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Concepts and Complexities of Monitoring and Adaptive Management

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A Framework for Monitoring and Adaptive Management

Priorities for Management and Monitoring

- *What are the most important species and locations to focus management and monitoring resources?*

Objective-based Monitoring

- *What are the most important management and monitoring questions?*
- *What are the most effective indicators to assess the management and monitoring questions?*

Monitoring Design

- *What study and sampling design most effectively and efficiently assesses the management and monitoring objectives?*

Monitoring Data and Adaptive Management

- *How does one use monitoring data to improve decision-making?*

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Priorities for Management and Monitoring

What are the most important species and locations to focus management and monitoring resources?

Not just whether a covered or listed species, need to assess:

- Rarity
- Population Decline
- Active or Proposed Management
- Threats
- Key Ecological Attributes
- Ecological Characteristics: duration, disturbance frequency

At different scales:

- Across whole MSHCP
- Within each jurisdiction

With clear, consistent criteria

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Objective-based Monitoring

What are the most important management and monitoring questions?

Assessment of condition and threats

- Population attributes
- Ecological attributes
- Key Threats

Desired Ecological Conditions

A range of ecological conditions preferred for a population, community or ecological system, **attainable** within the human context over a selected period of time, used to guide management, restoration and land use.

Described by the critical components (Key Ecological Attributes) of a target's life history: population size, population structure, population dynamics, habitat requirement, ecological processes and landscape context

Historic Pre-European Conditions

Historic Post-European Legacies

Current Human and Ecological Limitations (sidebars)

Future Resilience to Change (climate, invasive species)

- Restore and manage ecological systems that resemble past systems, attainable within current conditions and resilient to future change.

Conceptual Ecological Models

Conceptual or Heuristic Models include

- schematic diagrams that illustrate the working understanding of system behavior
- components of the model are states and processes

Can evolve into other models:

- Statistical and Simulation Models

“The most useful and strategic approach is to start with an initial model – no matter how crude – and use its formulation, parameterization and uncertainty to marshal field studies that will build and refine the model most efficiently.” Dean Urban

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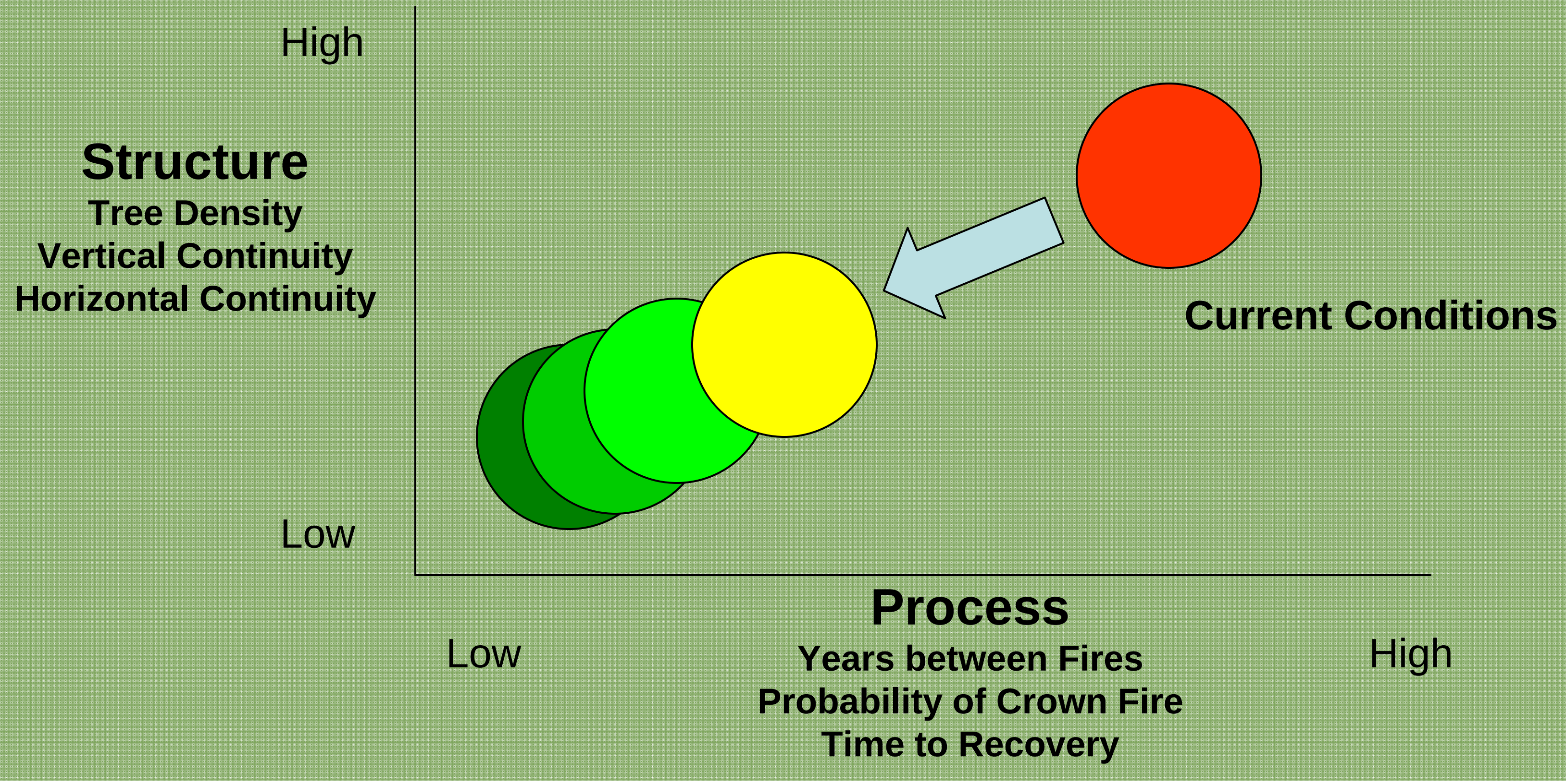
Conceptual Model of Ponderosa Pine Forests (Allen et al. 2002)



What Type of Monitoring Question is Being Asked?

