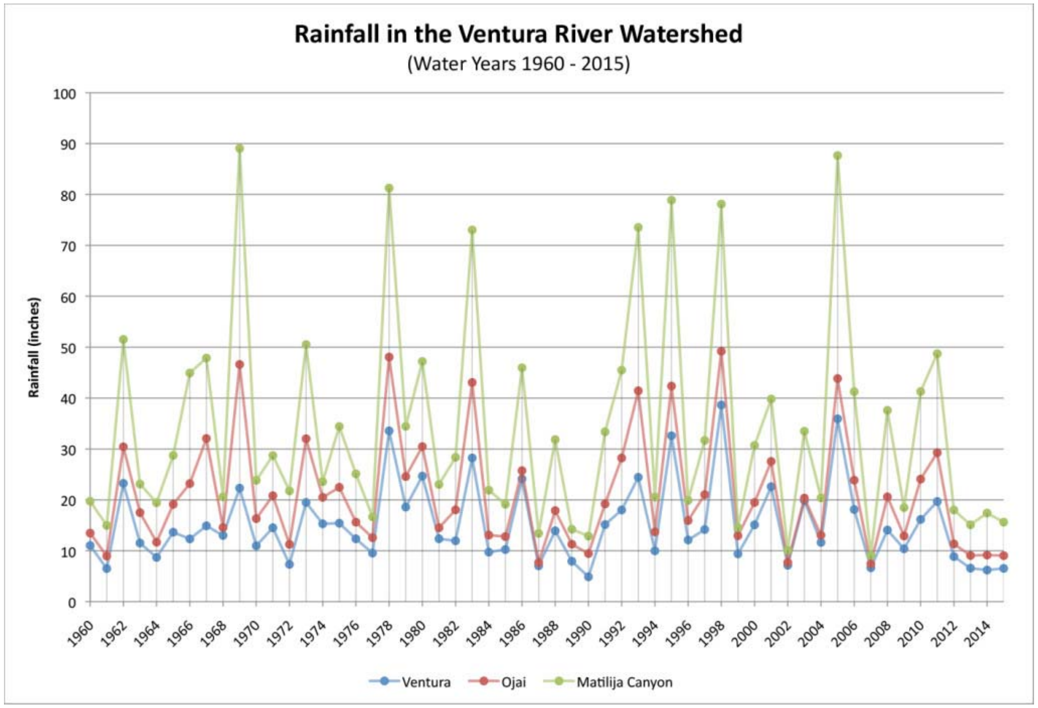
Assessing the environment

UCI – Environmental Science 101

July 2018

Collecting data in a messy world



Source: Ventura County Watershed Protection

Source: www.prlog.org

Collecting data in a messy world

Source: http://www.saguaro-juniper.com/i_and_i/san_pedro/ecoregions/plant_distribution.html

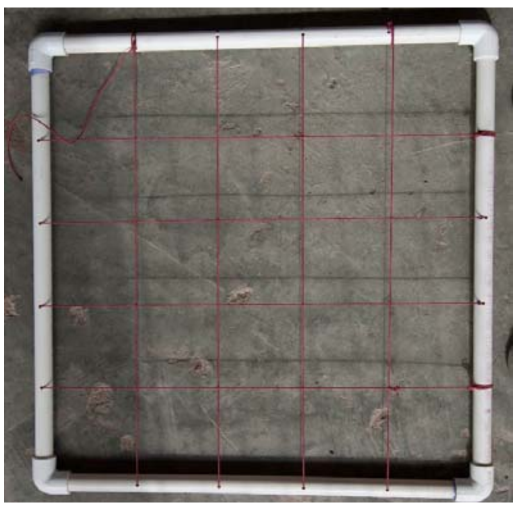
Source: www.prlog.org

How can we collect biological data that is:

- Representative
- Comparable
- Sufficient to test hypotheses

Plot sampling

- Plot: a manageable <u>area</u> of known size used for sampling
- Quadrat: a square or rectangular plot
- Multiple "replicate" plots used to obtain a representation of a community or parameter of interest



Source: http://hydrodictyon.eeb.uconn.edu/people/elphick/sparrows/saltmarsh_sparrows_research.htm

Plot sampling

- **Density** - # of individuals in a unit area
- **Relative species density** - number of individuals of a given group as a proportion of total number of all individuals from all groups
- **Frequency** - chance of finding a group within a sample
- **Relative frequency** - frequency of a given group as a proportion of the sum of frequencies for all species
- **Coverage** - proportion of the plot occupied

Transect sampling

- Simplest definition: a linear sampling method, often useful to identify gradients or systematically distribute sampling

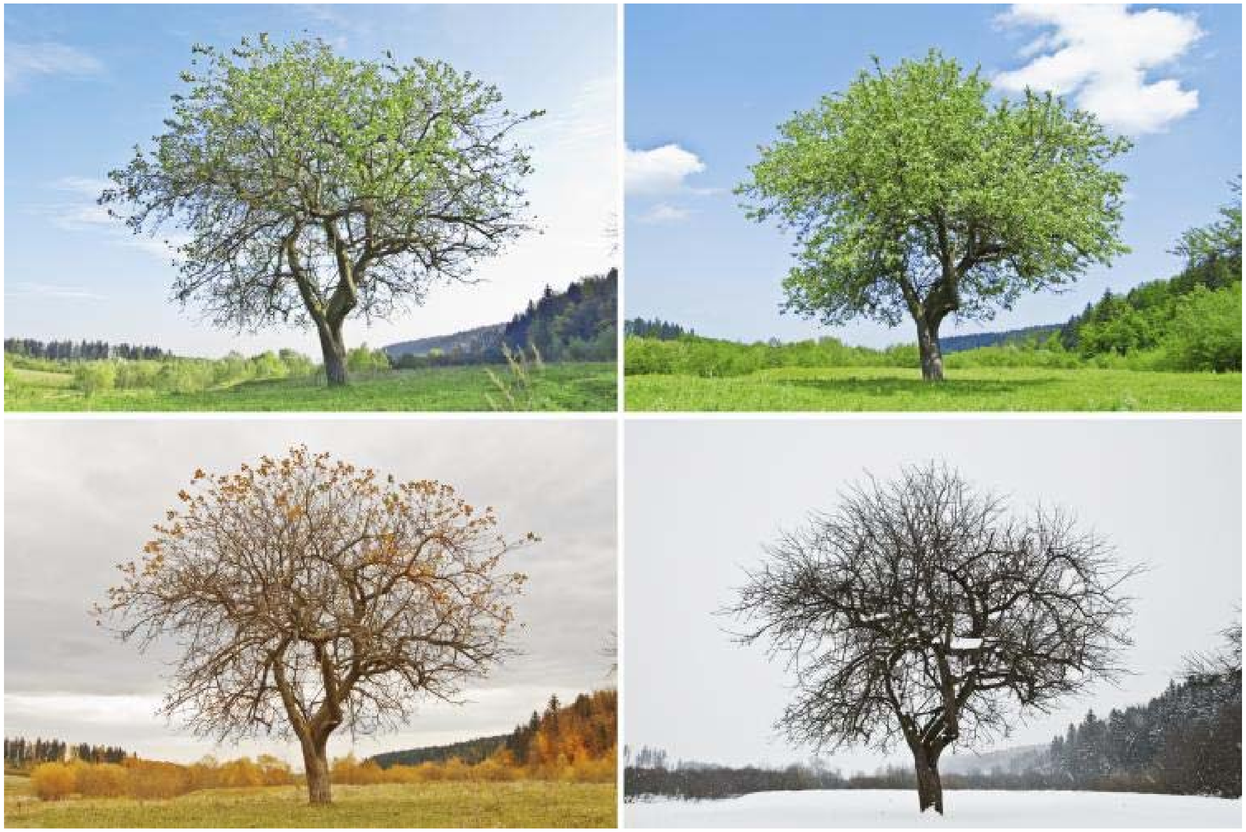
Source: http://sev.lternet.edu/content/plant-line-intercept-transects

Source: http://biodiversity.science.oregonstate.edu/sampling.html

Sample timing

Consider how answering your question may rely on sample:

- Frequency
- Timing
- Seasonality



Source: https://www.timeanddate.com/astronomy/seasons-causes.html

Approaches to answering ecological questions

- Observations of patterns
- Manipulative experiments
- Model building

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- Observations of patterns
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- Model building

Translating data into actionable information

- Visualization
- Ranking
- Predicting future conditions

Observations of patterns

- **Advantages:**
  - Observe patterns at scales that they naturally occur (i.e., much larger than experiments)
  - Easier to obtain many observations than experiments
  - See patterns without a full understanding of the mechanisms
  - Possible to do with endangered or introduced species without as many logistical, permitting, or ethical concerns
- **Disadvantages:**
  - Inferences are generally not as strong
  - Difficult to establish cause-effect relationships or clarify mechanisms
  - Patterns may be due to factors outside the scope of your observations

Observation of patterns

Source: https://mlsvc01-prod.s3.amazonaws.com/15d3008f301/3c740f71-ab87-480d-97a3-408b13e07831.jpg

