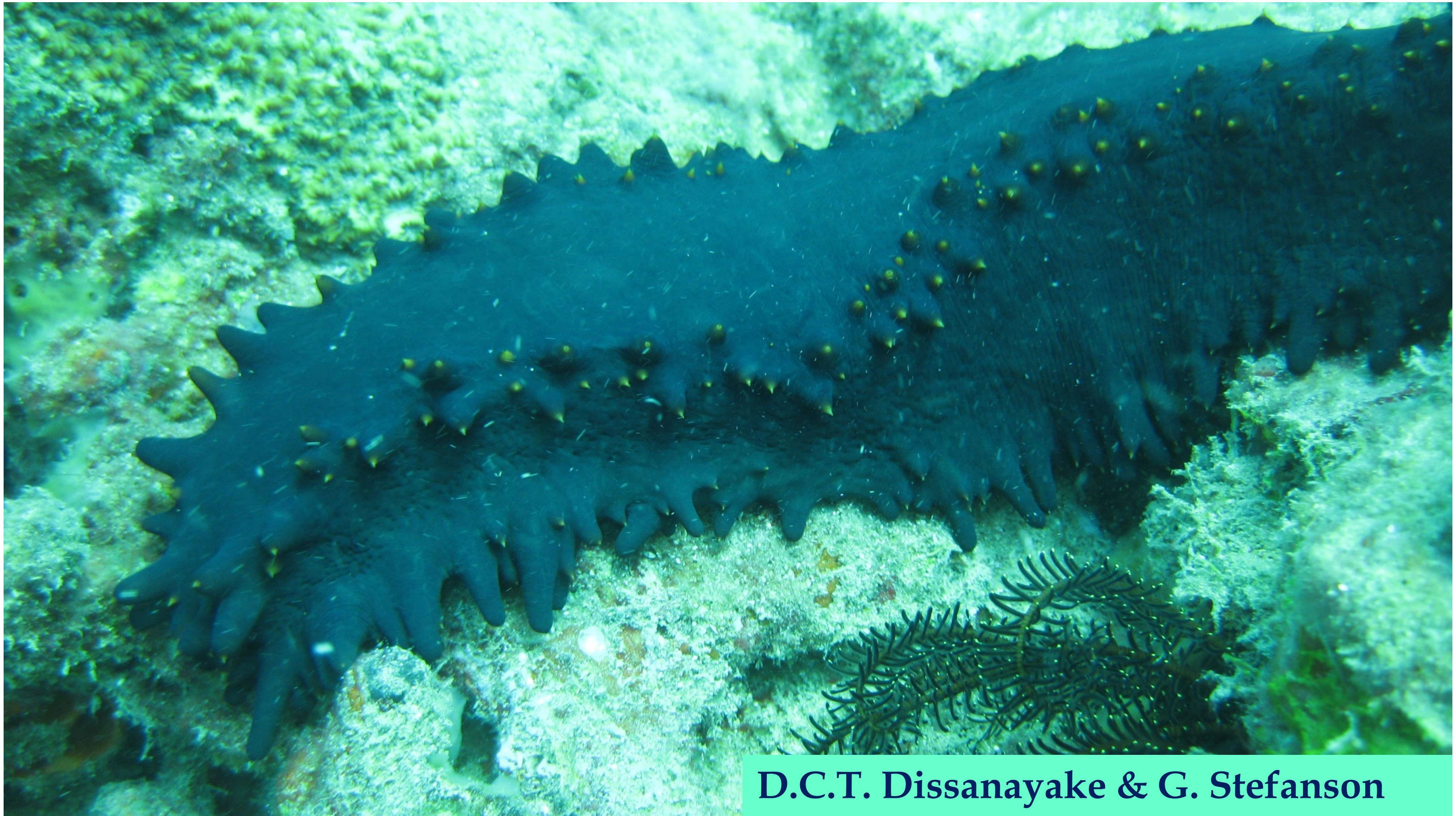
DESIGN MARINE PROTECTED AREAS (MPAS) FOR SEA CUCUMBERS IN THE COASTAL WATERS OF SRI LANKA



D.C.T. Dissanayake & G. Stefanson

Introduction

- Most of the sea cucumbers have been fished to the level of reproductive extinction

- Traditional fisheries management approaches have not been successful in protecting sea cucumbers

inadequate control over the human activities

Recently greater attention for Marine Protected Areas (MPAs)

MPAs are spatially delimited areas designed to conserve the coastal and marine resources under restricted human activities

