- Local extinction, colonization and occupancy dynamics as *f*(stuff).
  - Location relative to range center-edge.
  - Location relative to ecological boundaries.
  - Hypothesized guild membership.
  - Sexual dichromatism.
- Above inferences all influenced by nondetection.
- Lots of opportunities for addressing these relationships using occupancy models.

Conclusion

- Lots of neat opportunities to address new questions and revisit old questions using occupancy modeling.

- Such questions should be relevant to ecological science and conservation.

Camera-traps and Occupancy

- Most uses likely to address species-habitat relationships

- Also potential for:
  - Multi-species co-occurrence studies (predator and prey; competitors)
  - Species richness; adding secretive species
  - Certain identification for false positive studies