Source: http://robinjmf.com/art/wp-content/uploads/2013/09/AnacapaPelican.jpg

Observation of patterns

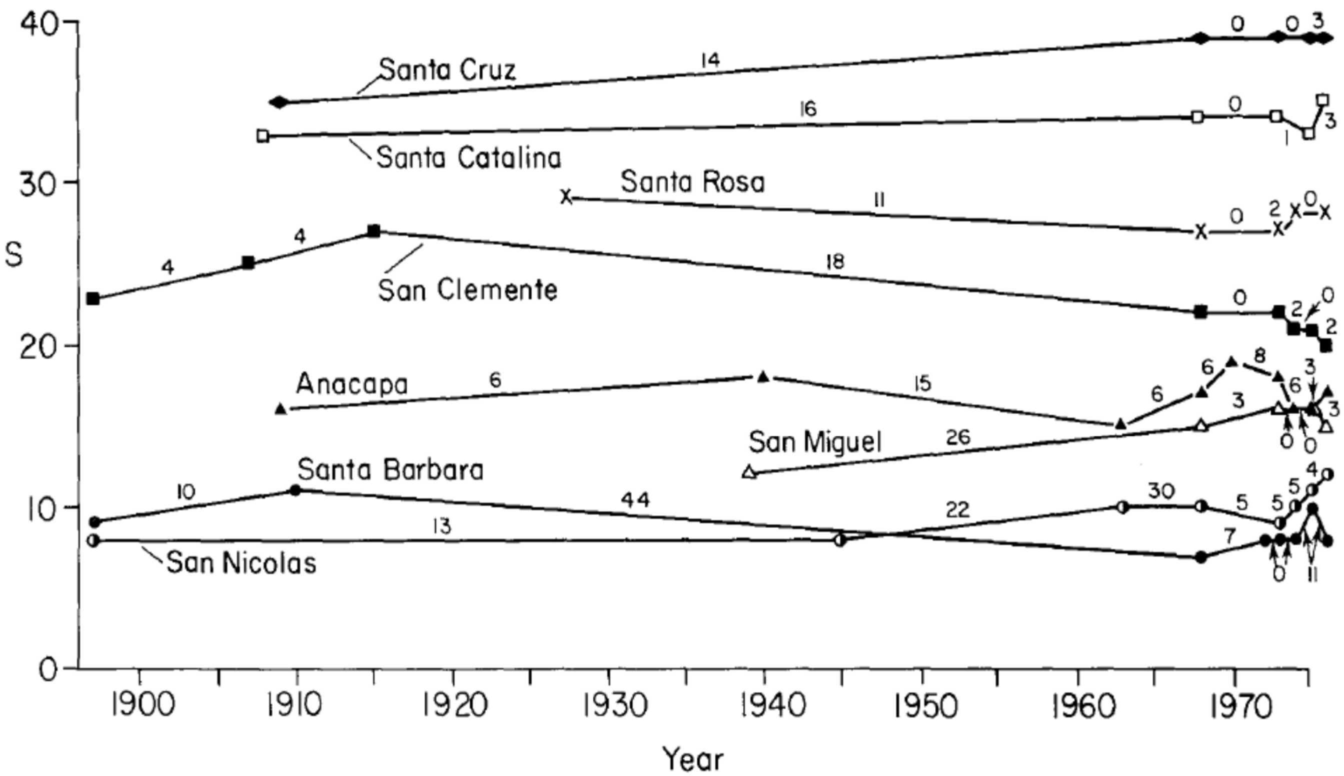


FIGURE 4. Fluctuations in number of breeding species S for each island (ordinate). The abscissa is the survey year. The number written over the line connecting each pair of the points is the percent turnover between surveys (not turnover rate).

Source: Jones and Diamond 1976

Observation of patterns

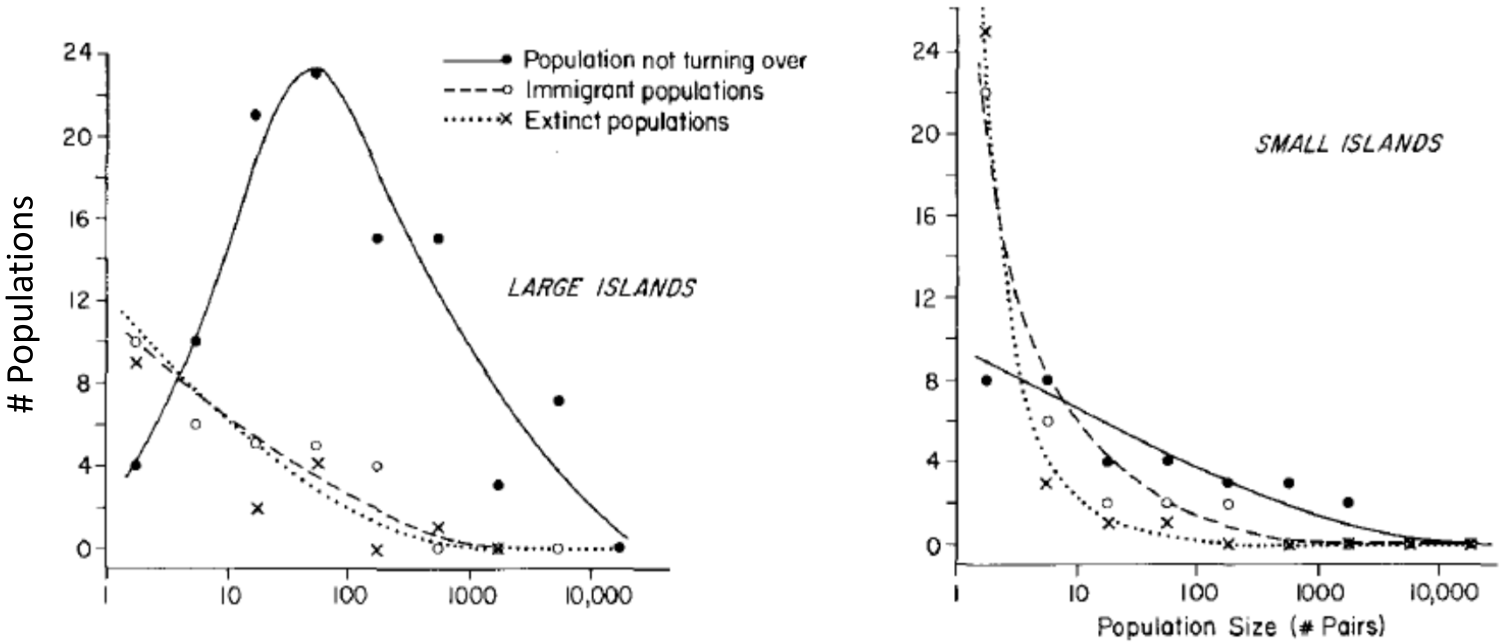


FIGURE 5. Population size and turnover on the Channel Islands. On each island the average breeding population of each species was estimated as falling into one of nine size classes (1–3 pairs, 4–10 pairs, 11–30 pairs, etc). Populations were then grouped as to whether they immigrated, became extinct, or never turned over since the first surveys. The number of populations (ordinate) in each size class (abscissa) was summed for the four larger islands (above) and for the four smaller islands (below).

