The Wisdom of the River: Why Argue with Several Million Years of Success?

Gary K. Meffe
Society for Conservation Biology
and
The University of Florida

Underlying Theme:

Nature has been managing the Colorado River for several million years, and humans have been at it for about 100...

...we still have a few things to learn from it.

Some background:

Some background:

1) I’m not an expert on the C.R.

Some background:

1) I’m not an expert on the C.R.

2) I don’t presume to tell you how to do your jobs.

Some background:

1) I’m not an expert on the C.R.

2) I don’t presume to tell you how to do your jobs.

3) I would like to suggest a big-picture perspective that could have some bearing on management of the C.R.

Much of this may not be new to many of you....but it deserves a periodic reminder.

Outline:

Outline:

I. Discuss command and control relative to natural resource management.

Outline:

I. Discuss command and control relative to natural resource management.

II. Explain how that leads to a pathology in natural resource management.

Outline:

I. Discuss command and control relative to natural resource management.

II. Explain how that leads to a pathology in natural resource management.

III. Examples of the pathology.

Outline:

I. Discuss command and control relative to natural resource management.

II. Explain how that leads to a pathology in natural resource management.

III. Examples of the pathology.

IV. Adaptive management as an alternative approach.

Outline:

I. Discuss command and control relative to natural resource management.

II. Explain how that leads to a pathology in natural resource management.

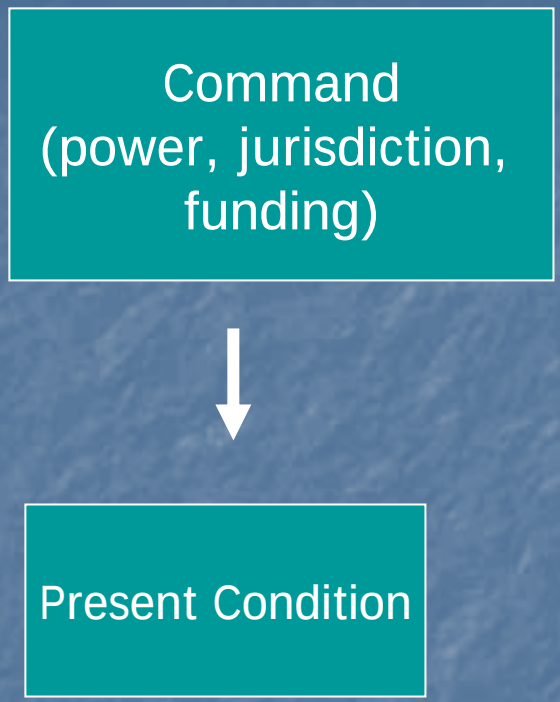
III. Examples of the pathology.

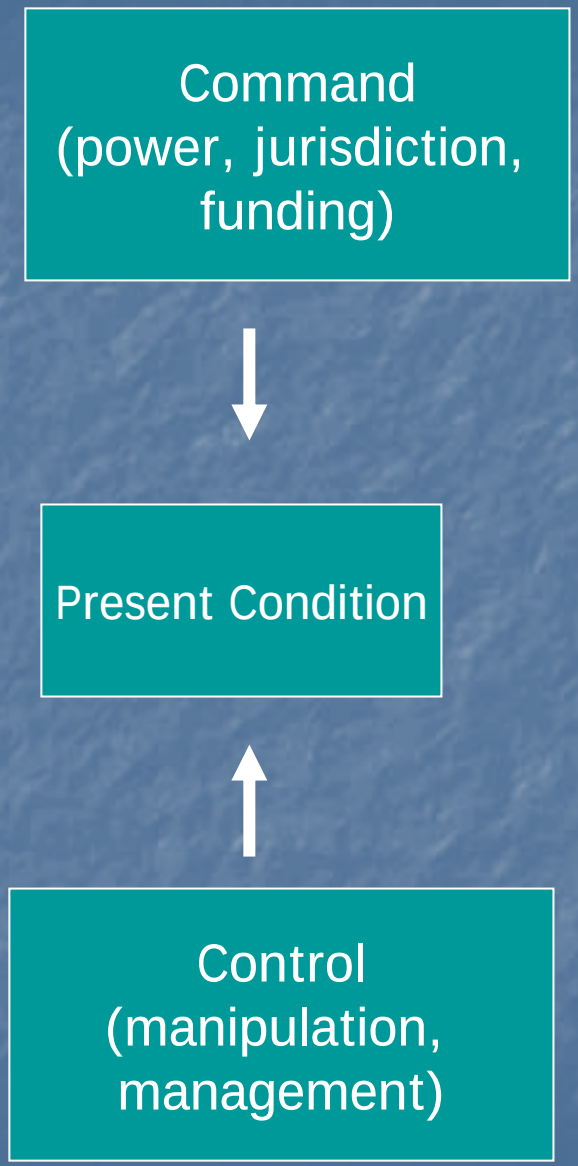
IV. Adaptive management as an alternative approach.

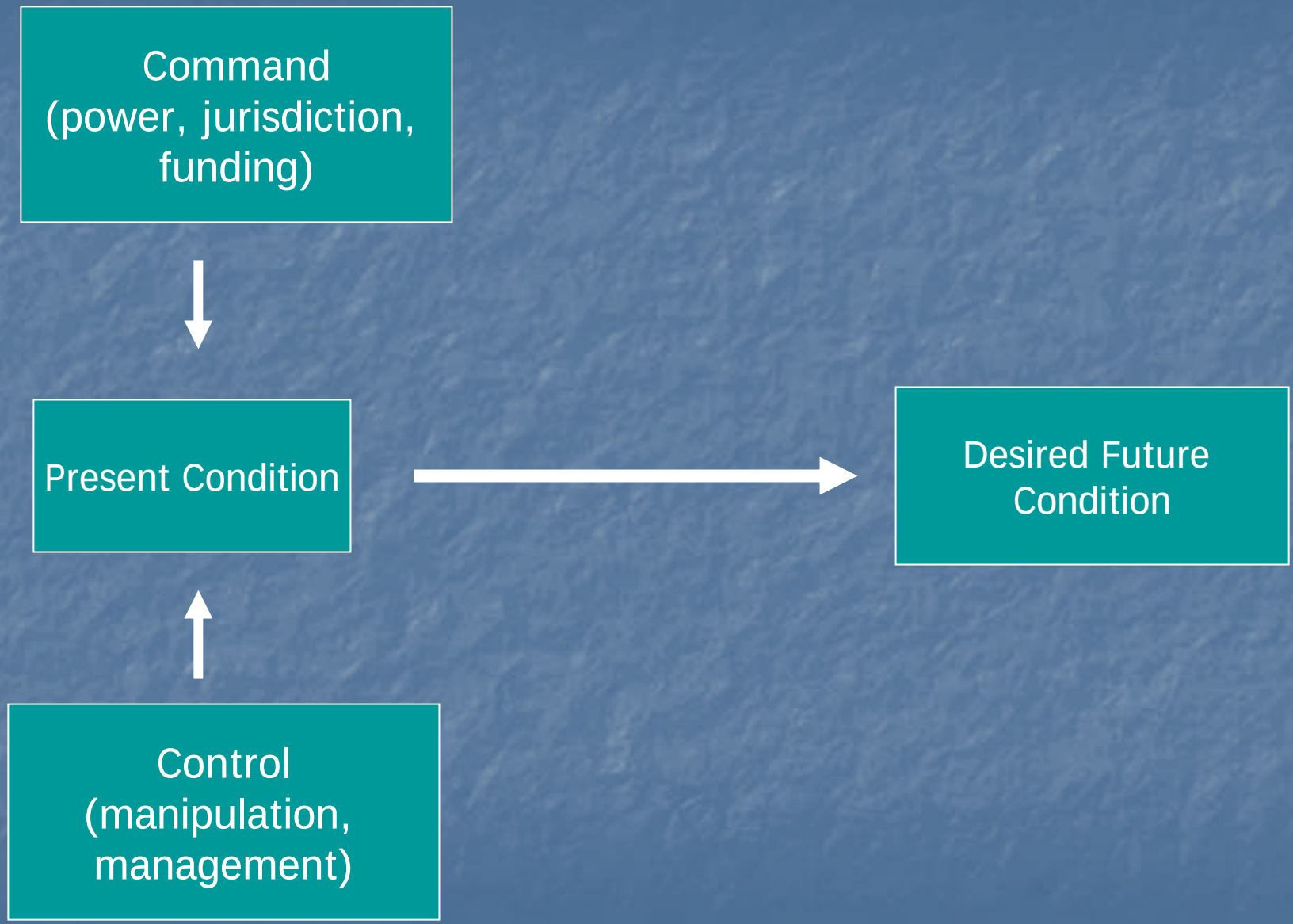
V. Data from Arizona fishes relative to flooding and command and control.