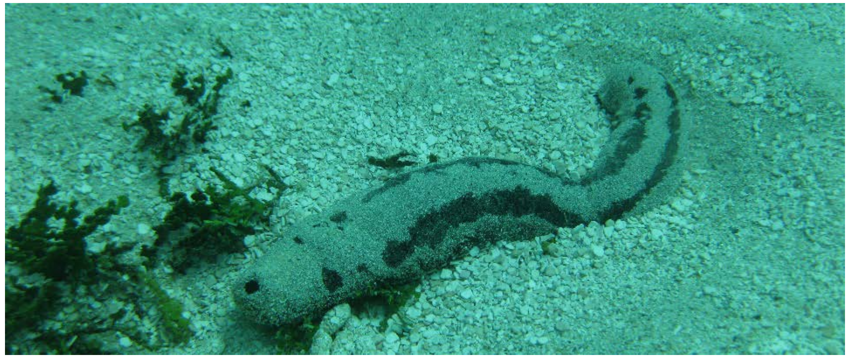
Wide range of roles in MPAs in fisheries management

- ✓Improve local catches due to spillover
- ✓Reverse the decline of species richness and genetic diversity caused by fishing
- ✓Eliminate by-catch of non-target species
- ✓Protect habitat from damage by fishing gear
- ✓Increase fecundity and reproductive capacity of protected species

MPAs are expected to perform best for sedentary species than pelagic or migratory species (Hilborn *et al.*, 2004)

MPAs have considerable potential for the restoration sea cucumbers

- ✓They are sedentary broadcast spawners
- ✓High population densities for successful spawning rarely exist in most of the "open" fishing grounds



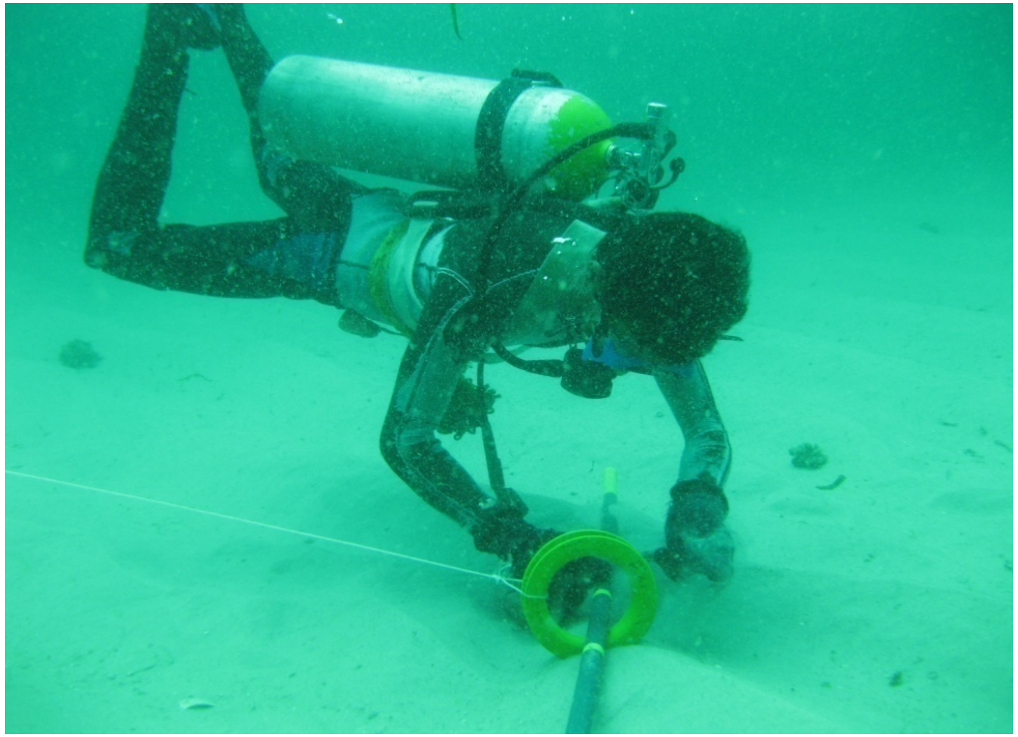

Objectives

Design MPA's to avoid further depletion of sea cucumber species in the east coast of Sri Lanka

Understand how MPAs will help to meet biological objectives under different biological situations