Source: Jones and Diamond 1976

Observation of patterns

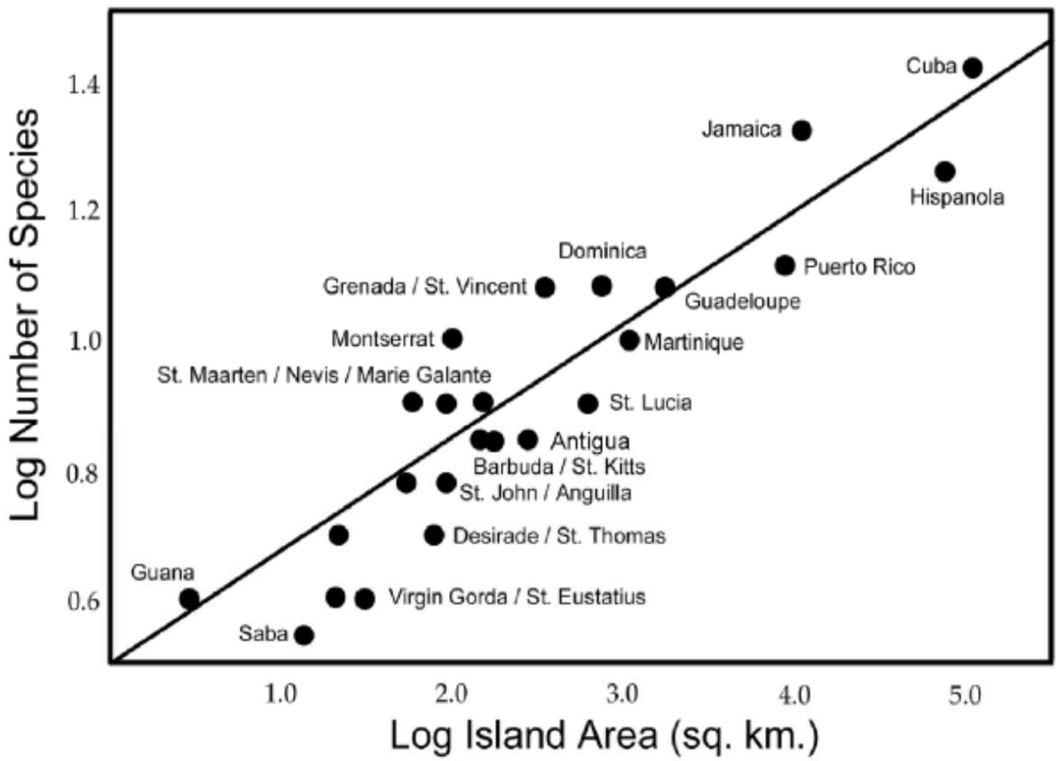
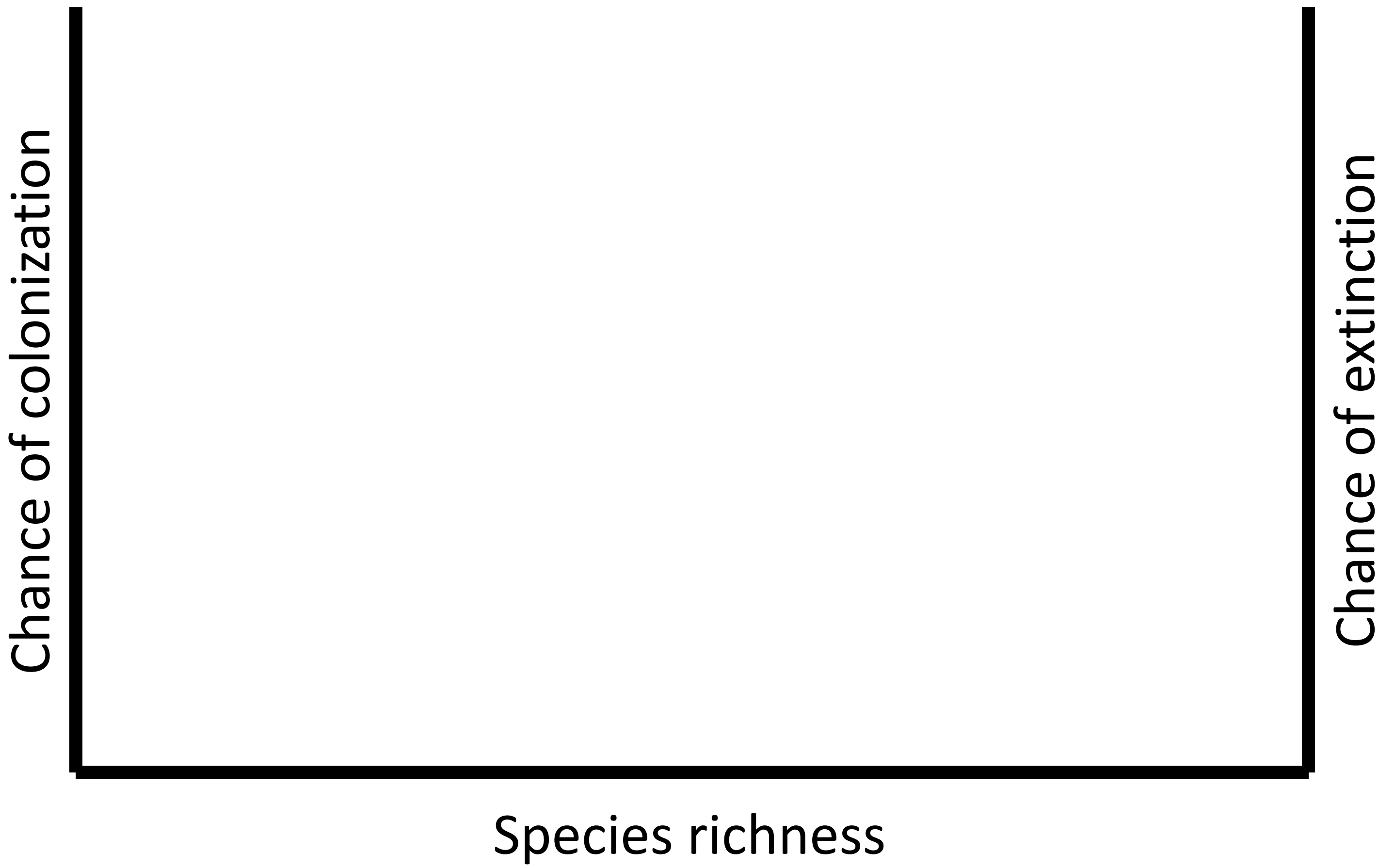


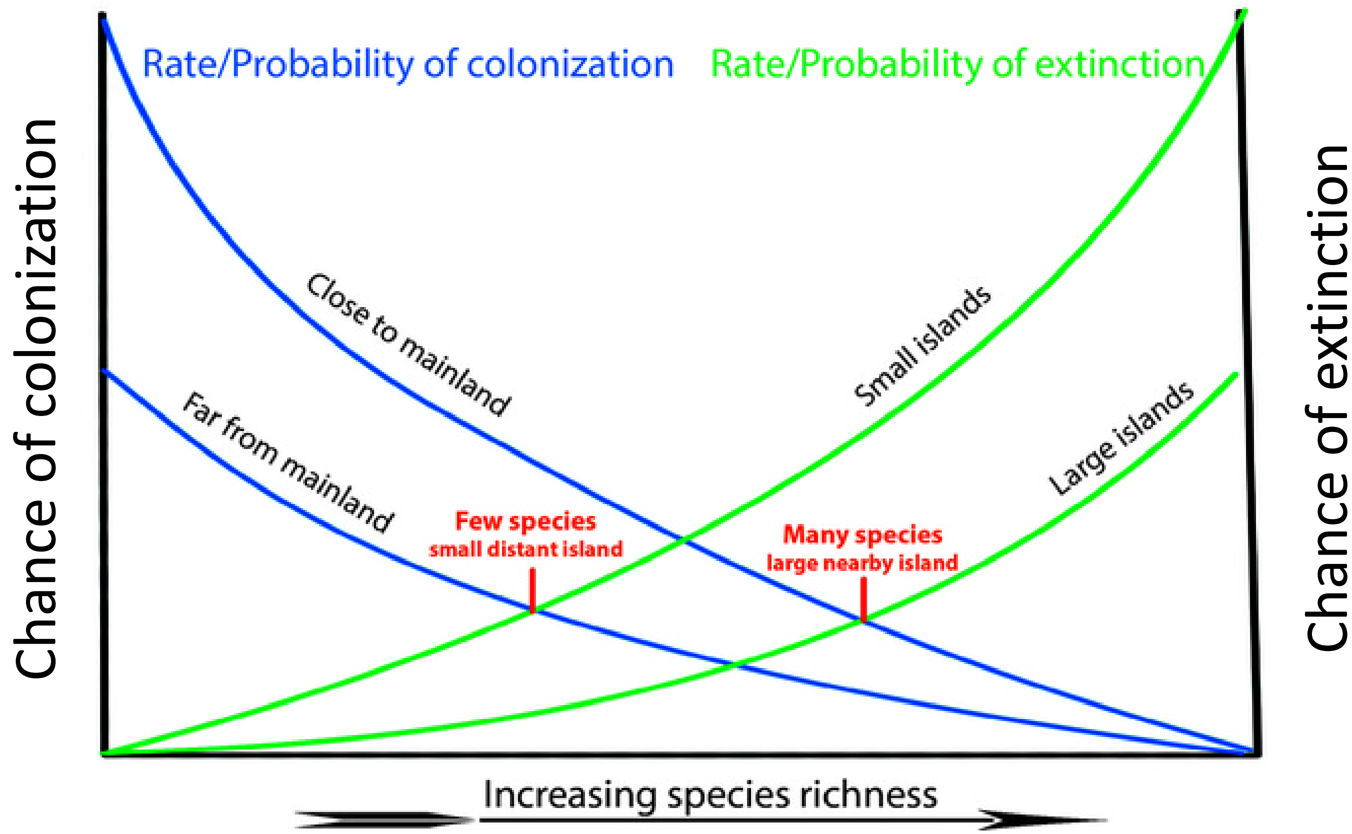
Figure 11.6. Species-area curve (Pedersen et al. 2005 after Genoways et al. 2001). Linear regression of log-transformed data: $y = 0.17x + 0.49$ ($R^2 = 0.81$).

