Multiple Attribute Scoring Test to Evaluate Ecological and User Capacities for National Parks

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Outline

A. Background
B. Definitions of ecological and user carrying capacities
C. Other methods
D. Proposed MASTEC method
E. Conclusions

A. Background

- In the mid-1930s, the National Park Service asked: “How large a crowd can be turned loose in a wilderness area without destroying its essential qualities?”

- Amendments to Public Law 91-383 (1970) require that general management plans for national park units include “identification of and implementation commitments for visitor carrying capacities for all areas of the unit.”

- Regulations implementing the National Forest Management Act of 1976 dictate that provision be made in wilderness management planning "for limiting and distributing visitor use of specific areas in accord with periodic estimates of the maximum levels of use that allow natural processes to operate freely and that do not impair the values for which wilderness areas were created."

- The National Outdoor Recreation Plan requires “each federal recreation land managing agency [to] determine the carrying capacity of its recreation lands.”

B. Ecological and User Carrying Capacities

Two kinds of carrying capacity:

- Ecological
- User

Ecological Carrying Capacity

- In range and wildlife management, ecological carrying capacity is defined as the maximum population of a particular species a habitat area can support in a given period of time without reducing the future ability of the area to support the species or damaging the area, or reducing the future ability of the area to support the species.

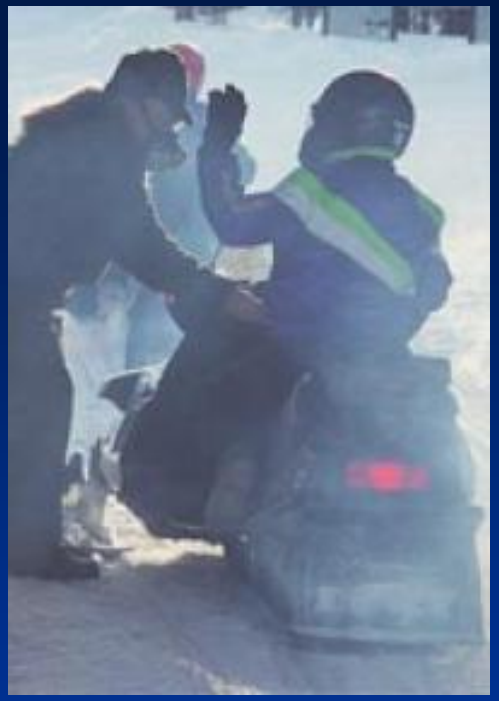
- Exceeding the ecological carrying capacity of a management area can result in irreversible ecosystem change, including decreases in plant community structure or species diversity, soil erosion, loss of vegetation, and degradation of wildlife habitat.

User Carrying Capacity

- The National Park Service defines user carrying capacity as “the type and level of visitor use that can be accommodated while sustaining desired resources and social conditions that complement the purpose of a park unit and its management objective.”

- User carrying capacity can also be defined as the maximum number and type of visitors an area can accommodate without degrading the biophysical quality of the area and without decreasing the quality of the visitor experience (i.e., visitor satisfaction and enjoyment).

