

Optimal Siting, Sizing, and Enforcement of Marine Protected Areas

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 **tabareCapitan**

Motivation

- Many countries are expanding their terrestrial and marine protected areas (Pereira et al., 2013).
- The outcomes depend on how people, as potential users of the protected area, respond to the protected area.

Related literature

- **Systematic conservation planning and reserve site selection**
Margules and Presley, 2000; Pressey and Bottrill, 2009; Onal et al., 2016; Albers et al., 2016.
- **Spatial fishery economics and MPAs**
Smith & Wilen, 2003; Sanchirico & Wilen 2001.
- **Leakage**
Delacote & Angelsen, 2015; Angelsen et al., 2012.
- **Terrestrial park effectiveness**
Ferraro et al., 2013; Sims, 2010; Andam et al., 2008.
- **Spatial renewable resource extraction**
Robinson et al., 2013; Albers & Robinson, 2011; Albers & Robinson, 2013.
- **Incomplete enforcement**
Milliman, 1986; Sutinen & Andersen, 1985; Bruner et al, 2004.

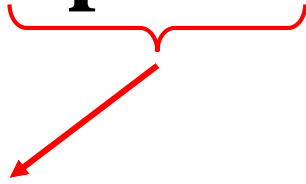
Contribution

We use a model of fishers' behavior to predict the reaction of fishers to a **Marine Protected Area (MPA)**, and use that reaction to determine the **optimal** size, sites, and enforcement of a MPA

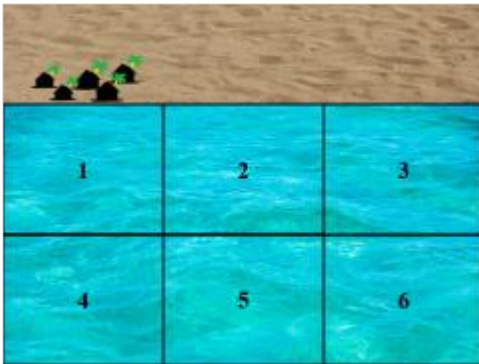
Model

Spatial bio-economic model

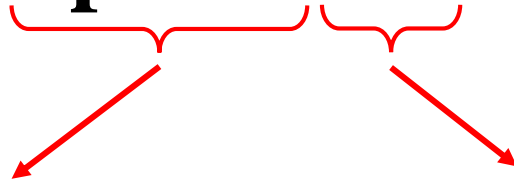
Spatial bio-economic model



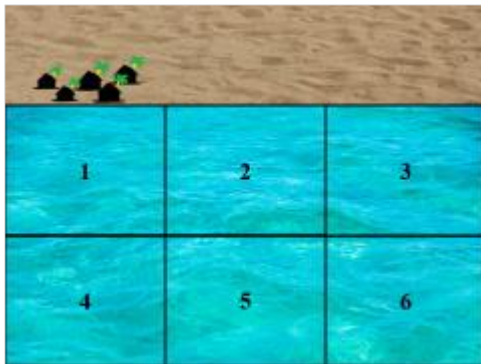
Spatial setting



Spatial bio-economic model



Spatial setting

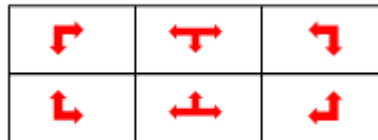


Fish dynamics

Fish dynamics

$$X_{t+1} = X_t + G(X_t, K) + DX_t - H_t$$

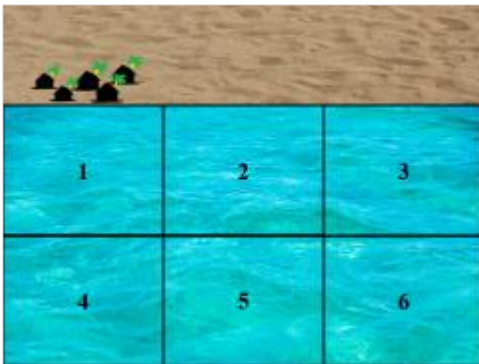
Fish dispersal



- Rook contiguity
- Density dispersal

Spatial bio-economic model

Spatial setting



Fish dynamics

Fish dynamics

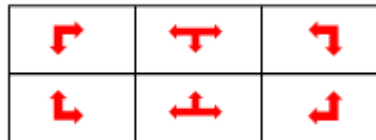
$$X_{t+1} = X_t + G(X_t, K) + DX_t - H_t$$

→ Villagers (fishers)

Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [ph_j(1 - \phi_j) + wl_w^y]$$

Fish dispersal



- Rook contiguity
- Density dispersal

→ Manager

Manager

$$\max_{S, \phi} [G_k(H)]$$

$k \in \{\text{yield, income, ASL MPA, ASL marinescape}\}$

(For any of the 4 goals)

Spatial setting

Model



1

2

3

4

5

6

Biological part

Model

Fish dynamics

$$X_{t+1} = X_t + G(X_t, K) + DX_t - H_t$$

Fish dynamics

$$\underbrace{X_{t+1}} = X_t + G(X_t, K) + DX_t - H_t$$

Vector of size = # fishing sites

$$X_t = \begin{pmatrix} x_{t,1} \\ \vdots \\ x_{t,6} \end{pmatrix} = \begin{array}{|c|c|c|} \hline x_{t,1} & x_{t,2} & x_{t,3} \\ \hline x_{t,4} & x_{t,5} & x_{t,6} \\ \hline \end{array}$$

Fish dynamics

Fish stock in time $t + 1$ and t

$$\overbrace{X_{t+1}} = \overbrace{X_t} + G(X_t, K) + DX_t - H_t$$

Fish dynamics

Fish stock in time $t + 1$ and t

$$\overbrace{X_{t+1}} = \overbrace{X_t} + \underbrace{G(X_t, K)} + DX_t - H_t$$

Fish net growth

Fish dynamics

Fish stock in time $t + 1$ and t

$$\overbrace{X_{t+1}} = \overbrace{X_t} + \underbrace{G(X_t, K)} + DX_t - \underbrace{H_t}$$

Fish net growth

Fishers' harvest

Fish dynamics

Fish stock in time $t + 1$ and t

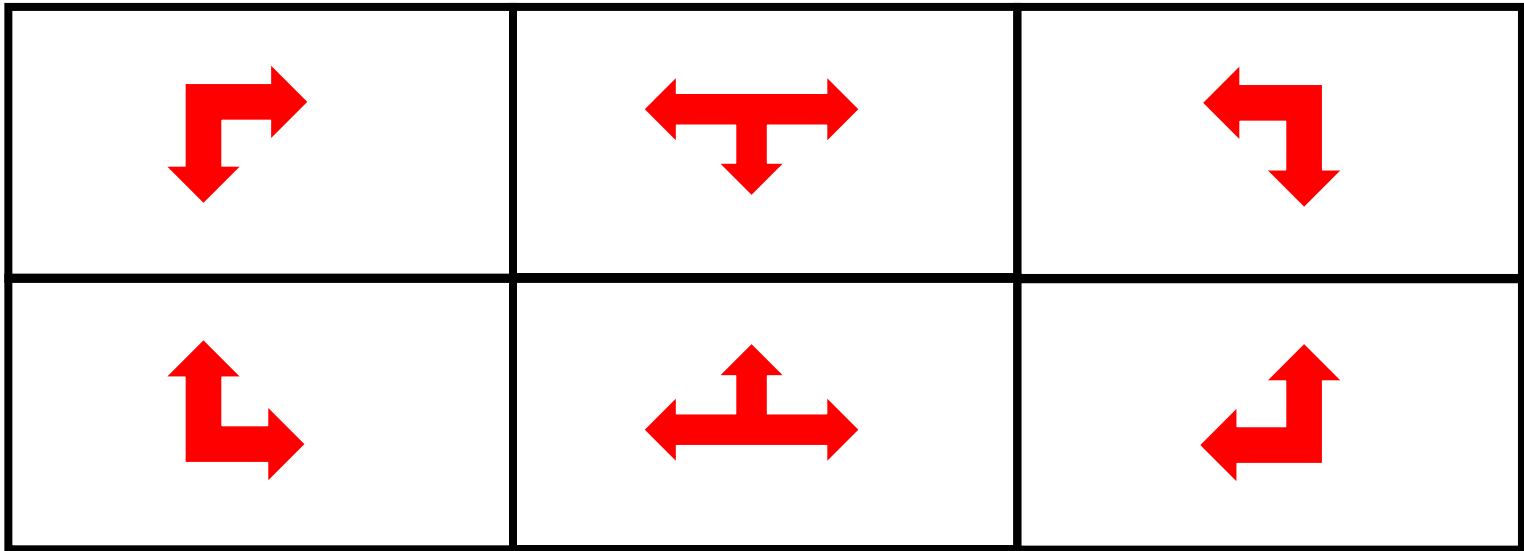
$$\underbrace{X_{t+1}} = \underbrace{X_t} + \underbrace{G(X_t, K)} + \underbrace{DX_t}_{\text{Fish dispersal}} - \underbrace{H_t}_{\text{Fishers' harvest}}$$

Fish net growth

Fish dispersal

Fishers' harvest

Fish dispersal



- **Rook contiguity**
- **Density dispersal**

Economics: Villagers

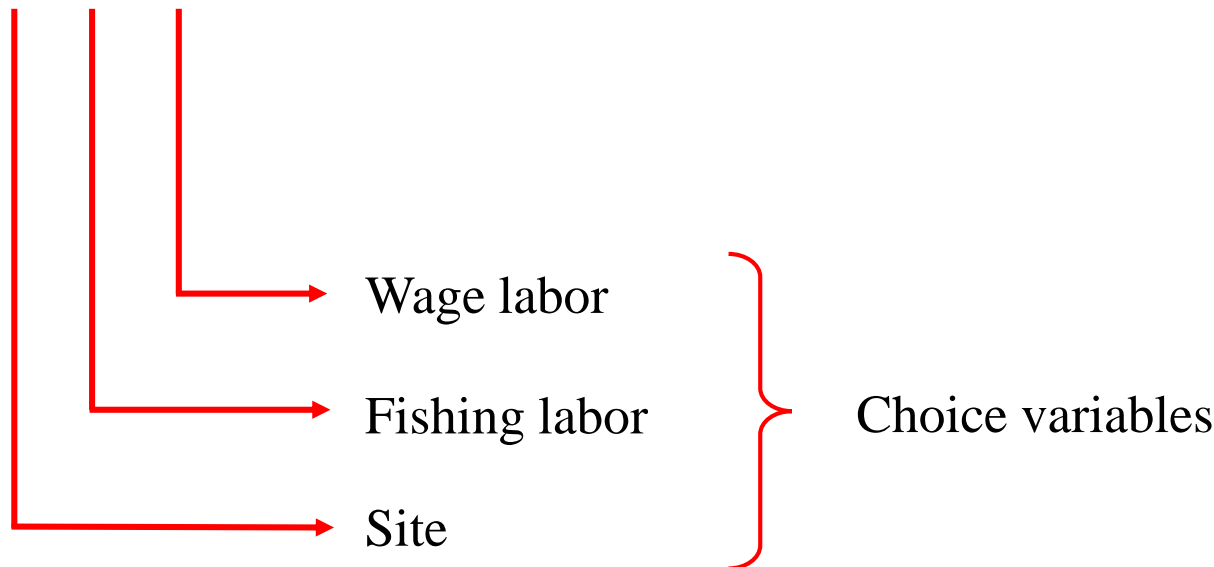
Model

Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [ph_j(1 - \phi_j) + wl_w^\gamma]$$

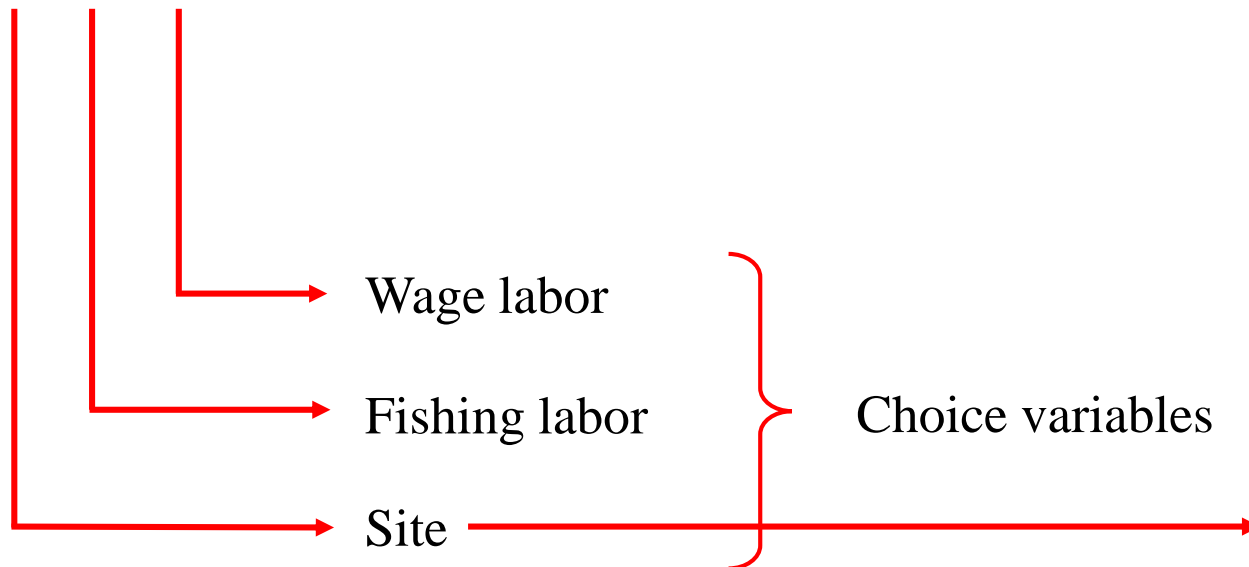
Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [ph_j(1 - \phi_j) + wl_w^\gamma]$$



Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [ph_j(1 - \phi_j) + wl_w^\gamma]$$



Just 1 site

Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [p h_j (1 - \phi_j) + w l_w^\gamma]$$

Price of fish

Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [p \mathbf{h}_j (1 - \phi_j) + w l_w^\gamma]$$

Fish harvest

Villagers (fishers)

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} [ph_j(1 - \phi_j) + wl_w^\gamma]$$