Strategy Effectiveness or Status Questions

The differences are in:

- the question being asked
- the study design used to collect the data
  - usually requiring a control

Can measure the same indicators/metrics and use the same methodology

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What Type of Monitoring Question is Being Asked?

Status Questions

Assesses the current condition (status and trend) of biodiversity, specific species, ecological systems, threats, management or protection

Does not explicitly link management actions and condition

- tracks the cumulative impact of all conservation actions and confounding factors

Provides a measure of overall success and an early warning of change

- Can be used to determine appropriate actions, either more in-depth monitoring or management

What Type of Monitoring Question is Being Asked?

Strategy Effectiveness Questions

Determines whether one or more strategic actions are having the intended impact on the target or threat

Explicitly links management actions and ecological responses

- Continuum of ability to discern the causal relationship between the conservation action and the response of the target or threat
  - Observational
  - Experimental

Most appropriate monitoring for adaptive management, to learn process, maximize success, reduce uncertainty

Objective-based Monitoring

What are the most effective indicators to assess the management and monitoring questions?

Types of Indicators

Strategic Action	→	Activity Indicators	→	Output Indicators	→	Outcome Indicators	→	Impact Indicators
		measures the implementation of strategy		measures proximate outcome of strategy		measures short-term response of threats		measures long-term/ ultimate response of targets

Selecting Indicators

How closely are the indicators related to the targets?

- Indicators directly related to changes in the target
  - Species: population size, fecundity
  - Systems: composition, structure
- Indicators hypothesized to be related to changes in the target (proxies)
  - Species: community structure, fire history, water quality, indicator species
  - Systems: community structure, fire history
- Indicators that reflect land use, land management and/or threat abatement
  - Land Use: urban, forest cover
  - Land Management: acres burned, sediment control
  - Land Protection: protected acres

Objective-based Monitoring

What are the most effective indicators to assess the management and monitoring questions?

- Understanding and Identifying the **different types of Measures and Indicators**
- Identifying the appropriate **Direct and Indirect Indicators** and understanding the **assumptions** associated with indirect indicators
- Selecting a **minimal set of indicators** for each population

What Level of Scientific Rigor/Precision is Desired?

Uncertainty in outcomes

Risk

- to the ecological systems or species
- to the organization

Level of financial investment

Partnerships

Resources

Opportunities to learn

Levels of Monitoring

Level 1: Qualitative Monitoring and Threat Assessment

– Qualitative and photographic assessment of management and land use activities including prescribed fire, invasive species control, restoration progress, erosion, etc. at locations with the targeted species

Level 2: Semi-quantitative Monitoring and Indicator Species Assessment

– Semi-quantitative (counts, area estimates) survey in immediate vicinity of photopoints for targeted species, indicator species and invasive species

Level 3: Quantitative Detection of Change

– quantitative monitoring of populations of rare species, including precise estimates of population size and stage classes with the objective of detecting change over time. This monitoring objective requires a thoughtful sampling design to maximize accuracy and precision

Level 4: Demographic Monitoring

– detailed life history/demographic assessment of the targeted population. This monitoring objective also requires a thoughtful sampling design to maximize accuracy and precision

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Study Design and Sampling Design

A plan of sampling that minimizes data variability and maximizes the detection of status, trend or change.

- <u>Precision</u>: describes the closeness of repeated measurements (of the same quantity) to one another
- <u>Repeatability</u>: ability of measurements to be repeated over time with limited non-sampling error
- <u>Efficiency</u>: ability of making the measurements easily and quickly, durability of project

Study Design and Sampling Design

Study Design

- Arrangement and grouping of sample units (plots) to maximize the ability to answer a monitoring or research question
  - Includes controls, comparisons, paired plots, BACI designs, and distribution of plots to make inferences about a population

Sampling Design

- Details on the selection and sampling of sample units (plots)

5 Sampling Design Decisions

What is the population of interest?

What is the appropriate sample unit and the appropriate sample unit size and shape?

What is the spatial allocation of sample units?

What is the temporal allocation of sample units? (How often should the sampling units be sampled? Should the sampling unit positions be permanent or temporary?)

How many sample units should be included in the sample?