Source: Pedersen et al 2005

Observation → Hypothesis

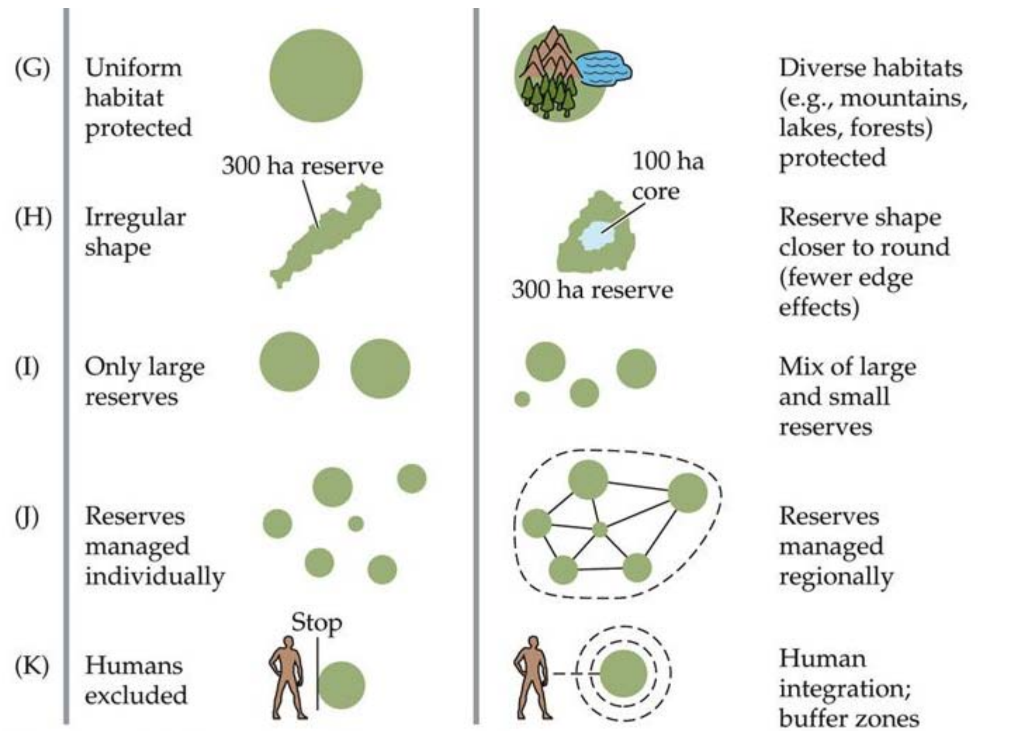


Observation → Hypothesis



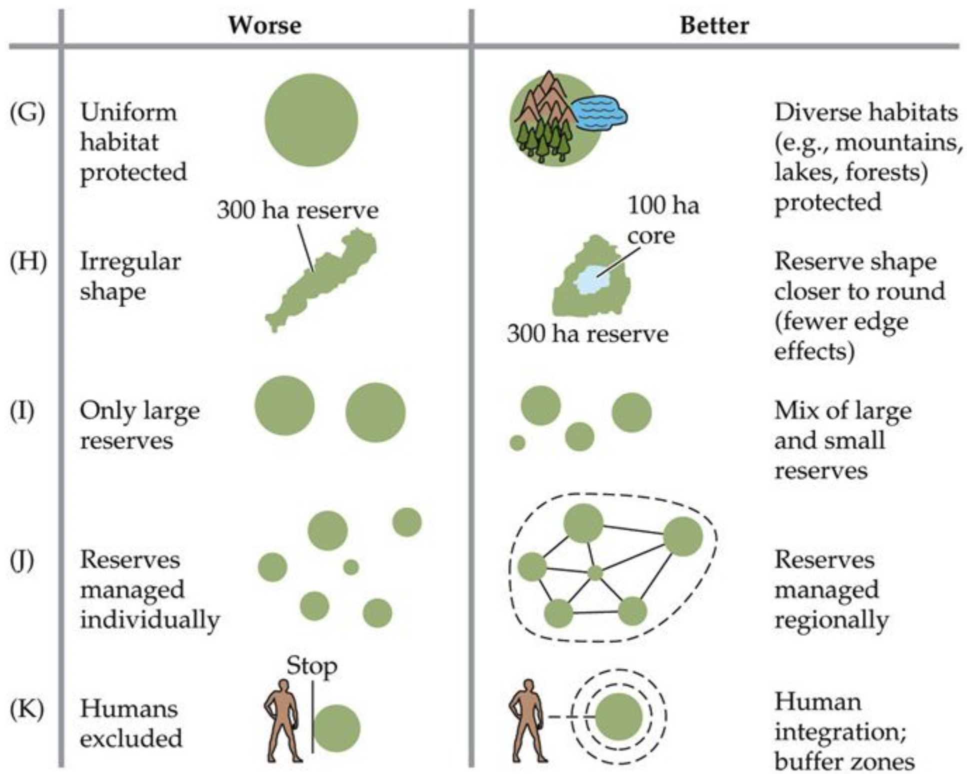
Source: http://www.islandbiogeography.org/uploads/6/6/8/0/6680387/1757075.jpg?639

Hypothesis → management decisions

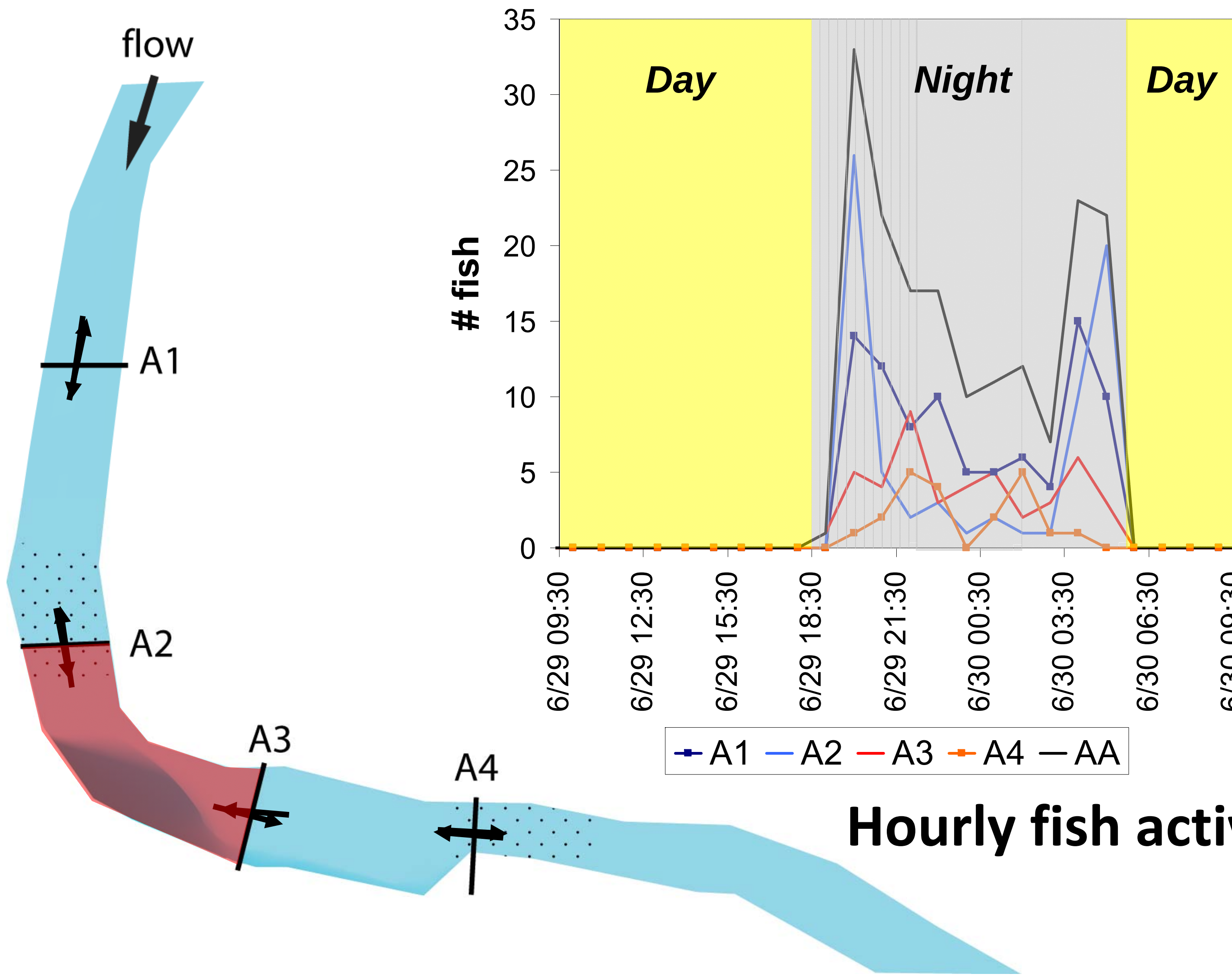


PRIMER OF CONSERVATION BIOLOGY 4e, Figure 7.6 (Part 2)