Enforcement level

$$\phi_j \in (0, 1)$$

Zero enforcement ← → Perfect enforcement

Villagers (fishers)

Fishing income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + w l_w^\gamma \right]$$

Villagers (fishers)

Fishing income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \mathbf{w} l_w^\gamma \right]$$

Onshore wage

Villagers (fishers)

Fishing income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + w l_w^\gamma \right]$$

Diminishing returns to wage labor

(~ Imperfect labor markets)

$$\gamma \in (0, 1)$$

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^y}^{\text{Wage-labor income}} \right]$$

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^\gamma}^{\text{Wage-labor income}} \right]$$

Constraints

4 constraints

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^y}^{\text{Wage-labor income}} \right]$$

Constraints

$$l_{fj} + l_{d(j)} + l_w \leq L \longrightarrow \text{Endowment of labor time}$$

$$\phantom{l_{fj} + l_{d(j)} + l_w \leq L} \longrightarrow \text{Wage-labor time}$$

$$\phantom{l_{fj} + l_{d(j)} + l_w \leq L} \longrightarrow \text{Travel to fishing site time}$$

$$\phantom{l_{fj} + l_{d(j)} + l_w \leq L} \longrightarrow \text{Fishing labor time}$$

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^\gamma}^{\text{Wage-labor income}} \right]$$

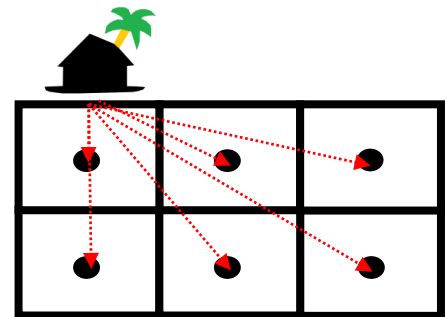
Constraints

$$l_{fj} + l_{d(j)} + l_w \leq L$$

Discreteness

Distance costs

Travel to fishing site time



Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^\gamma}^{\text{Wage-labor income}} \right]$$

Constraints

$$l_{fj} + l_{d(j)} + l_w \leq L$$

$$h_j = l_{fj} x_j q_j$$

Catchability coefficient

Fish stock in site j

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^\gamma}^{\text{Wage-labor income}} \right]$$

Constraints

$$l_{fj} + l_{d(j)} + l_w \leq L$$

$$h_j = l_{fj} x_j q_j$$

$$H_j = \sum_{n=1}^N h_j^n$$

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^\gamma}^{\text{Wage-labor income}} \right]$$

Constraints

$$l_{fj} + l_{d(j)} + l_w \leq L$$

$$X_{t+1} = X_t + G(X_t, K) + DX_t - H_t$$

$$h_j = l_{fj} x_j q_j$$

$$H_j = \sum_{n=1}^N h_j^n$$

Villagers (fishers)

Fishing income

Wage-labor income

$$\max_{j, l_f, l_w} [V] = \max_{j, l_f, l_w} \left[\overbrace{p h_j (1 - \phi_j)}^{\text{Fishing income}} + \overbrace{w l_w^\gamma}^{\text{Wage-labor income}} \right]$$

Constraints

$$l_{fj} + l_{d(j)} + l_w \leq L$$

$$H_j \leq x_j$$

$$h_j = l_{fj} x_j q_j$$

$$H_j = \sum_n^N h_j^n$$

Villagers (fishers)

Each individual villager knows and take into account
that the other villagers face the same optimization
problem

(strategic behavior)

Solution

Characterized by 3 conditions



SS



foc



NE

Solution

SS

Steady-state of fish stocks (long-run equilibrium)

$$X_{t+1} - X_t = 0$$

1

Solution

SS

Steady-state of fish stocks (long-run equilibrium)

$$X_{t+1} - X_t = 0$$

1

foc

Optimal allocation of fishing and wage labor per location

First-order conditions

2

Solution

SS

Steady-state of fish stocks (long-run equilibrium)

$$X_{t+1} - X_t = 0$$

1

foc

Optimal allocation of fishing and wage labor per location

First-order conditions

2

NE

Equilibrium across space in fishing location

Spatial Nash-Equilibrium

3

Economics: Manager

Model

Manager

Two choice variables define the MPA

- **Siting**

$$S = \begin{pmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{pmatrix}$$

$$s_i = \begin{cases} 1 & \text{if site } i \text{ is in the MPA} \\ 0 & \text{otherwise} \end{cases} .$$

Manager

Two choice variables define the MPA

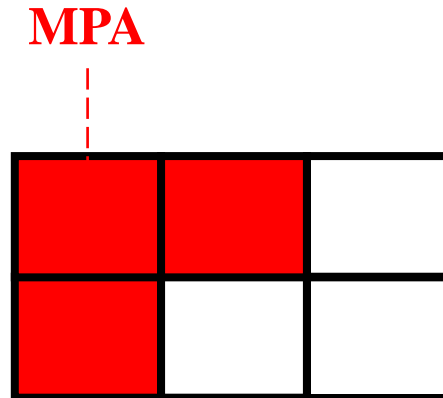
- **Siting**

$$\mathbf{s} = \begin{pmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \end{pmatrix}$$

$$s_i = \begin{cases} 1 & \text{if site } i \text{ is in the MPA} \\ 0 & \text{otherwise} \end{cases}$$

Defines size...

$$\mathbf{s} = \begin{pmatrix} 1 \\ 1 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$$



Size = 3

Manager

Two choice variables define the MPA

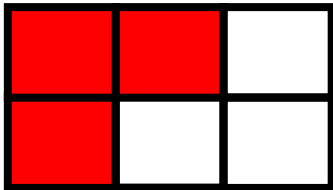
- **Siting**

$$\mathbf{s} = \begin{pmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \end{pmatrix}$$

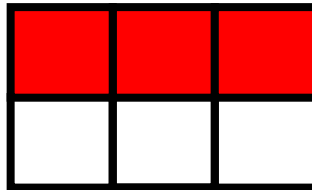
$$s_i = \begin{cases} 1 & \text{if site } i \text{ is in the MPA} \\ 0 & \text{otherwise} \end{cases}$$

...and configuration:

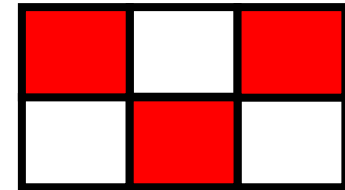
$$\mathbf{s} = \begin{pmatrix} 1 \\ 1 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix}$$



$$\mathbf{s} = \begin{pmatrix} 1 \\ 1 \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$



$$\mathbf{s} = \begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \\ 1 \\ 0 \end{pmatrix}$$



Manager

Two choice variables define the MPA

- **Siting**

$$S = \begin{pmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \\ s_5 \\ s_6 \end{pmatrix} \quad s_i = \begin{cases} 1 & \text{if site } i \text{ is in the MPA} \\ 0 & \text{otherwise} \end{cases}$$

- **Enforcement level**

$$\phi_j = \begin{cases} \phi & \text{if site } i \text{ is in the MPA} \\ 0 & \text{otherwise} \end{cases} \quad \phi \in (0,1)$$

Manager

Four alternative goals

Manager

Four alternative goals

Economic goals

Manager

Four alternative goals

Economic goals

$$\max_{S, \phi} \sum_i H_i (1 - \phi_i)$$

Aggregate yield

Manager

Four alternative goals

Economic goals

$$\max_{S, \phi} \sum_i H_i (1 - \phi_i)$$

Aggregate yield

$$\max_{S, \phi} \sum_i p H_i (1 - \phi_i) + \sum_n w l_{w,n}^y$$

Aggregate income

Manager

Four alternative goals

Ecological goals

Economic goals

$$\max_{S, \phi} \sum_i H_i (1 - \phi_i)$$

Aggregate yield

$$\max_{S, \phi} \sum_i p H_i (1 - \phi_i) + \sum_n w l_{w,n}^y$$

Aggregate income

Manager

Four alternative goals

Ecological goals

$$\max_{S, \phi} \sum_i s_i [x_i - x_{i,OA}]$$

ASL MPA

Economic goals

$$\max_{S, \phi} \sum_i H_i (1 - \phi_i)$$

Aggregate yield

$$\max_{S, \phi} \sum_i p H_i (1 - \phi_i) + \sum_n w l_{w,n}^y$$

Aggregate income

Manager

Four alternative goals

Ecological goals

$$\max_{S, \phi} \sum_i s_i [x_i - x_{i,OA}]$$

ASL MPA

$$\max_{S, \phi} \sum_i [x_i - x_{i,OA}]$$

ASL Marinescape

Economic goals

$$\max_{S, \phi} \sum_i H_i (1 - \phi_i)$$

Aggregate yield

$$\max_{S, \phi} \sum_i p H_i (1 - \phi_i) + \sum_n w l_{w,n}^y$$

Aggregate income

Manager

Four alternative goals

Ecological goals

$$\max_{S, \phi} \sum_i s_i [x_i - x_{i,OA}]$$

ASL MPA

$$\max_{S, \phi} \sum_i [x_i - x_{i,OA}]$$

ASL Marinescape

Economic goals

$$\max_{S, \phi} \sum_i H_i (1 - \phi_i)$$

Aggregate yield

$$\max_{S, \phi} \sum_i p H_i (1 - \phi_i) + \sum_n w l_{w,n}^y$$

Aggregate income

Manager

$$\max_{S, \phi} [G_k(H)]$$

$k \in \{\text{yield, income, ASL MPA, ASL marinescape}\}$

(For any of the 4 goals)