1. What is the Population of Interest?

Biological population

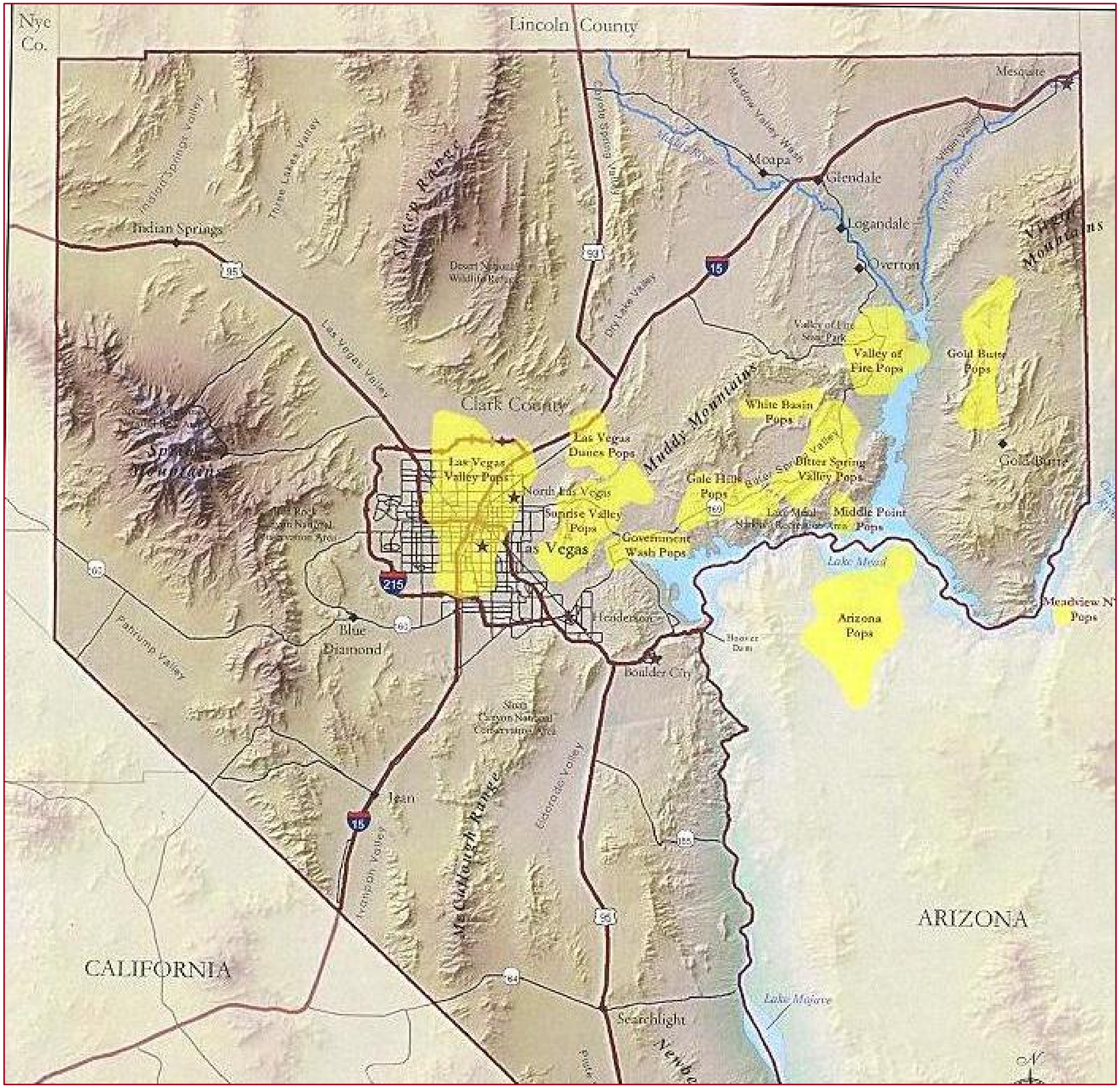
- all individuals within a specified area at a particular period in time that are assumed to be biologically (reproductively/ demographically) interrelated

The statistical, or “target” population

- the portion of the biological population that is of interest and can be sampled

The “index” population

- a portion of the target population that is selected to represent the whole population
- represents a biased and untestable estimate of parameters for a larger population


Nye Co.
Lincoln County
Mesquite
Moapa
Glendale
Logandale
Overton
Indian Springs
Sheep Range
Desert National Wildlife Refuge
Dry Lake Valley
Las Vegas Valley
Valley of Fire State Park
Valley of Fire Pops
Gold Butte Pops
Virgin Mountains
Clark County
White Basin Pops
Las Vegas Dunes Pops
Muddy Mountains
Spring Mountains
Las Vegas Valley Pops
North Las Vegas
Bitter Spring Valley Pops
Gale Hills Pops
Sunrise Valley Pops
Middle Point Pops
Lake Mead
Government Wash Pops
Las Vegas
Gold Butte
Henderson
Arizona Pops
Meadview N Pops
Blue Diamond
Hoover Dam
Boulder City
Pahrump Valley
Jean
McCullough Range
Eldorado Valley
ARIZONA
CALIFORNIA
Searchlight
Lake Mojave
215
15
95
93
160
164

2. Appropriate Sample Unit

Sample Units

Individuals

Quadrats (macroplots)

Lines (transects)

Points

Distance (plotless)

Depends on the Attribute

Density

Cover

Frequency

Individual Attributes

Size and Shape of the Sampling Unit

- Larger square or longer rectangular sampling units usually better balance precision and efficiency
  - More precise because they capture the variability of the population within rather than among sample units.
  - More efficient because fewer sampling units mean:
    - less time traveling to and finding a sampling location
    - less set-up time, fewer markers to prepare and carry
    - and perhaps less measurement and processing time
- Small sampling units have equal or better precision
  - In regular, random, populations
  - Could be less efficient if high cost of more sampling units