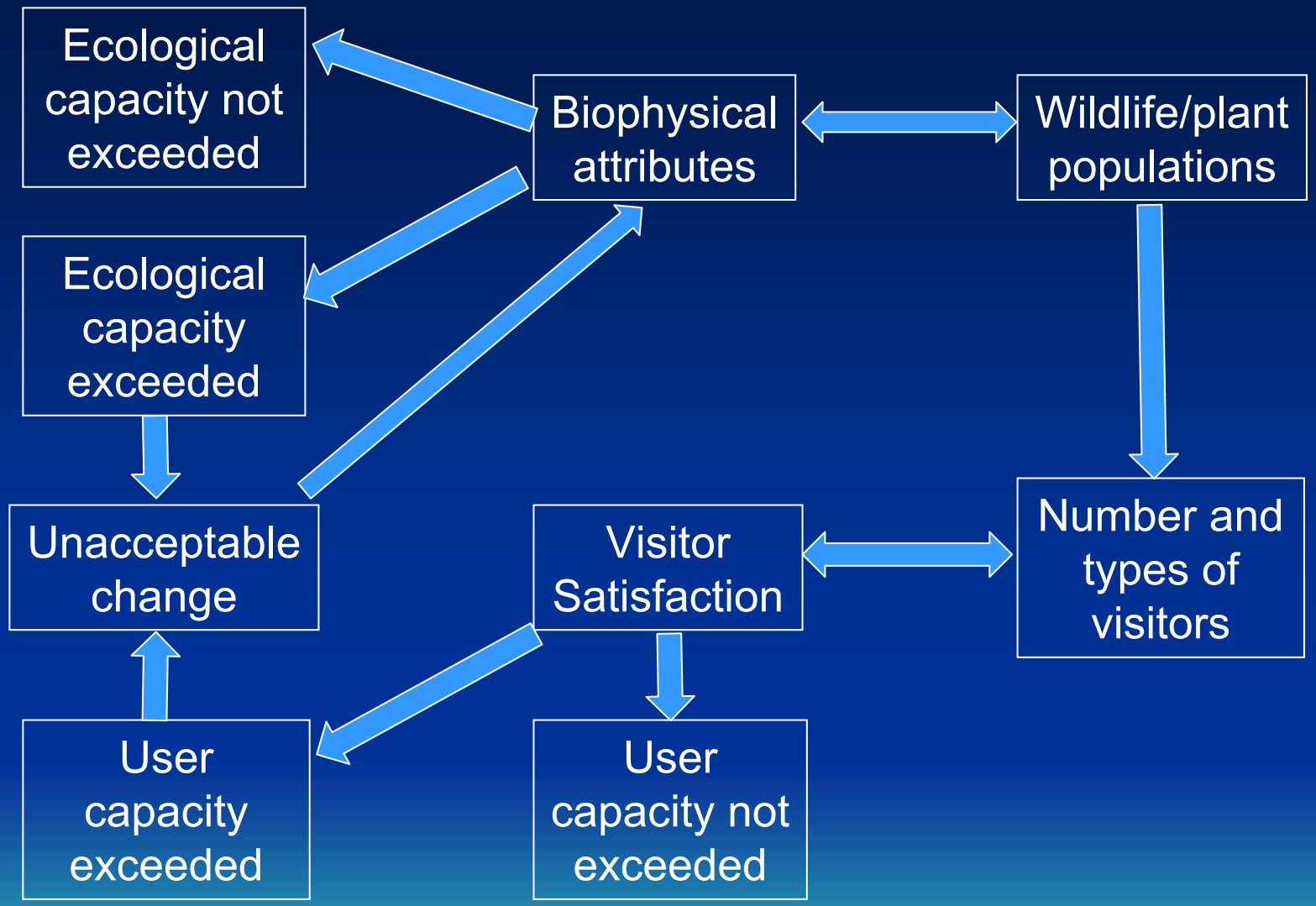
- Loss in visitor satisfaction and enjoyment can result from crowding, use conflicts, and resource and environmental degradation.



- Allowing snowmobiles in a national park can disturb wildlife, pollute the air, and diminish the quality of non-motorized recreational activities.

- Visitor use has several dimensions, including visitor behavior, and levels, types, timing, and location of use.

- Ecological and user carrying capacities are interrelated.


Ecological capacity not exceeded
Biophysical attributes
Wildlife/plant populations
Ecological capacity exceeded
Unacceptable change
Visitor Satisfaction
Number and types of visitors
User capacity exceeded
User capacity not exceeded

C. Other Methods

- Three most common evaluation methods:
  - Limits of Acceptable Change (LAC);
  - Visitor Impact Management (VIM); and
  - Visitor Experience and Resource Protection (VERP).