Manager

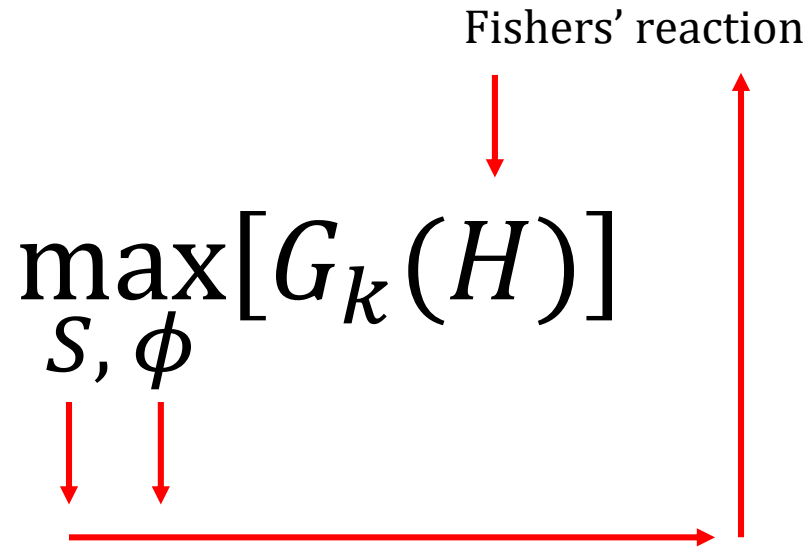
$$\max_{S, \phi} [G_k(H)]$$

Constraint

$$C = \sum_i s_i [c(\phi)]$$

$$B \geq C$$

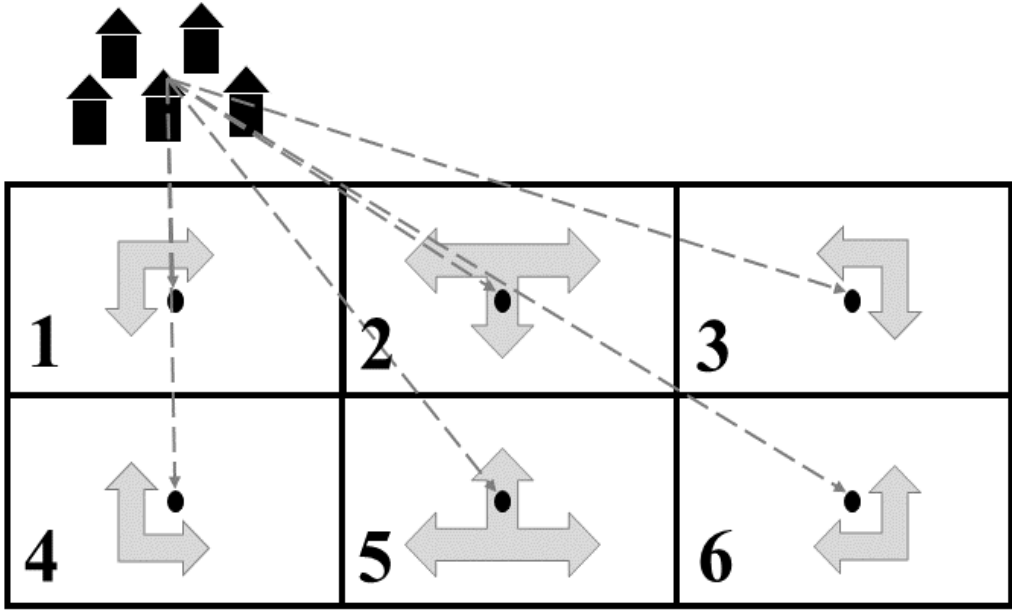
Manager



Constraint

Considers villagers' reaction to the MPA

Results

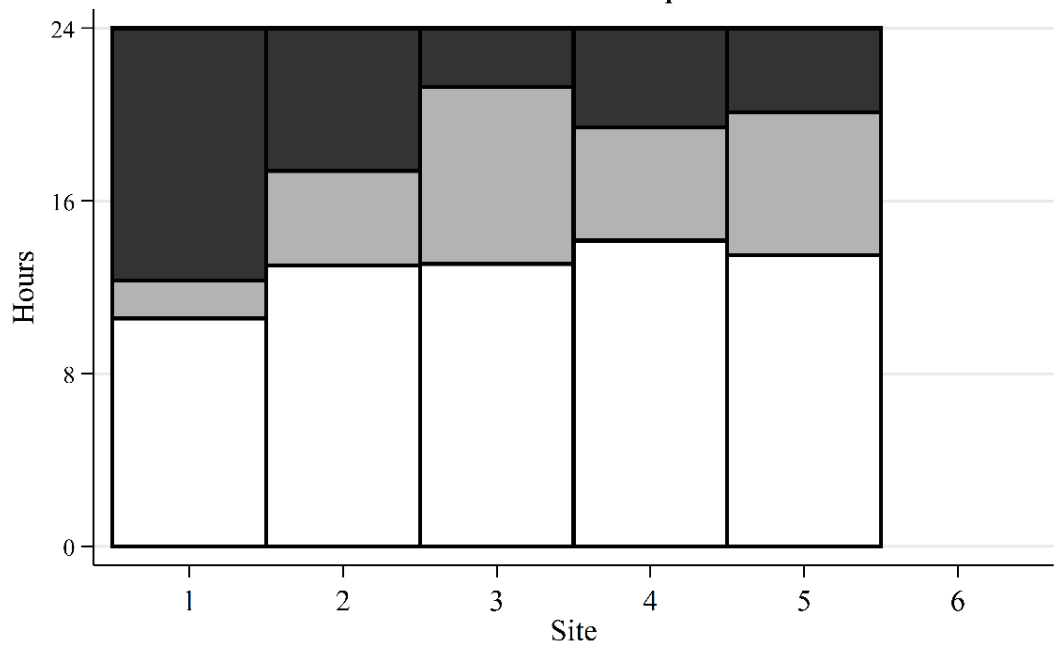


1	2	3	4	5	6
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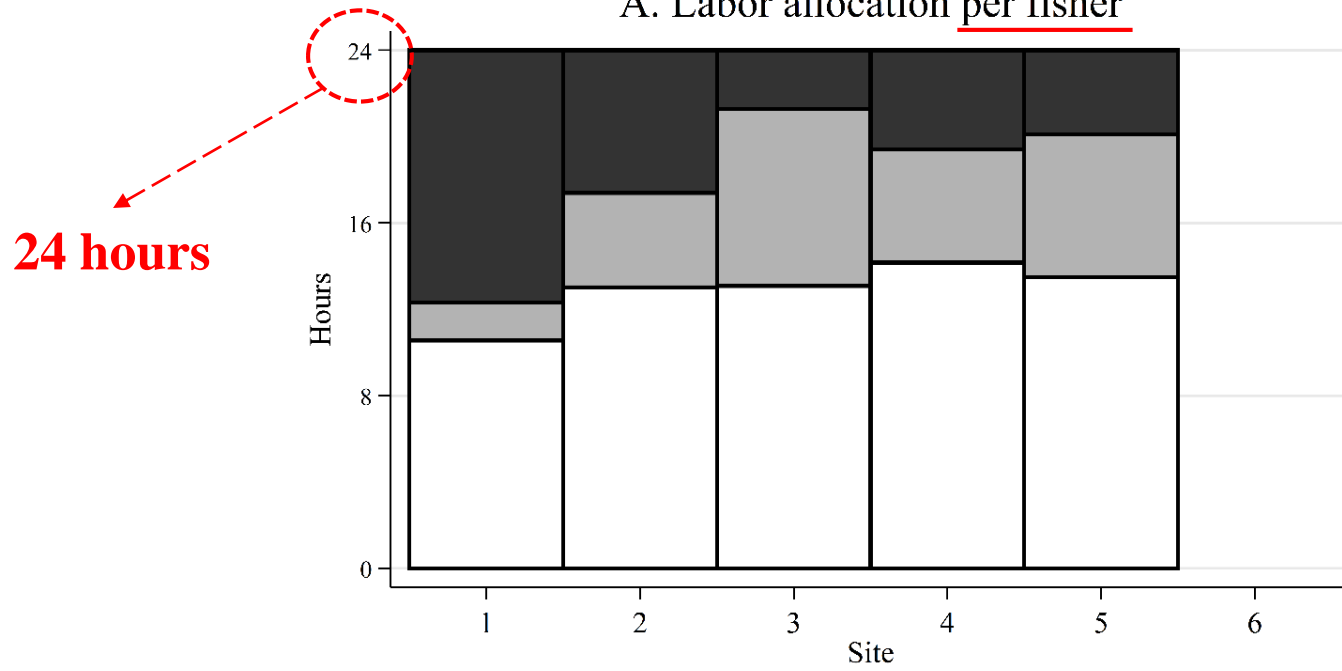
Open access

