Targeting Payments for Ecosystem Services

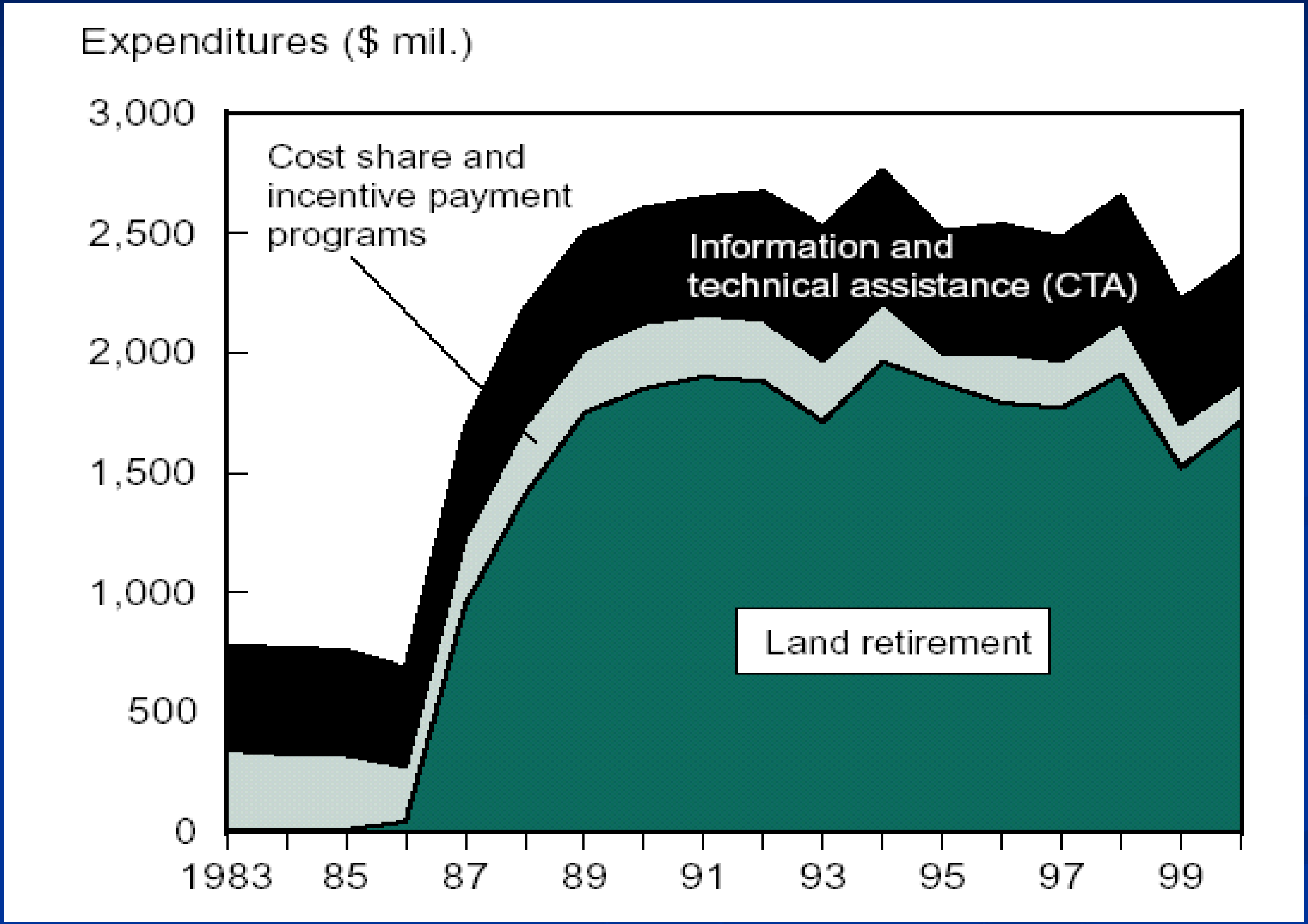
JunJie Wu

Oregon State University

Presented in

the Tenth Annual BIOECON Conference, Sidney Sussex College, Cambridge, September 28-30, 2008

U.S. Conservation Expenditures, 1983-2000

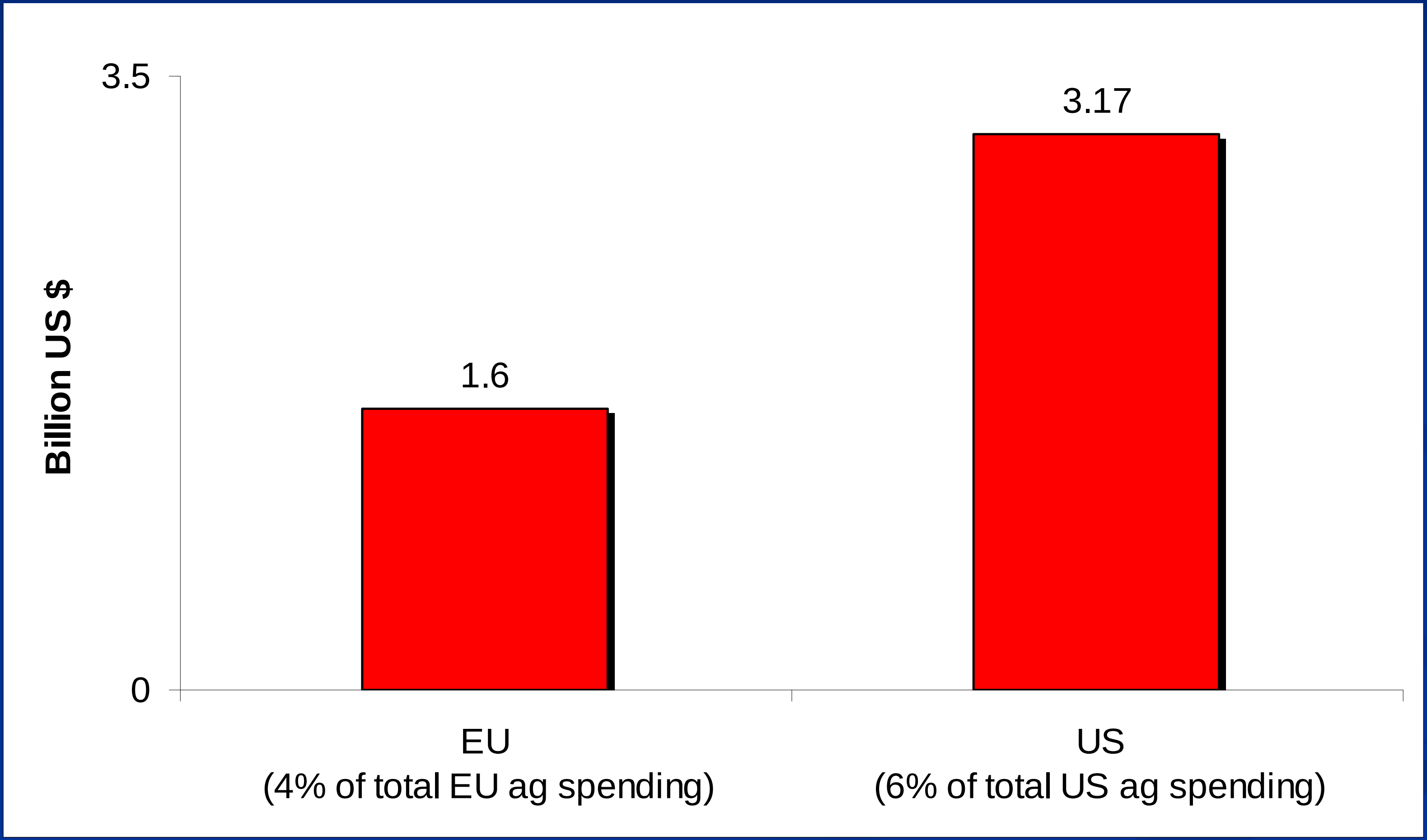


Source: Claassen et al (2001)

Agri-Environmental Programs in the 2008 U.S. Farm Bill

- Wildlife Habitat Incentives Program (WHIP)
- Conservation Stewardship Program (CSP)
- Environmental Quality Incentives Program (EQIP)
- Farmland Protection Program (FPP)
- Grasslands Reserve Program (GRP)
- Conservation Reserve Program (CRP)
- Wetland Reserve Program (WRP)

EU and US Expenditures on Agri-Environmental Programs in 1998

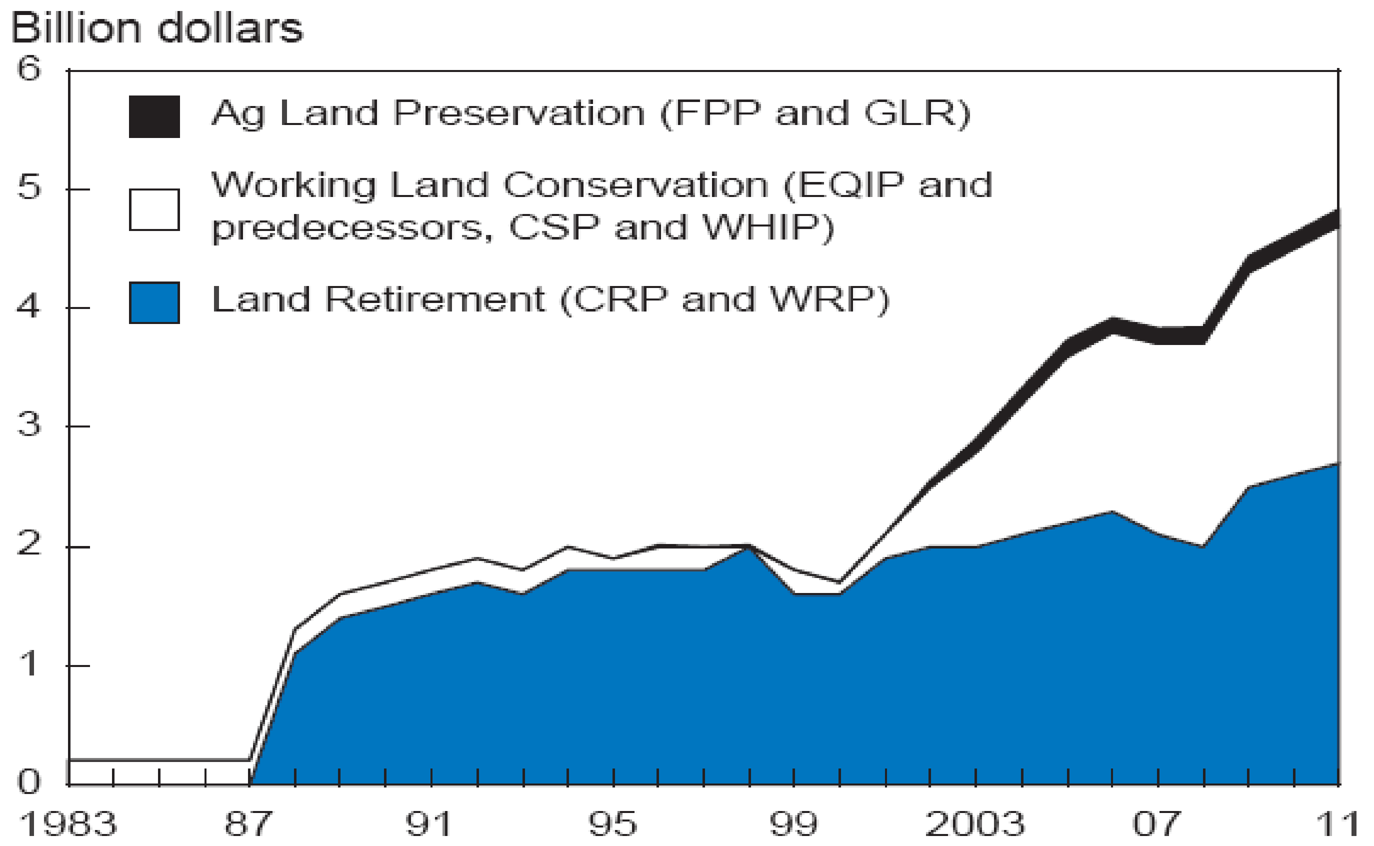


Source: Bernstein, Cooper, and Claassen (2004)

Broad Support for Agri-Environmental Programs

- Interest groups are accepting conservation payments as a viable alternative, although for different reasons
  - *To farmers:* A new way of delivering farm income supports
  - *To environmentalists:* A new way of encouraging resource conservation and environmental management
  - *To NGOs:* A new way of fighting poverty (pro-poor policy)
  - *To others:* A new way of preserving the status quo

Conservation Expenditures, 1983-2001, with Projection to 2011



Sources: Office of Budget and Policy Analysis, USDA, and the Congressional Budget Office.