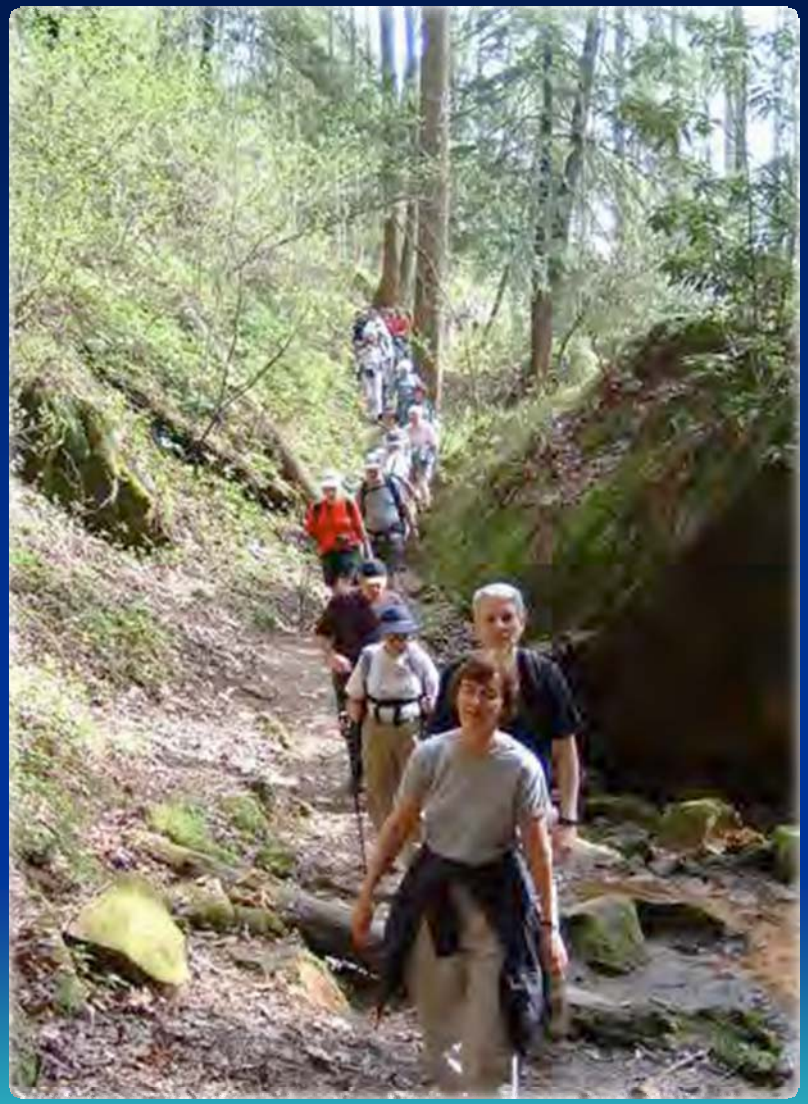
- These methods have already been discussed.

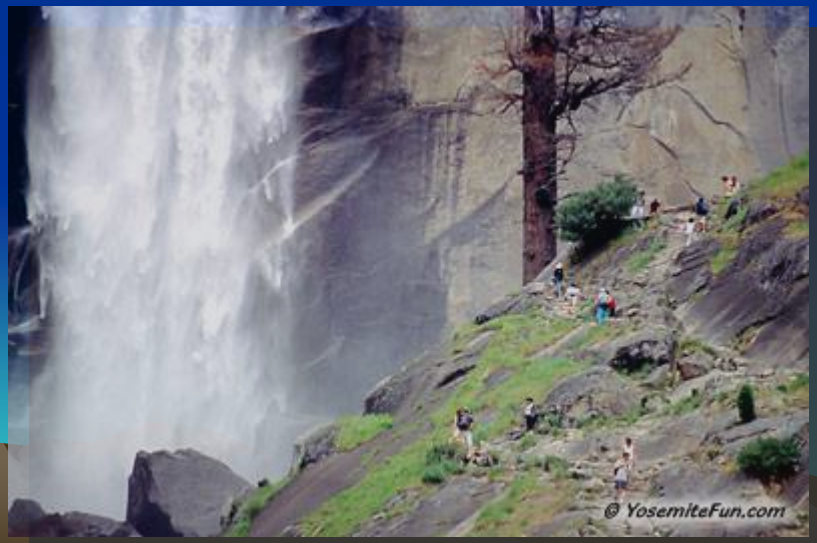
Resource and Social Impacts

- Exceeding user carrying capacity can have negative impacts on natural resources and visitor satisfaction.

- Resource impacts include loss in vegetation, tree damage, soil erosion and compaction, and wildlife disturbance.