Results

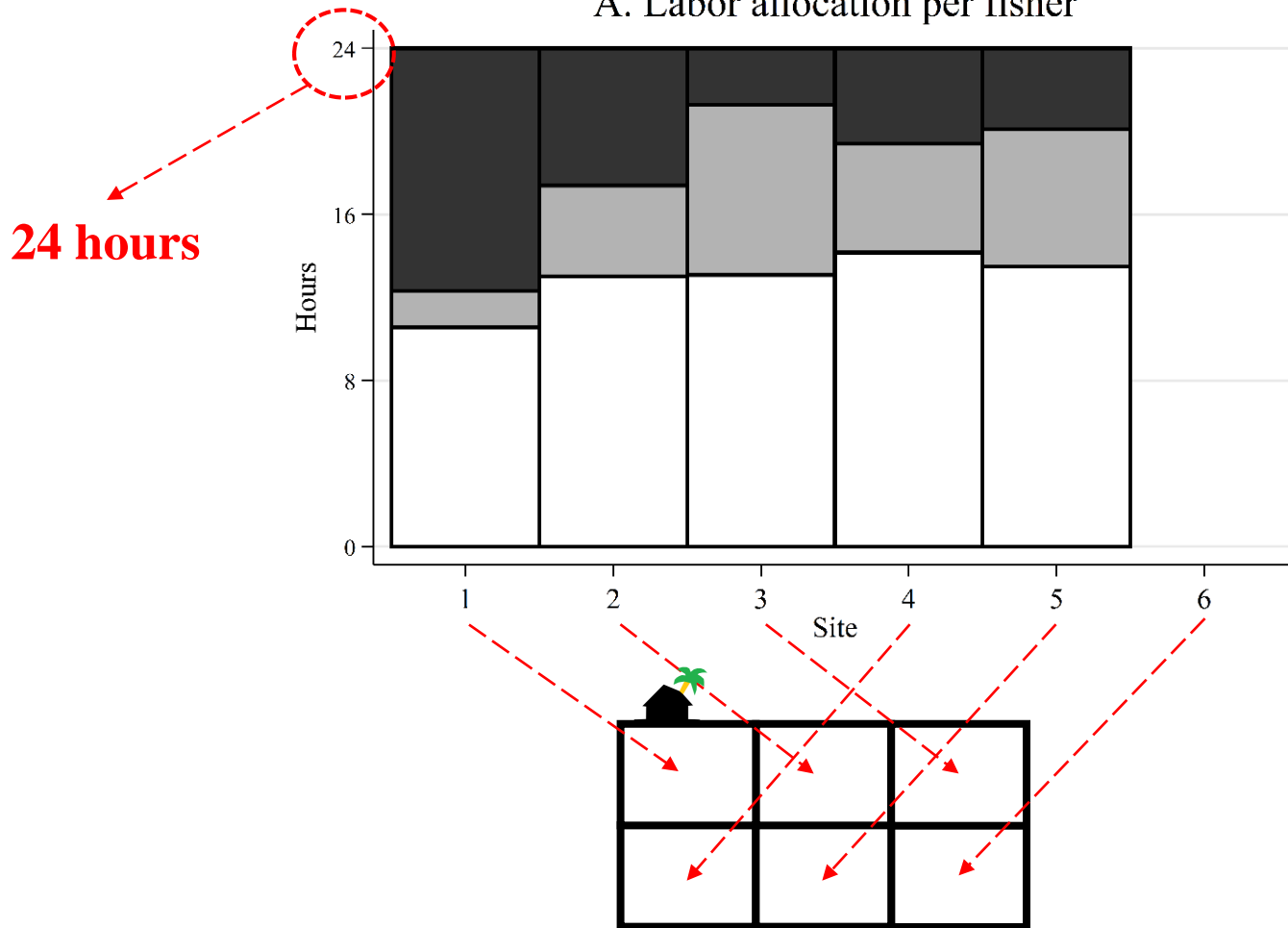
A. Labor allocation per fisher



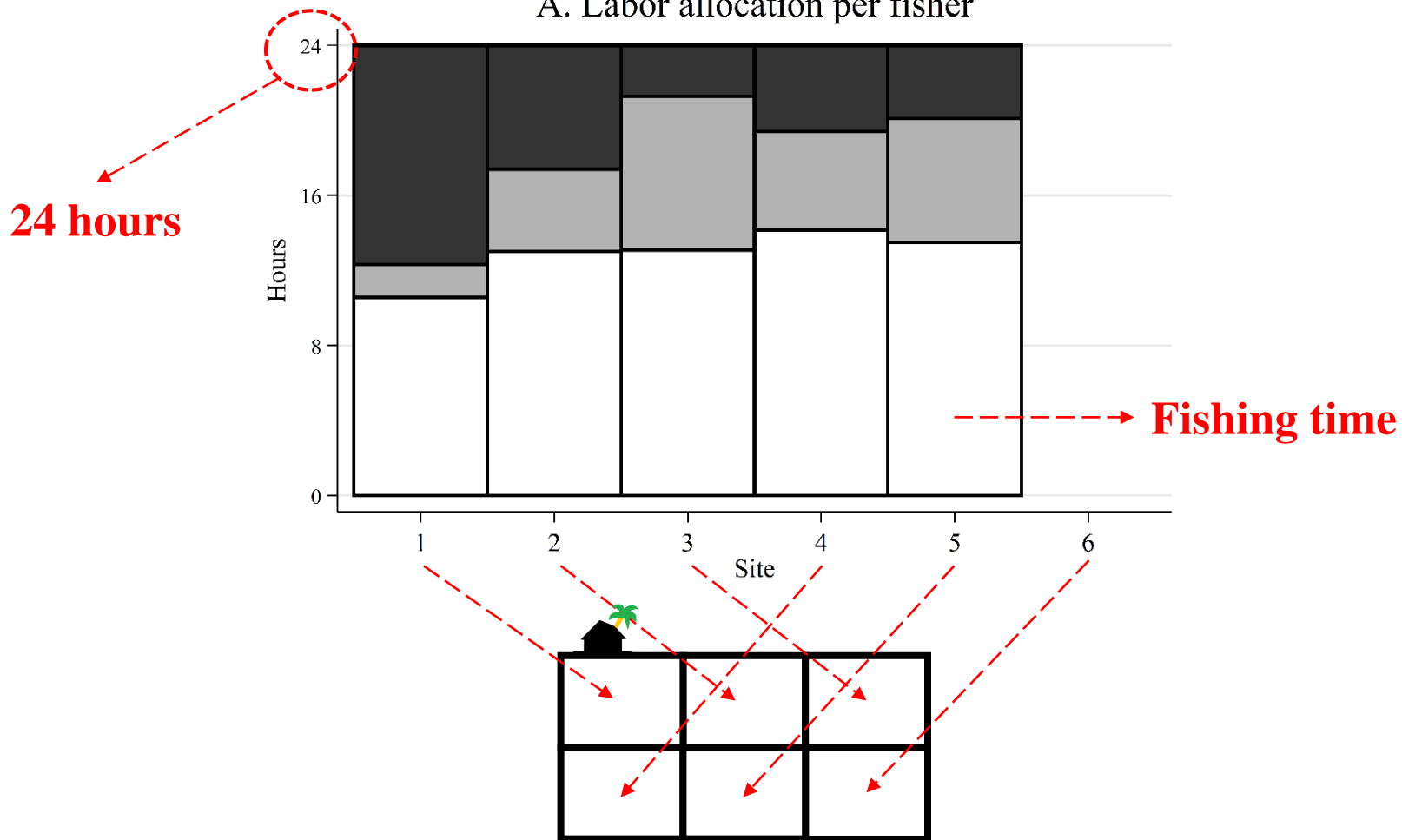
A. Labor allocation per fisher



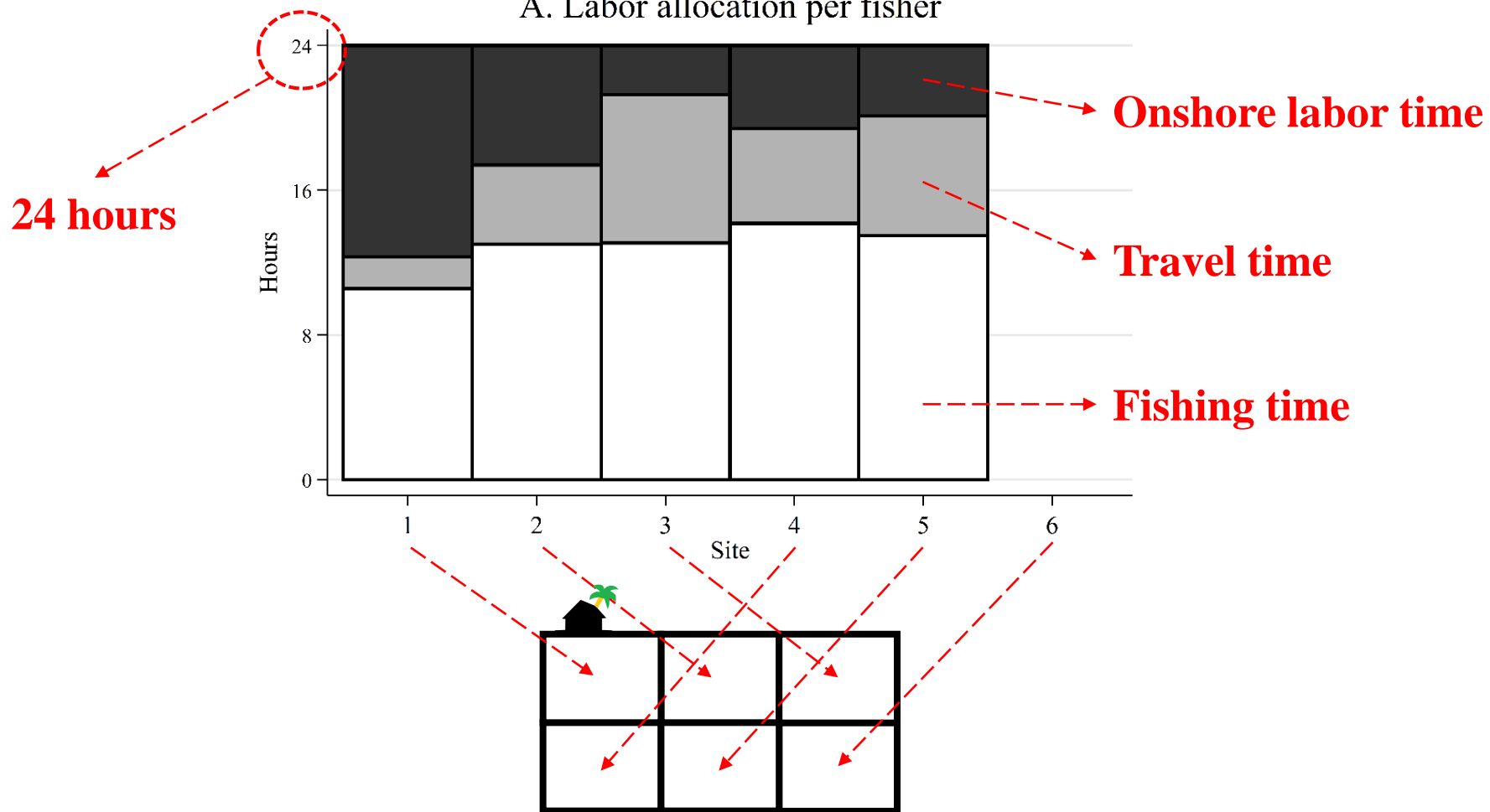
A. Labor allocation per fisher



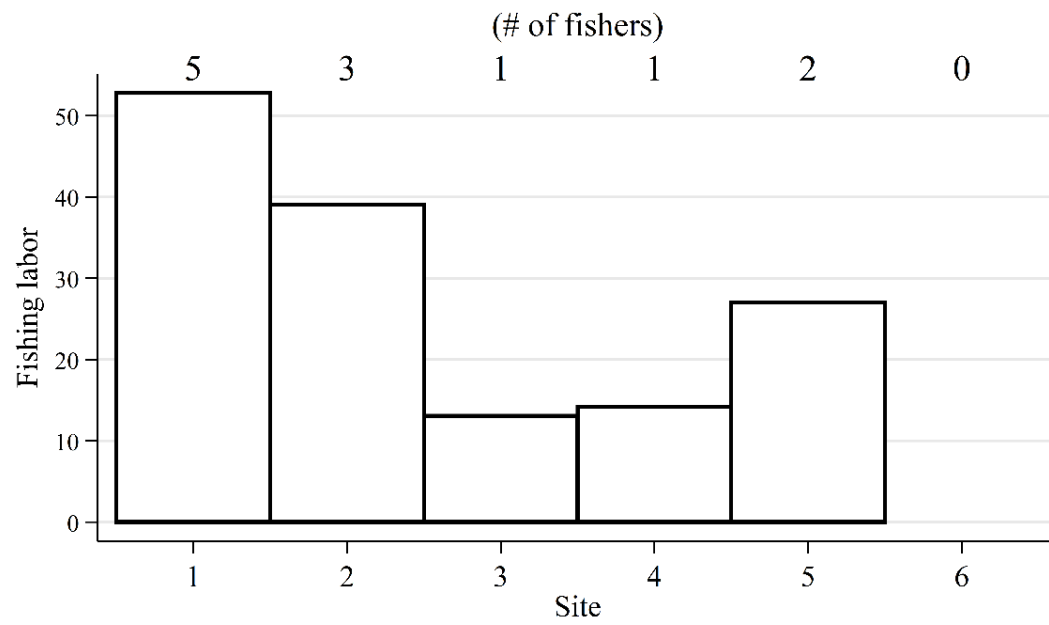
A. Labor allocation per fisher



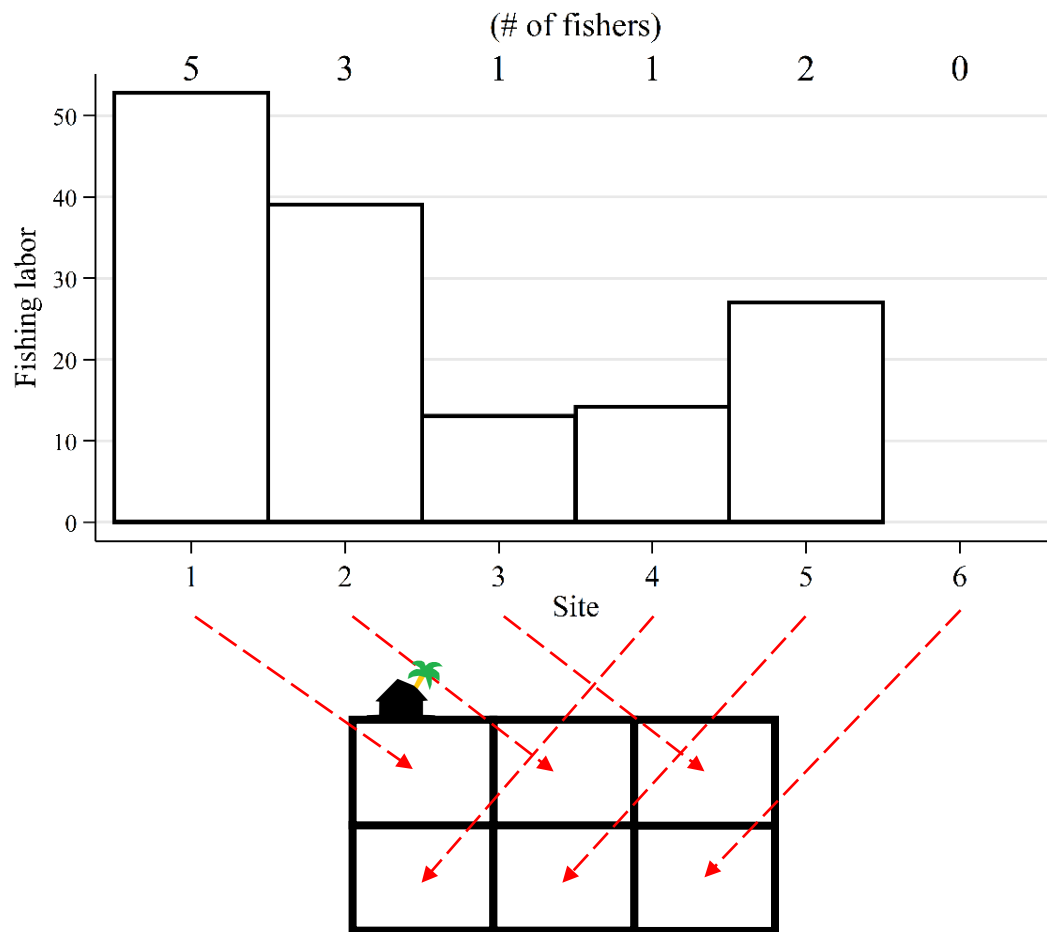
A. Labor allocation per fisher



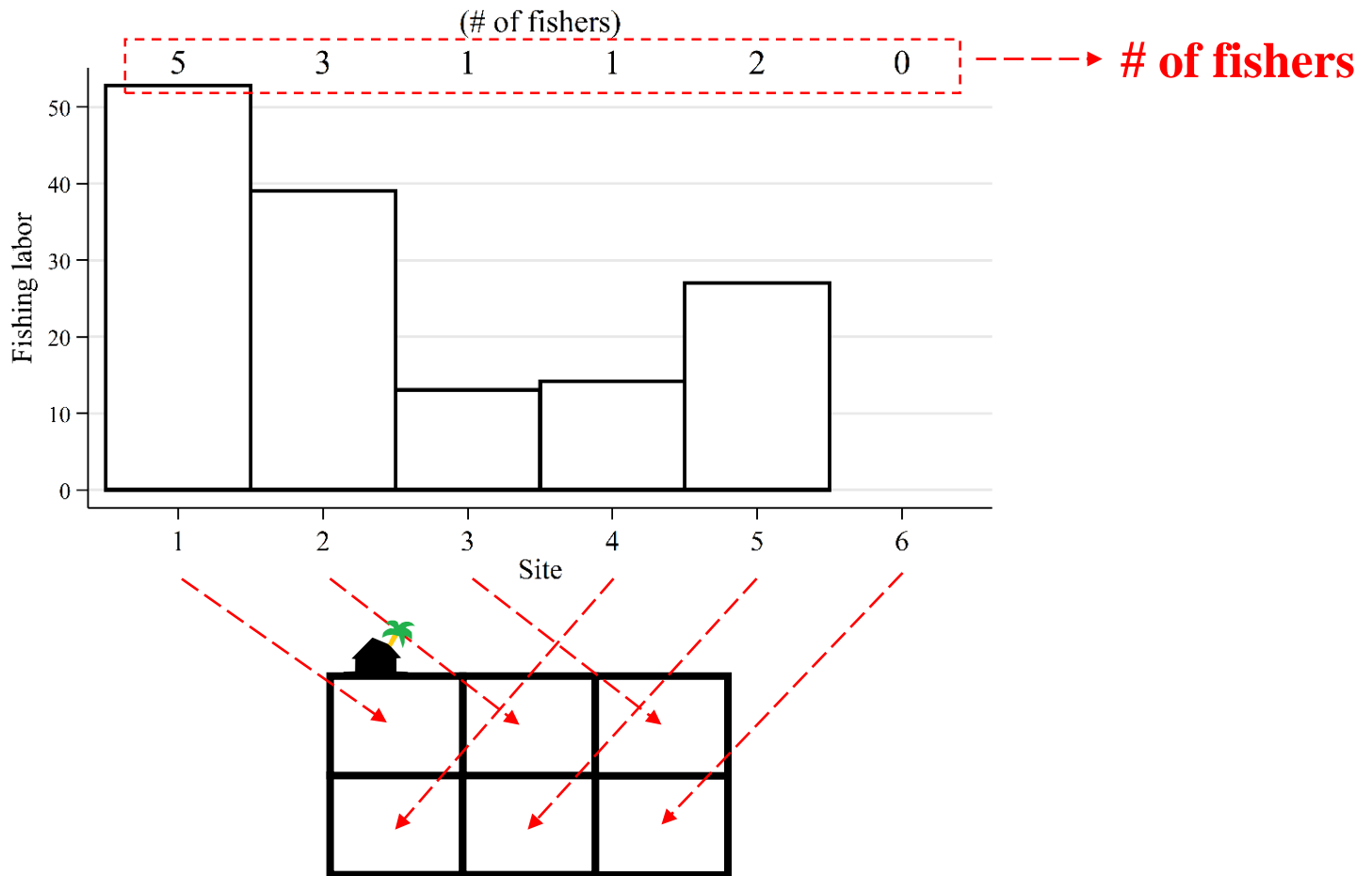
B. Total fishing labor

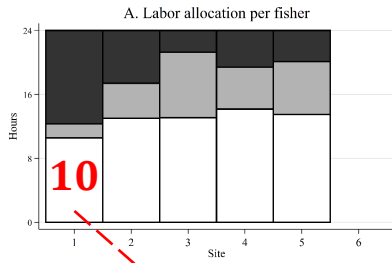


B. Total fishing labor



B. Total fishing labor

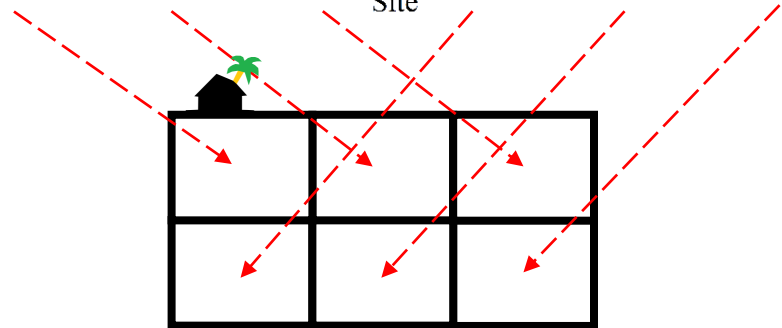
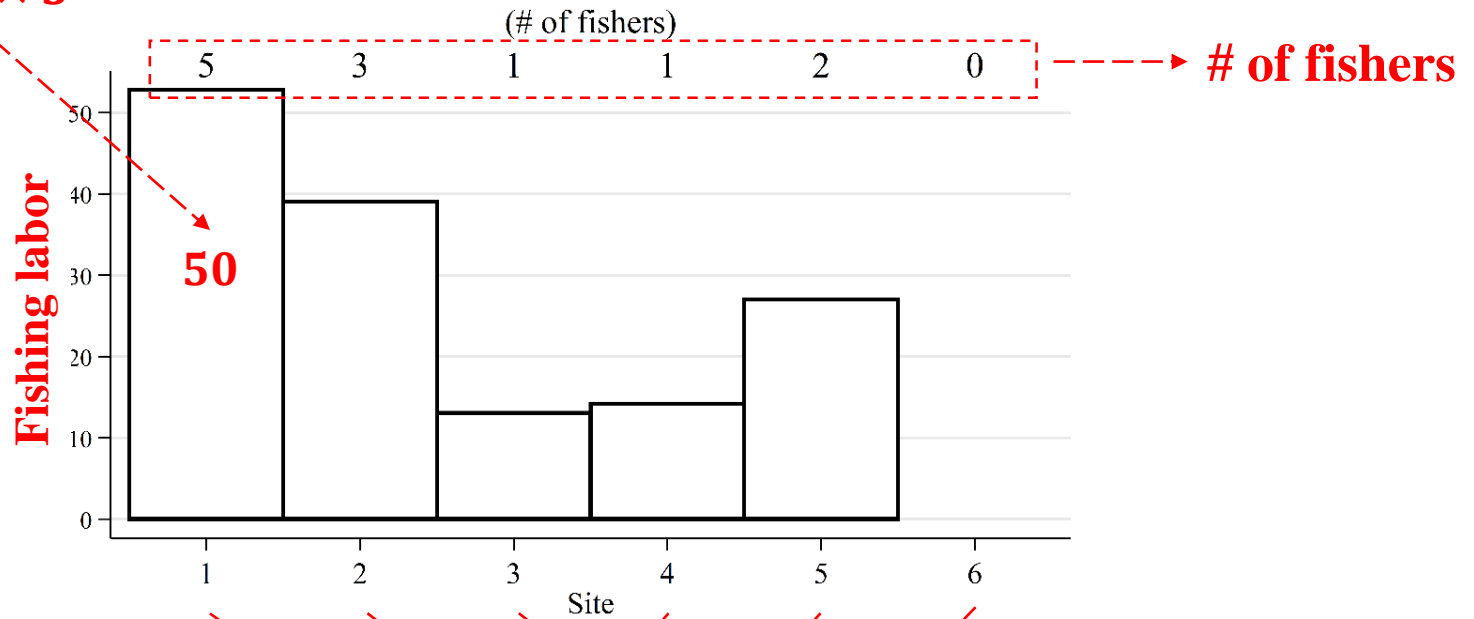