Major Issues

- How should conservation funds be allocated among geographic areas?
  - Should funds be concentrated on fewer watersheds or distributed over a wider geographic area?
  - Should funding priorities be given to areas with the worst environmental problems or areas that have made some environmental improvements?

Major Issues - cont.

- Within a given geographic area, what criteria should be used to target resources for conservation?
  - Should we target least productive resources or resources that are most vulnerable to environmental damage?
  - What should payments be based on? Should payments be based on adoption of certain conservation practices or some measures of environmental benefits?
  - If a bidding process is used, what criteria should be used to select bids for acceptance?

Major Issues - cont.

- What are the economic, environmental and distributional implications of alternative conservation targeting strategies?
    - If poverty reduction is a primary goal of resource conservation, what strategy is most effective for helping the poor?

Outline of the Presentation

1. Challenges for the design of a first-best conservation program

2. Current targeting approaches and their political economy implications

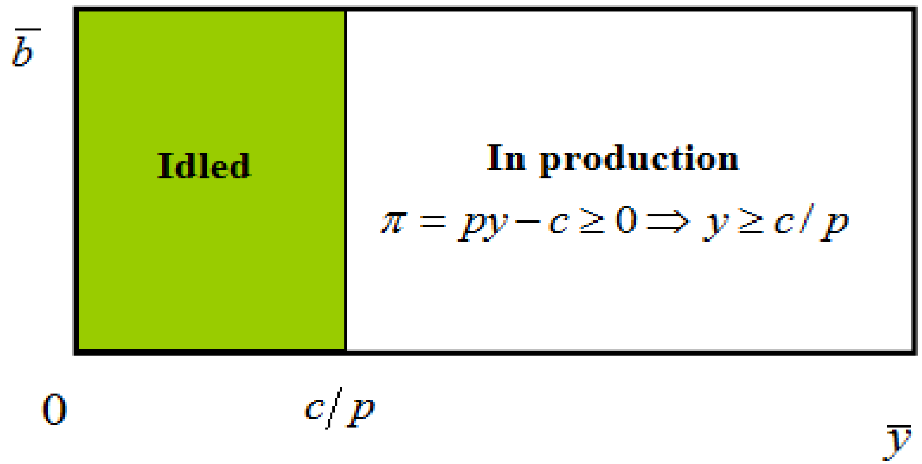
3. Problems associated with the current targeting approaches

4. Remedies for the problems

1. A Model of Conservation Targeting

Suppose a government agency with a given budget want to target some resources (e.g., land) for conservation.

Land Use under a Free Market



y = per-acre output

b = per-acre environmental benefit generated when the land is retired from crop production or put under conservation practices

c = per-acre production cost

p = output price

$f(y,b)$ = joint distribution function of (y,b)

The Optimal Land Use (Conservation) Decision

$$\max_{\{\delta(y,b)\}} \quad CS + PS + VB = \int_0^Y D^{-1}(z)dz - cQ + V(B)$$

where

CS = consumer surplus

PS = producer surplus

VB = value of environmental benefit

$\delta(y,b)$ = the share of land with (y, b) in conservation

$$Y = \int_0^{\bar{b}}\int_0^{\bar{y}} y[1-\delta(y,b)]\, f(y,b)\; dydb$$

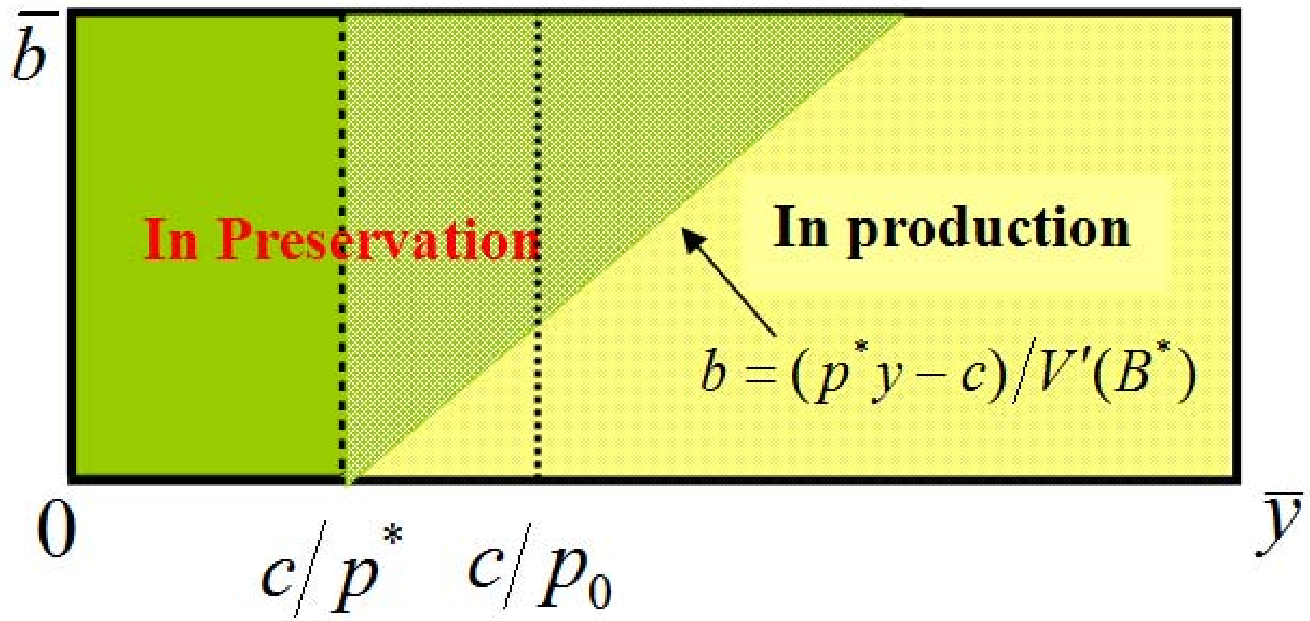
$$Q = \int_0^{\bar{b}}\int_0^{\bar{y}} [1-\delta(y,b)]\, f(y,b)dydb$$

$$B = \int_0^{\bar{b}}\int_0^{\bar{y}} b\delta(y,b) f(y,b)dydb.$$

$$VB = V\left(B, \left\{\delta(y,b), 0 \le y \le \bar{y}, 0 \le b \le \bar{b}\right\}\right)$$