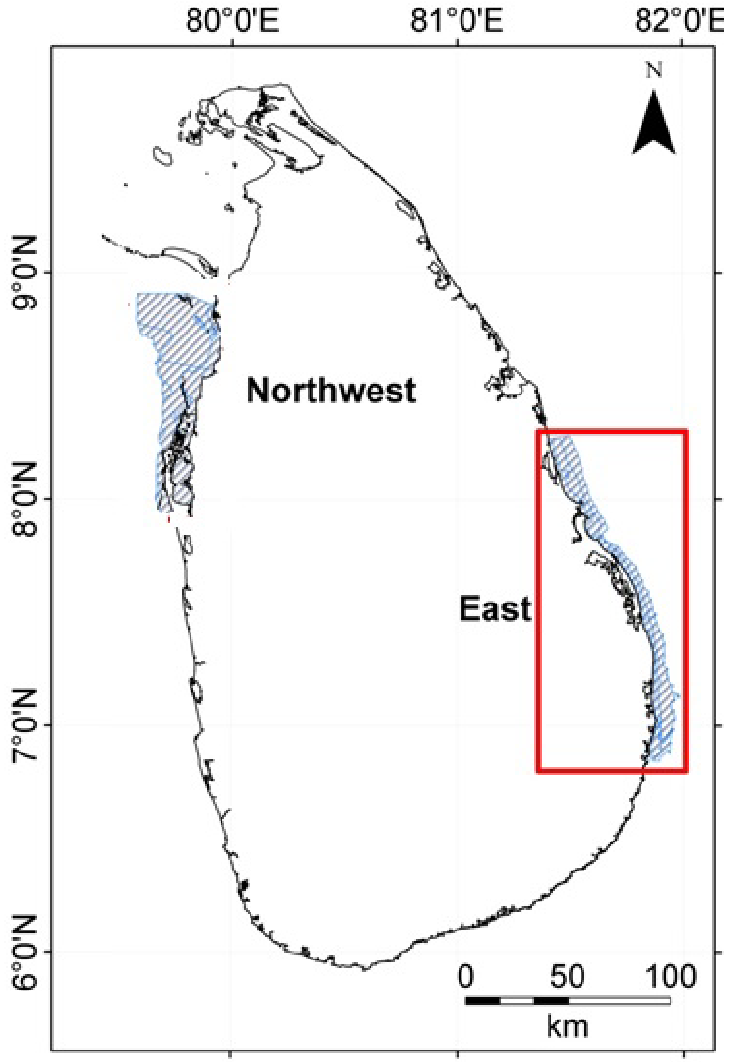
Methodology - Data Collection

Data were collected through underwater Visual Census



- Field work was undertaken by a team of divers
- Survey time : 2008 and 2009

Survey Area



Distance Along the shore **190 km**

Methodology - Data Analysis

(a) Population biomass

A simulation model developed by Stefansson and Rosenberg (2005) was used

$$\mathbf{B_{t+1} = B_t + rB_t\left(1 - {B_t}/{K}\right) - Y_t}$$

$\mathbf{B_t}$ - biomass at the beginning of time step t

$\mathbf{Y_t}$ - yield in biomass/catches during the same time-step

r - rate of production

K carrying capacity.

- This model is spatially disaggregated
- Considered multiple areas and migrations when building a bulk biomass population dynamics model

Bulk Biomass Population Dynamics Model

$$B_{t+1} = P_b^t (P_t - Y_t) + P_t^R R_{t-\tau}$$

B_t - Vector biomass by area

P_b^t - adult migration rate

τ - recruitment delay factor

R_t - vector of biomass production of each area

P_t^R - larval dispersal rate

- The multiple areas were arranged into grids
- Migrations
  - Adults - Feeding and spawning
  - Larval dispersal

$\}$ **Incorporated into model**

To link the production and biomass, the components of the production vector, R_t is defined for the first month of any year