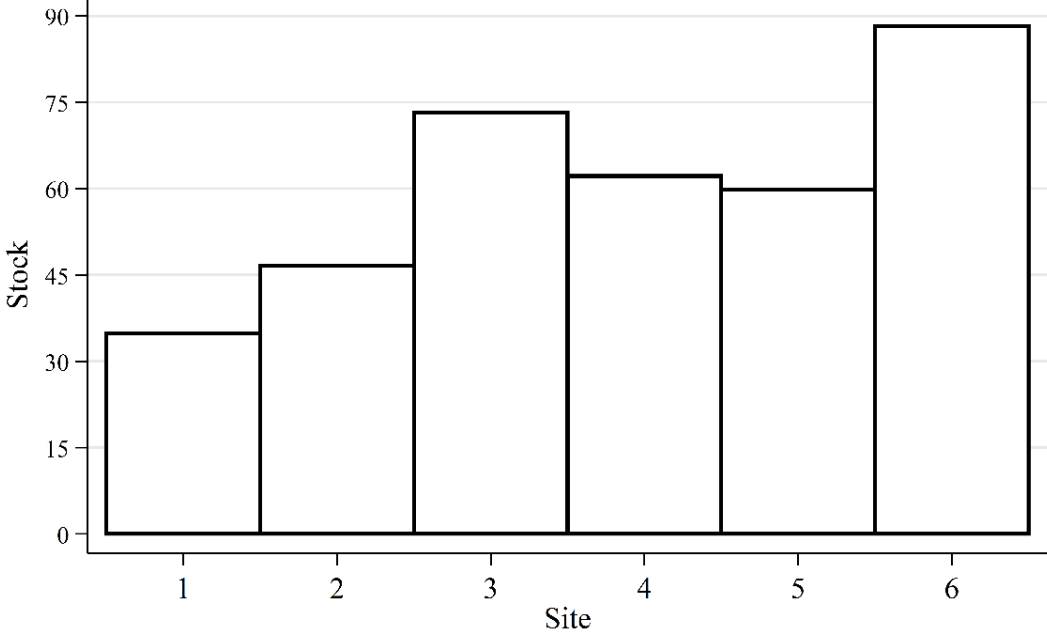
Fishing labor = fishing time per fisher × # fishers

× 5

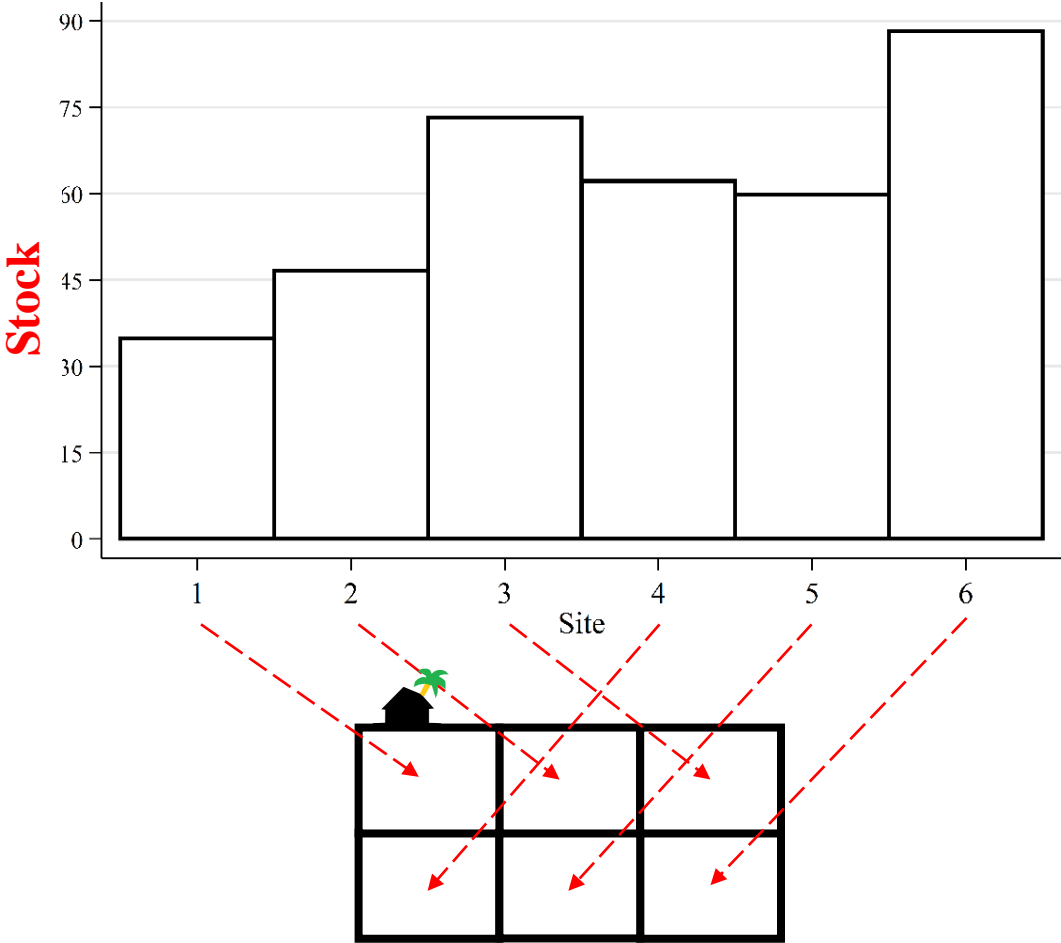
B. Total fishing labor




C. Fish stock

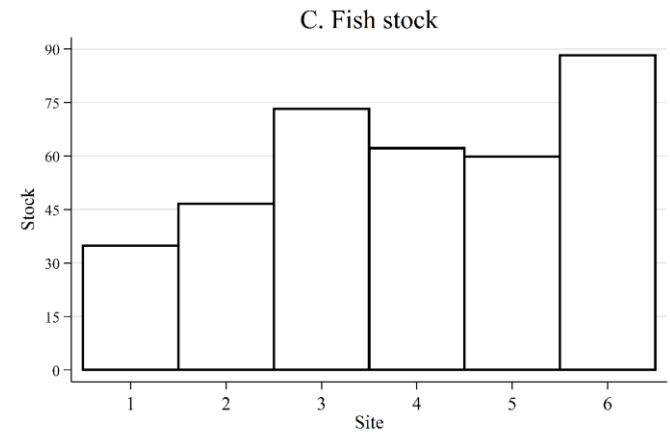
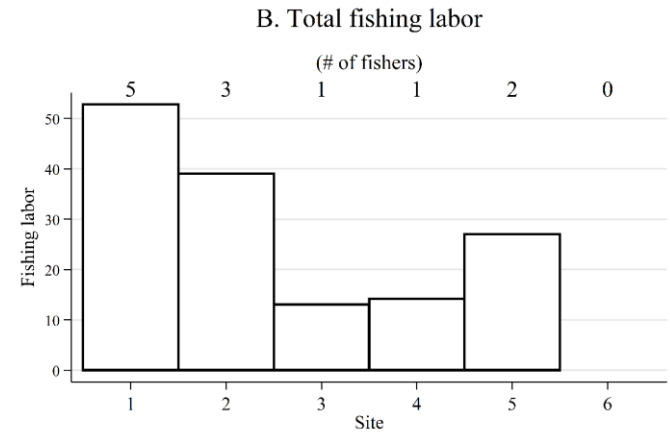
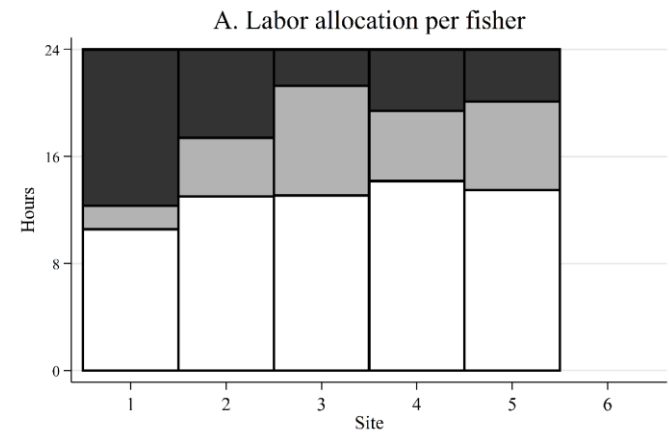


C. Fish stock

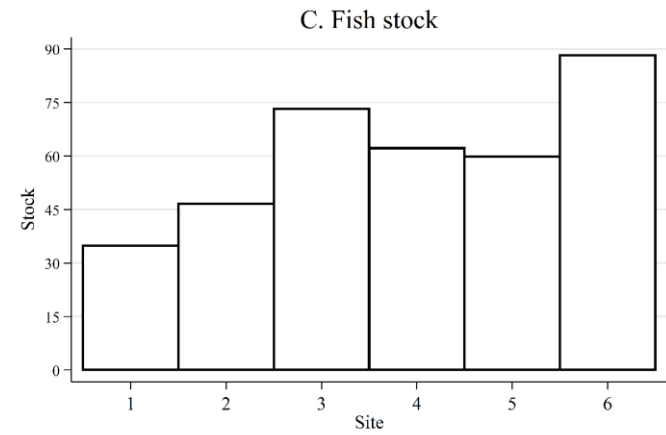
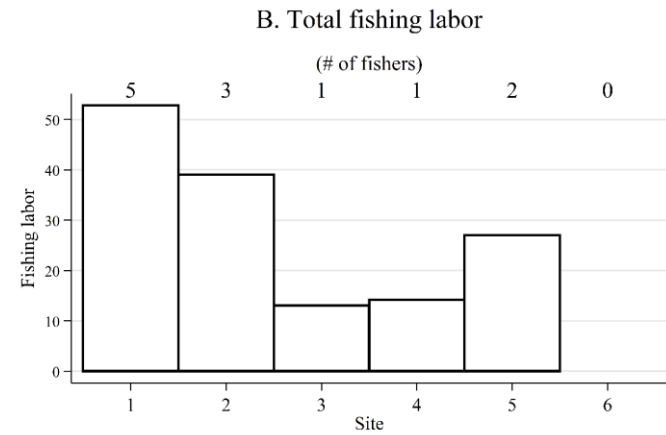
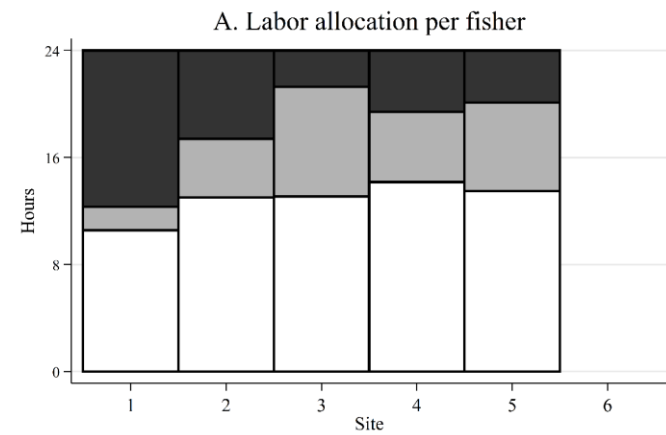




5	3	1
1	2	0

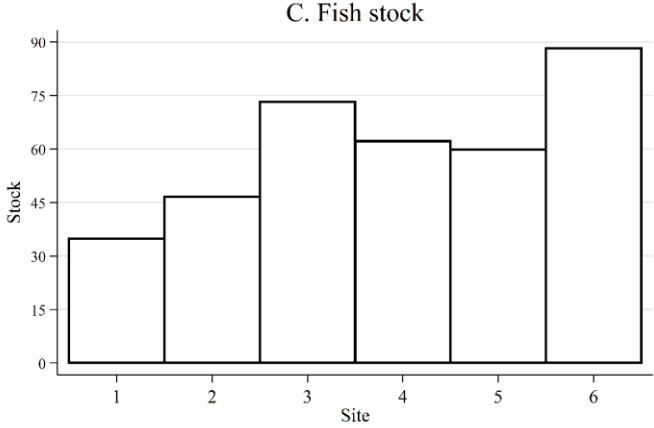
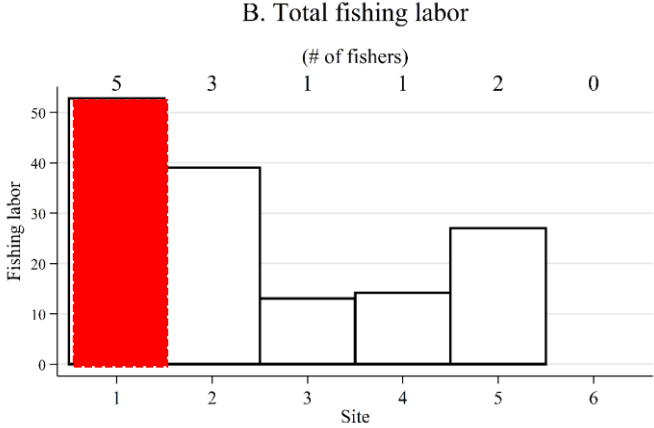
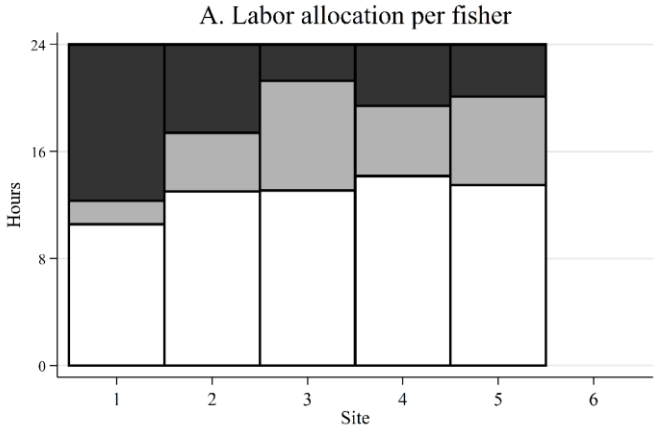


For example...