$D^{-1}(z)$ = inversed demand function for the output

Optimal Land Use (Conservation) Decision

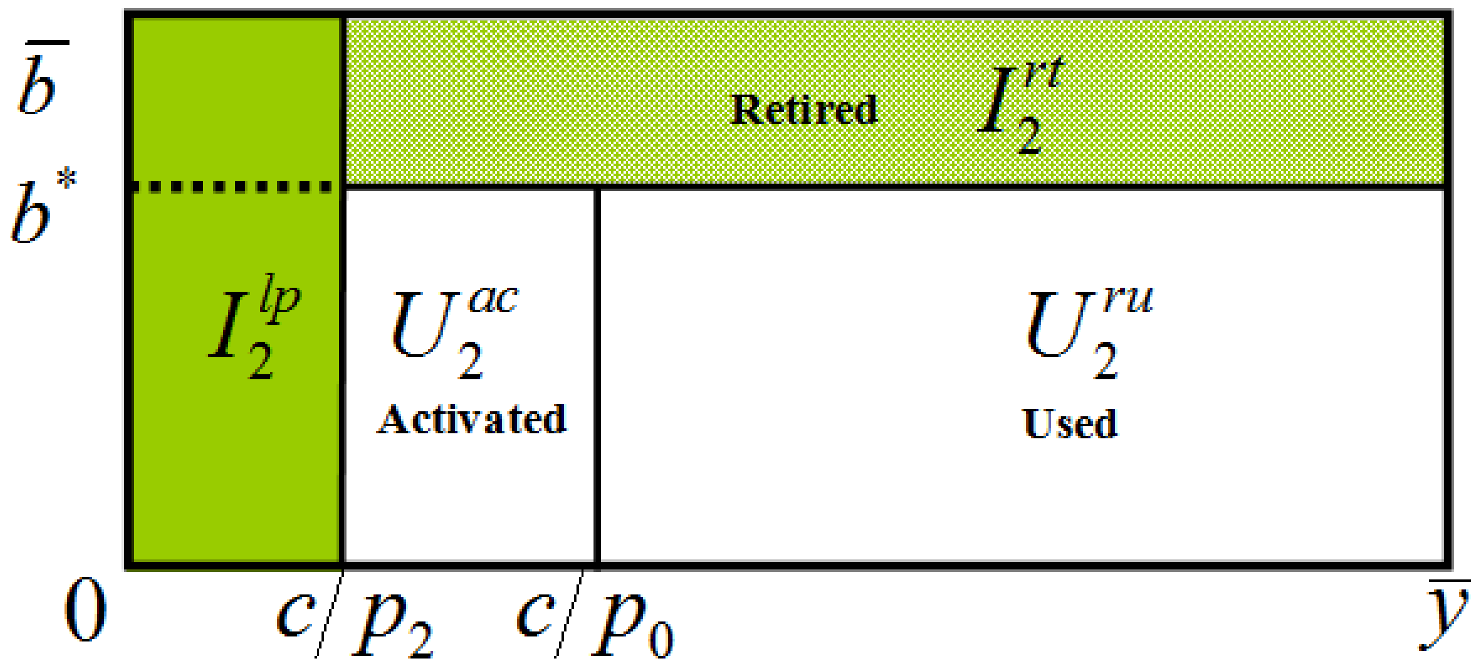


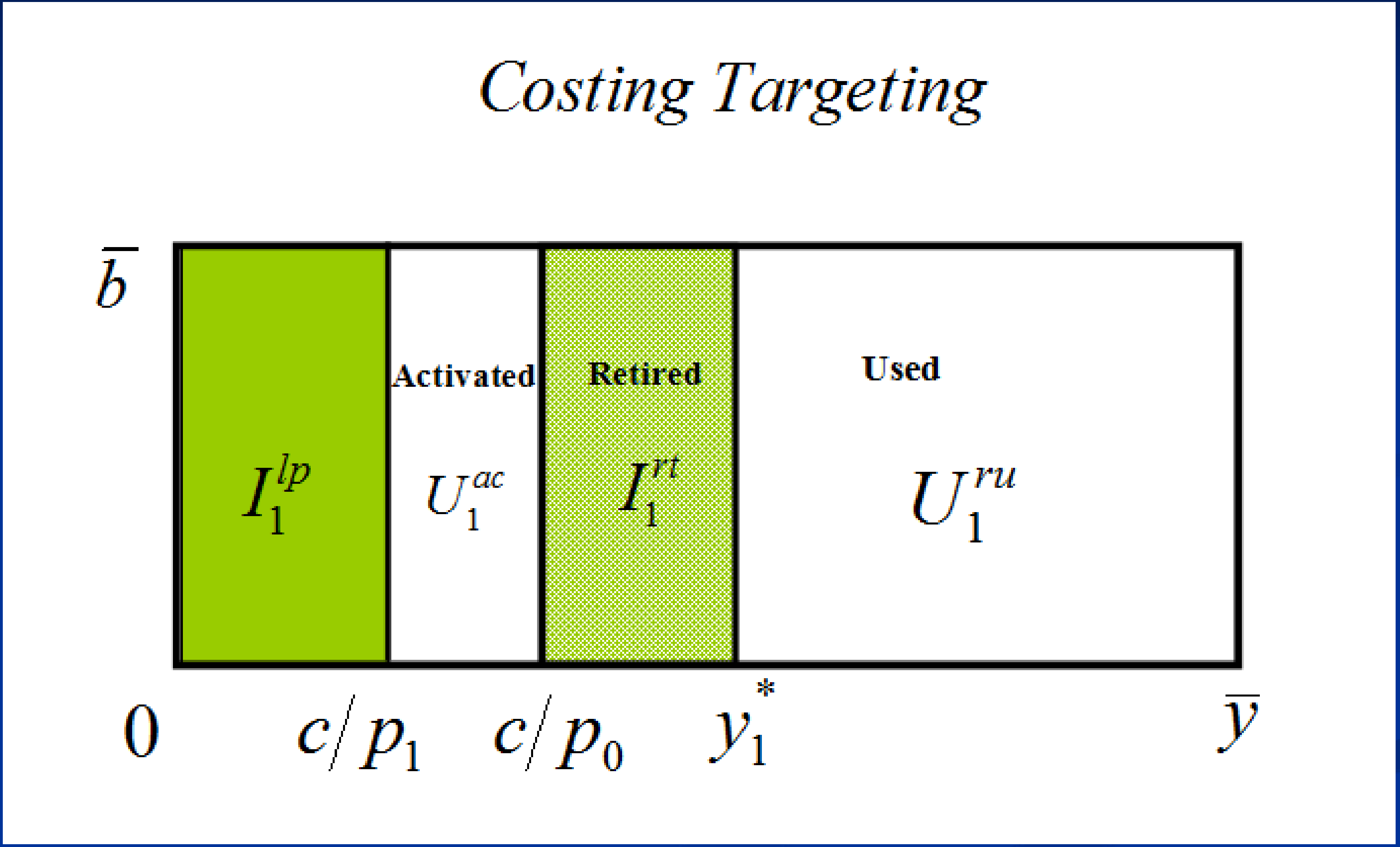
The optimal conservation budget $= B^* V'(B^*)$

2. Targeting Approaches

- Benefit targeting – to target resources that provide the highest environmental benefit per resource unit (e.g., the U.S. Fish and Wildlife Service).
- Cost targeting – to target least productive resources (e.g, CRP before 1992).
- Benefit-cost targeting – to target resources with the highest benefit-cost ratio (e.g., CRP in recent signups).
- Benefit-maximizing targeting – to target resources that provide the largest environmental benefit for a given budget (e.g., EQIP and CREP).

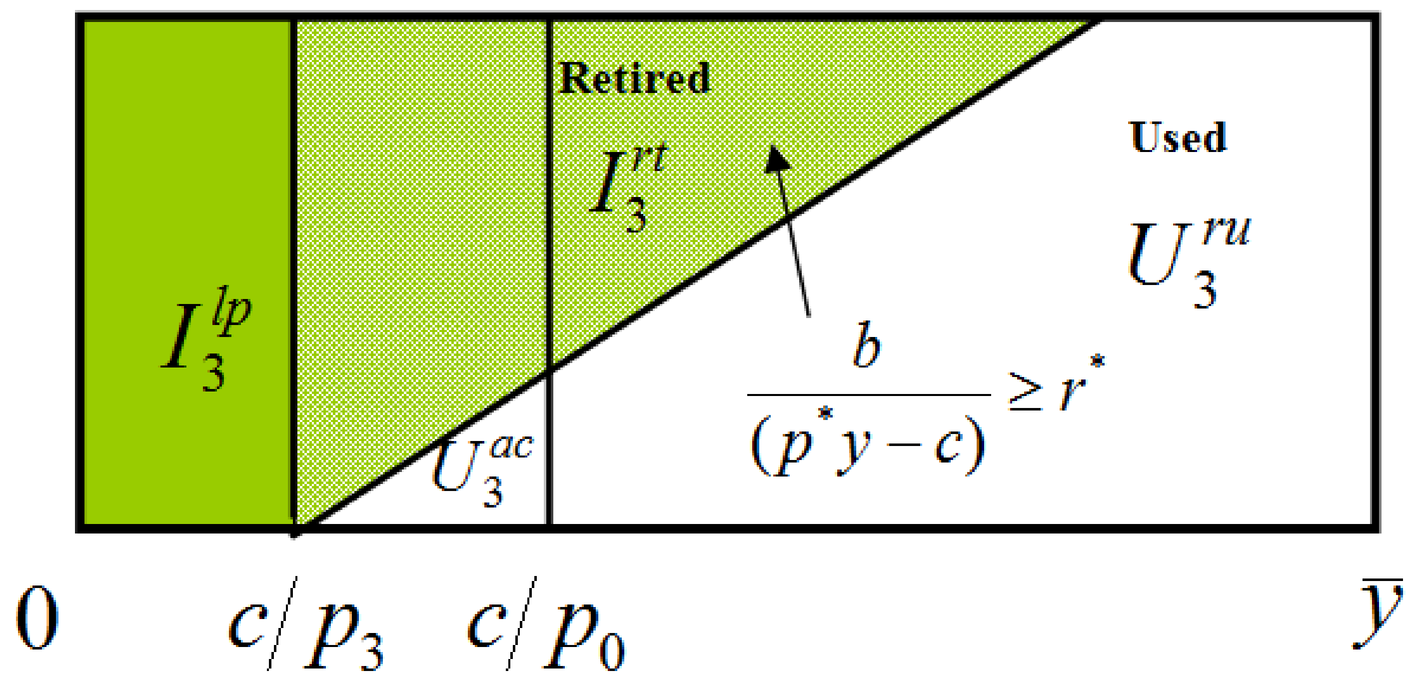
Benefit Targeting



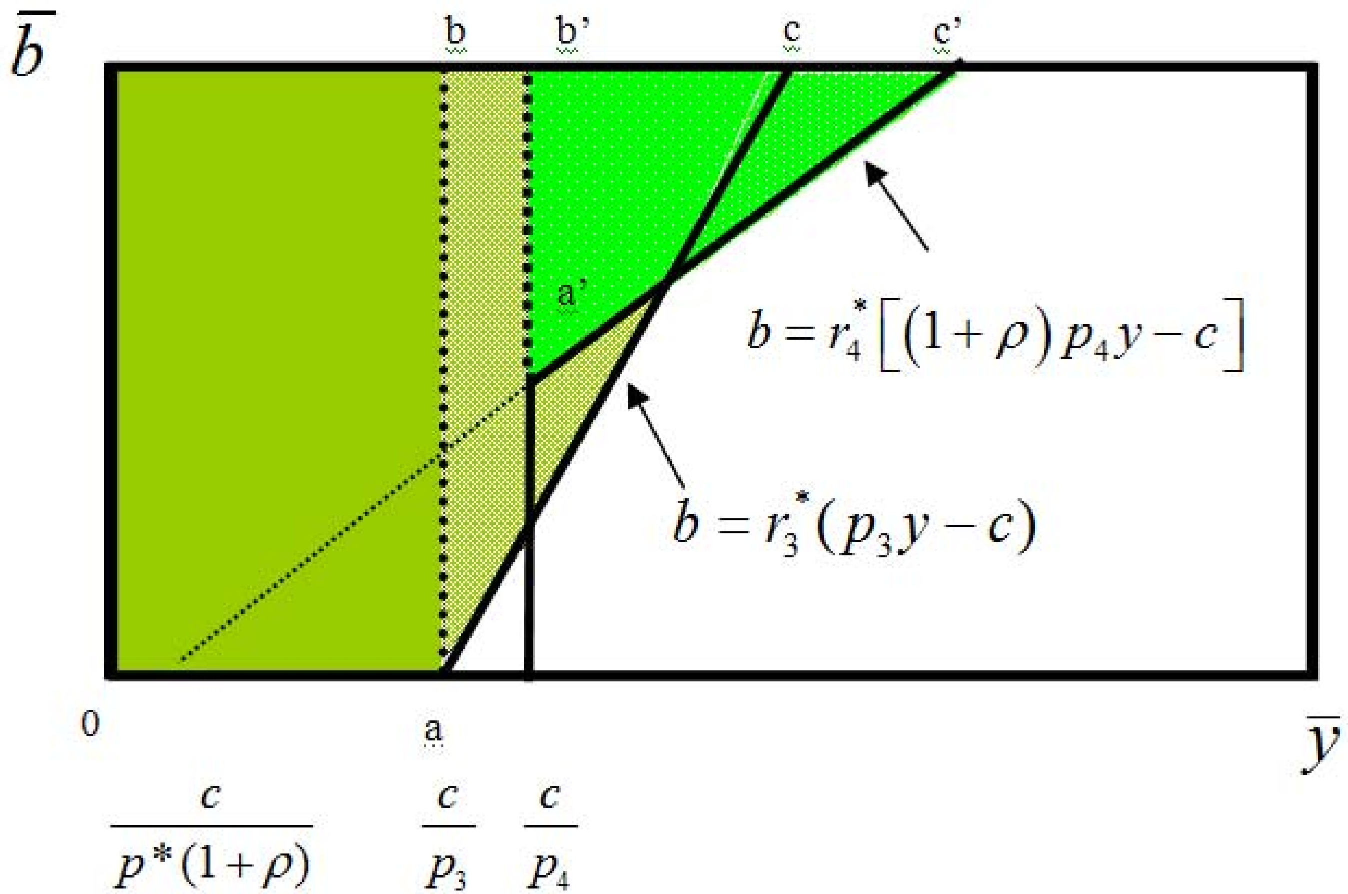

Costing Targeting
$\bar{b}$
Activated
Retired
Used
I_1^{lp}
U_1^{ac}
I_1^{rt}
U_1^{ru}
0
c/p_1
c/p_0
y_1^*
$\bar{y}$

$b = (p^* y - c) / V'(B^*)$

Benefit-Cost Targeting



Benefit-maximizing targeting vs. Benefit-cost targeting



Key Performance Measures of Targeting Criteria

i) Total amount of resource in conservation

$$Q(I_i) = Q(I_i^{lp} + I_i^{rt}) = \iint_{I_i^{lp}+I_i^{rt}} f(y,b)\,dy\,db$$

ii) Total amount of resource in production

$$Q(U_i) = Q(U_i^{ru} + U_i^{ac}) = \iint_{U_i^{ru}+U_i^{ac}} f(y,b)\,dy\,db$$

iii) Total output

$$Y_i = Y(U_i^{ru} + U_i^{ac}) = \iint_{U_i^{ru}+U_i^{ac}} y f(y,b)\,dy\,db$$

iv) Producer surplus

$$PS_i = [D^{-1}(Y_i)Y_i - cQ_i] + M,$$

v) Consumer surplus

$$CS_i = \int_0^{Y_i} D^{-1}(\delta)\,d\delta - D^{-1}(Y_i)Y_i.$$

vi) Total environmental benefit

$$B_i = S(I_i^{lp} + I_i^{rt} - U_i^{ac}) = \iint_{I_i^{lp}+I_i^{rt}-U_i^{ac}} s f(y,b)\,dy\,db$$

vii) Net gain in environmental benefit

$$\Delta B_i = B(I_i^{rt} - U_i^{ac}) = \iint_{I_i^{rt}-U_i^{ac}} b f(y,b)\,dy\,db$$

If $\Delta B_i < 0$, the program is counterproductive.