- Social impacts include crowding, use conflicts, lower quality of visitor experiences due to excessive resource degradation, and other factors that diminish visitor satisfaction.





- In 1906, Yosemite National Park had 5,000 visitors. Today, more than three million people and their cars visit the park each year.

THEY RUN IN PACKS AND UPSET THE ECOSYSTEM... I SAY WE TRANSPORT THEM TO CANADA.
YELLOWSTONE
Mike Keefe 1995

D. Proposed MASTEC Method

- The Multiple Attribute Scoring Test for Capacity (MASTEC) method assesses the current state of an ecosystem with respect to ecological and user carrying capacities when managers are uncertain about the relationships between ecological and user carrying capacities and measured resource and user conditions.

Certainty Case

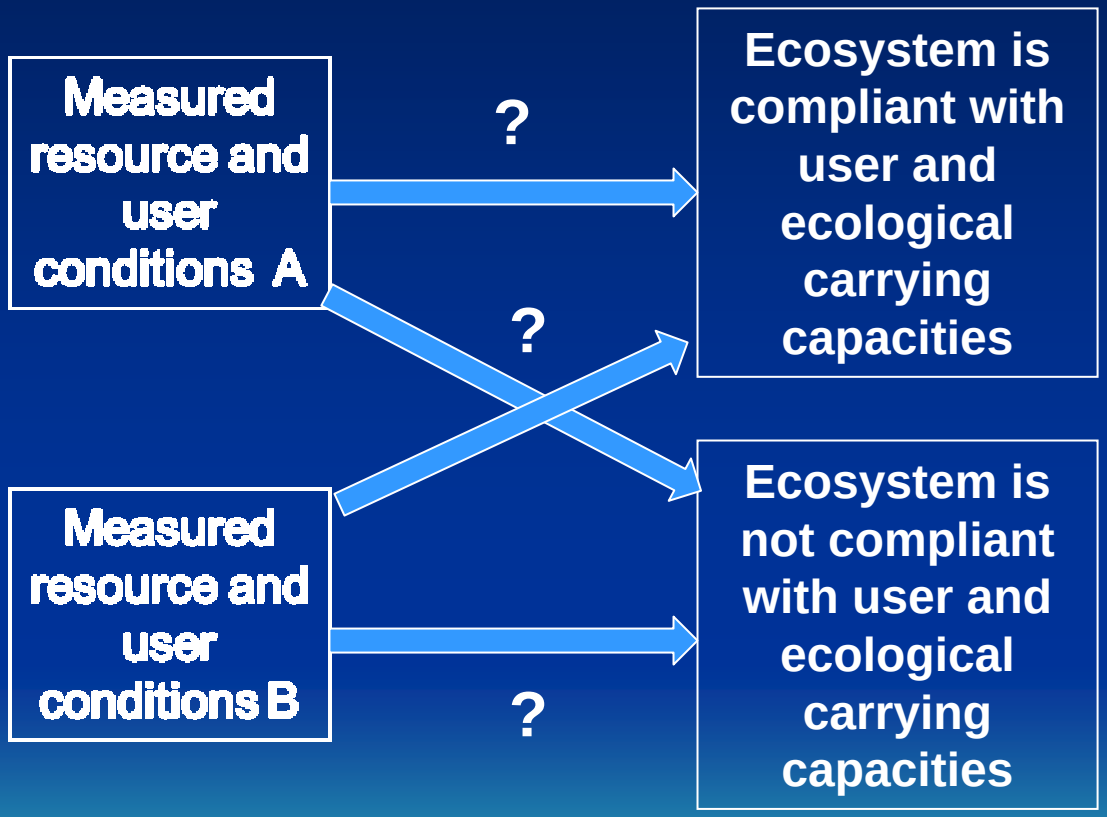
Measured resource and user conditions A → Ecosystem is compliant with user and ecological carrying capacities

Measured resource and user conditions B → Ecosystem is not compliant with user and ecological carrying capacities

- "If something can be measured accurately and with confidence, it is probably not particularly relevant in decision making."