Site 1 hosts the most fishing labor...

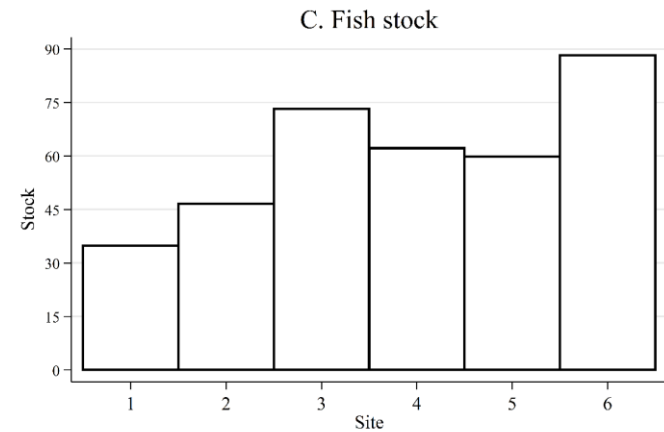
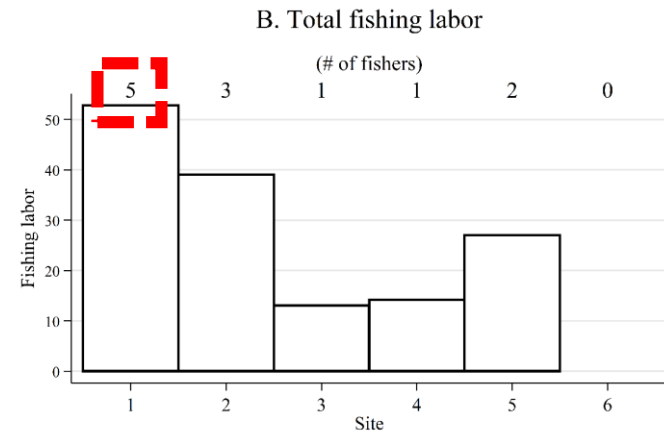
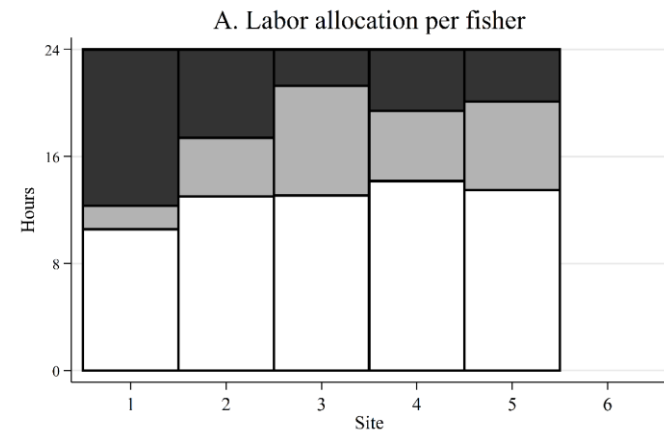
5	3	1
1	2	0



Site 1 hosts the most fishing labor...

because more fishers choose this site than any other...

5	3	1
1	2	0

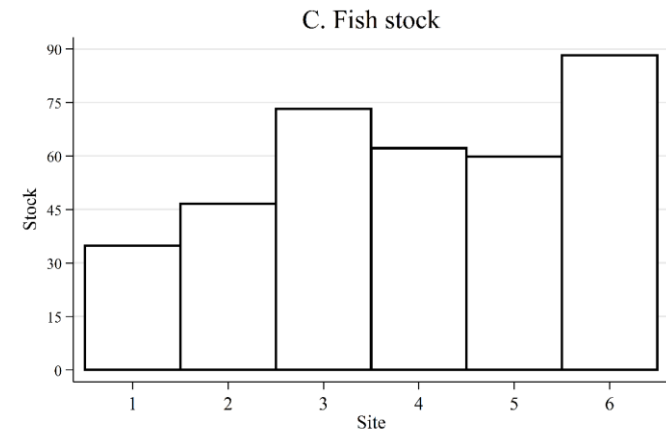
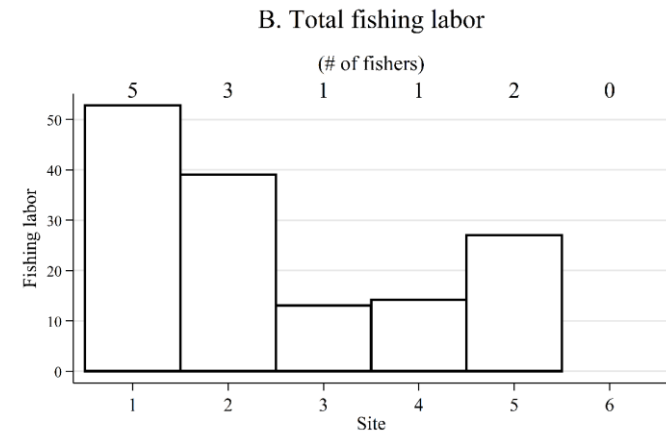
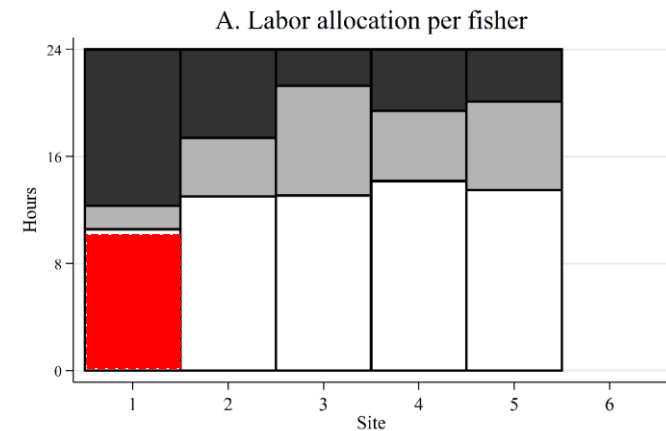


Site 1 hosts the most fishing labor...

because more fishers choose this site than any other, ...

but fishing per fisher is less than in the other sites with fishing...

5	3	1
1	2	0



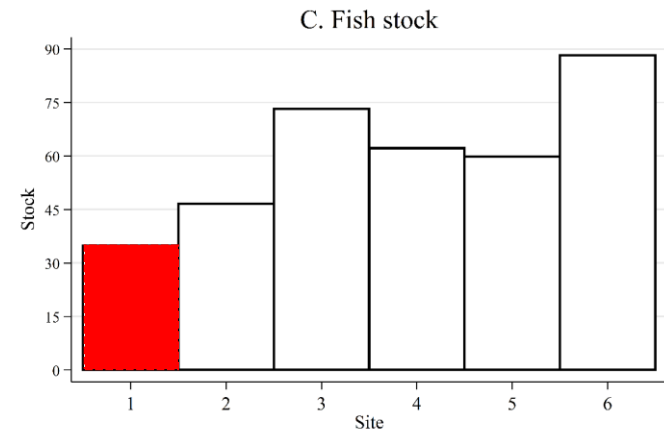
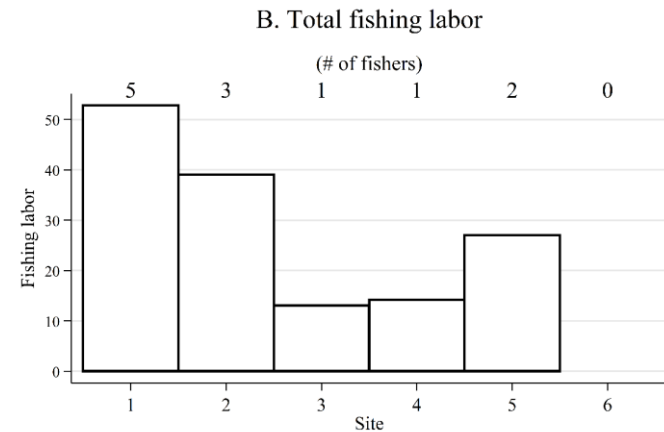
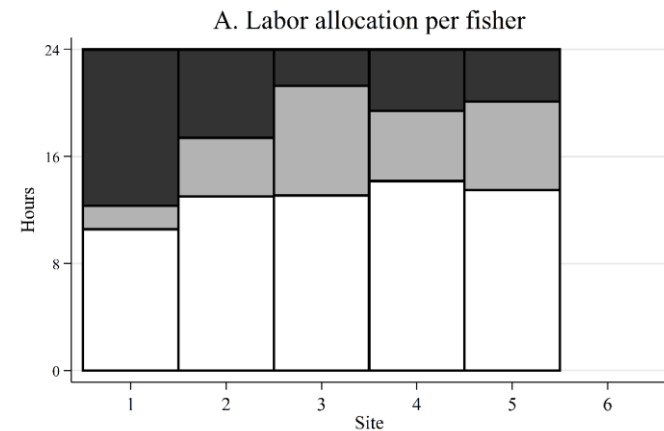
Site 1 hosts the most fishing labor...

because more fishers choose this site than any other, ...

but fishing per fisher is less than in the other sites with fishing...

because stock effects make fishing less profitable (no congestion effects).

5	3	1
1	2	0



Site 1 hosts the most fishing labor...

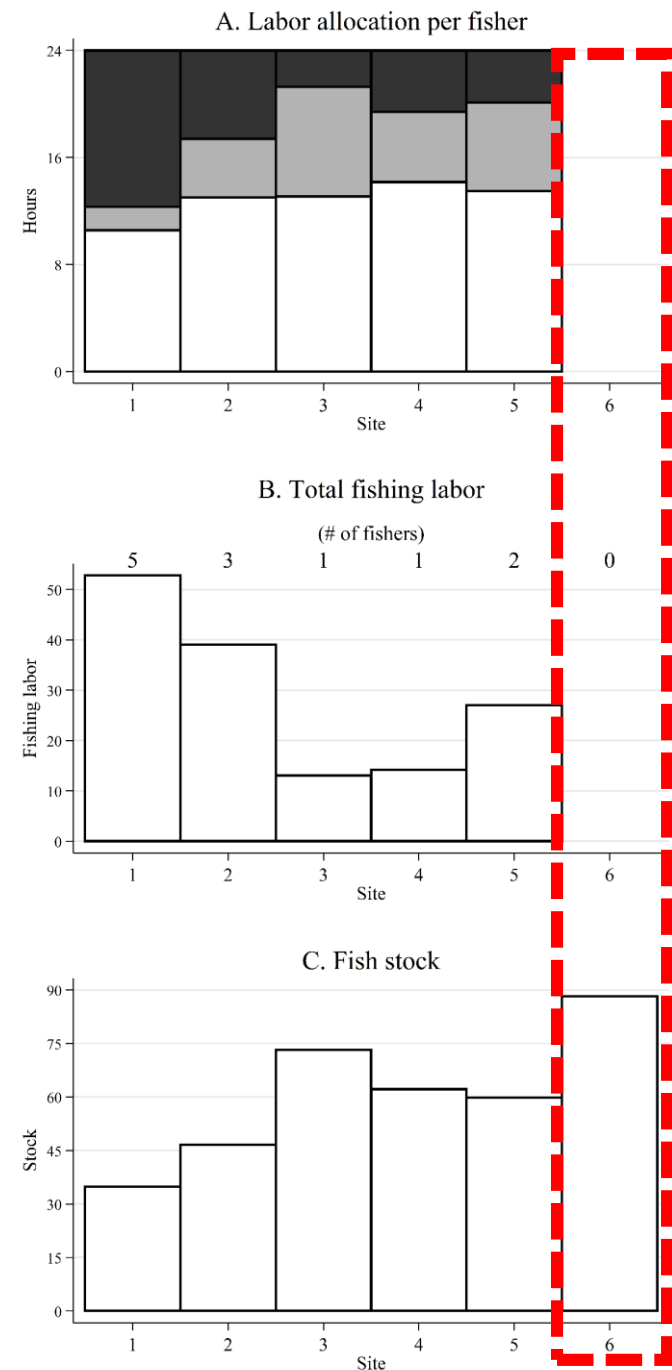
because more fishers choose this site than any other, ...

but fishing per fisher is less than in the other sites with fishing...

because stock effects make fishing less profitable (no congestion effects).

On the other hand, distance alone protects site 6 from fish extraction.