(i.e. when $t = 12y + 1$) by

$$\mathbf{R_{A,t} = rB_{At}\left(1 - {}^{B_{At}}/_{K_A}\right).}$$

Here production enters every month and **r** is a monthly production rate

For the other months,

$$\mathbf{R_{A,12y+i} = R_{A,12y+1},}\ \mathbf{{}^{i\,=\,2,\,\ldots..\,12}}$$

(b) Fishing mortality and harvests

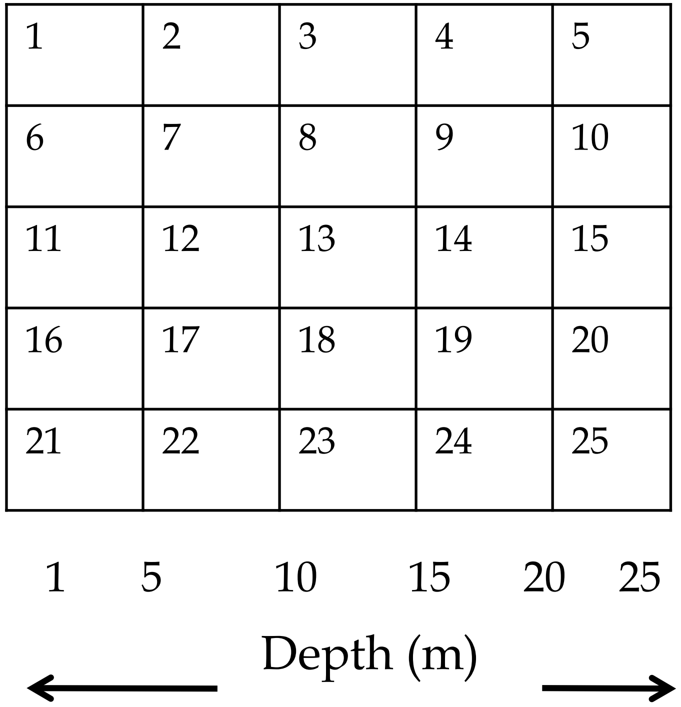
$$Y_{At} = F_{At}B_{At}$$

Y_{At} – Removal rate (catches)

F_{At} - Removal fraction (fishing mortality)

(c) Geometry and migration

- 25 squares in 5 x 5 grids to represent survey area ($08^0 17^0$ - 06^0 50^0 N and 81^0 25^0 - 82^0)
- Five depth categories



1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

Assumptions

- Migration can occur only between adjacent areas in any given month.
- Only allow migration of positive population growth

(d) Economic Model

Used economic model described in Stefansson and Rosenberg (2005)

For a given time step (t) and area (A), income (I) of the fishery is

$$\mathbf{I = \rho Y_{At}}$$

ρ - first sale price

Y_{At} - landings

Cost of operation (c) is assumed to be in the form

$$\mathbf{c = kE_{At}.}$$

E_{At} - local monthly effort in the area

Assuming a known profit level (δ) in a reference year, the base value for the multiplier **k** was determined

$$\mathbf{k = \rho Y_0 (1 - \delta)/E_0.}$$

Monthly yield in area A can be rewritten as;

$$\mathbf{Y_{At} = F_{At} B_{At} = q A_t E_{At} B_{At}.}$$

Profit function becomes

$$\mathbf{\prod_t = \sum_A c_{At} \, E_{At}.}$$

Where

$$\mathbf{c_{At} = (\rho q A_t B A_t - k).}$$

(e) MPAs

- Area closures were modeled by forcing fishing mortality of those areas to be zero.
- In the base simulation 6 contiguous rectangles in between the 10 - 25 m were considered as closed areas.

Input parameters to the model

Initial biomass (B) = 87 (Based on UVC 2008, 2009)

K = 870 (current biomass is at 10% of virgin biomass)

$r = 0.44$

$F_{hist} = F_{crash}$

where **$F_{crash} = r = 0.44$**

It was assumed that

✓Areas of 15 - 20 m depth range - historical MPAs for 25 years
✓Areas of 20 - 25m depth range - historical MPAs for 45 years

Sea cucumbers are sedentary species

↓

Feeding and spawning migrations were set at **0**

The model was simulated under different biological assumptions to understand the changes in biomass for next 15 years.