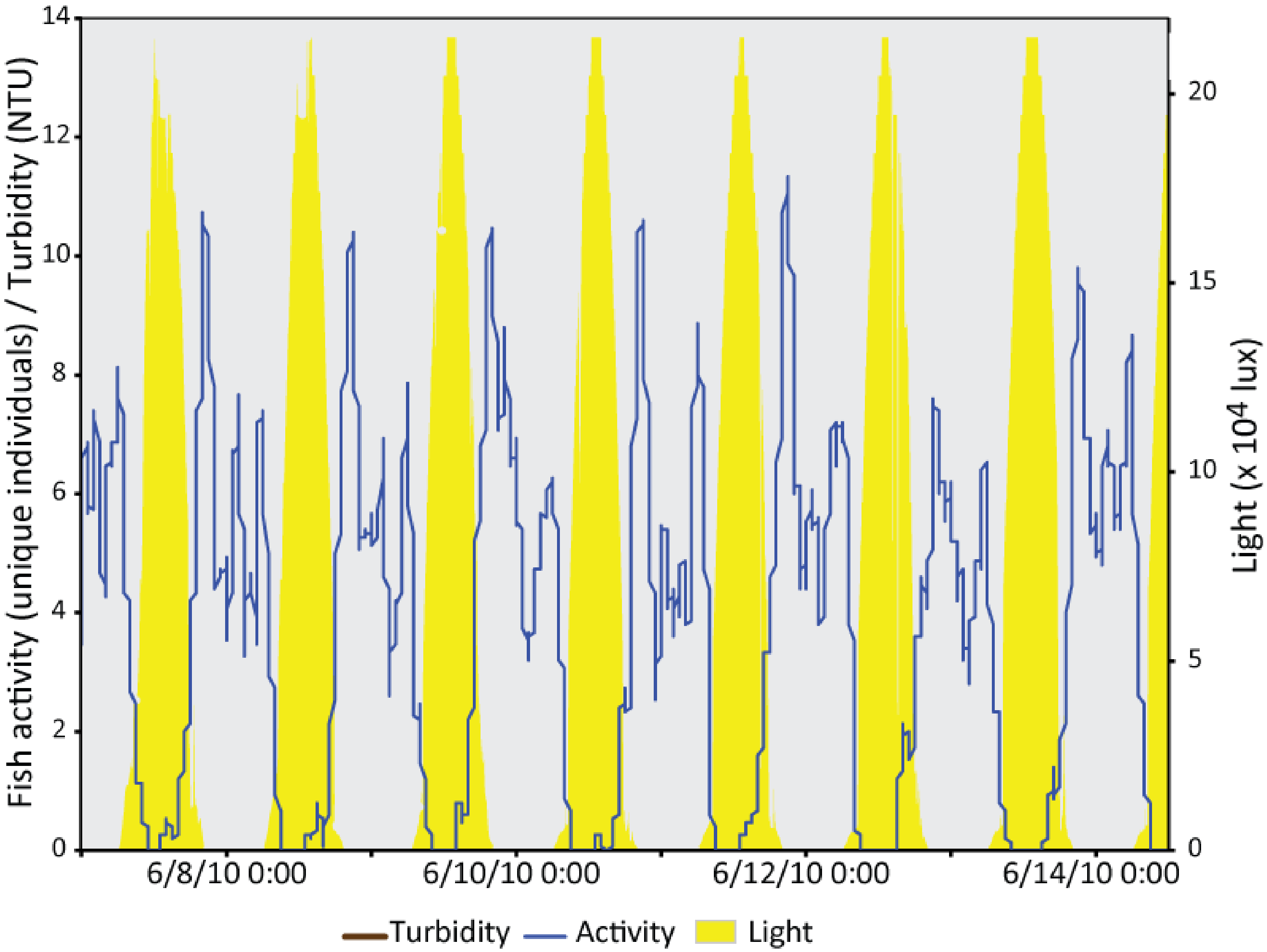
Hypothesis → management decisions



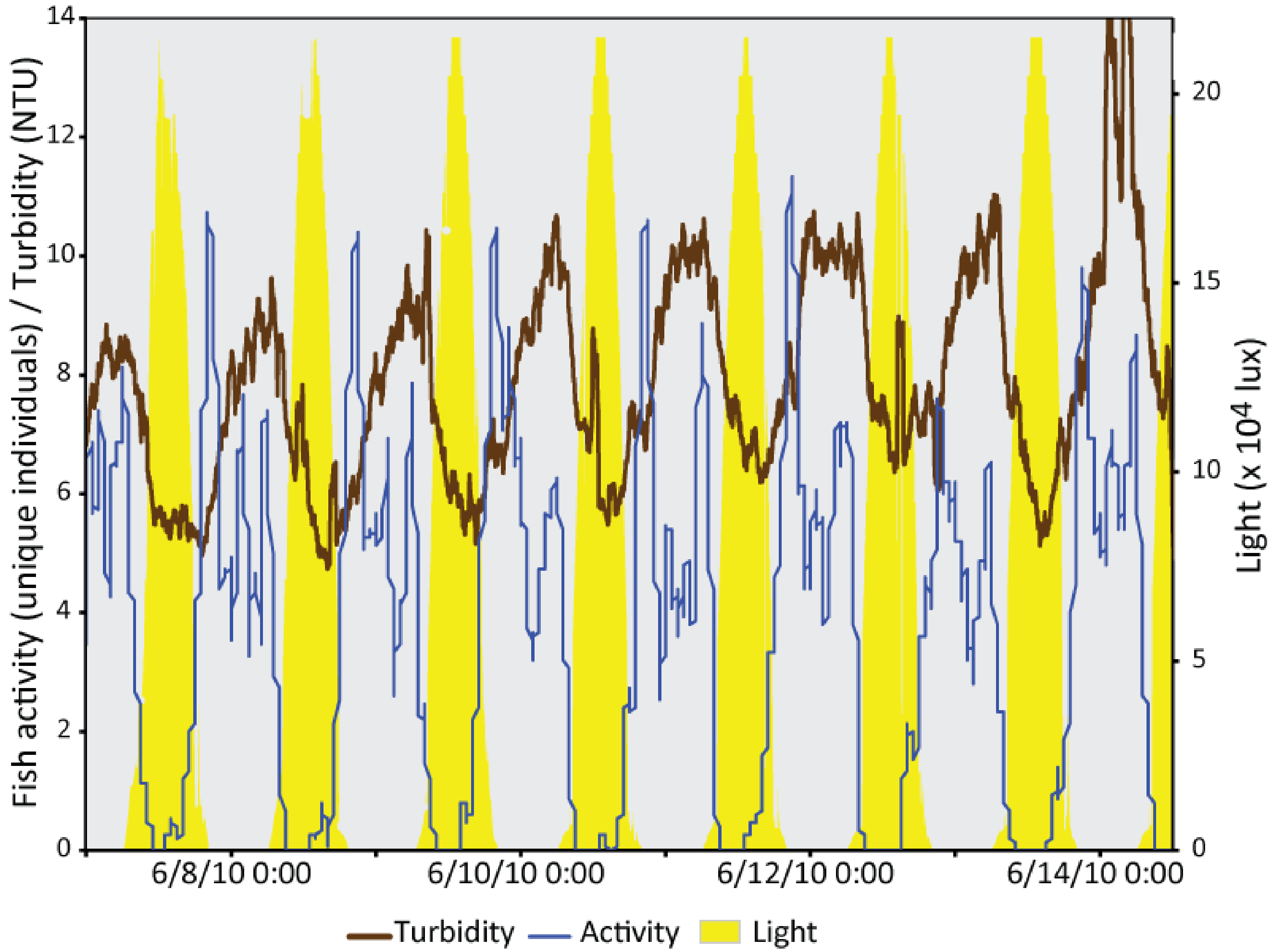
***PRIMER OF CONSERVATION BIOLOGY 4e*, Figure 7.6 (Part 2)**



Hourly fish activity



Fish activity (unique individuals) / Turbidity (NTU)
14
12
10
8
6
4
2
0
Light (x 10^4 lux)
20
15
10
5
0
6/8/10 0:00
6/10/10 0:00
6/12/10 0:00
6/14/10 0:00
Turbidity
Activity
Light



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6/14/10 0:00
Turbidity
Activity
Light

Manipulative experiments

Experiments require: *1) appropriate controls, 2) meaningful treatments, 3) replication of independent units, 4) randomization and interspersion of treatments*

- **Advantages:**
  - Can unambiguously establish cause and effect relationships
- **Disadvantages:**
  - Scale is often limiting, some processes are scale dependent
  - Establishing cause and effect can be difficult – is the experimental treatment actually doing what you intend?
  - Can only manipulate a handful of variables simultaneously
  - Often logistically challenging, time intensive, and expensive

Manipulative experiments

- Robert Paine Keystone species video
- https://www.hakaimagazine.com/videos-visuals/how-ecosystems-got-keystone/