5	3	1
1	2	0

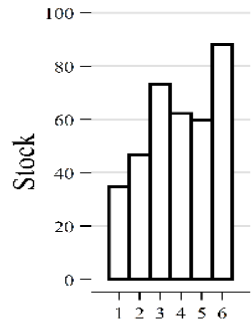
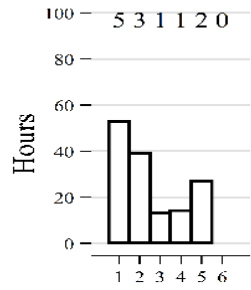
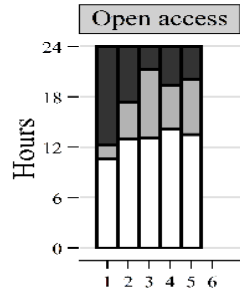


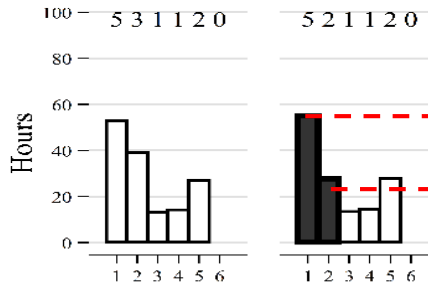
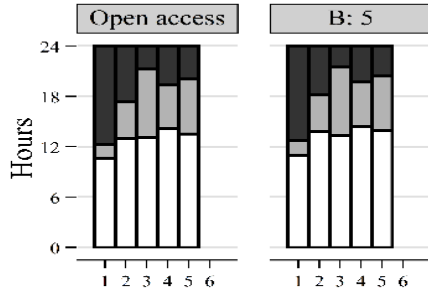
Goal: ASL Marinescape

$$\max_{S, \phi} \sum_i [x_i - x_{i,OA}]$$

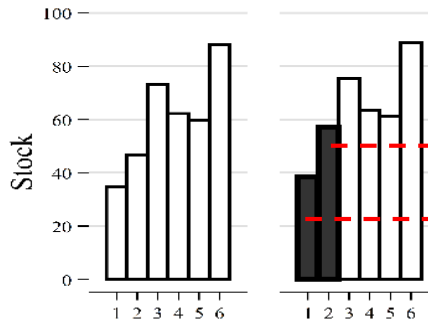
Results

(ASL: Avoided Stock Loss)

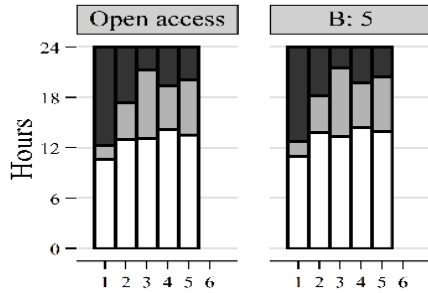




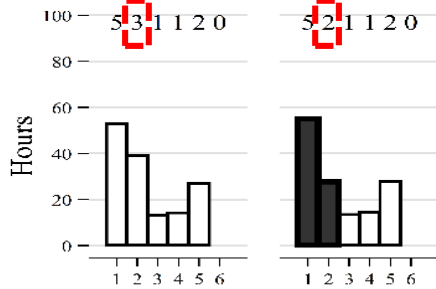
Protected



Protected

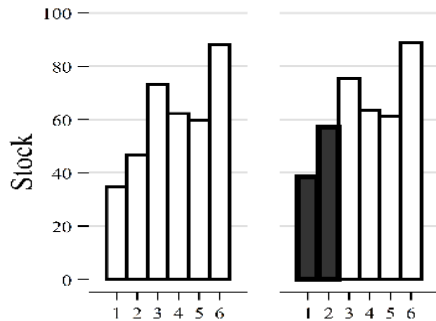


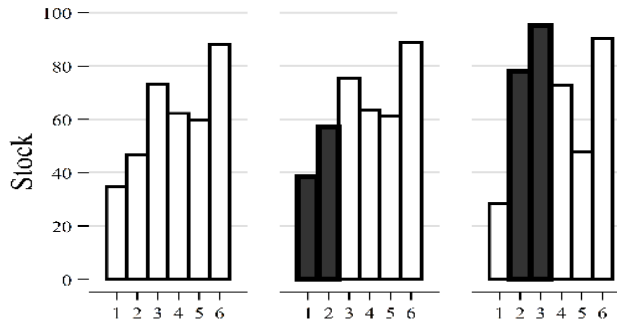
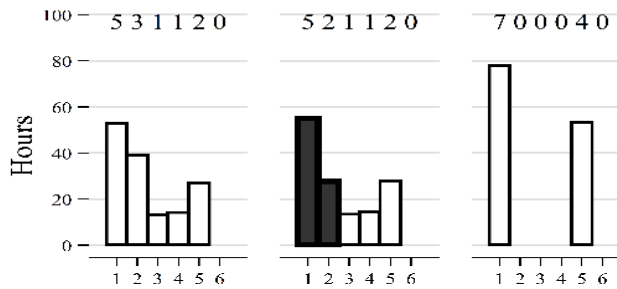
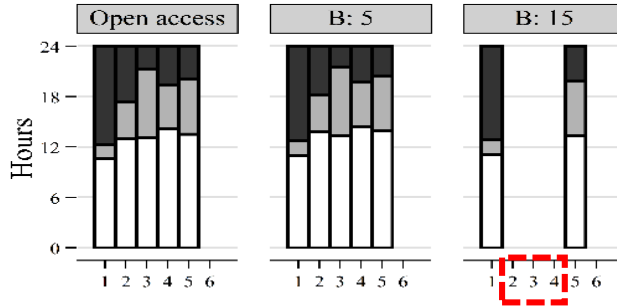
3 - - - -> 2