Results

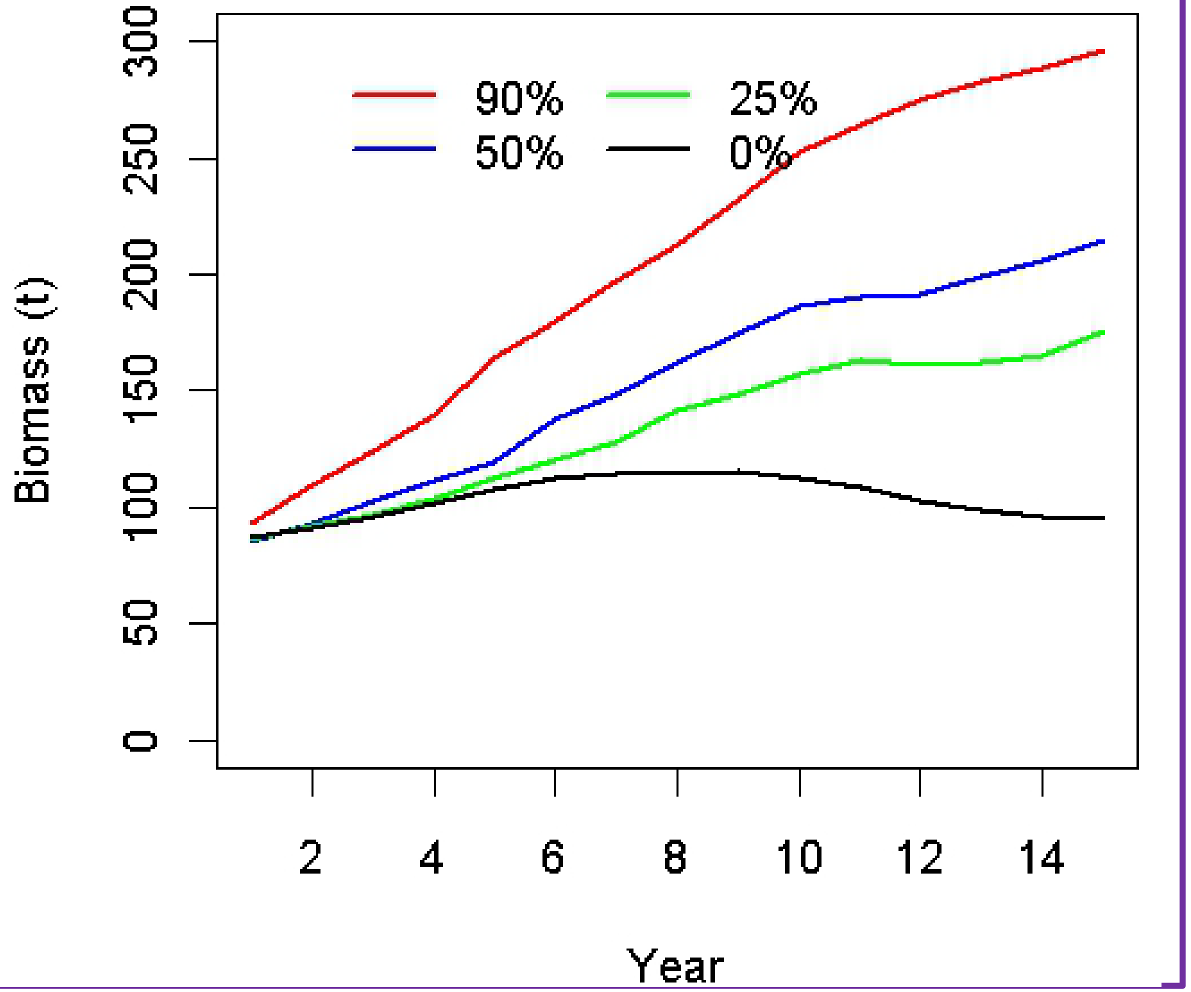
(a) Fluctuations of biomass for next 15 years under different larval dispersal rates

High level of biomass increase when rate of larval dispersal is high.