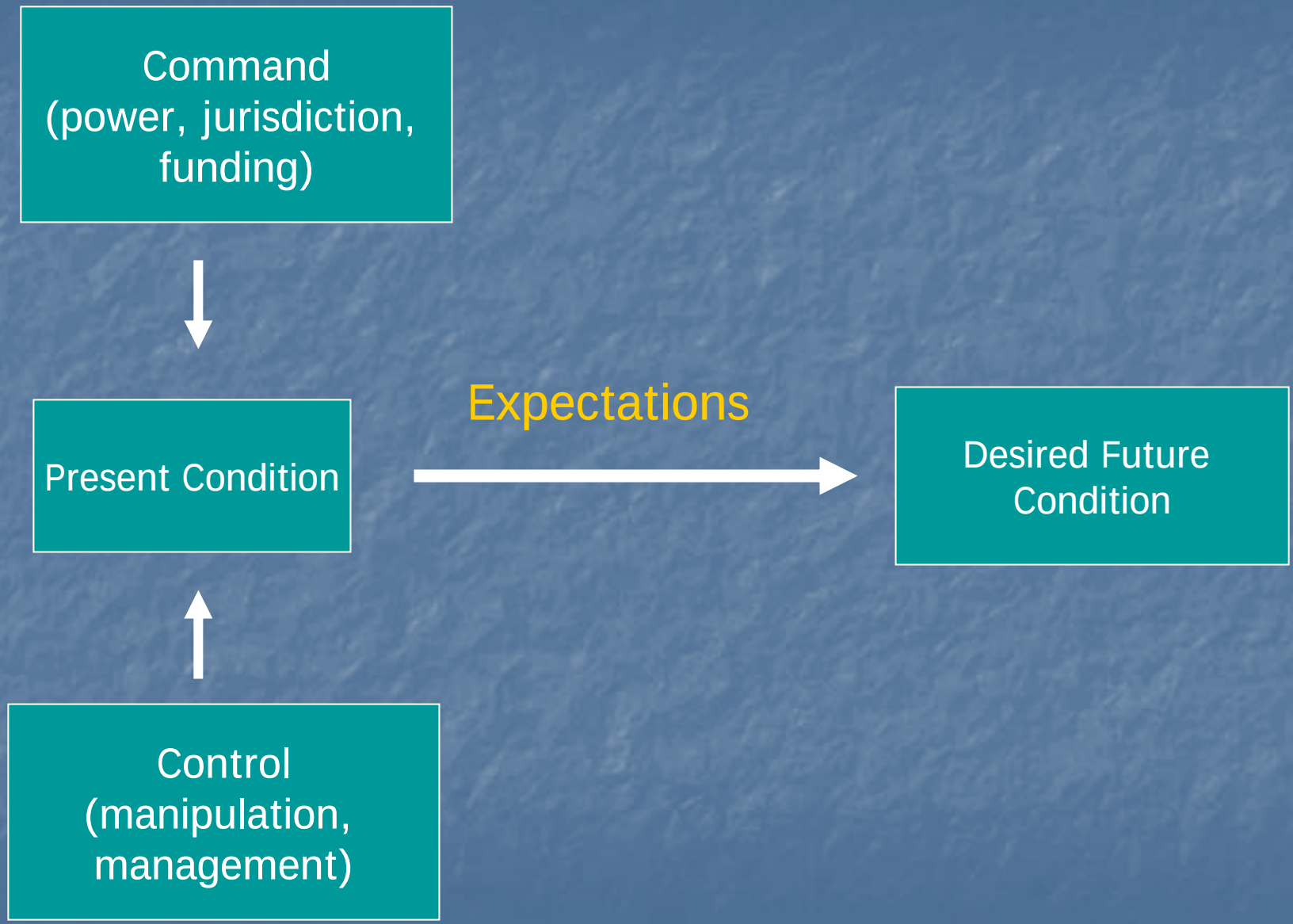
I) A look at command and control approaches to natural resource management

Present Condition


Command
(power, jurisdiction, funding)
Present Condition


Command
(power, jurisdiction, funding)
Present Condition
Control
(manipulation, management)


Command
(power, jurisdiction, funding)
Present Condition
Desired Future Condition
Control
(manipulation, management)


Command
(power, jurisdiction, funding)
Present Condition
Expectations
Desired Future Condition
Control
(manipulation, management)

Expectations:

The solution is:

Expectations:

The solution is:

--appropriate

Expectations:

The solution is:

--appropriate

--feasible

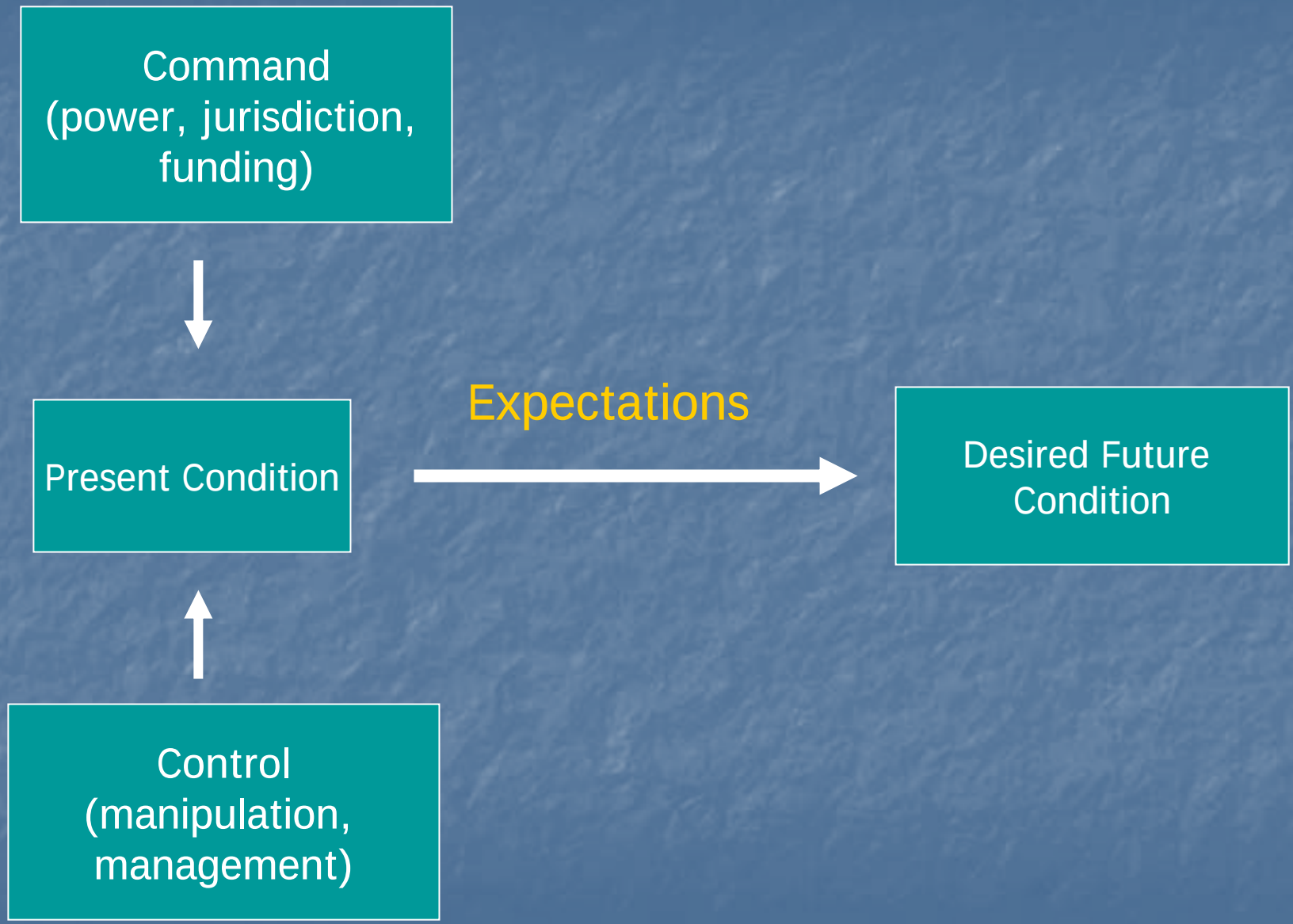
Expectations:

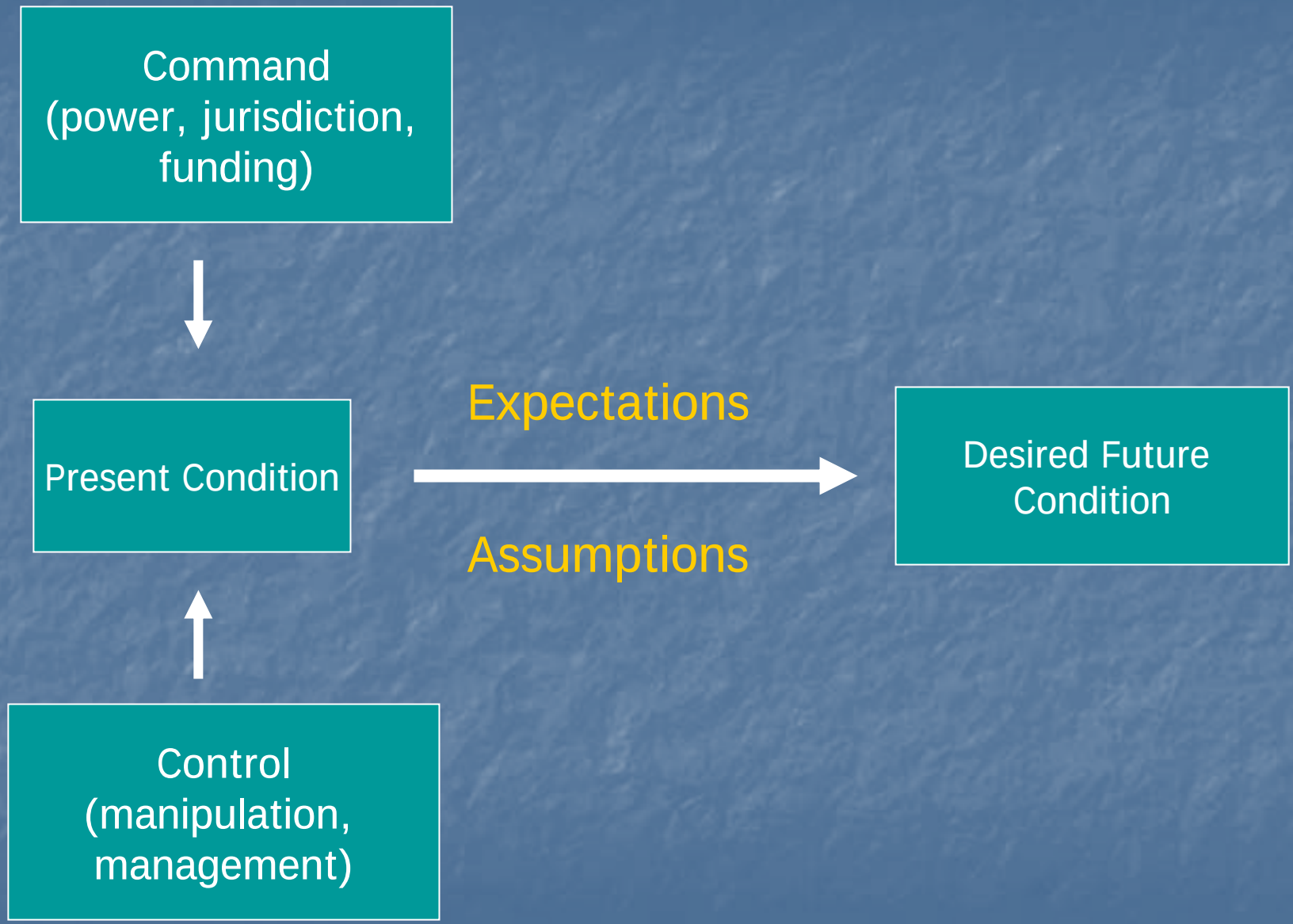
The solution is:

--appropriate

--feasible

--will work over relevant spatial and temporal scales


Command
(power, jurisdiction, funding)
Present Condition
Expectations
Desired Future Condition
Control
(manipulation, management)


Command
(power, jurisdiction, funding)
Present Condition
Expectations
Assumptions
Desired Future Condition
Control
(manipulation, management)

Assumptions:

The problem is:

Assumptions:

The problem is:

--well bounded

Assumptions:

The problem is:

--well bounded

--clearly defined

Assumptions:

The problem is:

--well bounded

--clearly defined

--relatively simple

Assumptions:

The problem is:

--well bounded

--clearly defined

--relatively simple

--generally responds linearly to manipulation

Assumptions:

The problem is:

--well bounded

--clearly defined

--relatively simple

--generally responds linearly to manipulation

--is without unforeseen consequences and externalities

Such assumptions are often (but not always) true in physics and engineering, but never entirely true in ecological systems because of their inherent complexities and accompanying uncertainties.

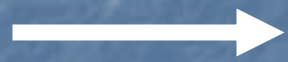
The underlying assumptions necessary for the expectations of command and control to be met are in fact usually not valid in ecological systems.

Thus, when applied uncritically to natural resources, the command-and-control approach often results in unforeseen and undesirable consequences
(= surprises and crises).

One frequent (perhaps universal) result of C & C when applied to natural resource management is *reduction of the range of natural variation of systems*—their structure, function, or both—in an attempt to increase their predictability or stability.

Unpredictable and "inefficient" natural system

C & C



System that produces products in a predictable and economically efficient way

...but that leads to a common and widespread problem or pathology:

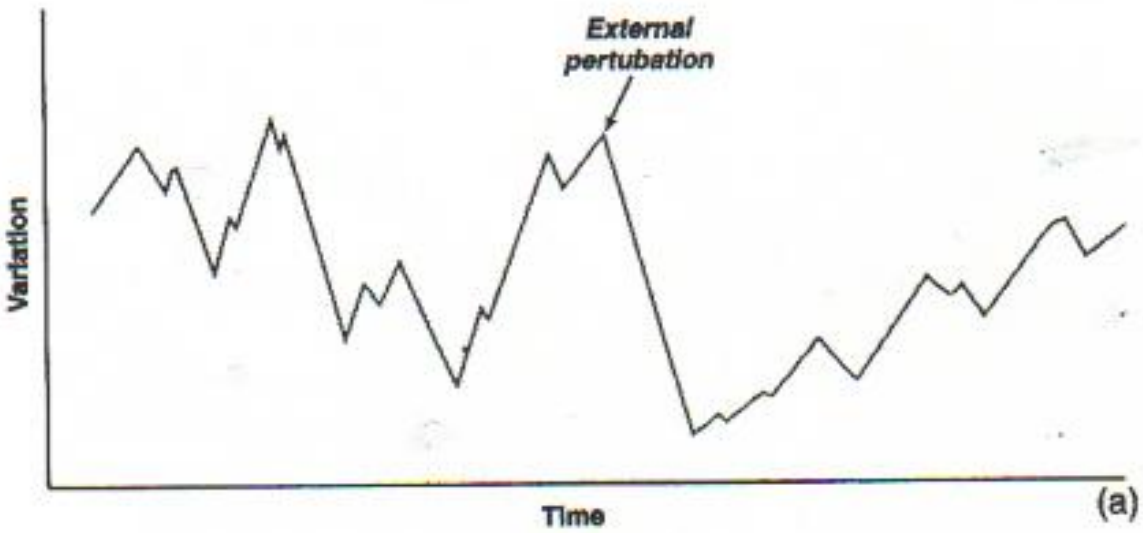
II) Pathology of Natural Resource Management:

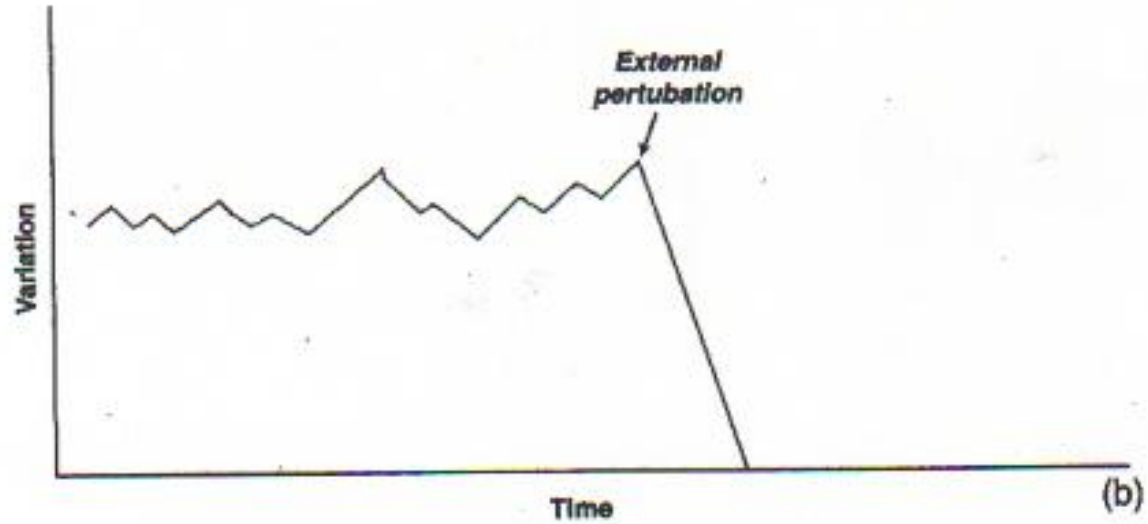
Pathology of Natural Resource Management:

"When the range of natural variation in a system is reduced, the system loses resilience when faced with new stressors."

Resilience: a measure of the magnitude of disturbance that can be absorbed or accommodated by an ecosystem before it fundamentally changes its structure.