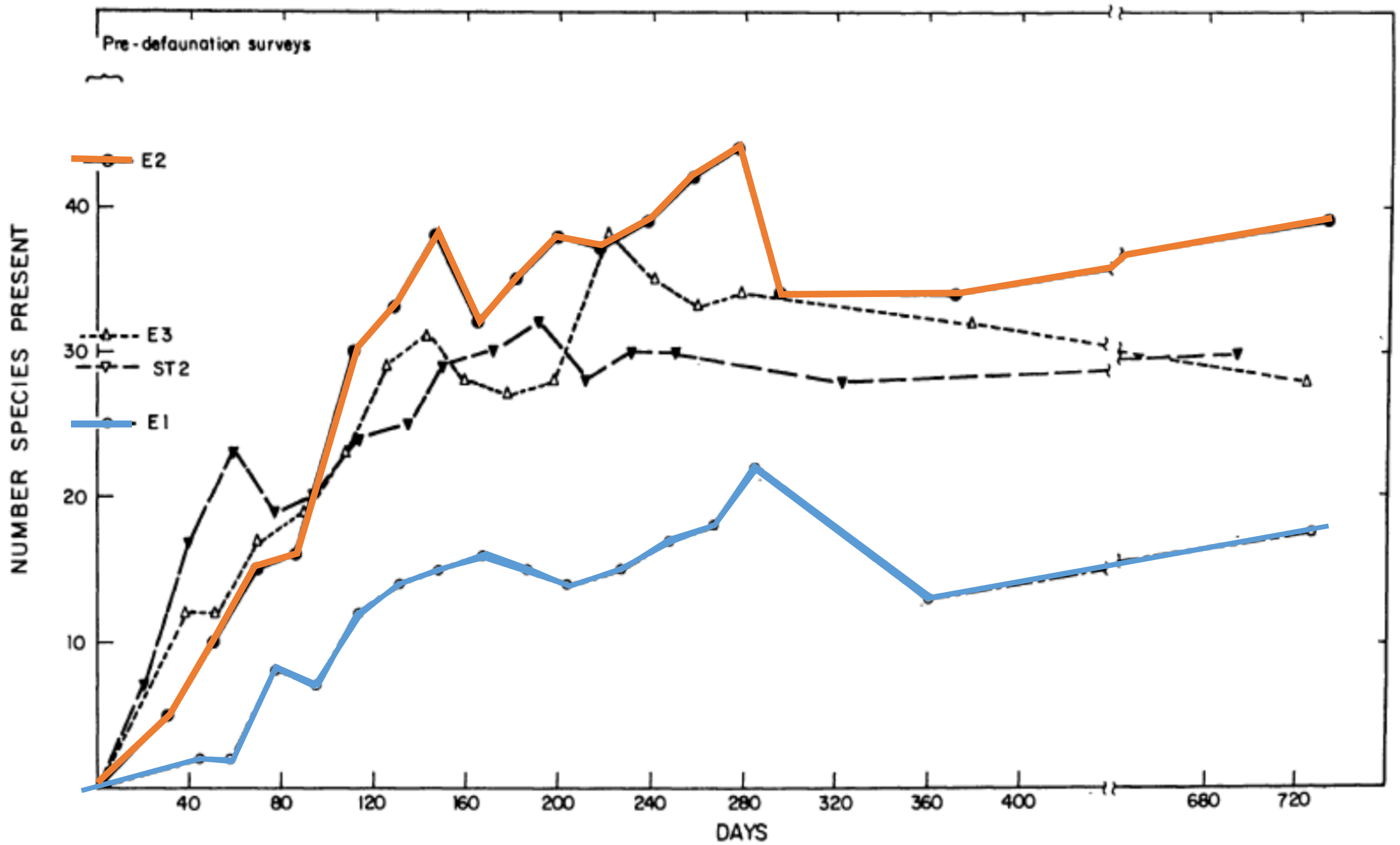
Manipulative experiments

(a)

(b)

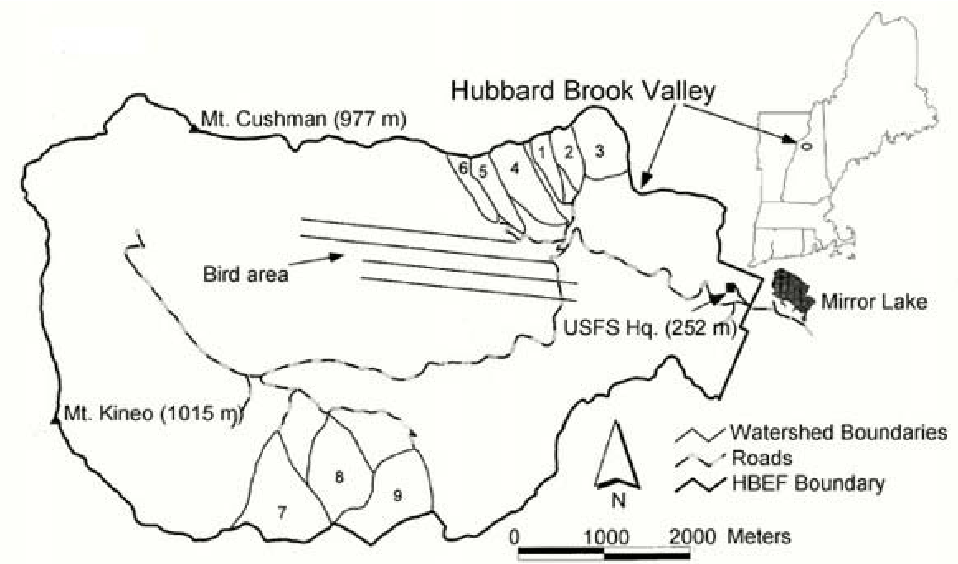
Source: http://slideplayer.com/slide/4424501/14/images/23/Dan+Simberloff+tested+MacArthur-Wilson+predictions+(turnover,+area+effect,+equilibrium)+with+defaunated+mangrove+islets,+Bay+of+Florida.jpg

Manipulative experiments



Source: Simberloff and Willson 1970

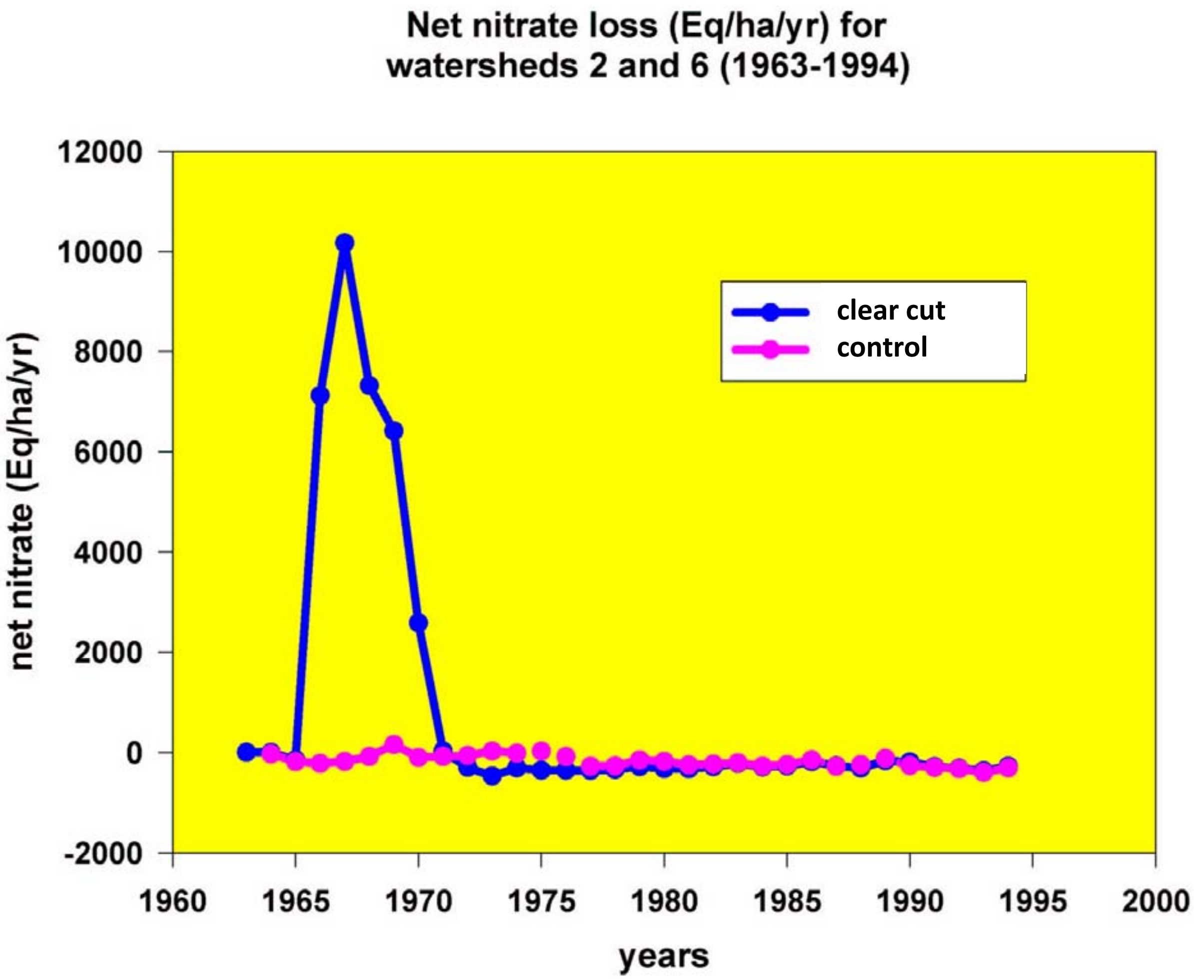
Manipulative experiments



Source: http://hubbardbrookfoundation.org/migratory_birds/Other%20images/HB_closeup_map.jpg

Source: https://lternet.edu/sites/default/files/photo1%5B5%5D_0.jpg

Manipulative experiments



- Spring snowmelt occurred earlier
- Streamflow increased in the first 3 years, but dropped for following 12 years
- Rapid growth of pioneer species

Model building

- **Advantages:**
  - Results can be general and identify mechanisms
  - Can help develop new hypotheses about how nature works or where to look for patterns
  - Can predict how systems will respond
  - Can identify alternative mechanisms or inconsistencies in current hypotheses
- **Disadvantages:**
  - Model structure may be inherently wrong or relationships poorly characterized but still fit the data
  - Prediction power may be limited if conditions exceed the model bounds

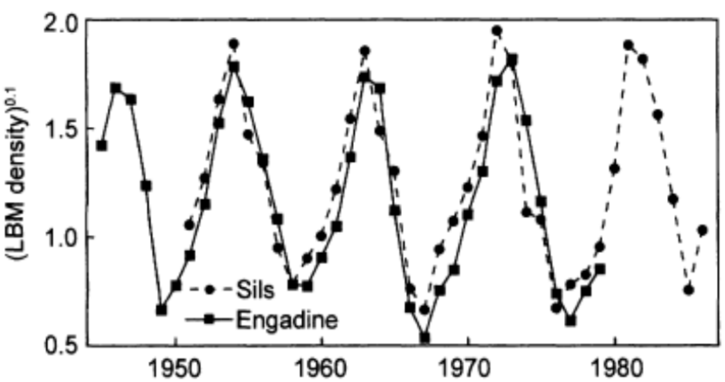
Model Building

Source: https://www.plantecology.unibas.ch/treeline_co2/6/y/2.jpg

Source: http://static.panoramio.com/photos/large/1796209.jpg

Ecological theory offers several potential explanations for such regular population cycles in forest insects:

- parasitoid-host interaction
- delayed effects of plant quality
- pathogen-host interaction*
- maternal effects*



Source: Turchin et al 2003

Model Building

Source: https://www.plantecology.unibas.ch/treeline_co2/6/y/2.jpg

Source: http://static.panoramio.com/photos/large/1796209.jpg

TABLE 1. Dynamic models and model equations for larch budmoth populations in Switzerland.