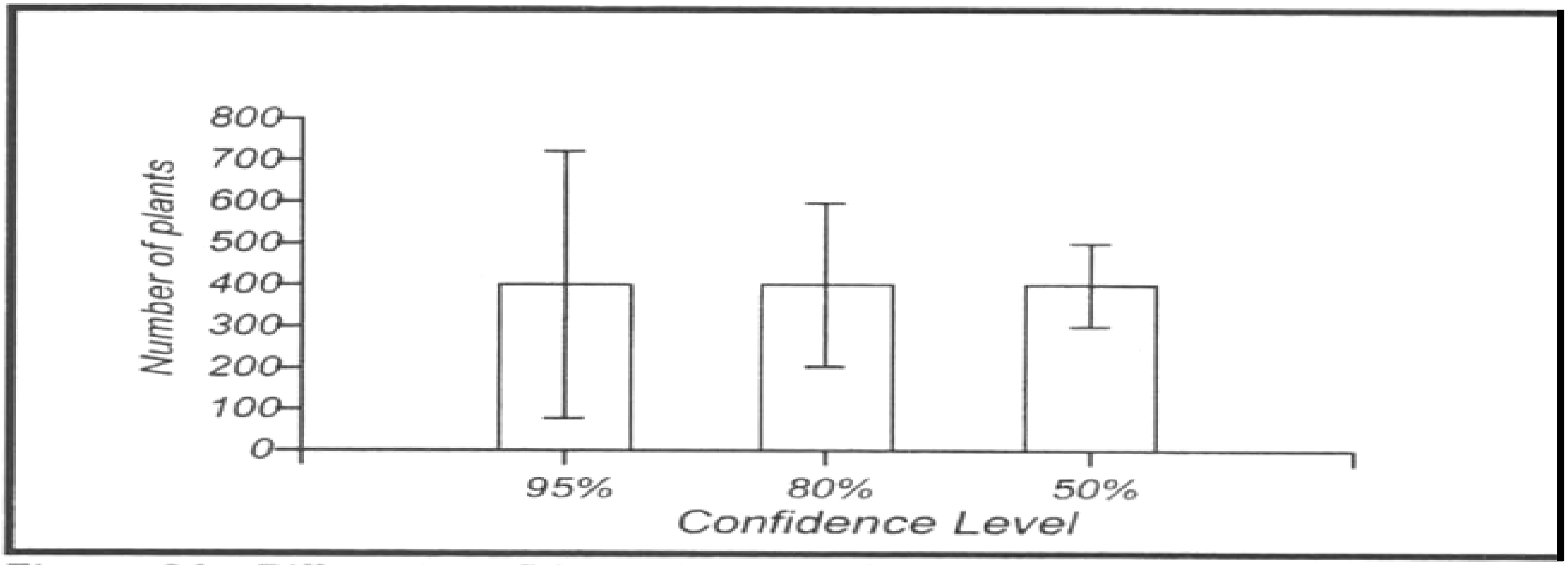


Figure 6A. Different confidence intervals for the 10 2m x 2m quadrat design.

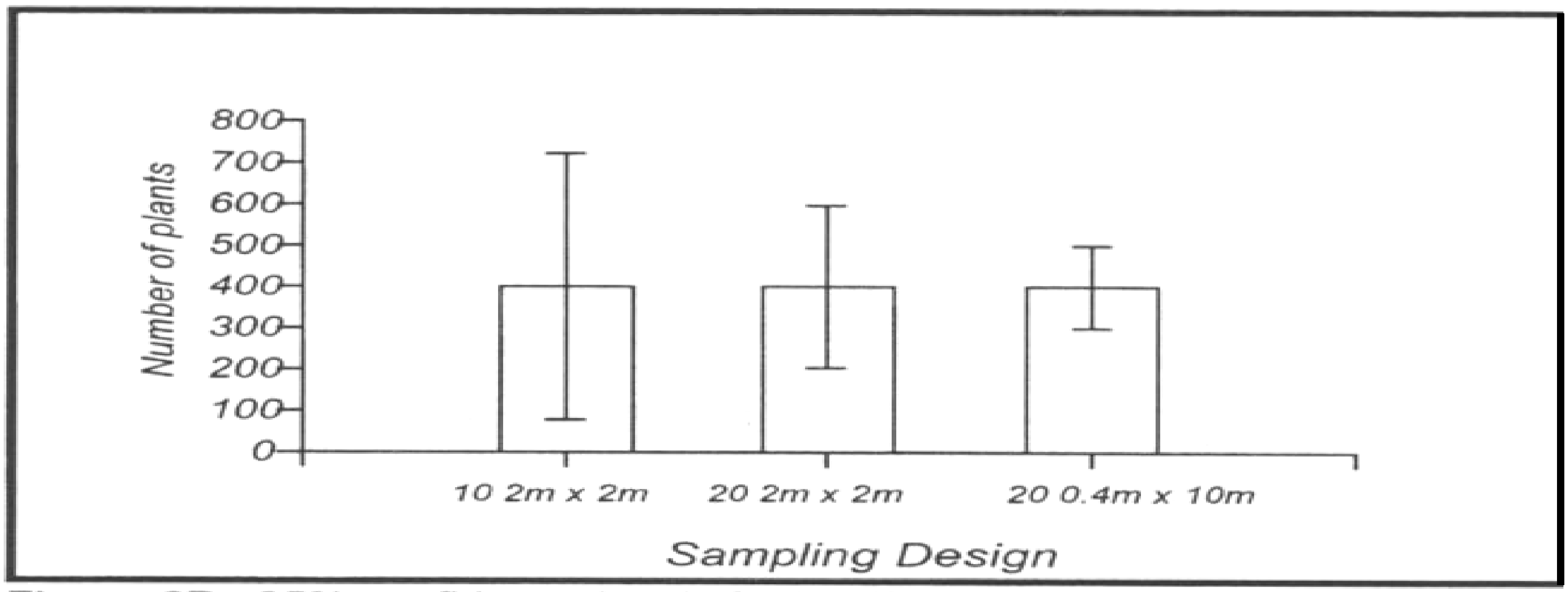


Figure 6B. 95% confidence levels for 3 different sampling designs.

Other Considerations Concerning the Size and Shape of Sample Units

Size of Individuals

Density/Abundance of Individuals

Edge Effects

Ease in Sampling

Investigator Impact

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3. Spatial Allocation of Sample Units

An anonymous early ecologist: “The most important decision an ecologist makes is where to stop the car.”

Spatial Allocation of Sample Units

Three characteristics:

Random Placement – Each sample unit has the same probability of being selected

Good Interspersion – Better representation of the target population

Independence – Selection of one sample unit is not tied to another

Why Random?

- Allows statistical inferences to be made to the target population
- Eliminates bias

Spatial Allocation of Sample Units

Ways to position sample units:

- Simple Random Sampling (Grid Cell)
- Stratified Random Sampling
- Systematic Sampling with a Random Start
- Restricted Random Sampling
- Two-stage/Multi-stage Sampling
- Cluster Sampling
- Adaptive Sampling
- Double Sampling
- Other Ways to Sample Individuals

4. Temporal Allocation of Sample Units

Are the sample units permanent, temporary or a combination of permanent and temporary?

What frequency of sampling is necessary to detect true trends in the population?

Permanent or Temporary Sample Units?