Result 2: A Comparison of Four Targeting Strategies

i) $Q(I_1) \geq Q(I_3) \geq Q(I_4) \geq Q(I_2)$

ii) $Q(U_2) \geq Q(U_4) \geq Q(U_3) \geq Q(U_1)$

iii) $Y_2 \geq Y_4 \geq Y_3 \geq Y_1$

iv) $p_1 \geq p_3 \geq p_4 \geq p_2$

v) $CS_2 \geq CS_4 \geq CS_3 \geq CS_1$

vi) $PS_1 \geq PS_3 \geq PS_4 \geq PS_2$

vii) $B_4 \geq B_3 \geq B_1$, $B_4 \geq B_2$

where

1 - cost targeting

2 - benefit targeting

3 - benefit-cost targeting

4 - benefit-maximizing targeting

Implications

Benefit Targeting:

- Consumers' most preferred strategy
- Labor and input suppliers may also support this strategy
- Resource owners' least preferred strategy

Implications – cont.

Cost Targeting:

- Resource owners' most favored strategy
- Most pro-poor policy if the poor are the resource owners
- Least pro-poor policy if the poor are the consumers, but not the resource owners
- CRP used cost targeting before 1992.

Implications – cont.

Benefit-cost targeting:

- The most efficient strategy
- Maximizes environmental benefits for a given budget when the output price is not affected
- However, when the output price is affected, it is no longer maximizing environmental benefits for a given budget.
- Not the most preferred strategy of any group.

Implications – cont.

Benefit-maximizing targeting:

- Less efficient than benefit-cost targeting
- But generate more environmental benefits because it considers slippage effects.
- Ignoring the slippage effects will reduce environmental gains and, in the worst scenario, could make a conservation program counter productive.
- Large slippage in the CRP (Wu 2000).

3. Problems with Current Approaches

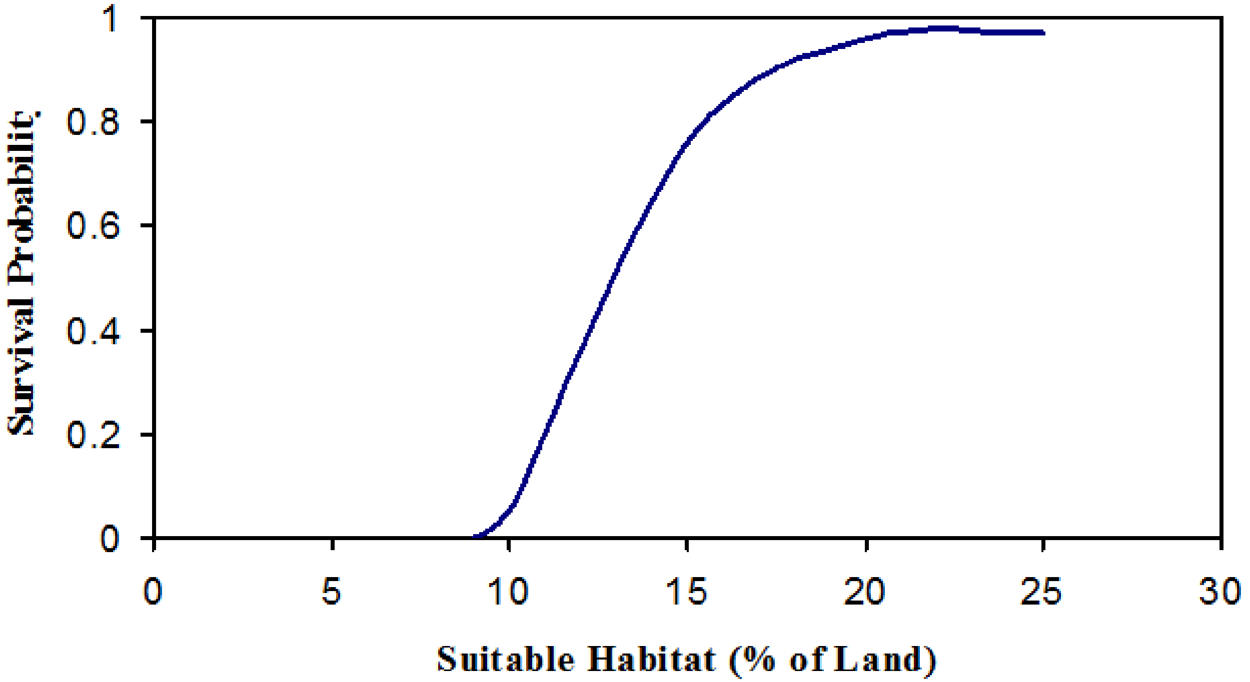
- Ignore key features of ecosystems
  - Threshold effects
  - Ecosystem linkages
  - Spatial interactions

Threshold effects

- A threshold effect is present when a significant environmental improvement can be achieved only after conservation efforts reach a certain threshold.
- Threshold effects have been found in many conservation efforts, particularly those involving fish and wildlife.

An example of Threshold Effects

Figure 1. Suitable Habitat and Northern Spotted Owl Survival



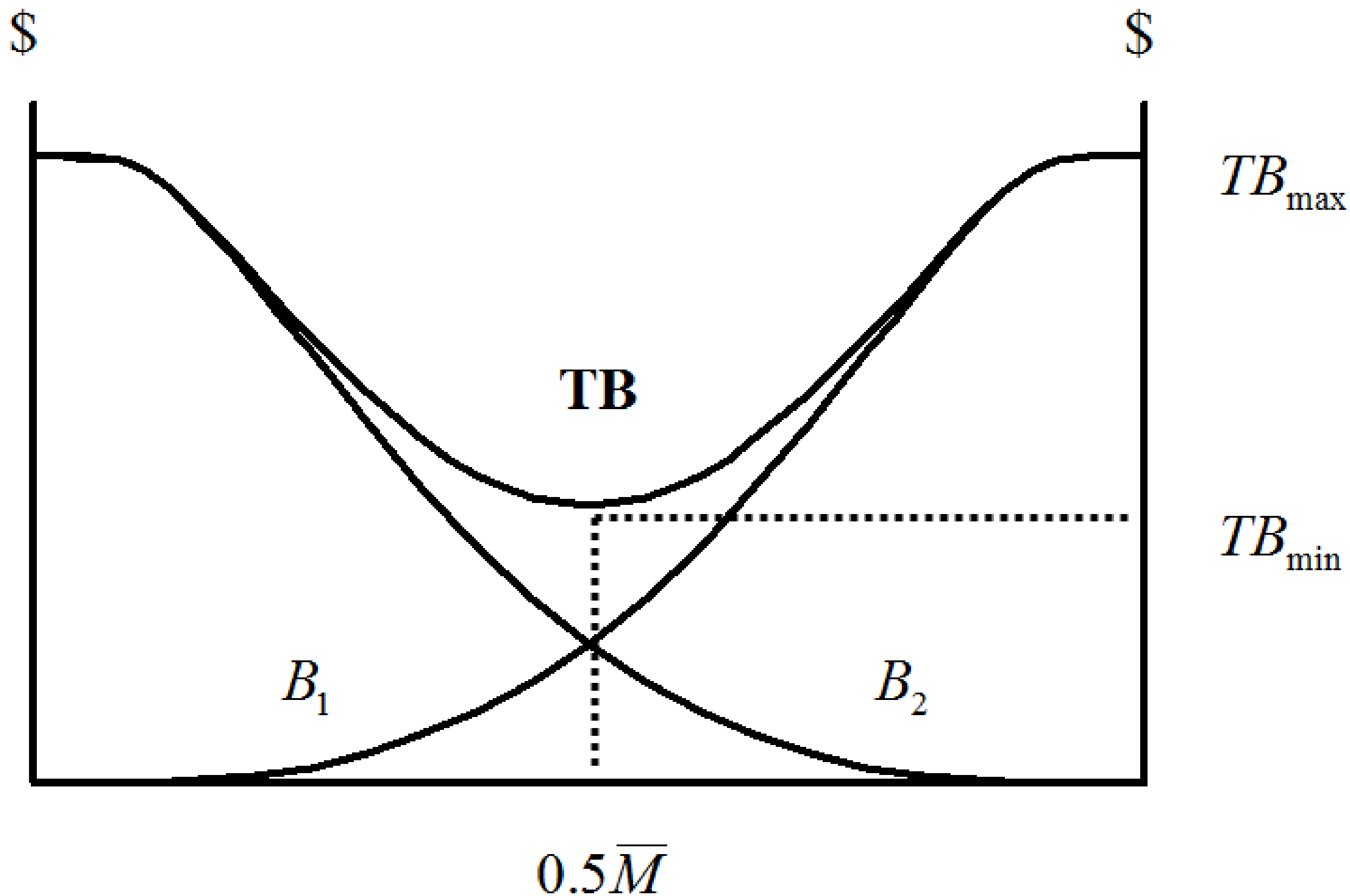
Source: Lamberson et al. (Fig. 7)

Consequences of Ignoring Threshold Effects

An Example

- Consider two identical watersheds.
- Land quality varies within each watershed.
- If the objective is to maximize the total amount of land preserved, the fund would be divided equally between the two watersheds.
- Such an approach would result in minimum, rather than maximum environmental benefit if a threshold effect is present and the conservation fund is limited.

Case a: $\bar{M} \le M^0$



Result 3: Consequences of Ignoring the Threshold Effects

The fund allocation that maximizes the total amount of resource preserved in two identical watersheds will result in minimum environmental benefit if

$$\overline{M} \leq 2M^m,$$

where $\overline{M}$ is the total conservation budget, and M^m is the funding level where the marginal benefit function is maximized.