Loss of resilience: ecosystem less likely to retain its basic characteristics after a perturbation and may change to fundamentally new state.


External pertubation
Variation
Time
(a)


External pertubation
Variation
Time
(b)

III) Examples of the pathology:

Examples of the pathology:

1) Control of fire in fire-prone ecosystems.

Examples of the pathology:

1) Control of fire in fire-prone ecosystems.

2) Control of flooding in flood-prone rivers.

Examples of the pathology:

1) Control of fire in fire-prone ecosystems.

2) Control of flooding in flood-prone rivers.

3) Development of monocultures and chemical control of insect pests in agricultural systems.

The pathology has three components:

The pathology has three components:

1) Human-imposed external control of a natural ecosystem;

The pathology has three components:

1) Human-imposed external control of a natural ecosystem;
2) Develop institutional emphases on increased efficiency and effectiveness of control;

The pathology has three components:

1) Human-imposed external control of a natural ecosystem;
2) Develop institutional emphases on increased efficiency and effectiveness of control;
3) Increasing economic dependency on control and overcapitalization within the controlled ecosystem.

The composite results of this pathology are:

The composite results of this pathology are:

1) Less resilient and more “brittle” ecosystems;

The composite results of this pathology are:

1) Less resilient and more “brittle” ecosystems;
2) Institutions more intently focused on control; and

The composite results of this pathology are:

1) Less resilient and more “brittle” ecosystems;
2) Institutions more intently focused on control; and
3) Increasingly dependent economic interests attempting to maintain short-term success.

The result is that, by pursuing command and control of natural resources, we may experience short-term success but *we build long-term failure into the system*.

A “Golden Rule” of Natural Resource Management:

A “Golden Rule” of Natural Resource Management:

Strive to retain critical types and ranges of natural variation in ecosystems.

Crisis, surprises, and failure occur when the problem and response have the following characteristics*:

*Adapted from C.S. Holling, 1995, in *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, Gunderson, Holling, and Light (eds)., Columbia University Press, NY.

Crisis, surprises, and failure occur when the problem and response have the following characteristics:

--a single target and piecemeal policy;

Crisis, surprises, and failure occur when the problem and response have the following characteristics:

--a single target and piecemeal policy;

--a single scale of focus, typically on the short term & the local;

Crisis, surprises, and failure occur when the problem and response have the following characteristics:

--a single target and piecemeal policy;

--a single scale of focus, typically on the short term & the local;

--failure to realize that all policies are experimental;

Crisis, surprises, and failure occur when the problem and response have the following characteristics:

--a single target and piecemeal policy;

--a single scale of focus, typically on the short term & the local;

--no realization that all policies are experimental;

--rigid management with no hypothesis testing of policies.

The typical response to such scenarios when they fail is to demand more data, more precision in data, more certainty, and more control of information and individuals.

IV) The pathology is broken when we switch to **adaptive policy management**, which requires:

The pathology is broken when we switch to **adaptive policy management**, which requires:

--integrated policies, not piecemeal ones;

The pathology is broken when we switch to **adaptive policy management**, which requires:

--integrated policies, not piecemeal ones;

--flexible, adaptive policies, not rigid ones;

The pathology is broken when we switch to **adaptive policy management**, which requires:

--integrated policies, not piecemeal ones;

--flexible, adaptive policies, not rigid ones;

--management and planning for learning, not simply for economic or social products;

The pathology is broken when we switch to **adaptive policy management**, which requires:

--integrated policies, not piecemeal ones;

--flexible, adaptive policies, not rigid ones;

--management and planning for learning, not simply for economic or social products;

--citizen involvement and partnerships to build "civic science," not public information programs to inform passively.

Thus, adaptive management, which you have chosen to embrace, seems the correct and only reasonable way to approach management of any natural resource, including the Colorado River.

V) Data demonstrating how maintaining natural variation in a system could help to maintain the system in the face of external perturbations.

The system is native fishes in Arizona and the perturbation is exotic fish species.

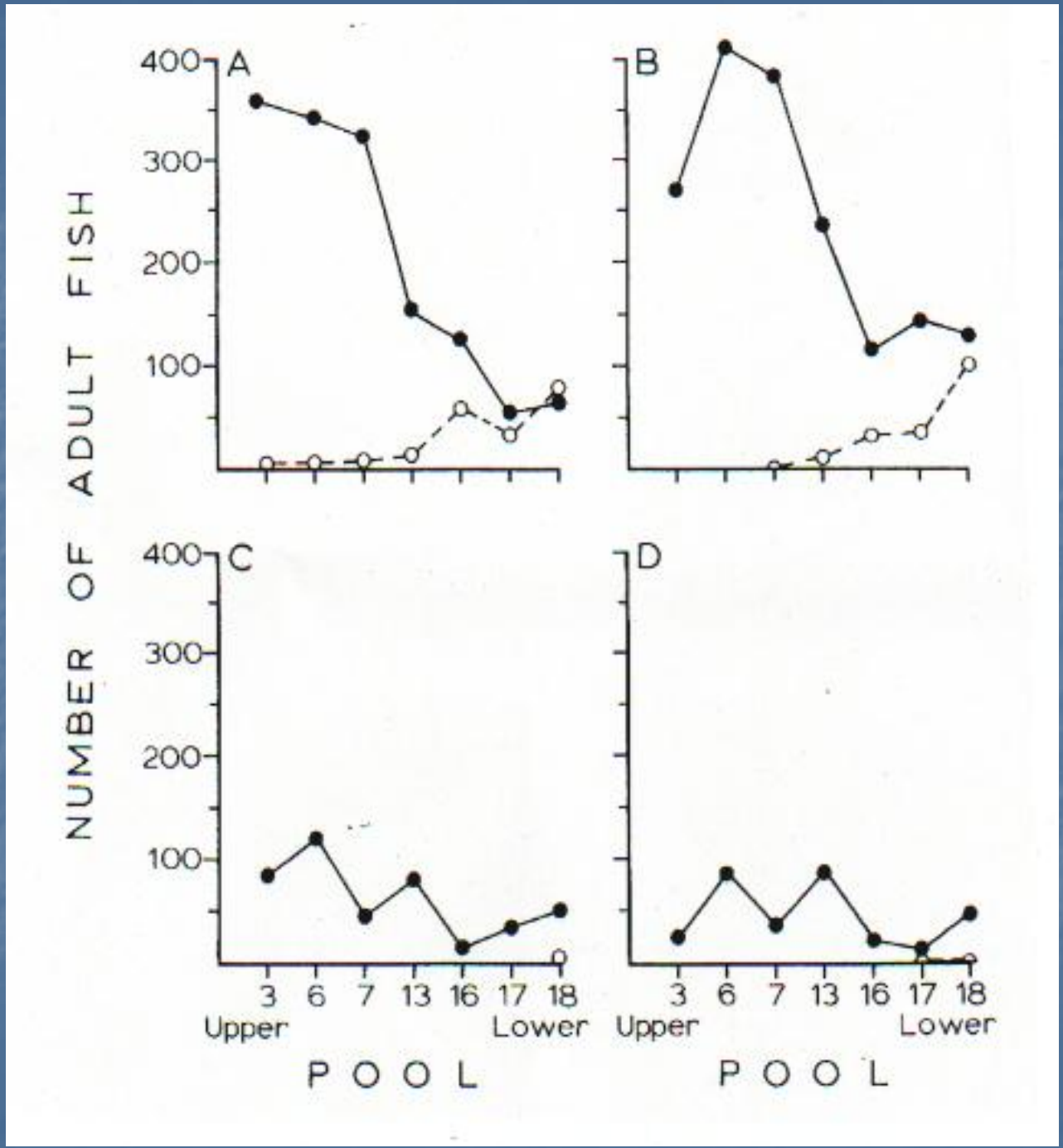
Fish tale # 1:

a simple interaction

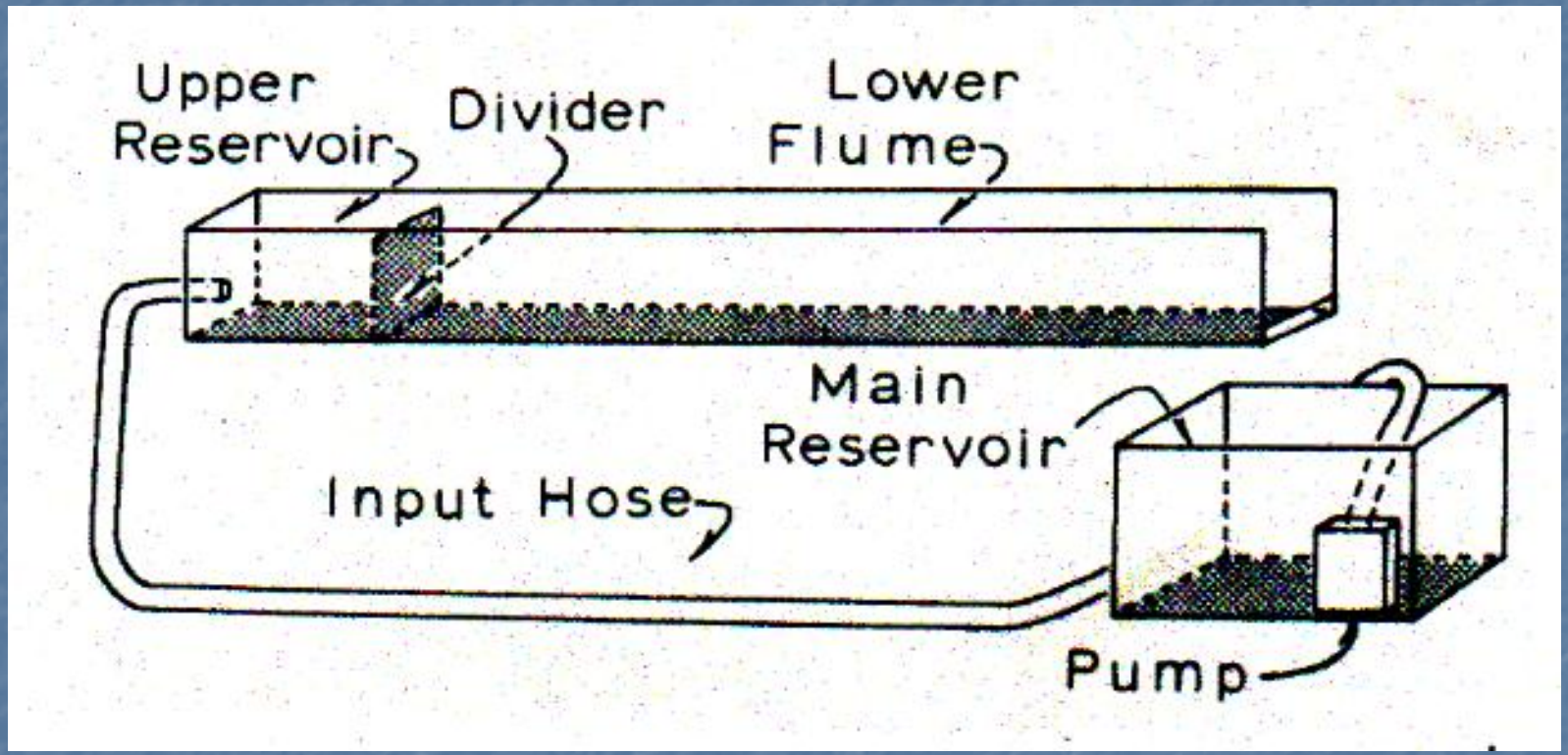
The Native Species: Gila topminnow (*Poeciliopsis occidentalis*)

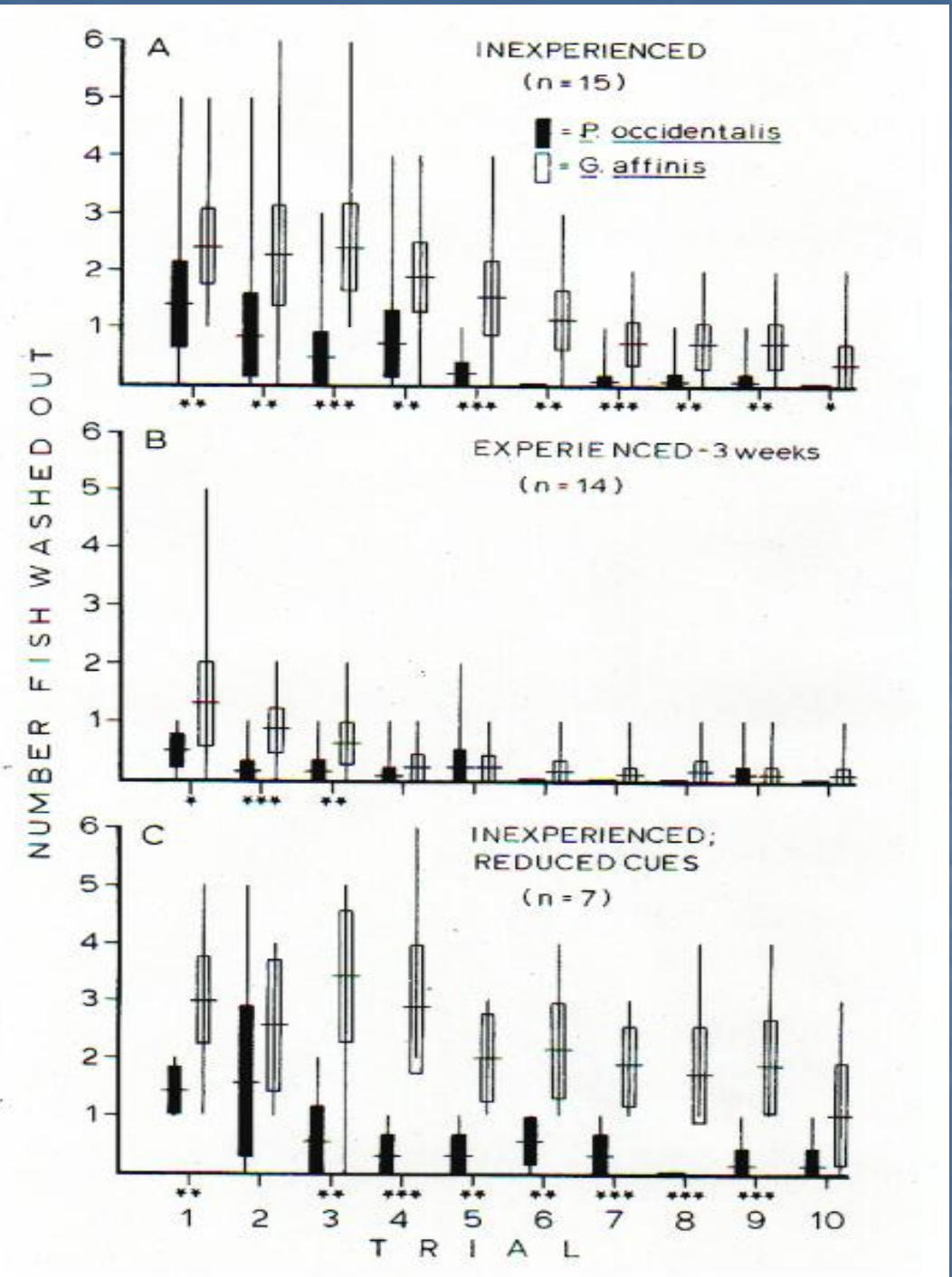
The Exotic Species: Western Mosquitofish (*Gambusia affinis*)

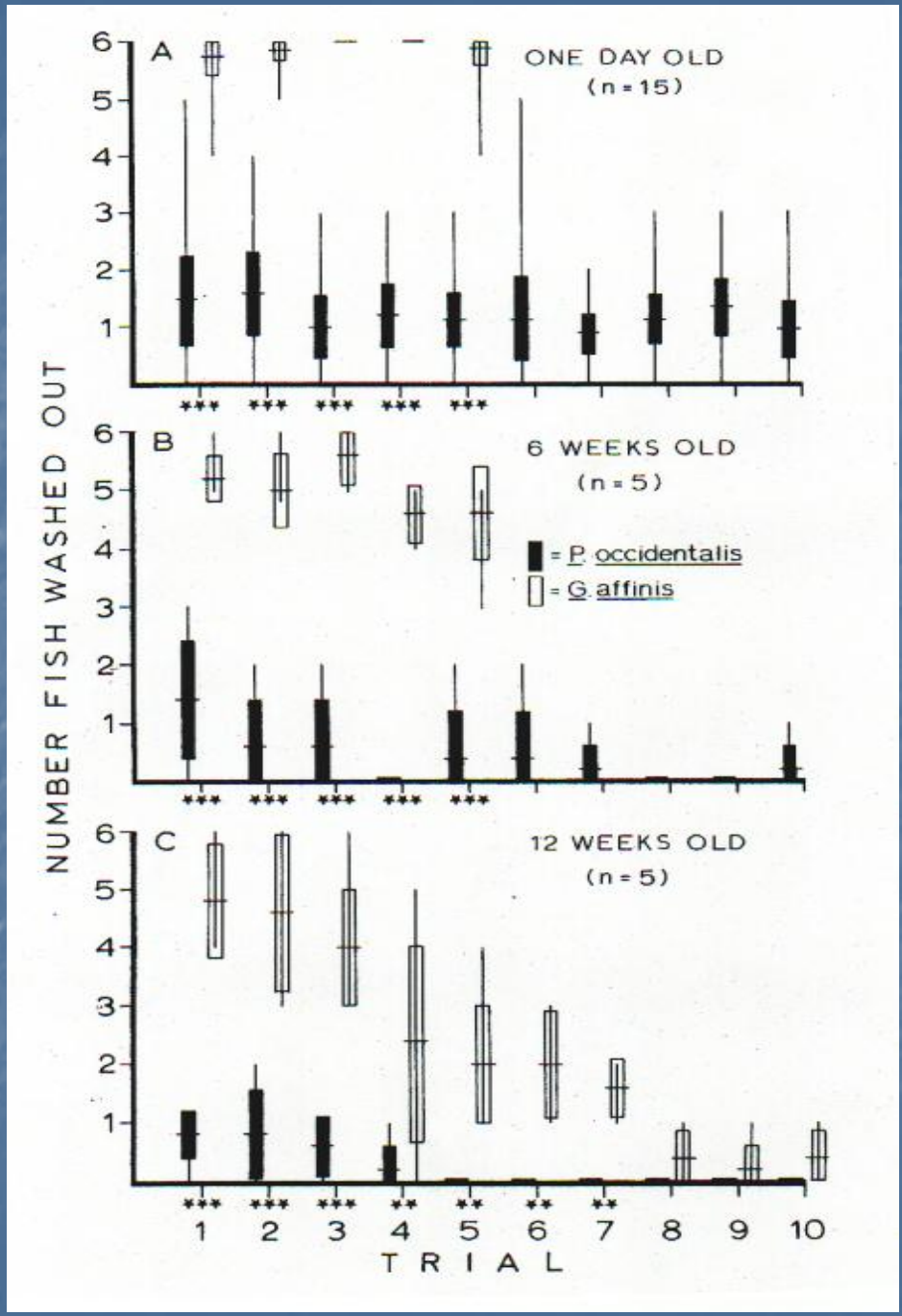
To make a long story short...