  Robert T. Lackey - *Axioms of Ecological Policy*

Uncertainty Case

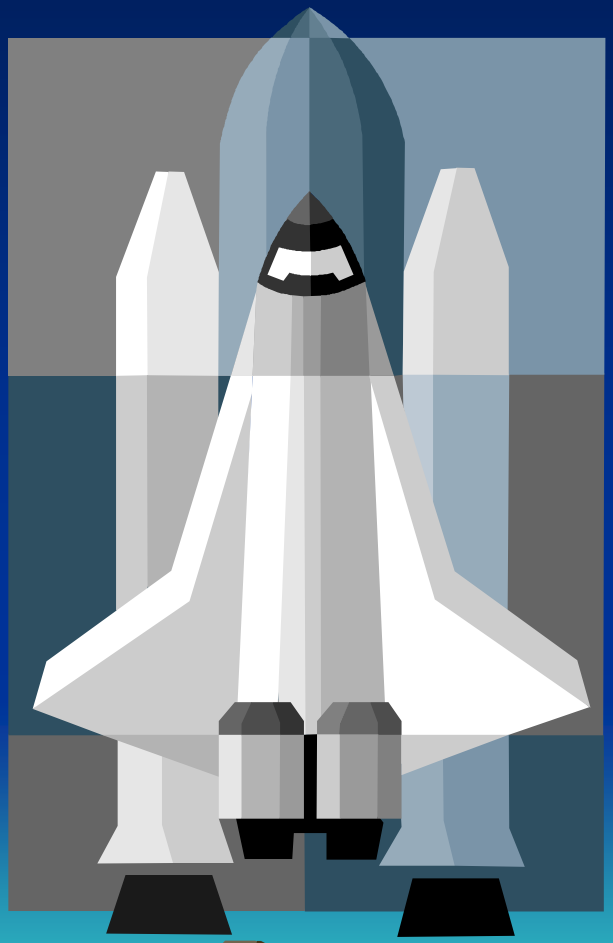


- In the uncertainty case, decision errors can be made when inferring ecosystem states for carrying capacity from measured resource and user conditions.

- The MASTEC method is designed to reduce these decision errors.

- MASTEC has elements in common with the LAC, VIM, and VERP methods.

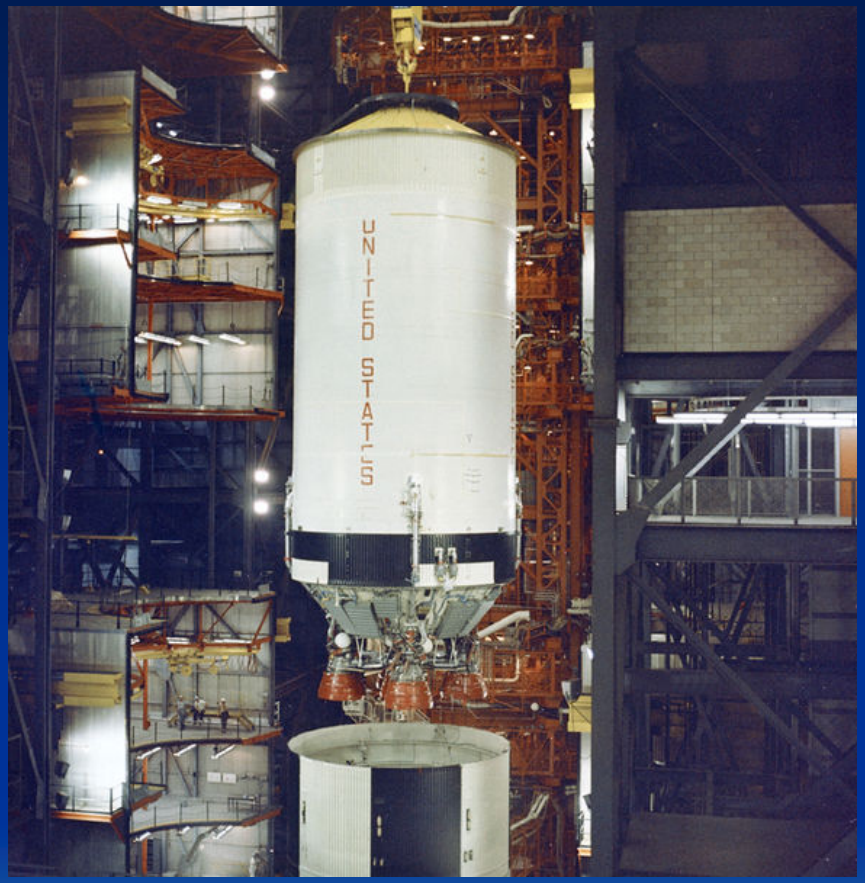
Two Stages in MASTEC Method



- In the first stage, the manager identifies the most likely state of the ecosystem with respect to ecological and user carrying capacities.