Permanent Sample Unit Advantages:

- easier to detect change
- fewer sample units

Permanent Sample Unit Disadvantages:

- markers: expensive, prep, carry to site
- markers: susceptible to loss or damage
- relocating markers time consuming
- investigator impact
- impact on wildlife

Statistical and Sampling Design Issue with Permanent Sample Units

All populations change distribution and condition with time (changes in population parameters), thus

- permanently marked plants or plots will lose their precision over time
- changes in statistical characteristics of the population
  - normality
  - homogeneity of variances

Major Temporal Designs

Complete Revisit

	Sampling Occasion					
Panal	1	2	3	4	5	6
1	■	■	■	■	■	■
2						
3						
4						
5						
6						
7						
8						

Repeating Panel

	Sampling Occasion					
Panal	1	2	3	4	5	6
1	■			■		
2		■			■	
3			■			■
4	■			■		
5		■			■	
6			■			■
7	■			■		
8		■			■	

Split Panel

	Sampling Occasion					
Panal	1	2	3	4	5	6
1	■	■	■	■	■	■
2	■			■		
3		■			■	
4			■			■
5	■			■		
6		■			■	
7			■			■
8	■			■		

Frequency of Sampling

Is once a year enough?

Is every year necessary?

- Several sequential years to assess status or trends
  - then choose the appropriate frequency for assessing status or detecting change

Is the same intensity of sampling needed at every sampling time?

- Baseline Sampling - usually more intensive data collection in first year
- Baseline intensity can be redone at an appropriate frequency
- Less intensity monitoring designed for intervening years

Dependent on:

- time frame of change
- trade-off between cost and the value of the data

5. Number of Sampling Units

Considerations:

- Level of precision desired in the data (Sampling Objective)
- Variation in actual measurements (pilot data)
- Use permanent or temporary sampling units
- Infinite or finite population

Precision increases with sample size, but not proportionately

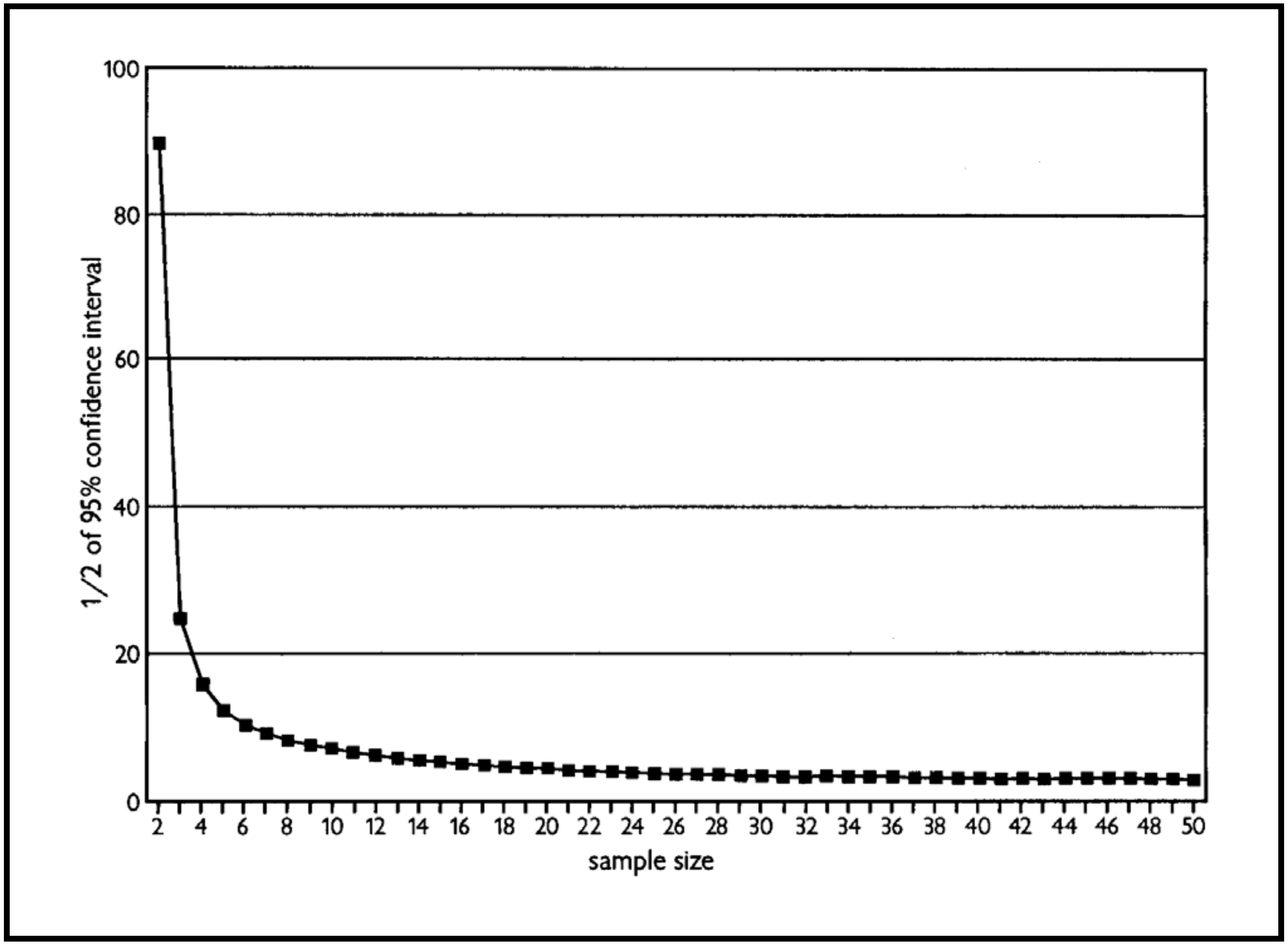

Figure 34. The influence of sample size on level of precision, using a t-distribution with a constant standard of deviation (sd = 10).