Model and parameters	Equation
Plant quality I (the "nonlinear" version)	
N_t: budmoth density	$N_{t+1} = \lambda_0 N_t \frac{Q_t}{\delta + Q_t} \exp[-gN_t]$
Q_t: plant quality index	$Q_{t+1} = (1 - \alpha)\left(1 - \frac{N_t}{\gamma + N_t}\right) + \alpha Q_t$
Plant quality II (alternative N_t equation, the "linear" version)	
N_t: budmoth density L_t: needle length	$N_{t+1} = N_t \exp[u + vL_t - gN_t]$
Parasitoid–host	
N_t: budmoth density	$N_{t+1} = \lambda_0 N_t \exp\left[-gN_t - \frac{aP_t}{1 + ahN_t + awP_t}\right]$
P_t: parasitoid density	$P_{t+1} = \phi N_t \left\{1 - \exp\left[-\frac{aP_t}{1 + ahN_t + awP_t}\right]\right\}$
Tritrophic I (full model)	
N_t: budmoth density	$N_{t+1} = \lambda_0 N_t \frac{Q_t}{\delta + Q_t} \exp\left[-gN_t - \frac{aP_t}{1 + ahN_t + awP_t}\right]$
P_t: parasitoid density	$P_{t+1} = \phi N_t \left\{1 - \exp\left[-\frac{aP_t}{1 + ahN_t + awP_t}\right]\right\}$
Q_t: plant quality index	$Q_{t+1} = (1 - \alpha)\left(1 - \frac{N_t}{\gamma + N_t}\right) + \alpha Q_t$
Tritrophic II (simplified "linear" version) N_t: budmoth density P_t: parasitoid density L_t: needle length	$N_{t+1} = N_t \exp\left[u + vL_t - \frac{aP_t}{1 + awP_t}\right]$

Source: Turchin et al 2003

Model building

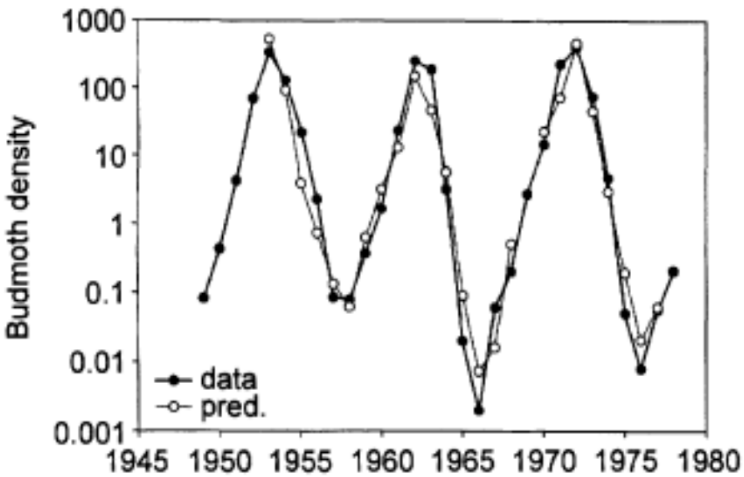


FIG. 2. Comparing predictions of the fitted parasitoid model to data. Predictions are obtained according to the following formula: $\hat{N}_t = N_{t-1} \exp[r - aS_{t-1}N_{t-1}/(1 + awS_{t-1}N_{t-1})]$ where N_t and S_t are observed budmoth density and proportion parasitized, and r, a, and w are fitted parameters.

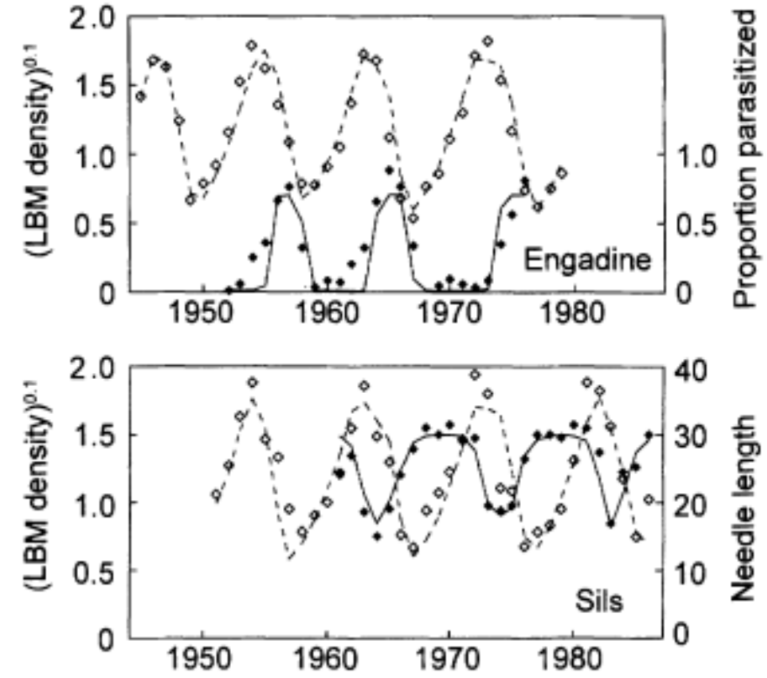


FIG. 3. Results of trajectory matching. Upper panel: Engadine data set (hollow symbols indicate budmoth density; filled symbols indicate proportion parasitized). Lower panel: Sils data set (hollow symbols indicate budmoth density; filled symbols indicate needle length).

Source: Turchin et al 2003

Model Building

Assessing how species distributions may change as global climate changes is key to conservation policy

Beale et al 2008 assess whether climate “envelopes” reasonably predict bird distributions –and so whether they can be used to assess change

Parameters include: annual growing degree days >5C, mean temperature of the coldest month, soil water availability

Model Building – Hypothesis testing

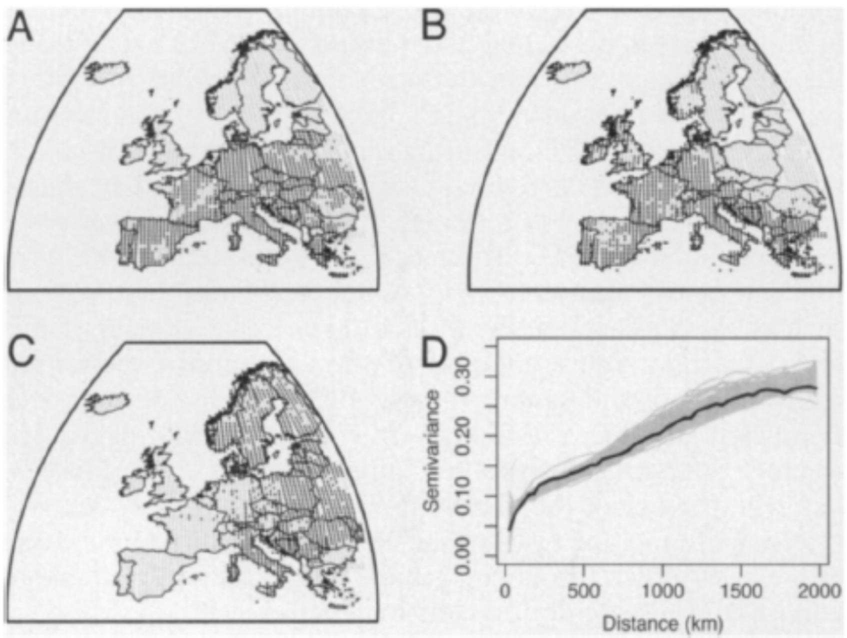


Fig. 1. Output from the null distribution algorithm. (*A*) Real distribution (*Serinus serinus*) with presence indicated in black, absence in gray. (*B* and *C*) Two realizations of the null distribution. (*D*) Semivariograms of the real distribution (black) and 99 simulations (thin gray): note that the real distribution falls entirely within the null distributions.