- If the state of the ecosystem is unacceptable with respect to carrying capacities (e.g., too many visitors at a particular location), then the second stage is implemented.

- In the second stage, the manager identifies and evaluates alternative management actions to achieve an acceptable ecosystem state.

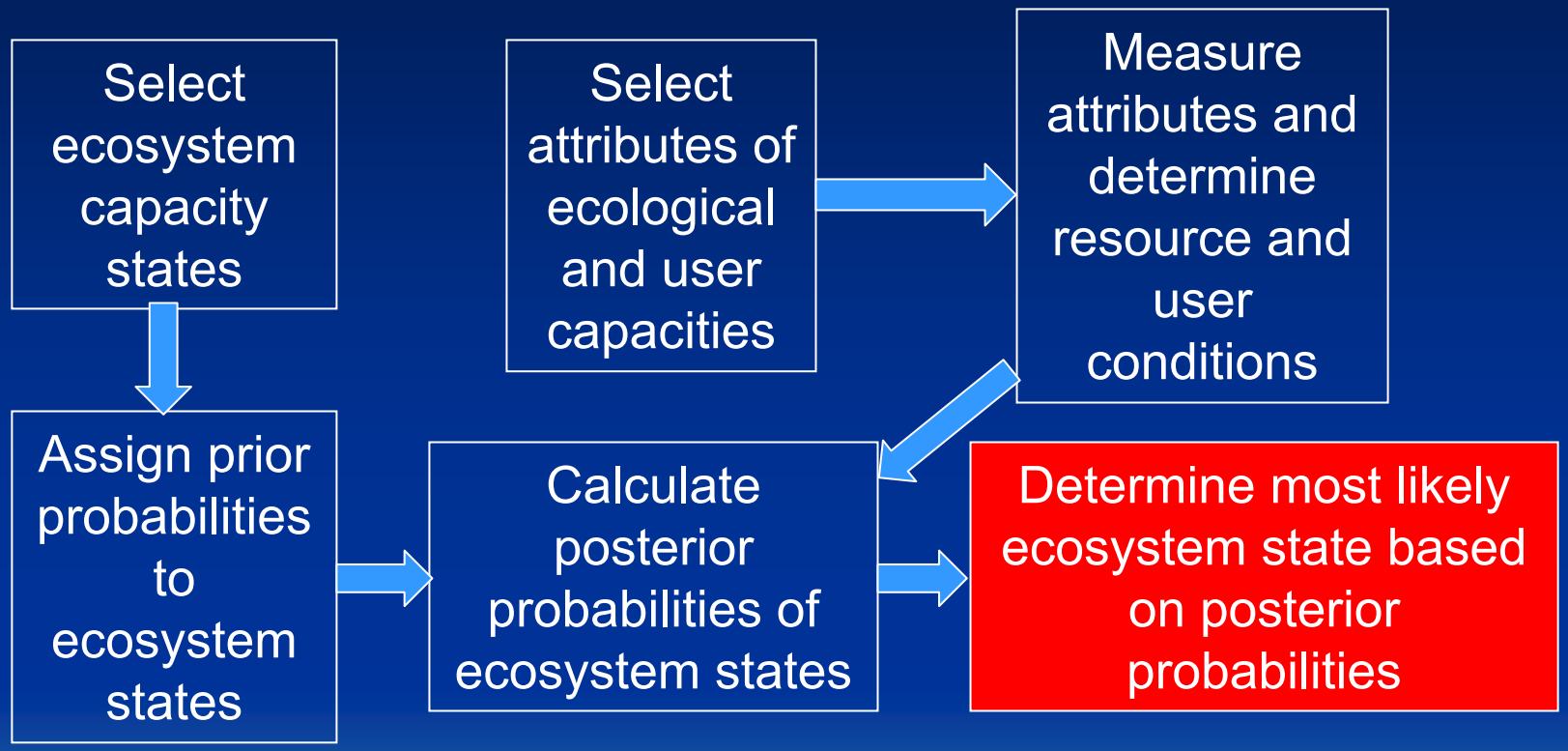


Example of First Stage

- In the first stage, the state of the ecosystem with respect to carrying capacities is inferred from resource and user conditions.