Take Home Messages

- Detectability
- Don’t say more than the data says
- Tradeoffs between size and number of sample units
- Repeated measures
- Plot size and cryptic species smaller, larger better for impacts, low density species…combine with nested plots
- Stage classes

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Detectability

- Counts represent some unknown fraction of organisms in sampled area
- Proper inference of population size requires information on detection probability
- Examples: dormancy, seed banks, plant size (mussels, birds, large mammals)

Solutions

- Develop a protocol that attempts to keep detectability constant over space and time.
- Measure covariates that influence detectability
- Estimate detection probability spatially and temporally as part of the monitoring design

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Monitoring Data and Adaptive Management –
Using Monitoring Data to Improve Decision-making

- Analysis, Interpretation and Presentation of Data
- Communicating Results
- Archiving Data and Results
- Adaptive Management

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Monitoring Data and Adaptive Management – Using Monitoring Data to Improve Decision-making

- Analysis, Interpretation and Presentation of Data
  - Simple and understandable
- Communicating Results
- Archiving Data and Results
- Adaptive Management

Analysis, Interpretation and Presentation of Data

- Simple: Confidence Intervals
  - Present description of
    - change (impact, effect size)
    - measures of uncertainty (reliability, power)
  - Complex results presented clearly, without oversimplification, to audience of non-scientist decision makers
  - Present both “internal” evidence with data, but also separate “external” evidence from other studies and understanding of the mechanisms involved

Figure 6. Mean change in cover for selected species in the ungrazed wet meadow macroplot (with 90% confidence intervals)

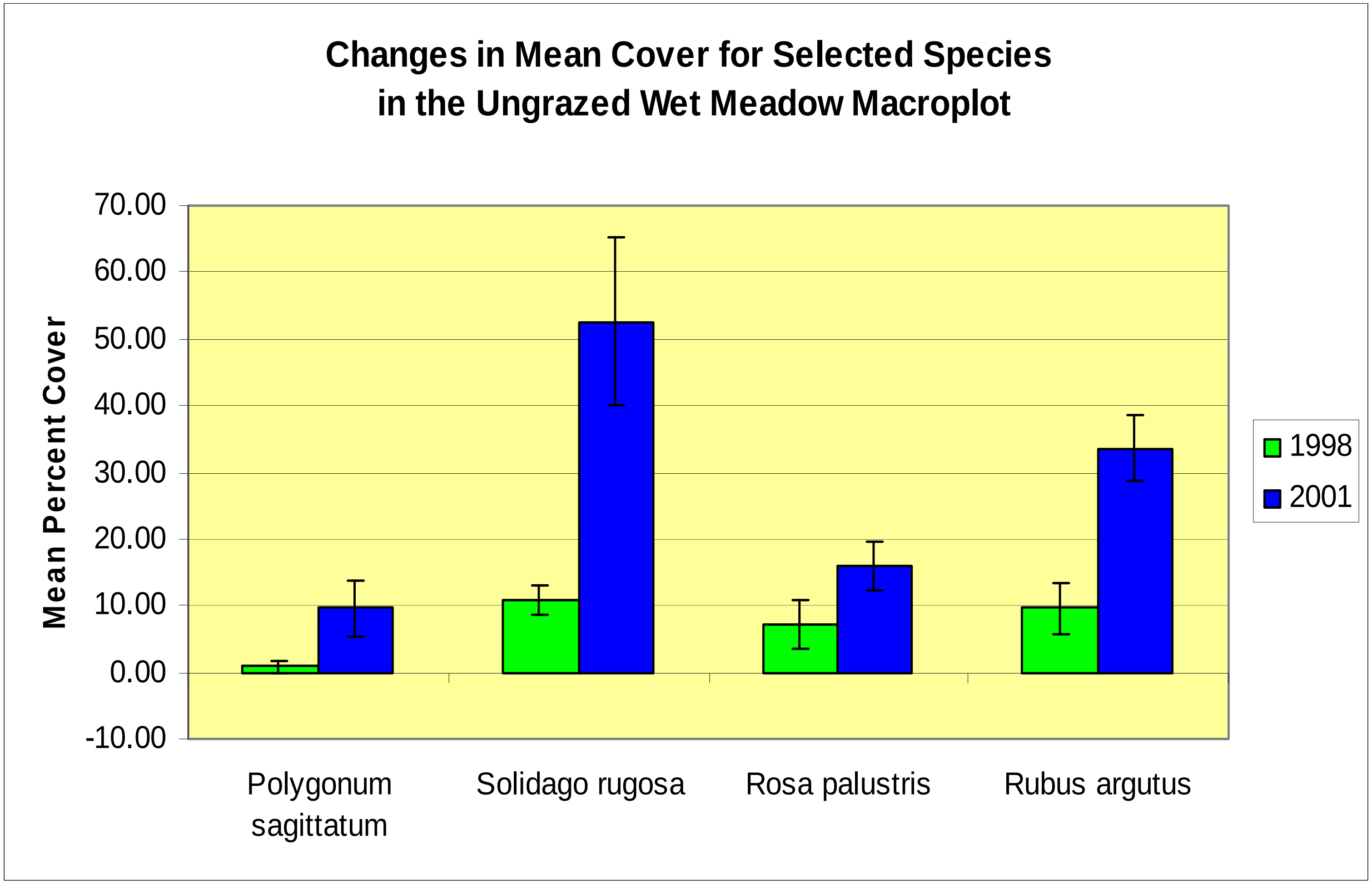
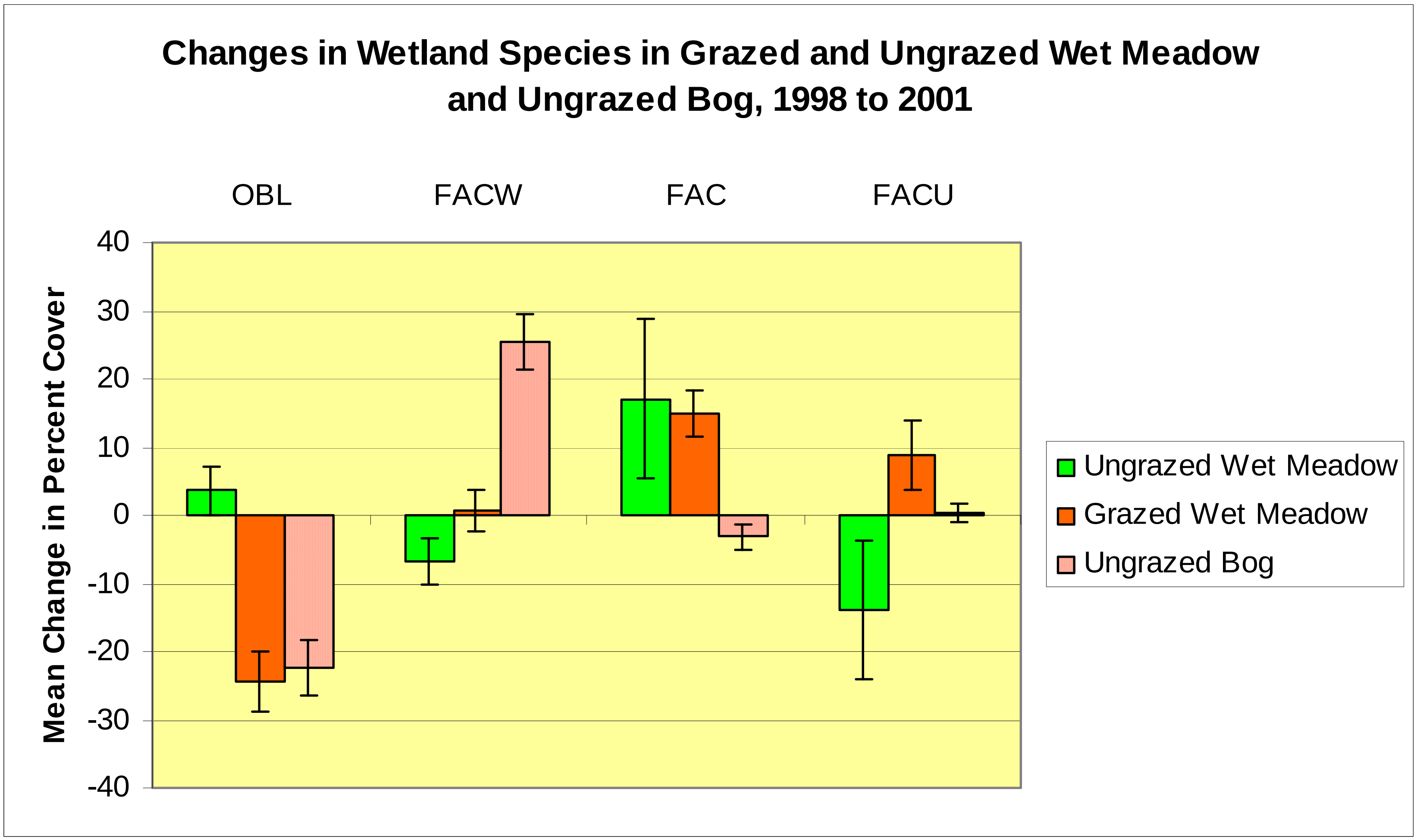