Source: Beale et al 2008

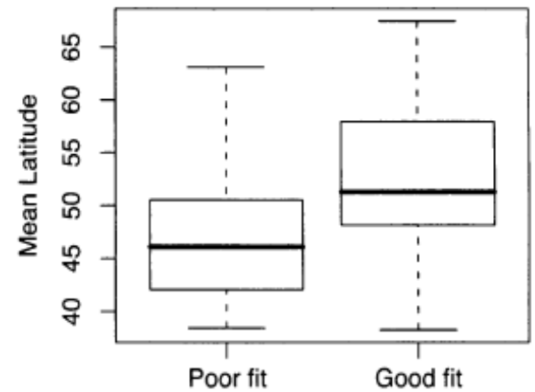
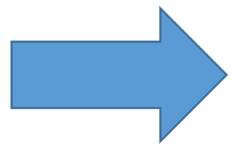


Fig. 3. Boxplot of the mean latitudes of the ranges of species that were poorly or well fit by climate envelopes. The median is indicated by the black line and first and interquartile range by the box. Whiskers cover the full range of the data.

Translating data into actionable information

Source: http://hydrodictyon.eeb.uconn.edu/people/elphick/sparrows/saltmarsh_sparrows_research.htm

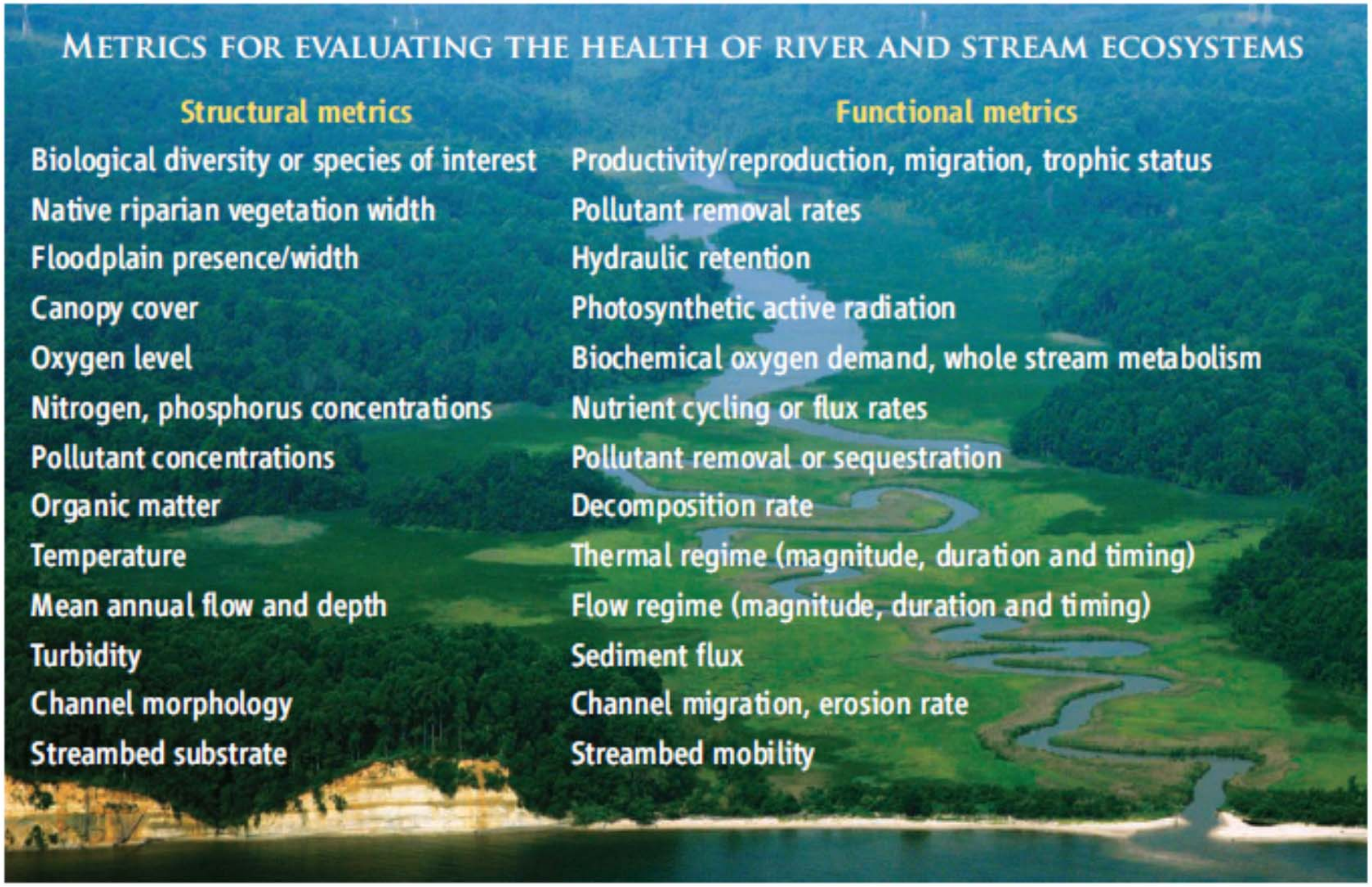


- Resource management
- Ecosystem health
- Conservation value
- Restoration prioritization
- Restoration success

Actionable information = Fuzzy topics?

- What is the balance between resources for the environment and resources for humans?
- What is a healthy ecosystem? How would it be measured?
- Conservation value – but for what?
- Restoration prioritization – target major problems or low hanging fruit?
- Restoration success – what is the target for restoration?

Defining ecosystem "health"



Source: Palmer and Febria 2012

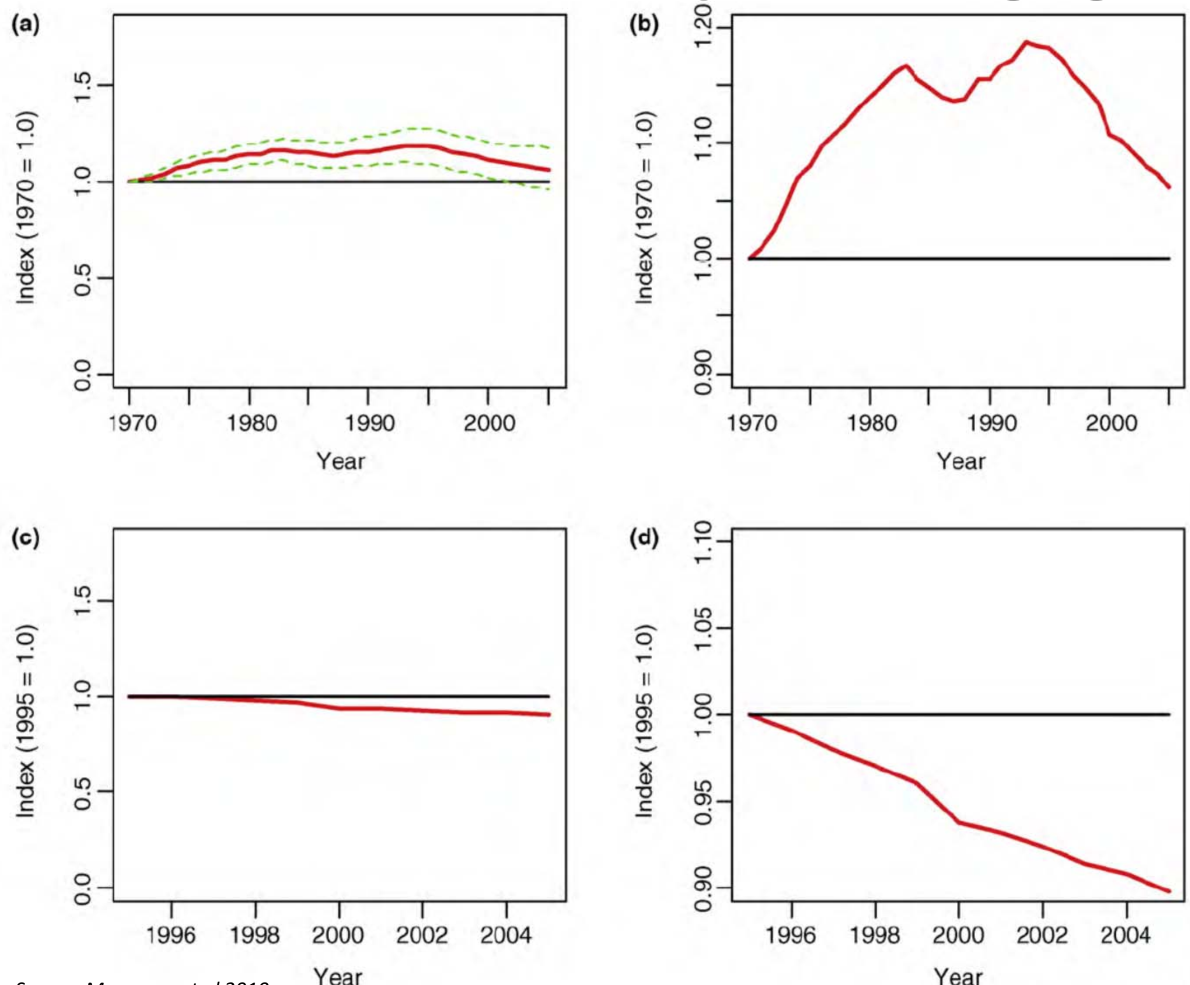
Actionable information

Limited funds + rapid changes in biological diversity =

Impetus to develop means to quickly and succinctly summarize the environment

- Rapid assessment protocols
- Indices of ecosystem health, e.g., ecological integrity indices
- Indicator species

Visualization – Interpreting graphs



Source: Magurran et al 2010