Protects 1 and 2

MPA incentivizes 1 fisher out of fishing

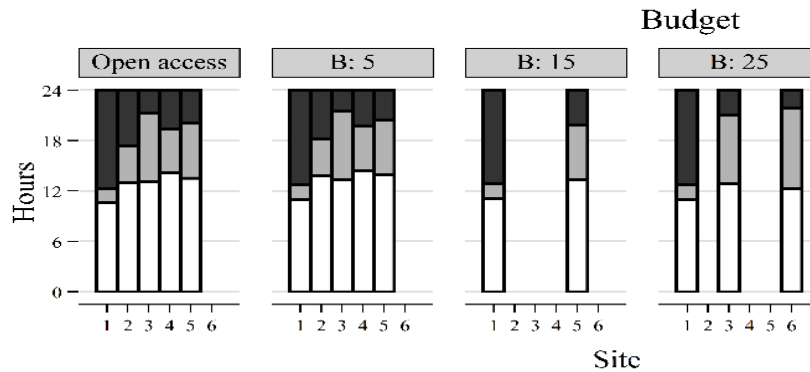




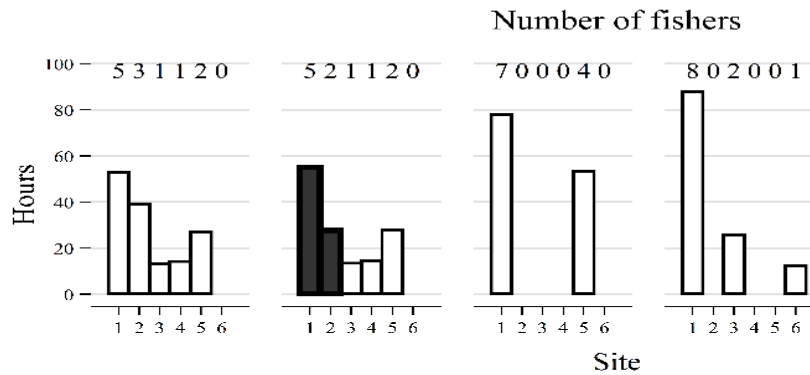
Protects 1 and 3

Deters all fishing in 2, 3, and 4

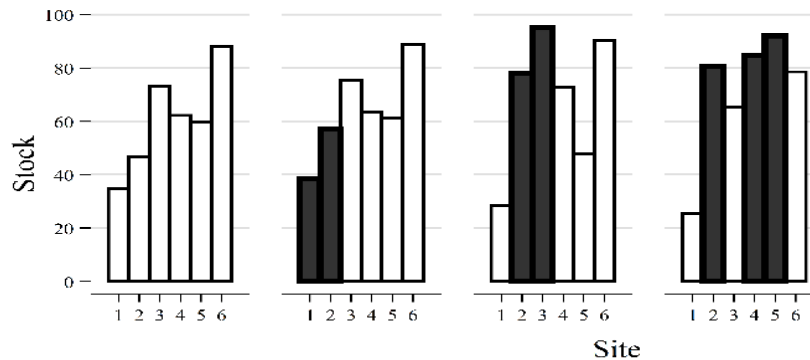
A. Labor allocation per fisher



B. Total fishing labor



C. Fish stock

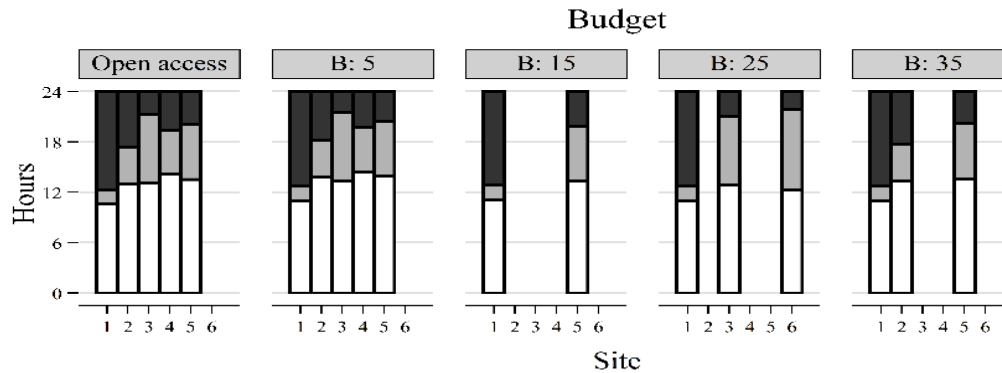


Protects 2, 4, 5

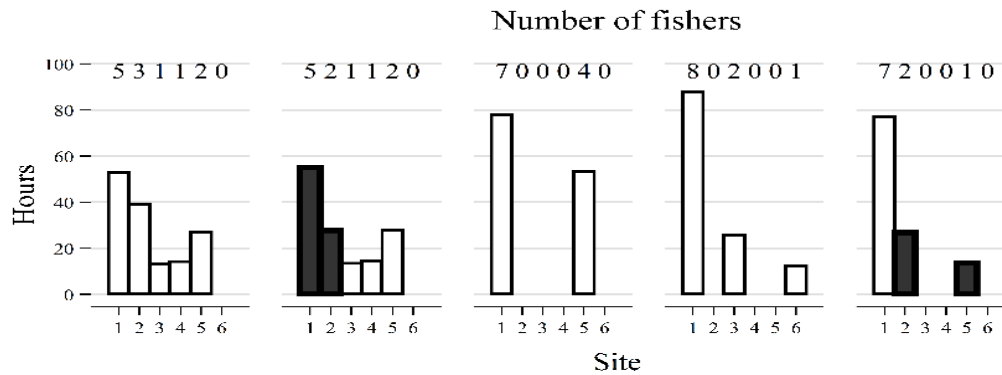
**Deters all fishing in
2, 4, 5**

Induces fishing in 6

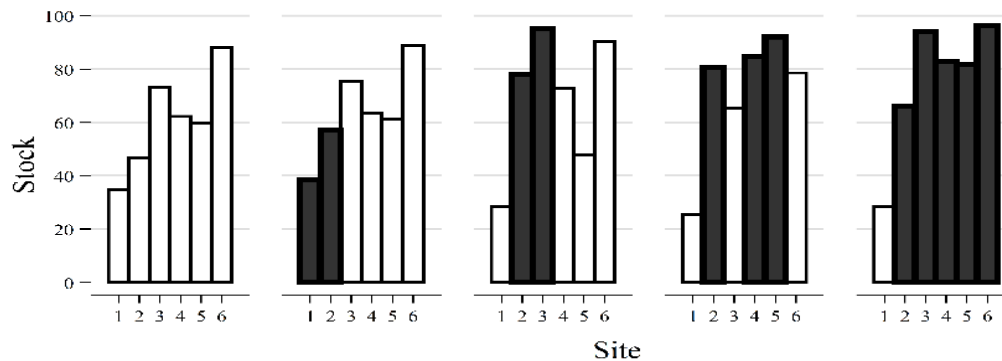
A. Labor allocation per fisher



B. Total fishing labor



C. Fish stock

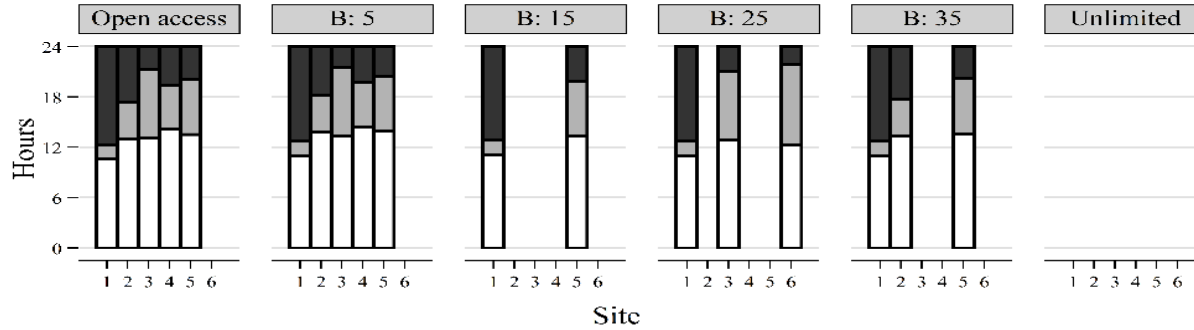


Protects 2 - 6

**Deters all
fishing in
3, 4, 6**

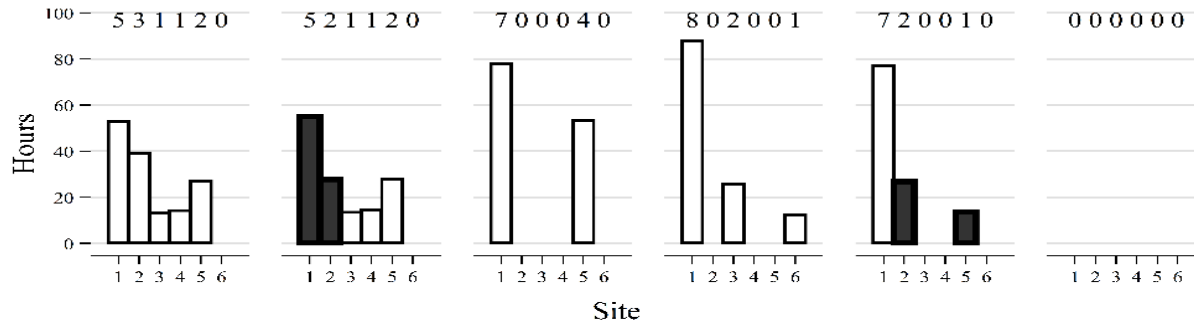
A. Labor allocation per fisher

Budget

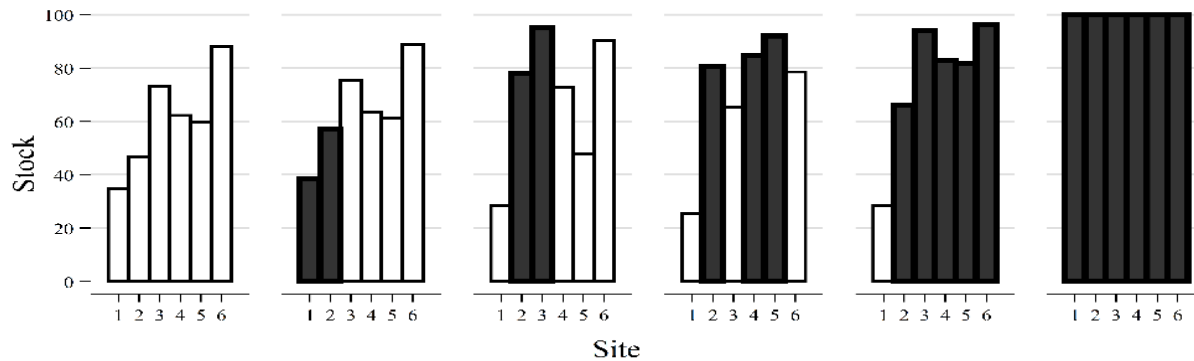


B. Total fishing labor

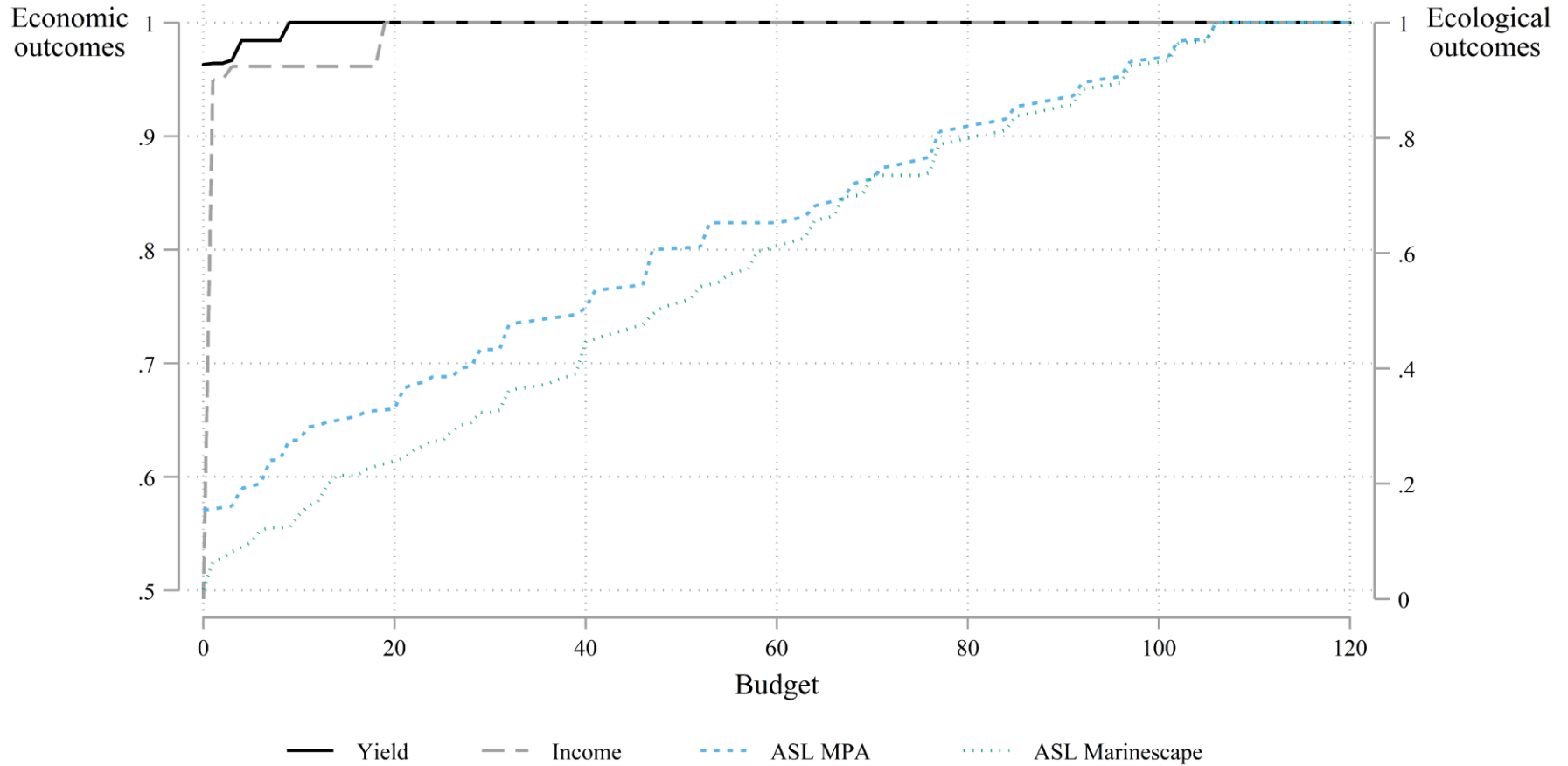
Number of fishers



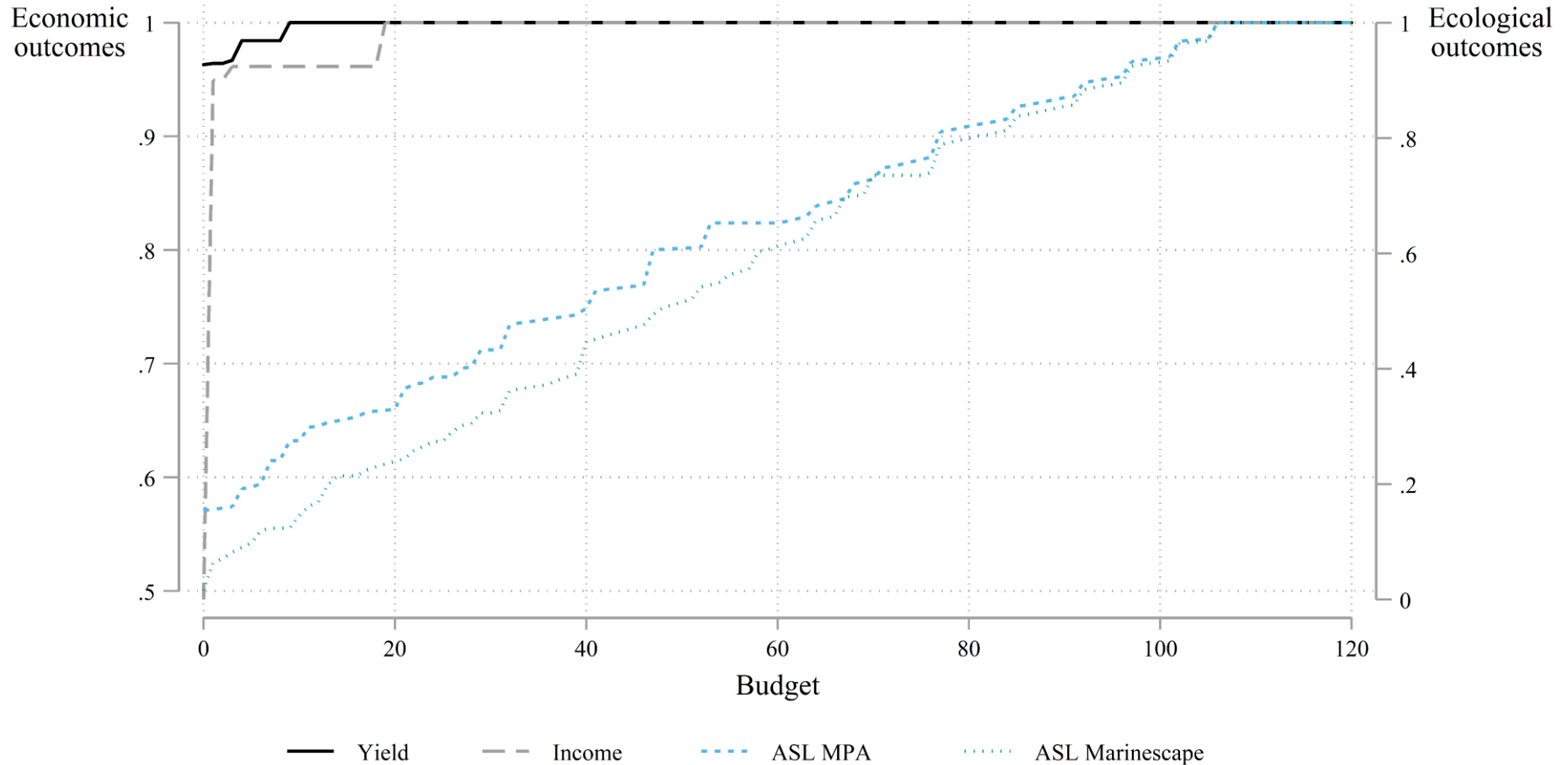
C. Fish stock



Relationship between budget and optimal outcomes



Relationship between budget and optimal outcomes



Along the lines: Changes in size, configuration, and enforcement level

Budget	Enforcement	Size	Configuration		
0					

Changes in size and configuration when budget increases

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			
12	0.13	3			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			
12	0.13	3			
13	0.09	5			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			
12	0.13	3			
13	0.09	5			
14	0.22	2			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			
12	0.13	3			
13	0.09	5			
14	0.22	2			
17	0.14	4			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			
12	0.13	3			
13	0.09	5			
14	0.22	2			
17	0.14	4			
22	0.18	4			

Budget	Enforcement	Size	Configuration		
0					
1	0.03	1			
3	0.05	2			
6	0.1	2			
7	0.11	2			
9	0.1	3			
10	0.08	4			
11	0.09	4			
12	0.13	3			
13	0.09	5			
14	0.22	2			
17	0.14	4			
22	0.18	4			

Budget	Enforcement	Size	Configuration		
23	0.19	4			
24	0.27	3			
26	0.22	4			
27	0.15	6			
29	0.24	4			
31	0.21	5			
32	0.21	5			
37	0.31	4			
47	0.31	5			
48	0.4	4			
52	0.35	5			
55	0.46	4			
58	0.32	6			
60	0.5	4			
76	0.42	6			

Different MPAs for different goals

	Open access	Budget																																								
		5	15	25	35	Unlimited																																				
Yield	0 <table border="1"> <tr><td>5</td><td>3</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	3	1	1	2	0	0 <table border="1"> <tr><td>4</td><td>4</td><td>1</td></tr> <tr><td>2</td><td>0</td><td>1</td></tr> </table>	4	4	1	2	0	1	0 <table border="1"> <tr><td>5</td><td>1</td><td>2</td></tr> <tr><td>1</td><td>3</td><td>0</td></tr> </table>	5	1	2	1	3	0	0 <table border="1"> <tr><td>5</td><td>1</td><td>2</td></tr> <tr><td>1</td><td>3</td><td>0</td></tr> </table>	5	1	2	1	3	0	0 <table border="1"> <tr><td>5</td><td>1</td><td>2</td></tr> <tr><td>1</td><td>3</td><td>0</td></tr> </table>	5	1	2	1	3	0	0 <table border="1"> <tr><td>5</td><td>1</td><td>2</td></tr> <tr><td>1</td><td>3</td><td>0</td></tr> </table>	5	1	2	1	3	0
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Enforcement	0	0.106	0.15	0.15	0.15	0.15																																				
Income	0 <table border="1"> <tr><td>5</td><td>3</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	3	1	1	2	0	1 <table border="1"> <tr><td>5</td><td>2</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	2	1	1	2	0	1 <table border="1"> <tr><td>5</td><td>2</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	2	1	1	2	0	2 <table border="1"> <tr><td>4</td><td>2</td><td>1</td></tr> <tr><td>2</td><td>0</td><td>1</td></tr> </table>	4	2	1	2	0	1	2 <table border="1"> <tr><td>4</td><td>2</td><td>1</td></tr> <tr><td>2</td><td>0</td><td>1</td></tr> </table>	4	2	1	2	0	1	2 <table border="1"> <tr><td>4</td><td>2</td><td>1</td></tr> <tr><td>2</td><td>0</td><td>1</td></tr> </table>	4	2	1	2	0	1
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Enforcement	0	0.038	0.038	0.204	0.204	0.204																																				
ASL Marinescape	0 <table border="1"> <tr><td>5</td><td>3</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	3	1	1	2	0	1 <table border="1"> <tr><td>5</td><td>2</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	2	1	1	2	0	1 <table border="1"> <tr><td>7</td><td>0</td><td>0</td></tr> <tr><td>0</td><td>4</td><td>0</td></tr> </table>	7	0	0	0	4	0	1 <table border="1"> <tr><td>8</td><td>0</td><td>2</td></tr> <tr><td>0</td><td>0</td><td>1</td></tr> </table>	8	0	2	0	0	1	2 <table border="1"> <tr><td>7</td><td>2</td><td>0</td></tr> <tr><td>0</td><td>1</td><td>0</td></tr> </table>	7	2	0	0	1	0	12 <table border="1"> <tr><td>0</td><td>0</td><td>0</td></tr> <tr><td>0</td><td>0</td><td>0</td></tr> </table>	0	0	0	0	0	0
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Enforcement	0	0.082	0.22	0.266	0.232	0.584																																				
ASL MPA	0 <table border="1"> <tr><td>5</td><td>3</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	3	1	1	2	0	1 <table border="1"> <tr><td>5</td><td>2</td><td>1</td></tr> <tr><td>1</td><td>2</td><td>0</td></tr> </table>	5	2	1	1	2	0	2 <table border="1"> <tr><td>4</td><td>4</td><td>0</td></tr> <tr><td>1</td><td>1</td><td>0</td></tr> </table>	4	4	0	1	1	0	1 <table border="1"> <tr><td>8</td><td>0</td><td>2</td></tr> <tr><td>0</td><td>0</td><td>1</td></tr> </table>	8	0	2	0	0	1	2 <table border="1"> <tr><td>7</td><td>2</td><td>0</td></tr> <tr><td>0</td><td>1</td><td>0</td></tr> </table>	7	2	0	0	1	0	12 <table border="1"> <tr><td>0</td><td>0</td><td>0</td></tr> <tr><td>0</td><td>0</td><td>0</td></tr> </table>	0	0	0	0	0	0
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0	0	1																																								
7	2	0																																								
0	1	0																																								
0	0	0																																								
0	0	0																																								
Enforcement	0	0.04	0.1	0.266	0.232	0.584																																				

Policy implications

- Management goals (beyond fishery management)

Income instead of yield?

Ecological goals.

- Policy effectiveness

Target avoided stock loss (ASL) instead of stock levels.

- Consider incomplete enforcement and fisher re-optimization at time of MPA selection

“Naïve” MPA managers leave money on the table.

- Beyond No-take zones

IUCN classifications

- MPA- vs Marinescape-focused manager

MPA-focused manager does not account for the impact of leakage

Thanks

Comments are much appreciated!

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