Figure 9. Mean change of cover in wetland species groups in three wetland communities (with 90% confidence intervals)



Demographic Monitoring / Population Viability Analyses (PVA)

From just numbers to information about reproduction, establishment and survival

What demographic monitoring can provide:

- estimate percent growth rate and project future population size
- understand and project population structure and contribution of different types of individuals to future reproduction
- understand contributions of each age/stage class to growth rate (sensitivity and elasticity)

Demographic Monitoring / Population Viability Analyses (PVA)

Powerful tool -- with substantial limitations

Logistical concerns for conservation

- resource (time, cost) consuming
- long-term commitment
- some parameters very difficult to measure
- confidence intervals

Different types of demographic analyses

- Census counts, matrix models, metapopulations

When is a demographic analyses worth doing?

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Monitoring Data and Adaptive Management – Using Monitoring Data to Improve Decision-making

- Analysis, Interpretation and Presentation of Data
- Communicating Results
  - Getting the information to decision-makers
  - Improve the work of others
  - Peer review to improve your work
- Archiving Data and Results
- Adaptive Management

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Monitoring Data and Adaptive Management – Using Monitoring Data to Improve Decision-making

- Analysis, Interpretation and Presentation of Data
- Communicating Results
- Archiving Data and Results
  - Does your agency archive project reports well?
  - Is there a central depository for archiving data?
  - Publishing as archiving
- Adaptive Management

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Adaptive Management

an approach that recognizes the **inherent complexity and uncertainty** in managing natural resources and **structures management into a learning process** that **maximizes management success and reduces uncertainty**.

Management in the **context of uncertainty**.

The process of linking ecological management within a **learning framework, that adapts to the gain of information**.

An **iterative process** of planning, management, monitoring, evaluation and adjusting management.