The optimal allocation rule that maximizes the total environmental benefit is

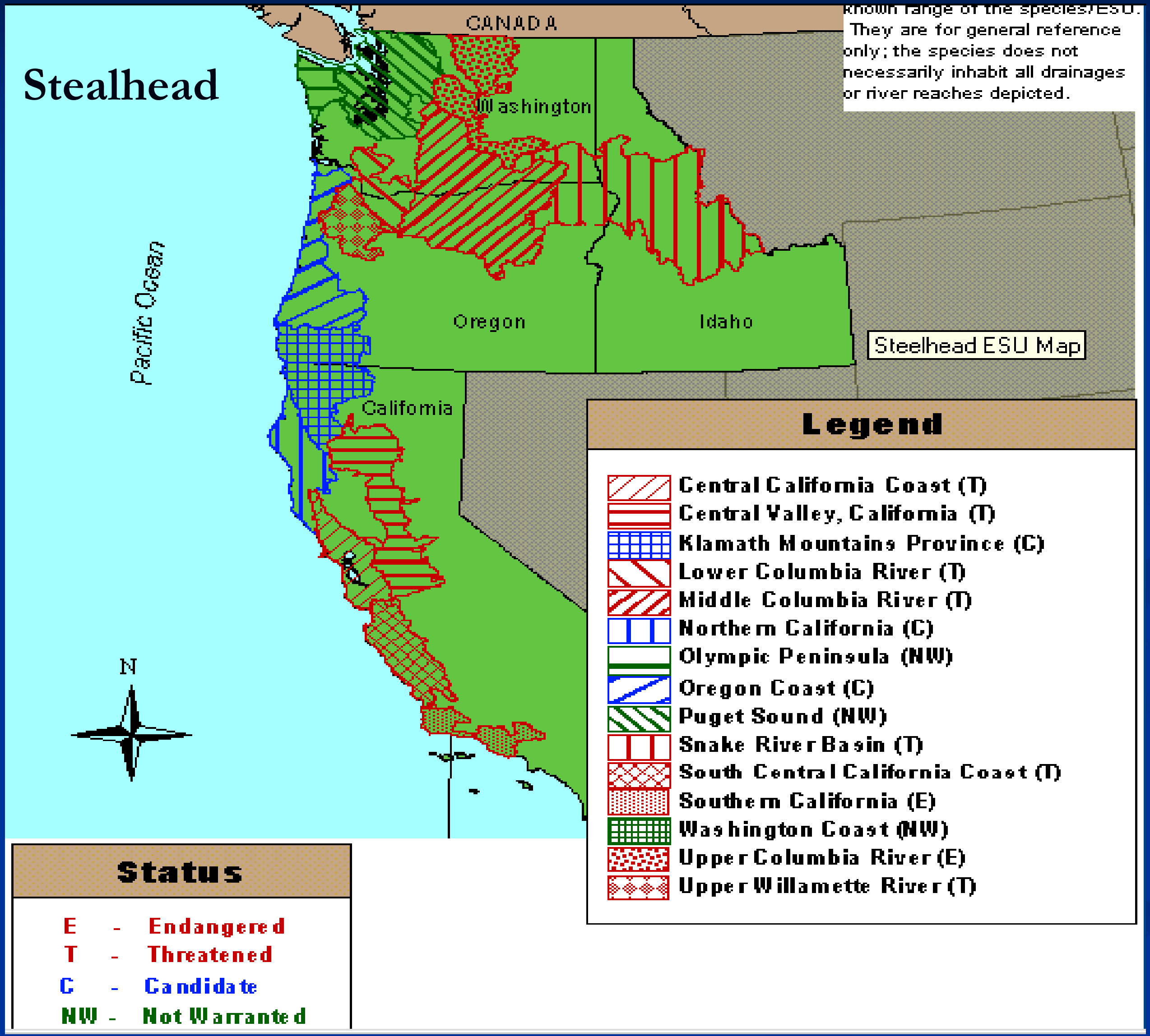
a) If $\overline{M} \leq M^0$, allocate all money to one watershed;

b) If $M^0 < \overline{M} \leq 2M^m$, both watersheds receive money, but not equal amounts;

c) If $\overline{M} > 2M^m$, divide the money equally between the two watersheds;

where M^0 is the funding level where the total benefit function is maximized.

Case Study: Salmon Restoration in PNW



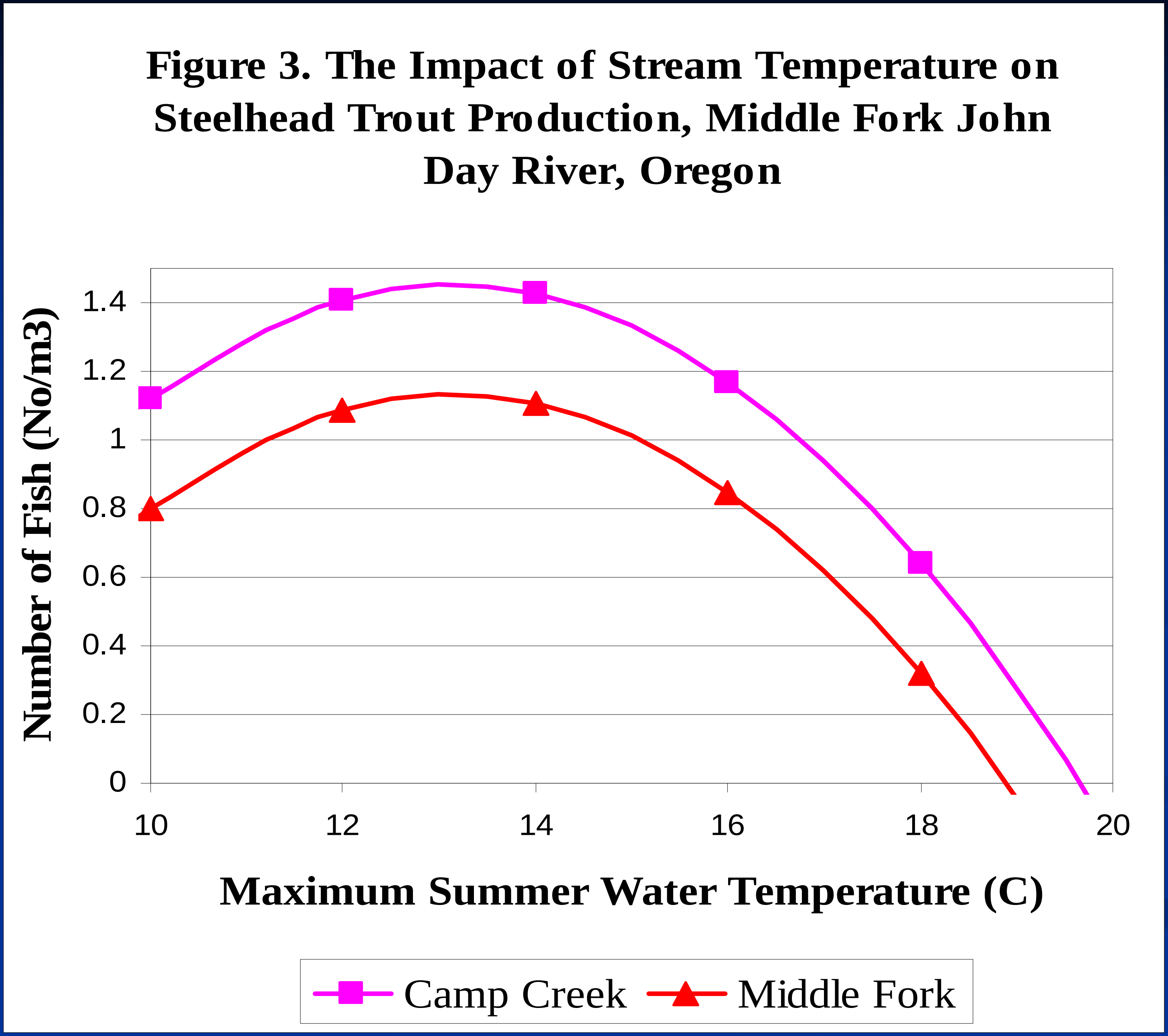


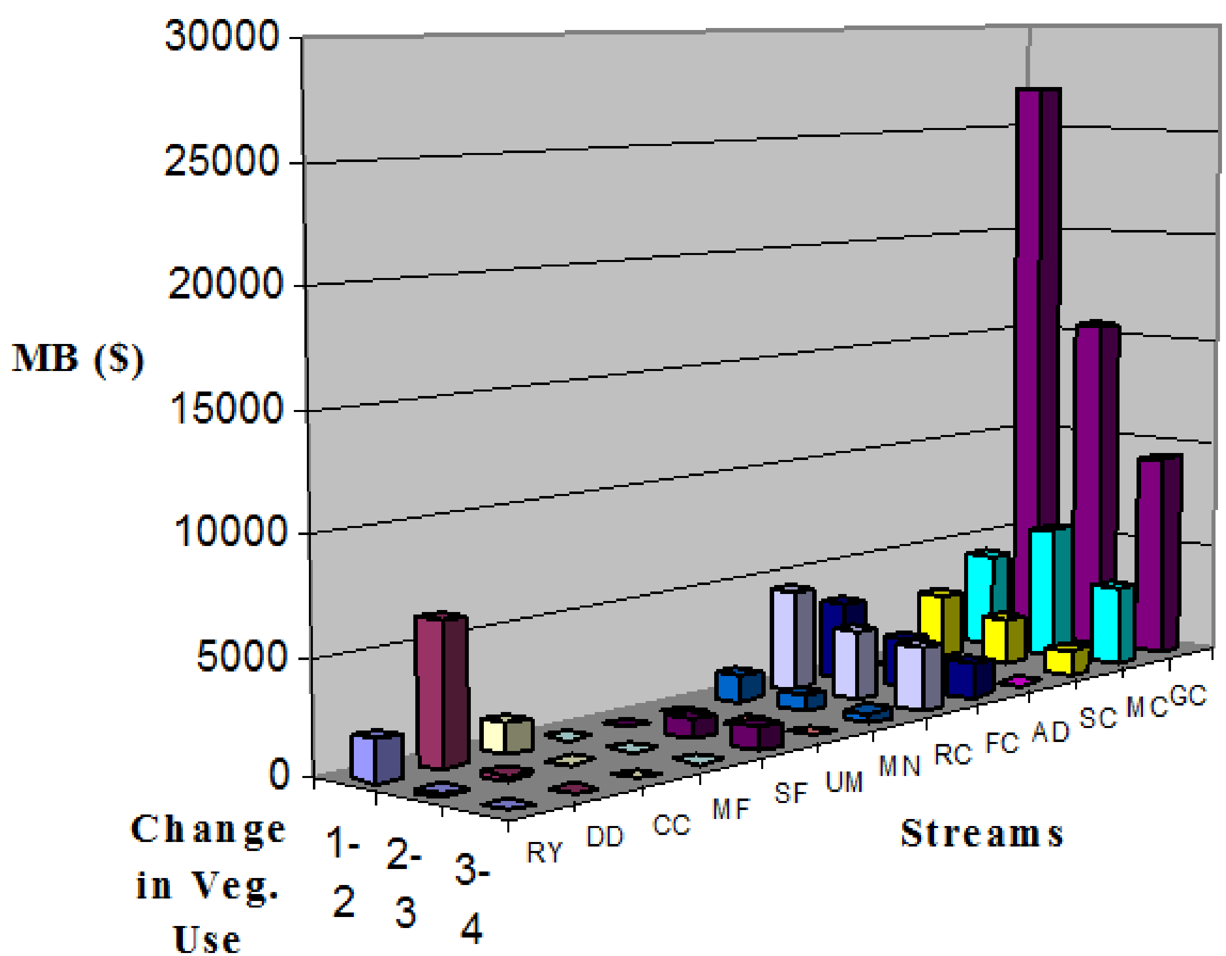
Figure 3. The Impact of Stream Temperature on Steelhead Trout Production, Middle Fork John Day River, Oregon
Number of Fish (No/m3)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
12
14
16
18
20
Maximum Summer Water Temperature (C)
Camp Creek
Middle Fork

Misallocations from Ignoring Threshold Effects

- Streams with very high temperatures may receive funding, even if conservation efforts will not lower temperatures enough so that fish can survive.