No larval dispersal

↓

No recovery of biomass even though MPA's are existed.



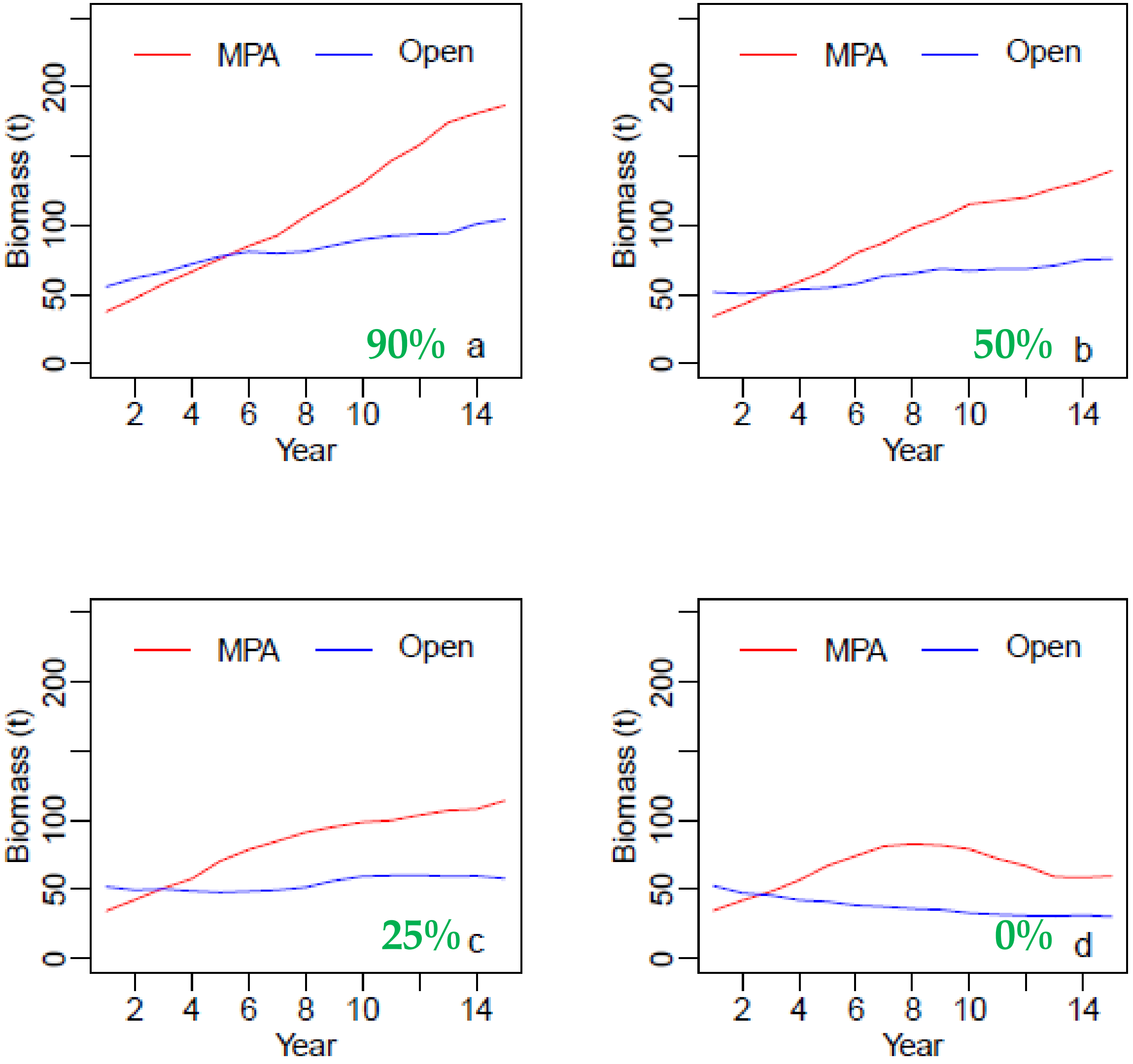
(b). Biomass changes in open and closed areas (MPAs) under different larval dispersal rates