- The following diagram illustrates the steps in the first stage.

Schematic of First Stage



Hypothetical Example

- The first stage is described using a hypothetical example of a management unit in national park that can be in one of four mutually exclusive states with respect to ecological and user carrying capacities.

- Suppose there are four states and prior probabilities of states:
  - M_1 and $p(M_1)$
  - M_2 and $p(M_2)$
  - M_3 and $p(M_3)$
  - M_4 and $p(M_4)$

- $p(M_i)$ is the prior probability that the ecosystem state is M_i

- Prior probabilities sum to one

- In terms of ecological and user carrying capacities:
  - M_1 is highly unacceptable
  - M_2 is moderately unacceptable,
  - M_3 is moderately acceptable, and
  - M_4 is highly acceptable.

- An interdisciplinary panel composed of park managers, scientists, and technicians select the possible ecosystem states for management units and assign prior probabilities to them.

- The ecosystem state is inferred from the prior probabilities and measured resource and user conditions.

- The example measures resource and user conditions in terms of four attributes of carrying capacity as follows:

Ecological capacity attributes:

- percent of native species present, and
- percent of ecosystem with good habitat for endangered species

User capacity attributes:

- percent of backcountry hiking trails that are not congested, and
- percent of the time visitors have to wait less than 30 minutes for in-park transportation.

- The four attributes are positive because higher levels of the attribute imply better conditions.

- Attributes can be negative (e.g., soil erosion and siltation of streams). For negative attributes, higher levels of the attribute imply worse conditions.

- The four attributes are used to define four ecosystem conditions:

R_1 - Very poor conditions:

- < 60% of native species present
- < 60% of ecosystem has good habitat for endangered species
- < 50% of hiking trails not congested
- < 30% of park visitors have to wait less than 30 minutes for in park transit

R_2 - Poor conditions:

- 60-75% of native species present
- 60-75% of ecosystem has good habitat for endangered species
- 50-70% of hiking trails not congested
- 30-45% of park visitors have to wait less than 30 minutes for in-park transit

R_3 – Good conditions:

- 75-85% of native species present
- 75-85% of ecosystem has good habitat for endangered specie
- 70-80% of hiking trails not congested
- 45-60% of park visitors have to wait less than 30 minutes

R_4 - Very good conditions:

- 85-100% of native species present
- 85-100% of ecosystem has good habitat for endangered species
- 80-100% of hiking trails are not congested
- 60-100% of park visitors have to wait less than 30 minutes for park transit.

Ecosystem conditions improve from R_1 to R_4.

Decision

The park manager must decide the state of the ecosystem based on prior probabilities and ecosystem conditions.

Decision Errors

- Two decision errors can occur:
  - First error: The manager decides the ecosystem state is M_3 or M_4 (acceptable) when it is really M_1 or M_2 (unacceptable).

  - With this error, the manager is not likely to take action to achieve an acceptable ecosystem state, even though such action is needed.

- Second error: The manager decides the ecosystem state is M_1 or M_2 (unacceptable) when it is really M_3 or M_4 (acceptable).

- With this error, the manager is likely to take action to achieve an acceptable ecosystem state, even though such action is not needed.

Most Likely Ecosystem State

- Decision errors can be reduced by using Bayesian statistical analysis to identify the ecosystem state having the highest posterior probability, $p(M_i|R_j)$.

- For example, $p(M_1|R_2)$ is the probability the ecosystem state is highly unacceptable (M_1) given the measured ecosystem conditions are poor (R_2).