NUMBER OF ADULT FISH
400
300
200
100
A
B
C
D
3 6 7 13 16 17 18
Upper
Lower
POOL

Into the lab...


Upper
Reservoir
Divider
Lower
Flume
Main
Reservoir
Input Hose
Pump


A
INEXPERIENCED
(n = 15)
= P. occidentalis
= G. affinis
B
EXPERIENCED - 3 weeks
(n = 14)
C
INEXPERIENCED;
REDUCED CUES
(n = 7)
NUMBER FISH WASHED OUT
TRIAL
1 2 3 4 5 6 7 8 9 10


A
ONE DAY OLD
(n = 15)
B
6 WEEKS OLD
(n = 5)
= P. occidentalis
= G. affinis
C
12 WEEKS OLD
(n = 5)
NUMBER FISH WASHED OUT
TRIAL
1 2 3 4 5 6 7 8 9 10

Conclusion: a natural disturbance (flooding) selectively washes out the exotic species and allows persistence of the native species that is otherwise replaced by the exotic (many examples). The behaviors involved seem to be innate.

This suggests that natural variation in a riverine system is not only handled well by native species but can be important in maintaining their populations in the face of an external stress (exotic species).

When we control that variation by preventing flooding, the external stress fundamentally changes the system (native species is lost).

What about beyond this simple example? Does this pattern hold?

Fish tale # 2:

Larger, more complex systems

What we’re really doing is asking how patterns of environmental variation differ in mesic zone vs. arid zone rivers (and thus how the biota might be adapted to different patterns and types of variation).

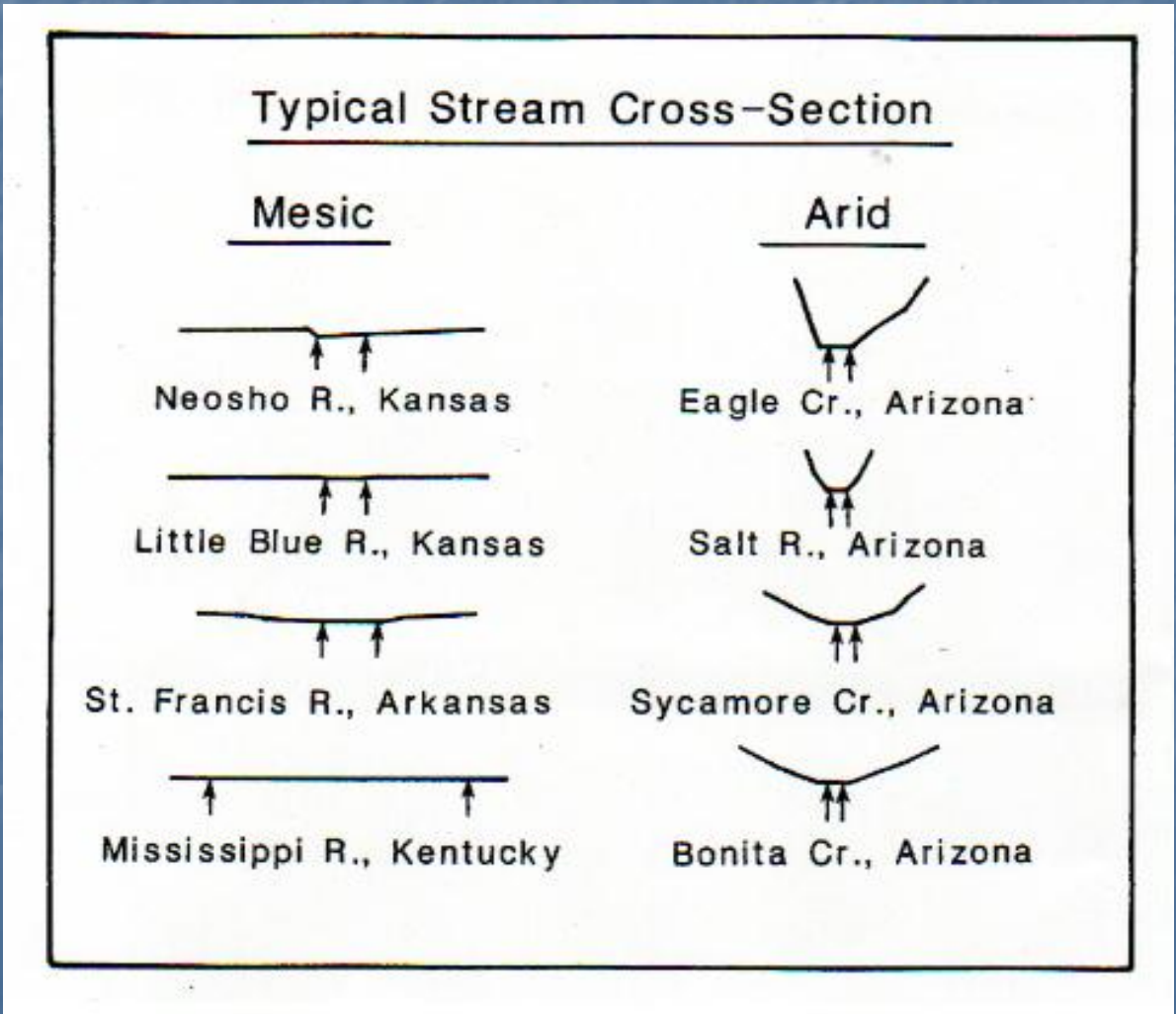
Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid

Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid
Unconstrained, broad floodplains	Constrained by steep-sided channels & canyons

We compared species that evolved in systems that look like this:



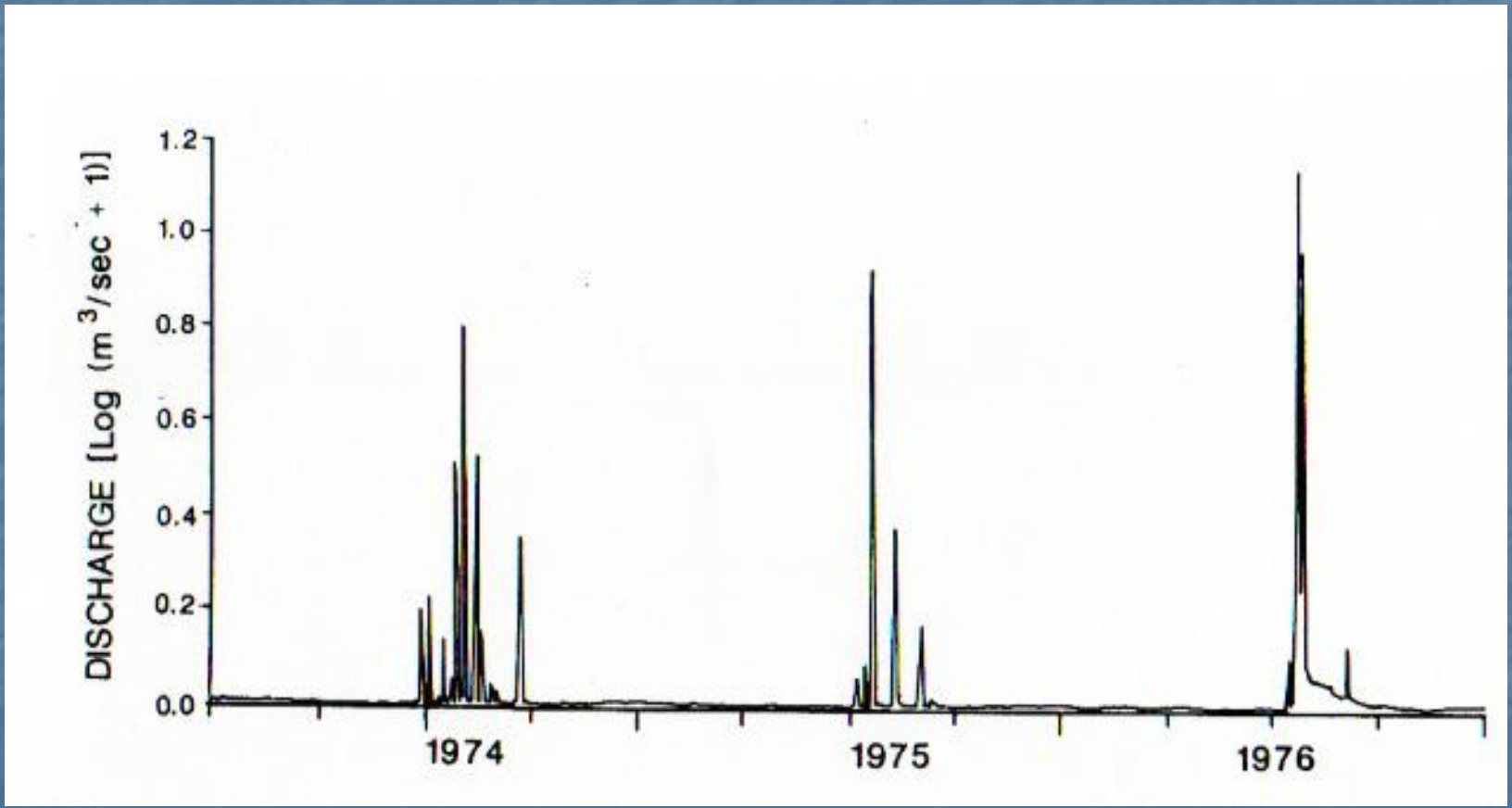
Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid
Unconstrained, broad floodplains	Constrained by steep-sided channels & canyons
Low stream gradients	High stream gradients

Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid
Unconstrained, broad floodplains	Constrained by steep-sided channels & canyons
Low stream gradients	High stream gradients
Flood onset slow & gradual	Flood onset rapid

Typical pattern of Arizona river discharges:



Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid
Substrate fine-grained, organic	Substrate coarse-grained, inorganic or bedrock

Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid
Substrate fine-grained, organic	Substrate coarse-grained, inorganic or bedrock
Low competency	High competency

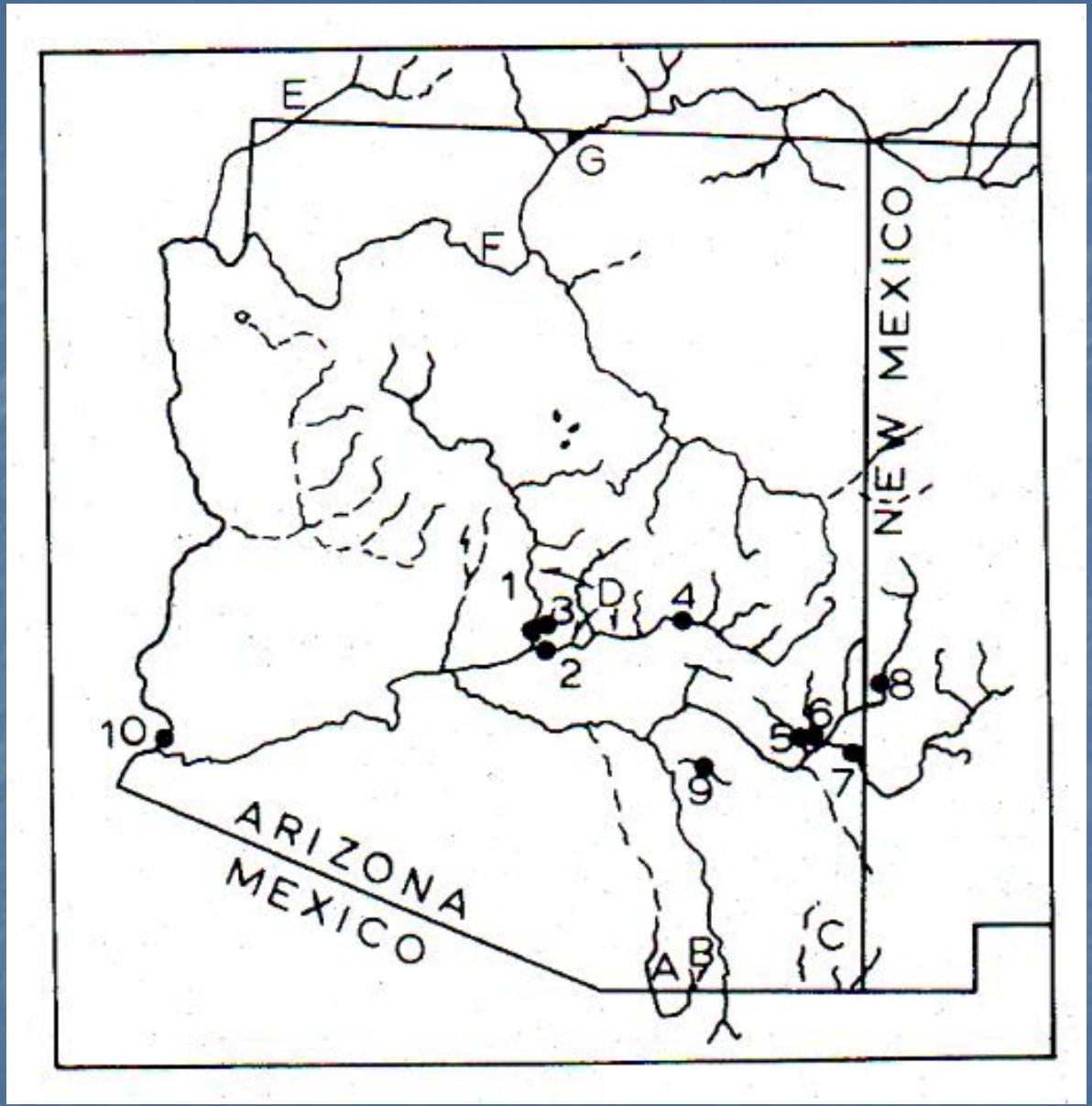
Comparisons of mesic zone and arid zone riverine systems:

Mesic	Arid
Substrate fine-grained, organic	Substrate coarse-grained, inorganic or bedrock
Low competency	High competency
Refugia: floodplains, marshlands, side channels	Refugia: streamsides, eddies behind obstructions

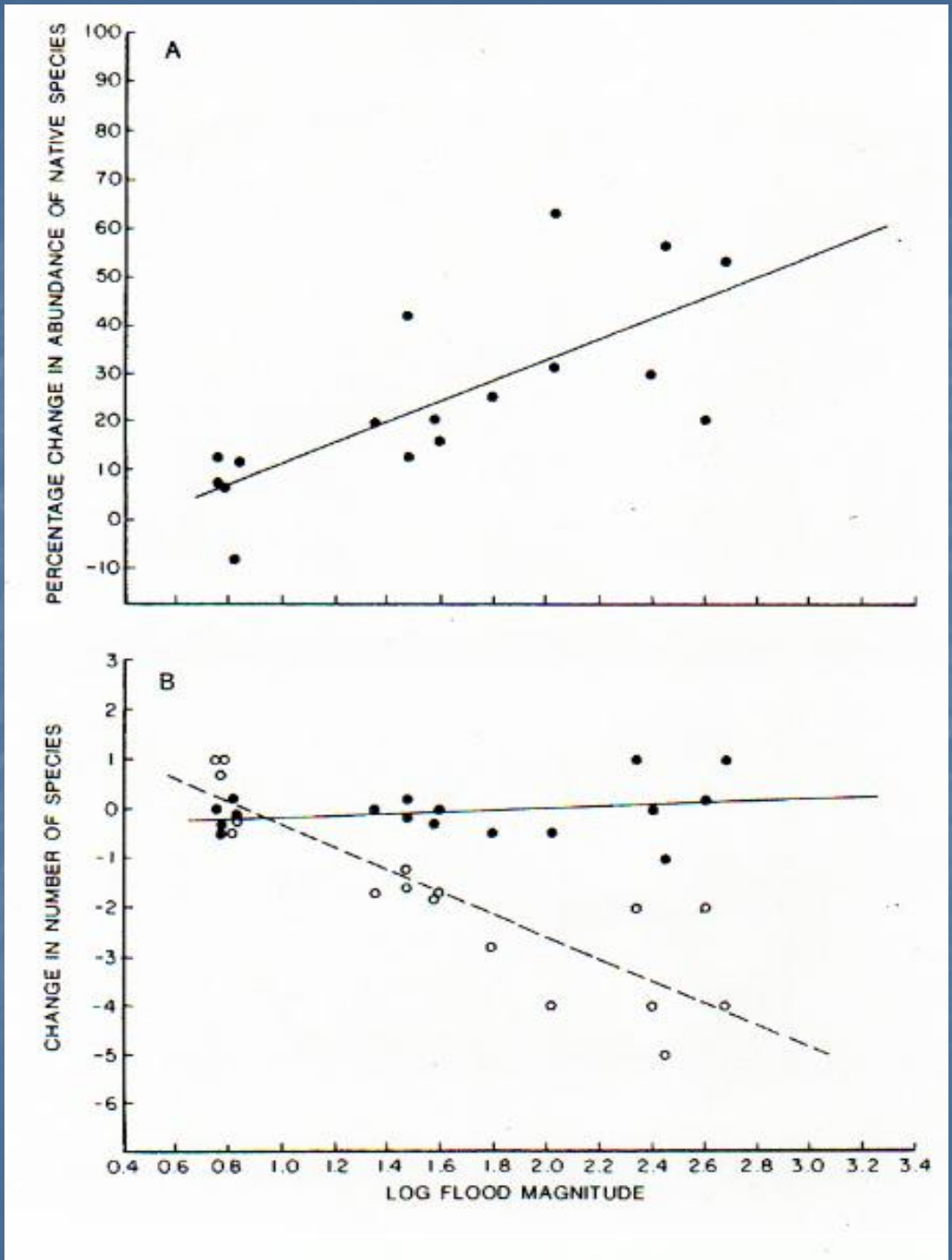
Consequently, biota evolving in these types of systems evolved with very different selection pressures with respect to variance in their ecosystems.