Biomass recovery is related to the larval dispersal rates

Under 90% larval dispersal

Highest biomass in both open and MPAs

No larval dispersal, no biomass recovery in open areas



(c) Biomass changes in five different depth categories for next 15 years (90% larval dispersal rate and 6 contiguous MPA's)

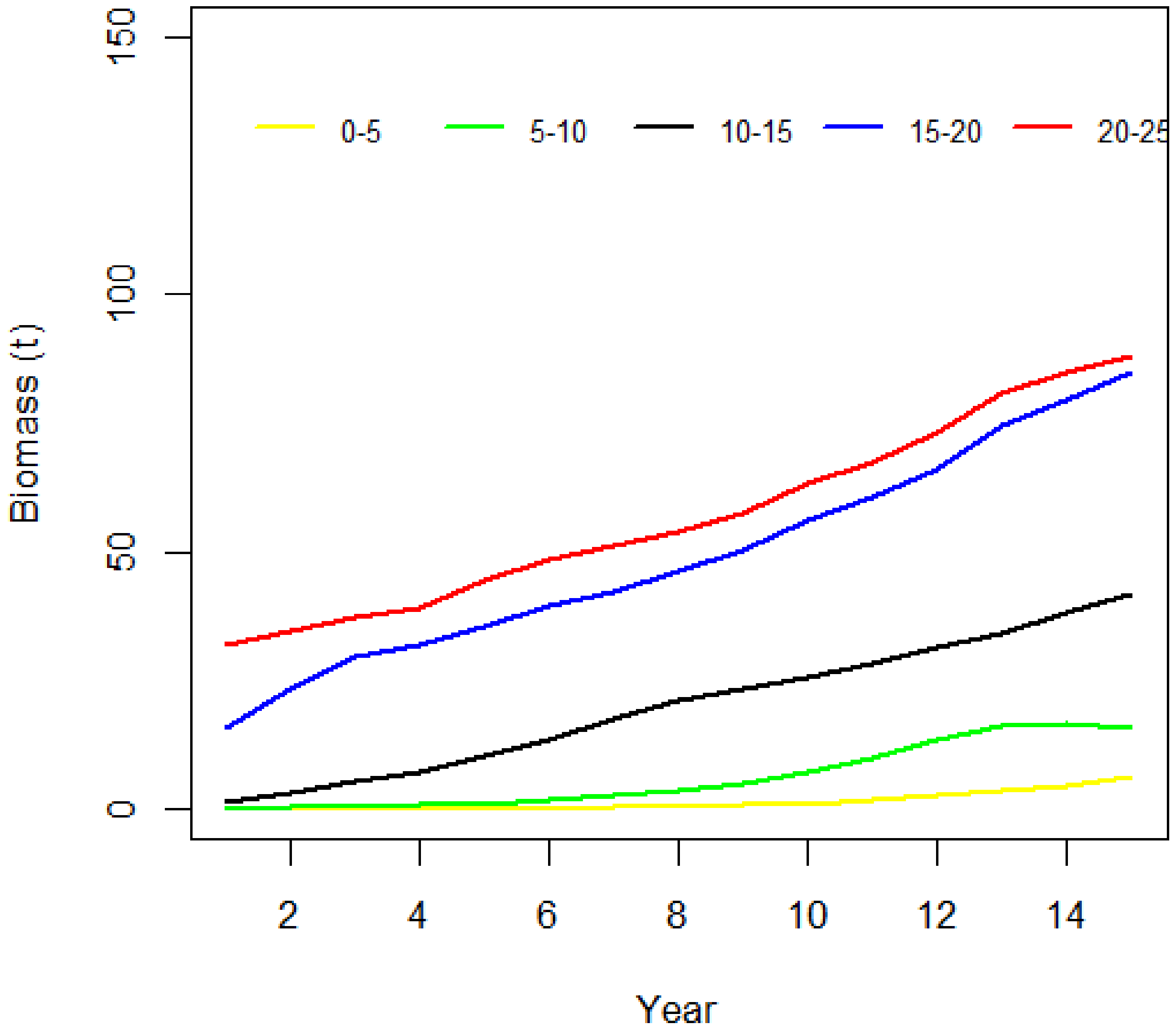
High biomass in deeper areas

0- 5m depth category

>10 years to show any gain in biomass

5 – 10 m depth category

Biomass increase after 6 years

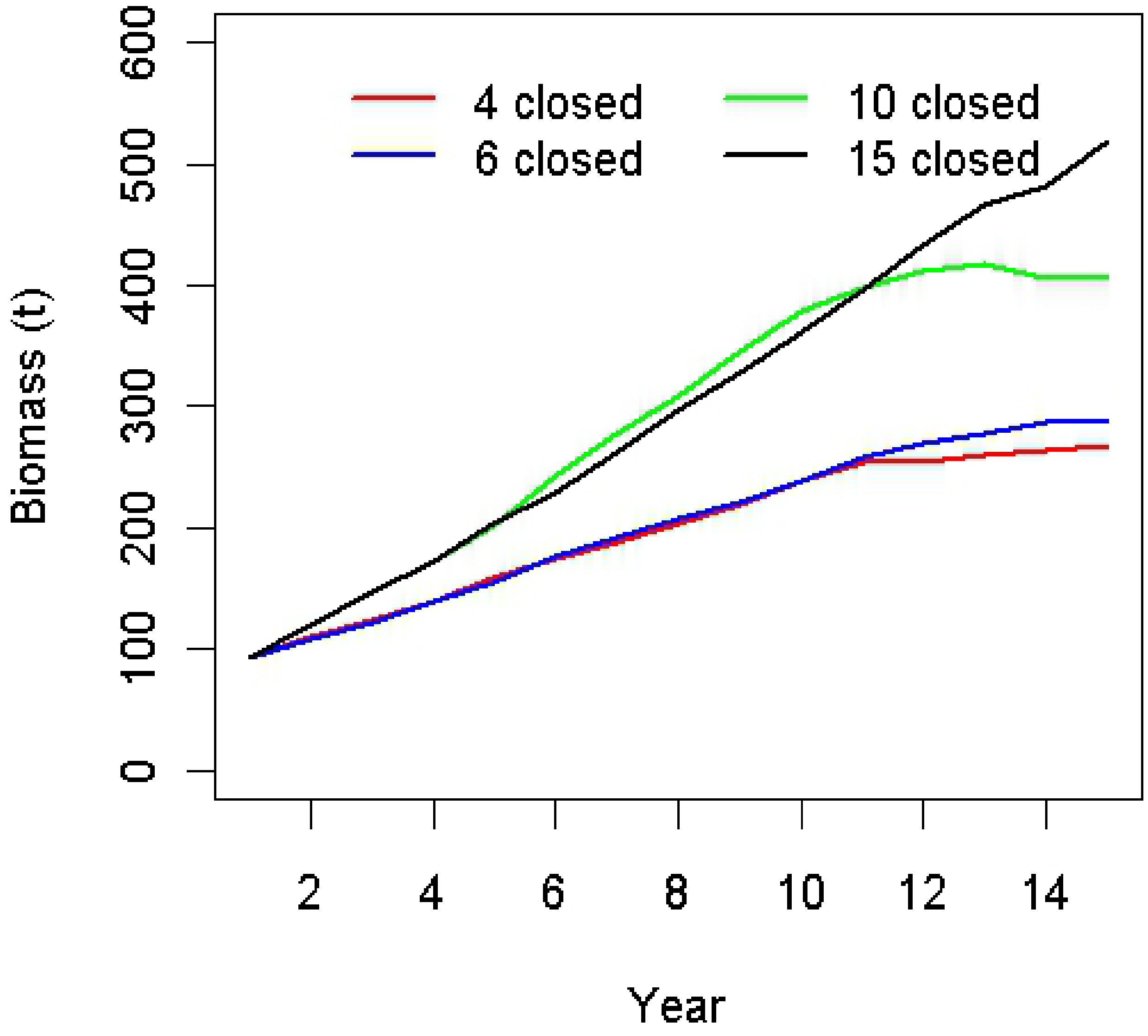


(d) Biomass change in open and closed areas under 4 different closures