- Suppose measured values of the four attributes indicate the ecosystem condition is R_1.
- The posterior probabilities of the four ecosystem states given R_1 are as follows:

$\sum_{i=1}^{I}$

Posterior Probabilities Given R_1

State	$p(M_i)$	$p(R_1\|M_i)$	$p(M_j\|R_1)$[a]
M_1	0.4	0.5	0.63
M_2	0.3	0.3	0.28
M_3	0.2	0.1	0.13
M_4	0.1	0.1	0.06

M_1 is highly unacceptable.

a. $p(M_i|R_1) = [p(R_1|M_i)\ p(M_i)]/[\Sigma_i\ p(R_1|M_i)\ p(M_i)]$ based on Bayes' theorem.

Second Stage

- Since R_1 is not consistent with an acceptable ecosystem state (M_3 or M_4), the manager proceeds to the second stage.

- In the second stage, the manager selects and implements several management actions, measures ecosystem conditions under those actions, and determines the most likely ecosystem state.

- For example, if management action A_3 is implemented and monitoring and evaluation indicate that the ecosystem condition is R_3, then the posterior probabilities of the four ecosystem states given R_3 are as follows:

$\sum_{i=1}^{I}$

Posterior Probabilities Given R_3

State	$p(M_i)$	$p(R_3\|M_i)$	$p(M_i\|R_3)$
M_1	0.4	0.1	0.19
M_2	0.3	0.2	0.29
M_3	0.2	0.4	0.38
M_4	0.1	0.3	0.14

M_3 is moderately acceptable.

a. $p(M_i|R_3) = [p(R_3|M_i)\ p(M_i)]/[\Sigma_i\ p(R_3|M_i)\ p(M_i)]$

E. Conclusions

- The proposed MASTEC method allows park managers to determine whether the current state of an ecosystem with respect to ecological and user carrying capacities is acceptable, and, if not, to identify those implemented management actions that result in an acceptable ecosystem state.

- The MASTEC method is advantageous relative to other carrying capacity evaluation methods when:
  1. The manager is likely to commit decision errors when inferring the state of the ecosystem with respect to ecological and user capacities from measured ecosystem conditions, and
  2. Making such decision errors is unacceptable to the manager.

- The MASTEC method is not advantageous relative to other carrying capacity evaluation methods when:
  1. The manager is unlikely to commit such decision errors (i.e., the state of the ecosystem can be precisely inferred from measured ecosystem conditions), or

  2. The manager is willing to accept the consequences of such decision errors should they occur.

References

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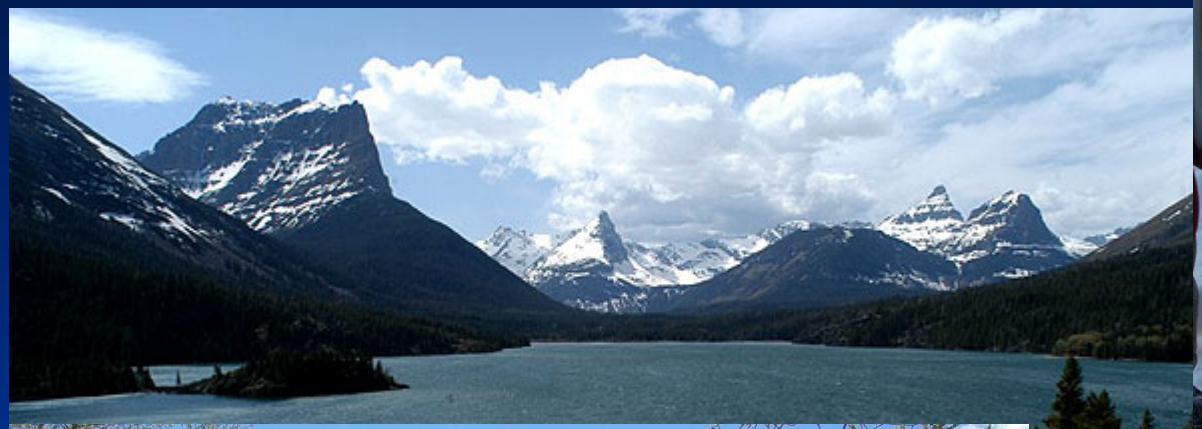
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