- Streams that have very low temperatures, but poor riparian vegetation, may be funded. Improving streamside vegetation in those streams will not generate any benefit.

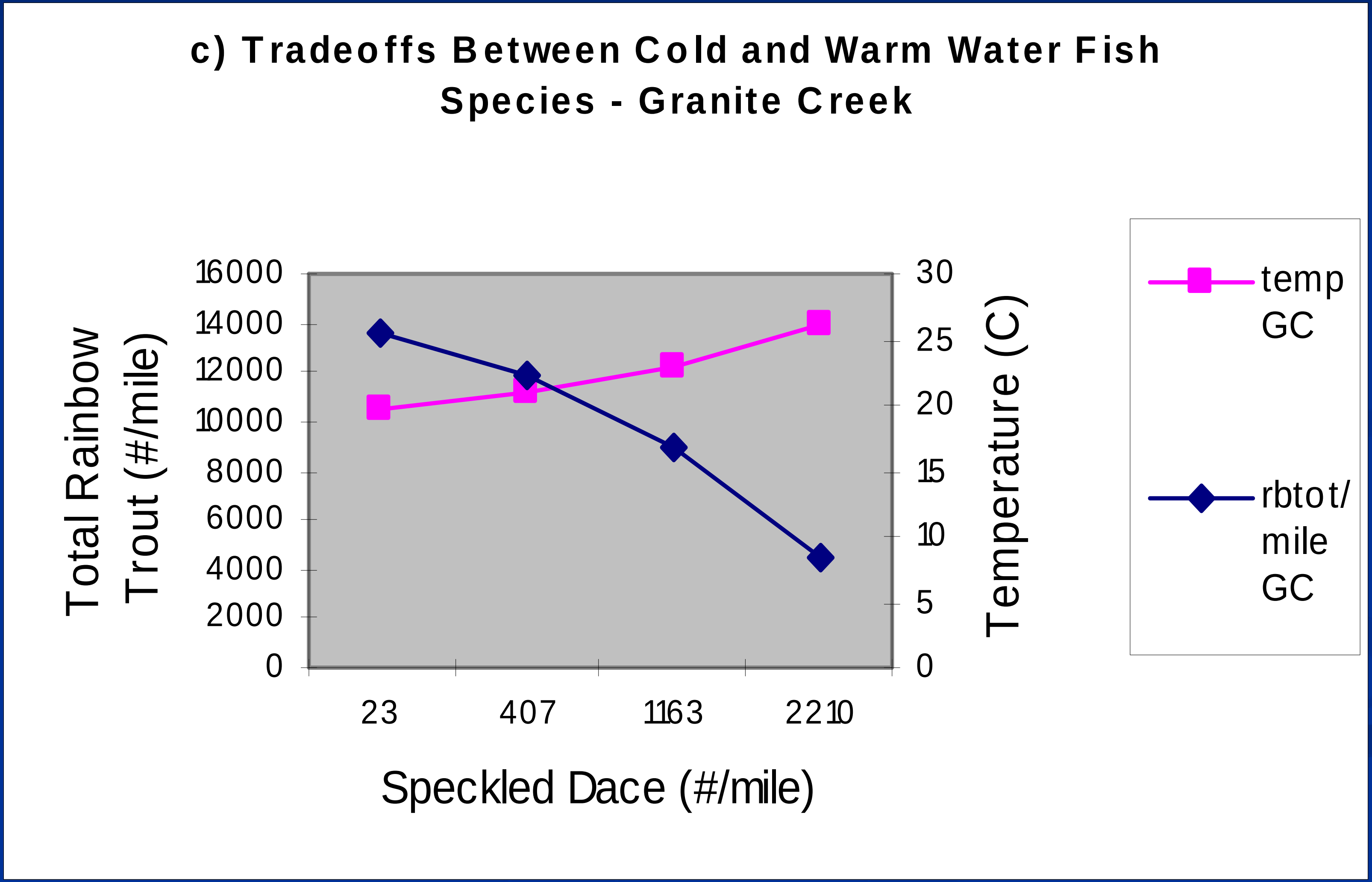
Figure 5. Marginal Benefits of Improving Streamside Vegetation as a Result of Increased Fish Production in the Thirteen Streams of the John Day River Basin, Oregon



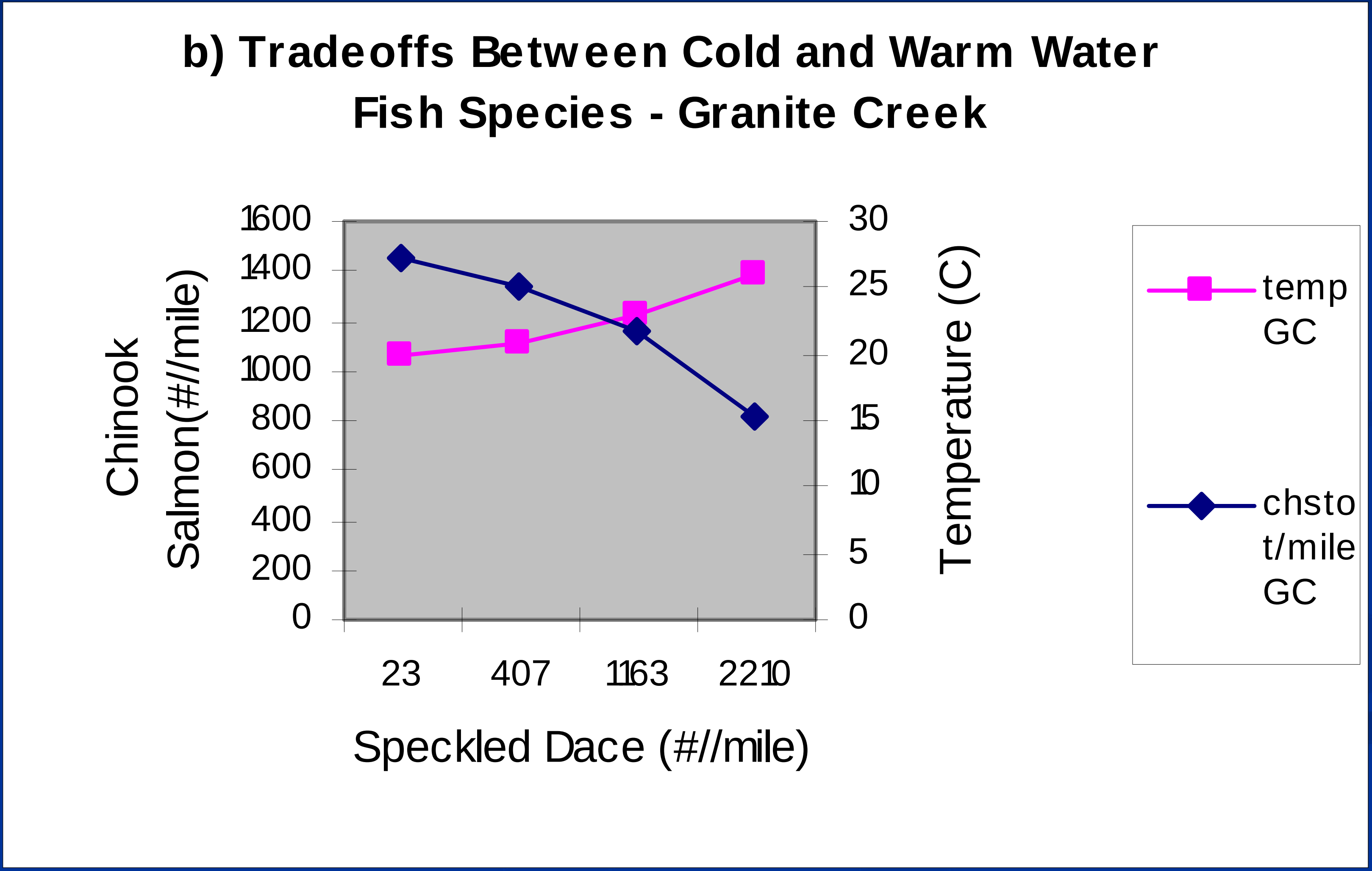
Ecosystem Linkages

- Interaction: The causal relationships between different environmental benefits (e.g., improving water quality enhances fish habitat)
- Correlation: Two environmental benefits are jointly produced by the same conservation effort, although the they have no causal relationship.

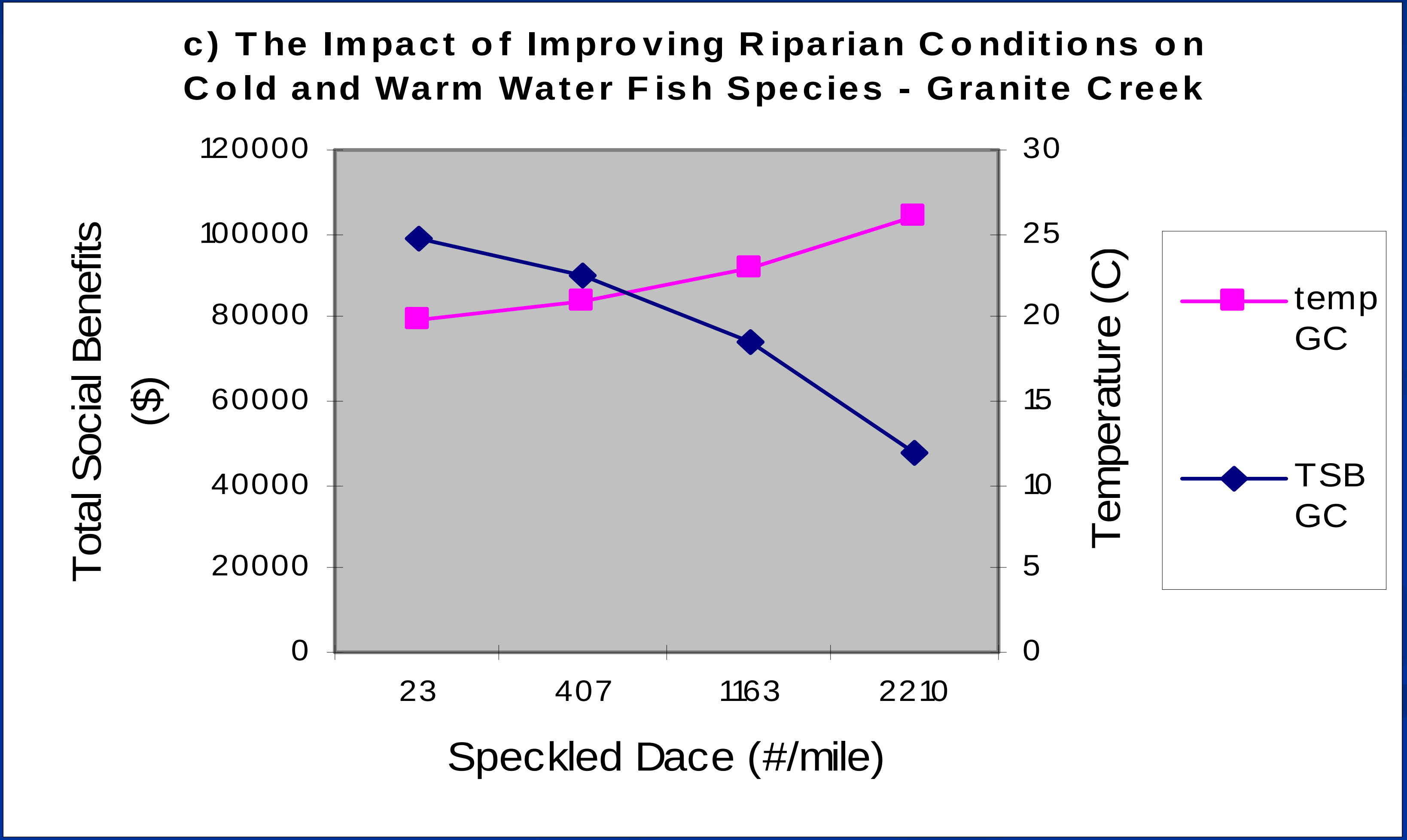
Consequences of Ignoring Ecosystem Linkages: An Example



Consequences of Ignoring Ecosystem Linkages: An Example



Consequences of Ignoring Ecosystem Linkages: An Example



Spatial Interactions

- Spatial interactions of ecosystems can take different forms.
  - Land use upstream affects water quality down stream.
  - Conservation in one area may affect environmental quality in the surrounding areas.
  - Thus, the location of conservation may affect both its economic value and ecological value.