To compare general patterns of success of native Arizona fishes and exotic species from mesic areas with respect to ecosystem variation, W.L. Minckley and I analyzed fish data he had collected for years throughout Arizona.

We looked at the relative abundances and number of native and exotic fish species in several Arizona riverine systems before and after floods of various magnitudes.


E
G
F
NEW MEXICO
1
3
D
4
2
8
6
5
7
10
9
ARIZONA
MEXICO
A
B
C

Again, long story short...


A
PERCENTAGE CHANGE IN ABUNDANCE OF NATIVE SPECIES
100
90
80
70
60
50
40
30
20
10
0
-10
B
CHANGE IN NUMBER OF SPECIES
3
2
1
0
-1
-2
-3
-4
-5
-6
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4
LOG FLOOD MAGNITUDE

What I have *not* shown are the many examples of losses of native fishes and explosions of exotic species in Arizona rivers that have been stabilized and controlled by dams.

In fact, the only places where native species are doing well at all is in free-flowing systems or isolated systems where exotics have not been introduced.

Conclusion: an uncontrolled system that undergoes normal ranges of variation is better able to maintain its normal structure and function than one that has been controlled.

This goes back to the pathology:

When the range of natural variation in a system is reduced, the system loses resilience when faced with new stressors.

Translated to Arizona fishes:

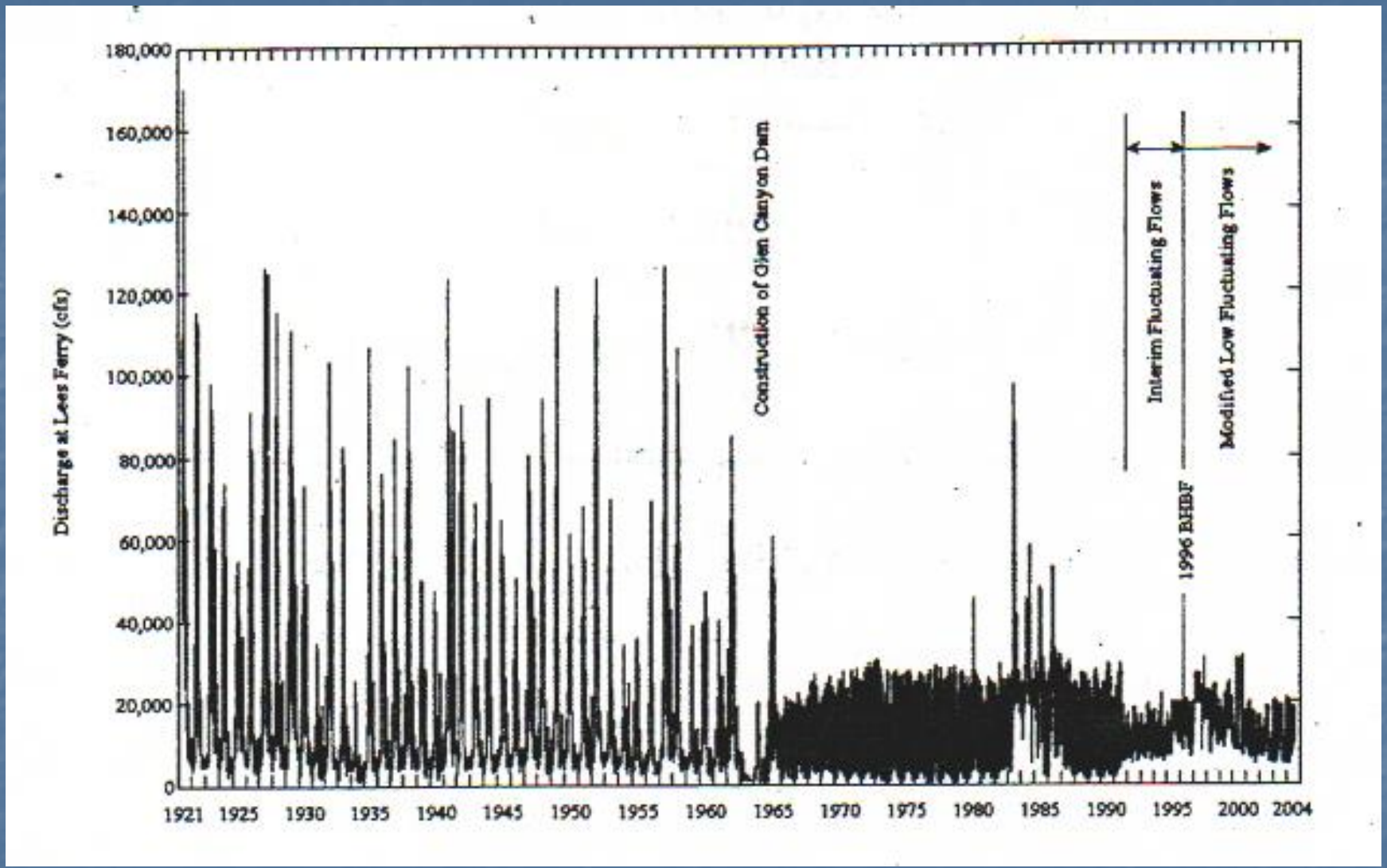
When you reduce or stop normal flooding events, native fishes are unresilient and in fact disappear in the presence of exotic species.

Q: How do you maintain native fishes (and presumably other native biota)?

A: Maintain free-flowing rivers and let nature periodically flush out damaging exotic species.

Obviously we will not remove Glen Canyon Dam any time soon. So how do you maintain native biota and normal geophysical processes within the Grand Canyon?

Try to get as close as possible to the normal disturbance regime of the system.


Discharge at Lees Ferry (cfs)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1921
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2004
Construction of Glen Canyon Dam
Interim Fluctuating Flows
1996 BHBF
Modified Low Fluctuating Flows

You seem to be making strides toward getting back to some level of natural variation, through adaptive management.

If you are *truly* embracing adaptive management, if you are *truly* learning from management experiments, if you are *truly* willing to evolve and change as a result of learning, then you are doing the right things.

Summary:

Summary:

- Command and control in natural resource management typically fails in the long term due to complexities in natural ecosystems, which lead to surprises and eventual failure.

Summary:

- Reducing the range of natural variation in ecosystems through command and control leads to a pathology that results in loss of resilience of the ecosystems.

Summary:

- Reducing the range of natural variation in ecosystems through command and control leads to a pathology that results in loss of resilience of the ecosystems.
  - External control of the system.

Summary:

- Reducing the range of natural variation in ecosystems through command and control leads to a pathology that results in loss of resilience of the ecosystems.
  - External control of the system.
  - Focus on efficient control and loss of knowledge of natural ecosystem behavior.

Summary:

- Reducing the range of natural variation in ecosystems through command and control leads to a pathology that results in loss of resilience of the ecosystems.
  - External control of the system.
  - Focus on efficient control and loss of knowledge of natural ecosystem behavior.
  - Growing economic dependencies on control.

Summary:

- Adaptive management breaks the pathology and brings us a better level of understanding of the managed systems.

Summary:

- Data from Arizona native fishes demonstrate the importance of understanding natural variation and incorporating it into management practices.

We must remember that the Colorado River by nature is dynamic and changing. It and its biota do not respond well to control.

Underlying Theme:

Nature has been managing the Colorado River for several million years, and humans have been at it for about 100...

...we still have a few things to learn from it.