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Adaptive Management

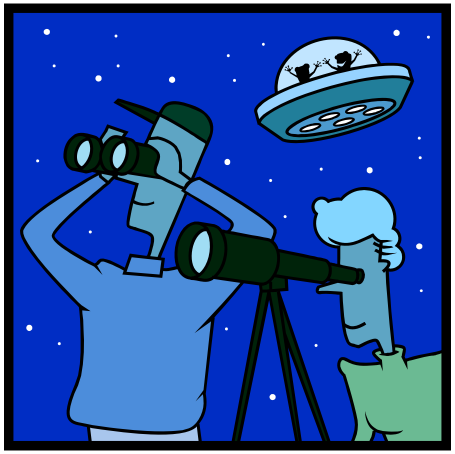
More than just the management and monitoring with feedback

The successful implementation of adaptive management requires:

- a thoughtful approach to the development and implementation of conservation and management actions
- a well designed process of monitoring the effects of conservation and management
- a formal process of analyzing and interpreting data and using the data and results in decision making
- an institutional structure that allows for adaptive action and active learning

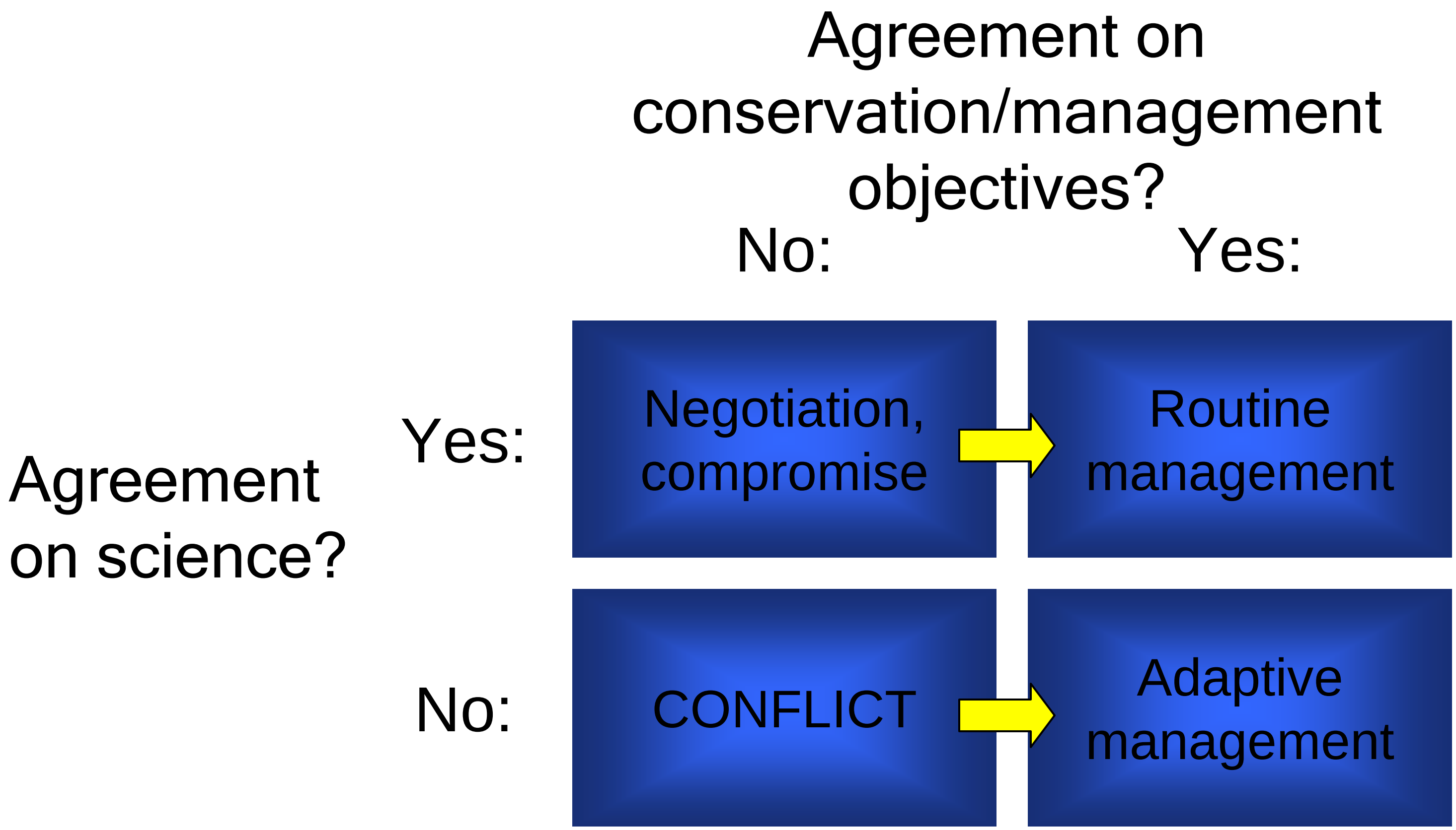
Controversy and Paralysis in Decision Making: Why does it exist?

Failure to separate ***disagreements about objectives*** from ***uncertainty about science***



Controversy in Resource Management:

Negotiate objectives first, resolve uncertainty through management



from Lee (1993)

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Why is Adaptive Management a Misunderstood Concept?

- Simple interpretation: “a willingness to change” or “flexible management”
  - “… means try something initially, then try something else if that fails.”
  - **Adaptive management is a guided, formal decision making process**
- Complex interpretation: research using an experimental design to determine cause and effect
  - **Adaptive management focuses on the appropriate means to assess and refine management outcomes.**
- Complex explanations that do not resolve management questions
  - **Adaptive management is only as complex as the population, species or system being managed, and it can range from simple to complex.**

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Summary

- Framework provides a bigger picture
- Objective-based Monitoring
  - ask questions worth assessing with monitoring data
  - monitoring priorities and resources based on:
    - uncertainty in science, management, status
    - organizational risk
    - financial investment
- Need to network and collaborate
- Results needed to be integrated into decision making
- Complex, but challenging and solvable with knowledge and collaboration

Keys to a Successful Adaptive Management Program

Approach

- develops clear, explicit conservation and management goals and objectives
- approaches conservation and management as hypotheses to reduce uncertainty
- develops the appropriate monitoring protocol
- analyses data and communicates results to decision-makers

Leadership

- develops focused objectives
- provides funding and skilled personnel
- links results to decision makers

Institutional Structure

- supports sequential decision making
- supports integration (programs, projects) and communication
- supports a learning culture, that allows the questioning of the way conservation and management is done