Spatial Interactions: A Case Study

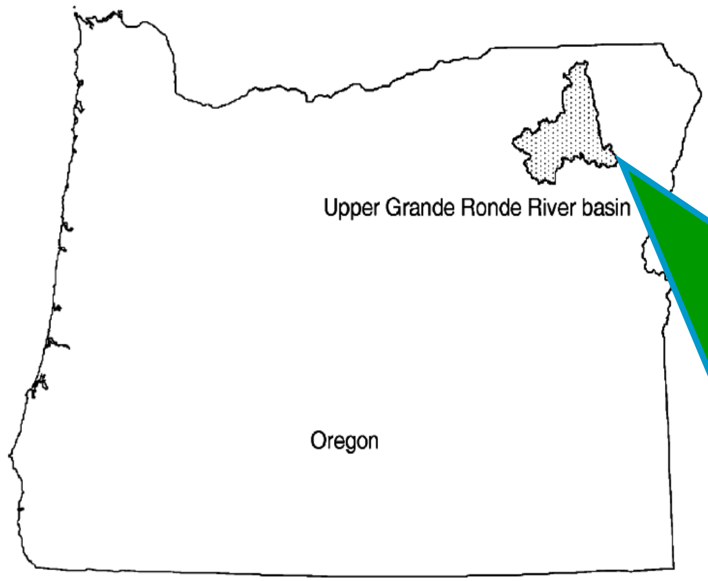


Fig. 1. Location of the Upper Grande Ronde River Basin.

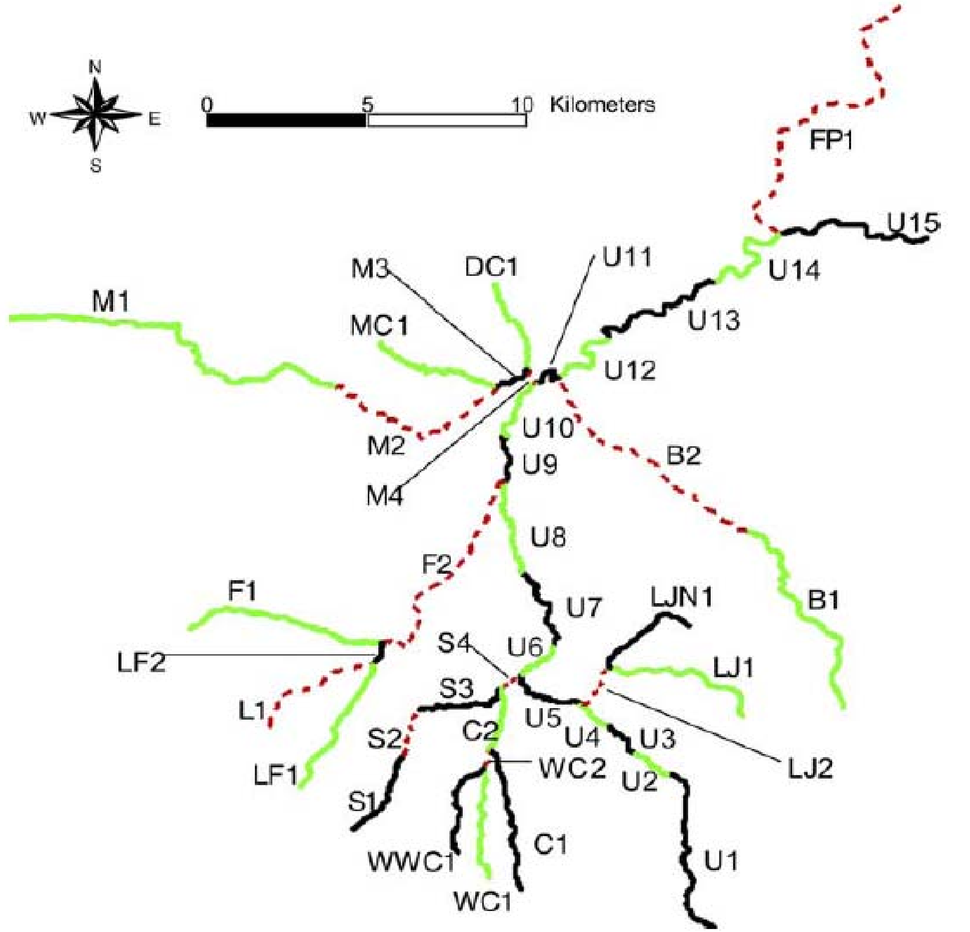


Fig. 2. The Upper Grande Ronde River basin and reaches.

Spatial Interactions: A Case Study

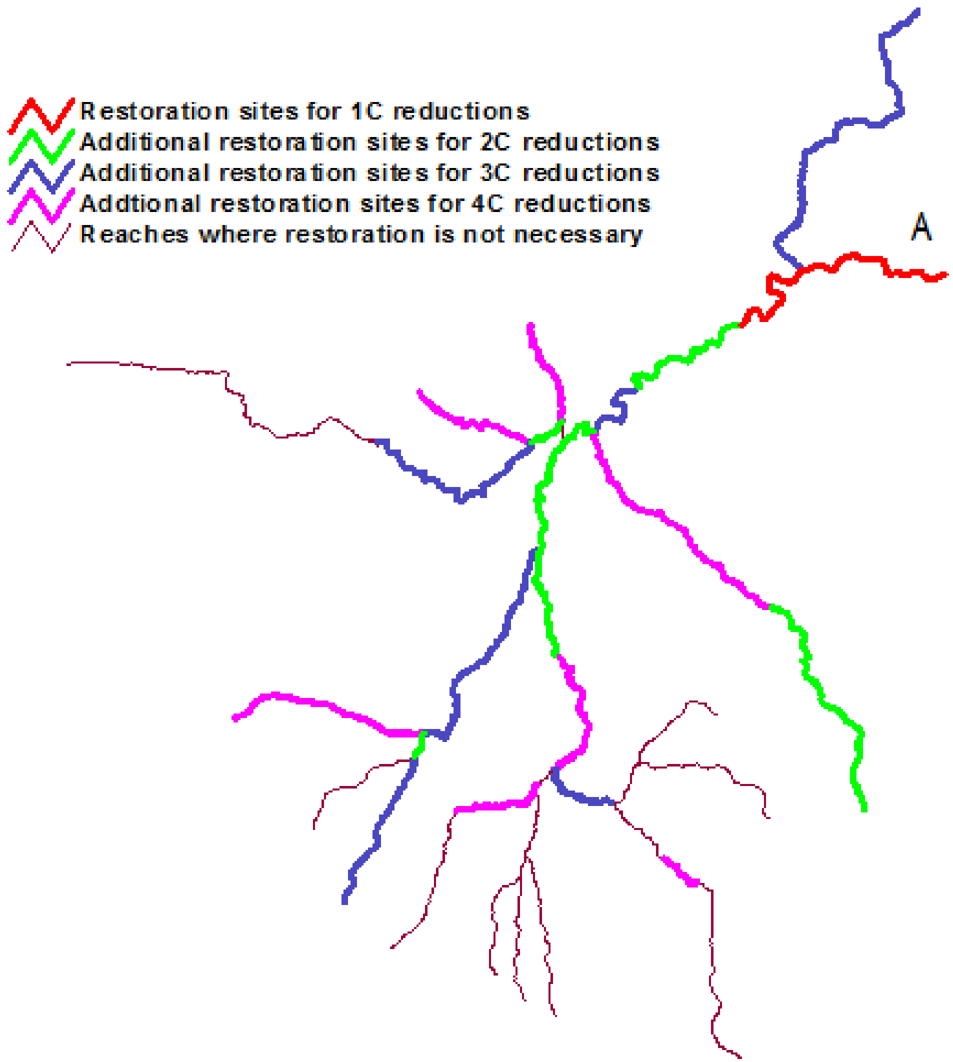


FIG. 6. Minimum cost restoration efforts, by reach, when water temperature at point A is reduced by 1, 2, 3 and 4 °C for a 40 year time frame.

Spatial Interactions: A Case Study

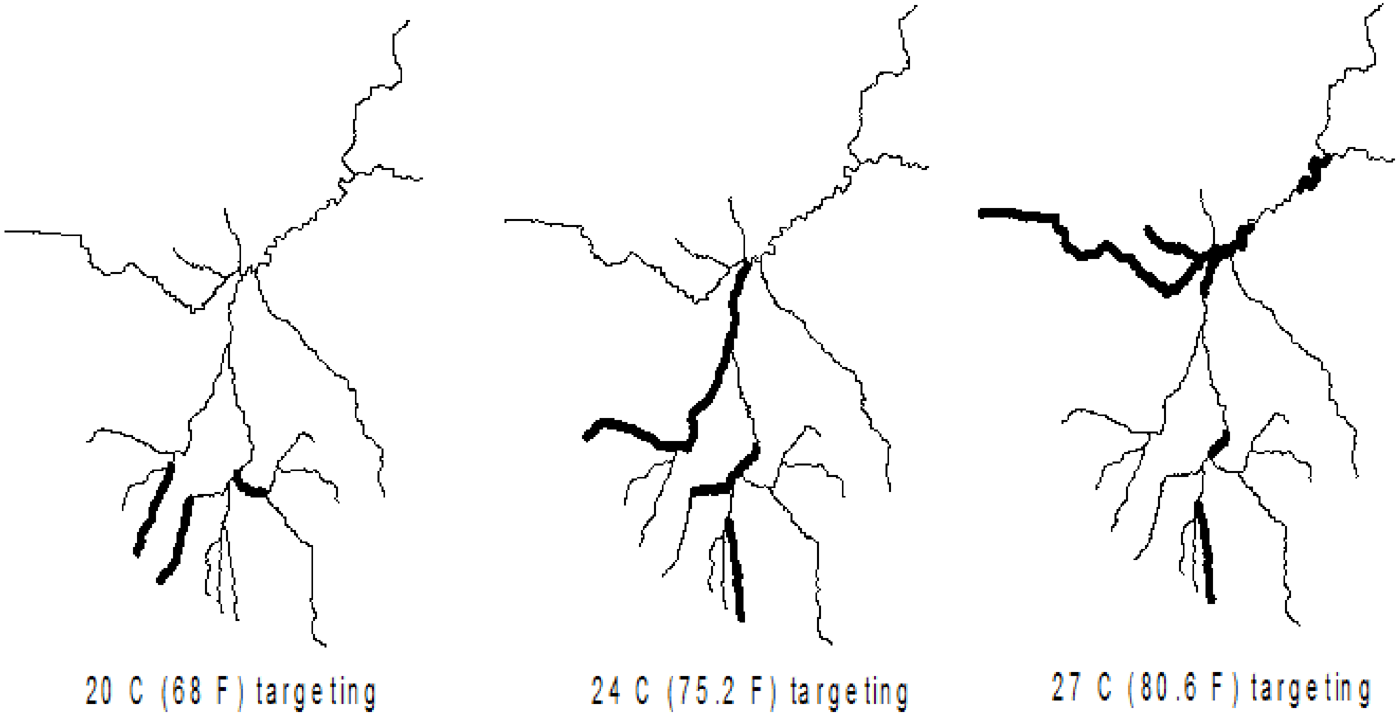


FIG. 8. Efficient allocation of restoration efforts when the objective is to maximize stream length whose temperature is below target Levels with a given budget ($100,000)

Spatial Interactions: A Case Study

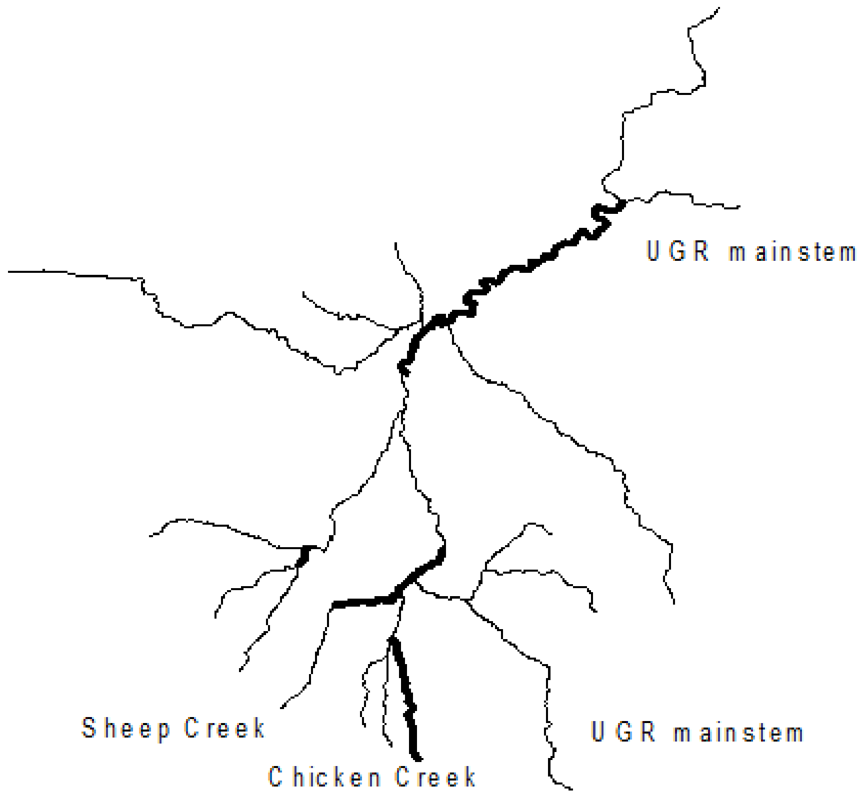


FIG. 10. Restoration sites, by reach, to maximize fish populations with a given budget ($100,000)

Spatial Interactions: An Example

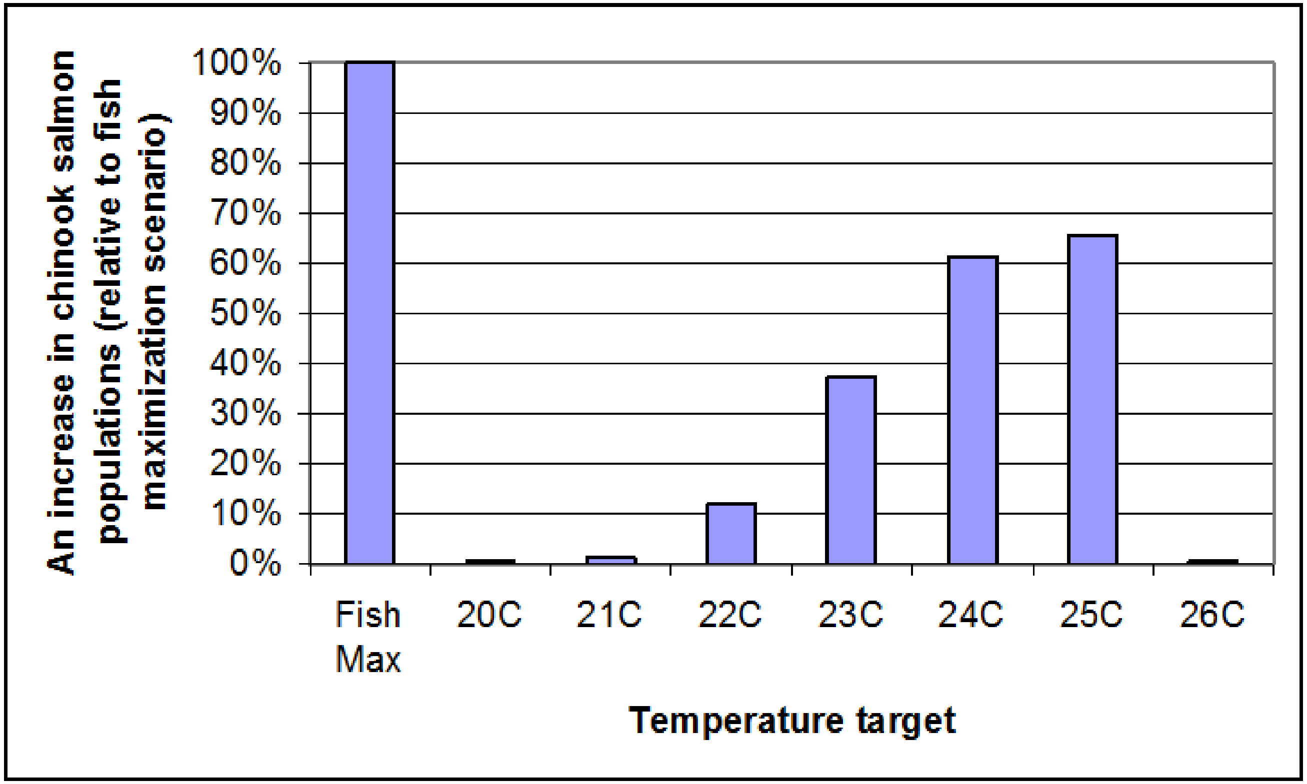


FIG. 11. Effects of temperature targeting alternatives on Chinook salmon populations in 40 year time frame with a budget constraint ($100,000)

Lessons learned

1. The world is not linear; do not spread money evenly across the landscape; try to target and prioritize problems.
2. We live in multiple species ecosystems. Interactions between different species and environmental benefits must be considered in conservation targeting.
3. Ecosystems are spatially interconnected. We must adopt an approach that is geographically focused and ecologically defined.

4. Remedies: A Three-Step Approach

Step 1: Divide the landscape into sub-landscapes ("ecological districts").

Step 2: Use a biding process like CRP to solicit conservation proposals.

Step 3: Accept proposals into the program based on benefit-cost ratios and ensure that
a) thresholds are reached in all funded districts
b) marginal benefits of conservation spending are equalized between districts.

Step 1: Divide the Landscape into Sub-Landscapes

- The definition of sub-landscapes requires a thorough consideration of the topography, geology, climate, soils, vegetation, and biological features of the region.
- Each sub-landscape must be large enough to include whole watersheds and biological communities and small enough to capture the spatial variations across the landscape.
  - USEPA uses a watershed approach to address water resource challenges, and claims that it is the most effective framework.
  - New Zealand is divided into 85 ecological regions and 268 ecological districts because of the need to establish a reserve system that reflects its biological diversity.
  - More research is needed as to how to define sub-landscapes.

Step 3: Bid Selection

- To ensure that threshold effects are reached in each sub-landscape.
- If thresholds are unobservable, it may make sense to adopt an all-or-nothing approach, that is, conserve all or nothing in a sub-landscape.
- This all-or-nothing approach could be more efficient than an approach that pays for the benefit explicitly, if threshold effects and spatial relationships give rise to a convex marginal benefit function (Lewis, Plantinga, and Wu 2008).

To Illustrate

- Suppose we want to create "core forest habitat" by converting non-forest parcels to forest, with a total budget \$8.
- The "core-only" policy can only create 5 core forest parcels, while the all-or-nothing approach can create 9 core forest parcels.

Sub-landscape 1

Sub-landscape 2

Step 3: Bid Selection

- Using benefit-cost ratio targeting
- If the conservation generates multiple environmental benefits, let the local communities to decide how much weight to give to each benefit.
- If local communities make optimal allocation among the alternative benefits, the optimal allocation of conservation funds among sub-landscapes can be achieved based on only one benefit (Wu and Boggess 1999).

Concluding Comments

- In most conservation investments, there are likely some strong non-linearities and ecosystem linkages that militate against the politically palatable funding criteria.
- The design of conservation programs must recognize these complexities.
- Formulas or guidelines based on political consideration, or keyed to a specific on-site physical criterion, are likely to result in substantial benefit losses.
- While the challenges are daunting, payoffs are potentially high for the use of sciences in the design of conservation programs.

This presentation is based on

1. Wu, J., and W.G. Boggess. 1999. "The Optimal Allocation of Conservation Funds." *Journal of Environmental Economics and Management* 37: 302-321.
2. Wu, J., R.M. Adams, and W.G. Boggess. 2000. "Cumulative Effects and Optimal Targeting of Conservation Efforts: Steelhead Trout Habitat Enhancement in Oregon." *American Journal of Agricultural Economics* 82: 400-413.
3. Wu, J., D. Zilberman, B.A. Babcock. 2001. "Environmental and Distributional Effects of Conservation Targeting Strtegies." *Journal of Environmental Economics and Management* 41: 333-350.
4. Wu, J., and K. Skelton. 2002. "Targeting Conservation Efforts in the Presence of Threshold Effects and Ecosystem Linkages." *Ecological Economics* 42(August): 313-331.
5. Wu, J., K. Skelton, W.G. Boggess, and Richard M. Adams. 2003. "Pacific Salmon Restoration: Tradeoffs Between Economic Efficiency And Political Acceptance." *Contemporary Economic Policy*. 21(1): 78-89.
6. Watanabe, M., R.M. Adams, and J. Wu. 2006. "The Economics of Environmental Management in a Spatially Heterogeneous River Basin." *American Journal of Agricultural Economics* 88(August 2006): 617-631.
7. Langpap, C., I. Hascic, and J. Wu. "Protecting Watershed Ecosystems through Targeted Local Land Use Policies." *American Journal of Agricultural Economics* 90(August 2008): 684-700.
8. Lewis, D., A. Plantinga, and J. Wu. 2008. "Targeting Incentives to Reduce Habitat Fragmentation" *American Journal of Agricultural Economics* (under review).

Thank you!