High number of closed areas

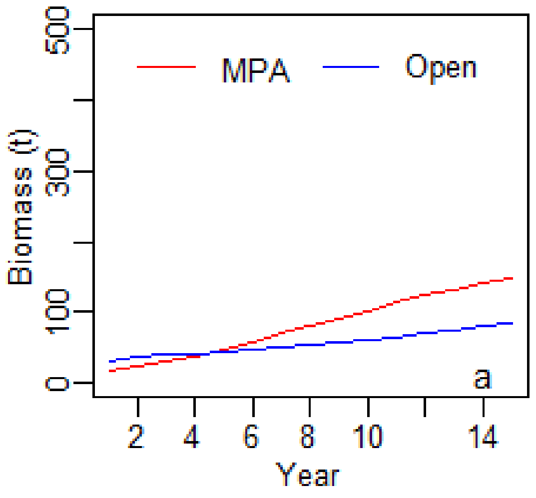
⬇

High level of biomass increase

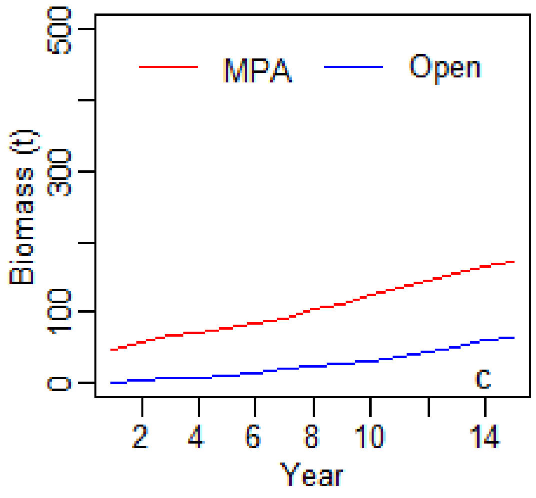


(e) Fluctuations of biomass in open and closed areas under different closures

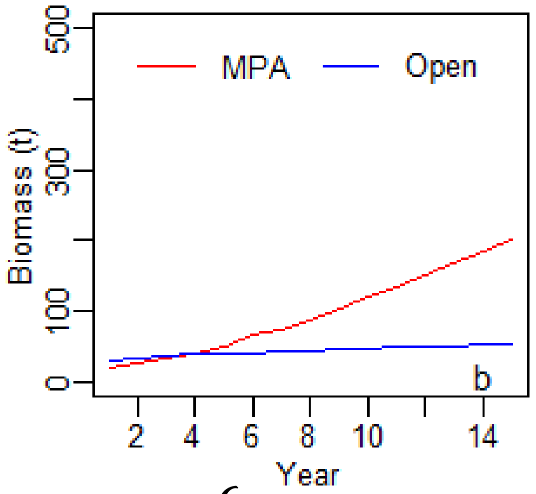
- Level of biomass increase is related to the number of closed areas
- The highest biomass within MPAs was recorded when 15 areas are closed
- Biomass in open areas starts to increase after 10 years
- Gradual increase in biomass within MPAs even under 4 and 6 closures



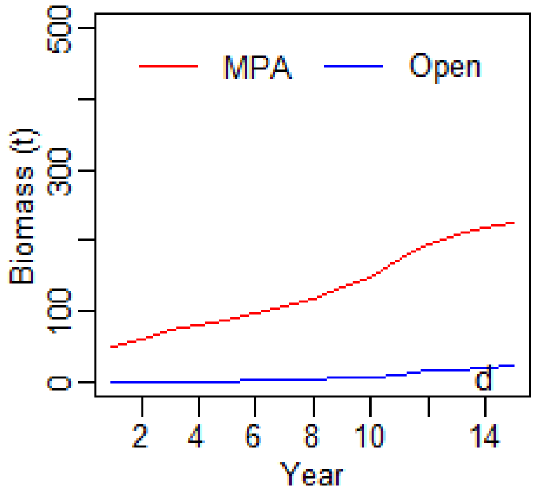
4 areas



10 areas



6 areas



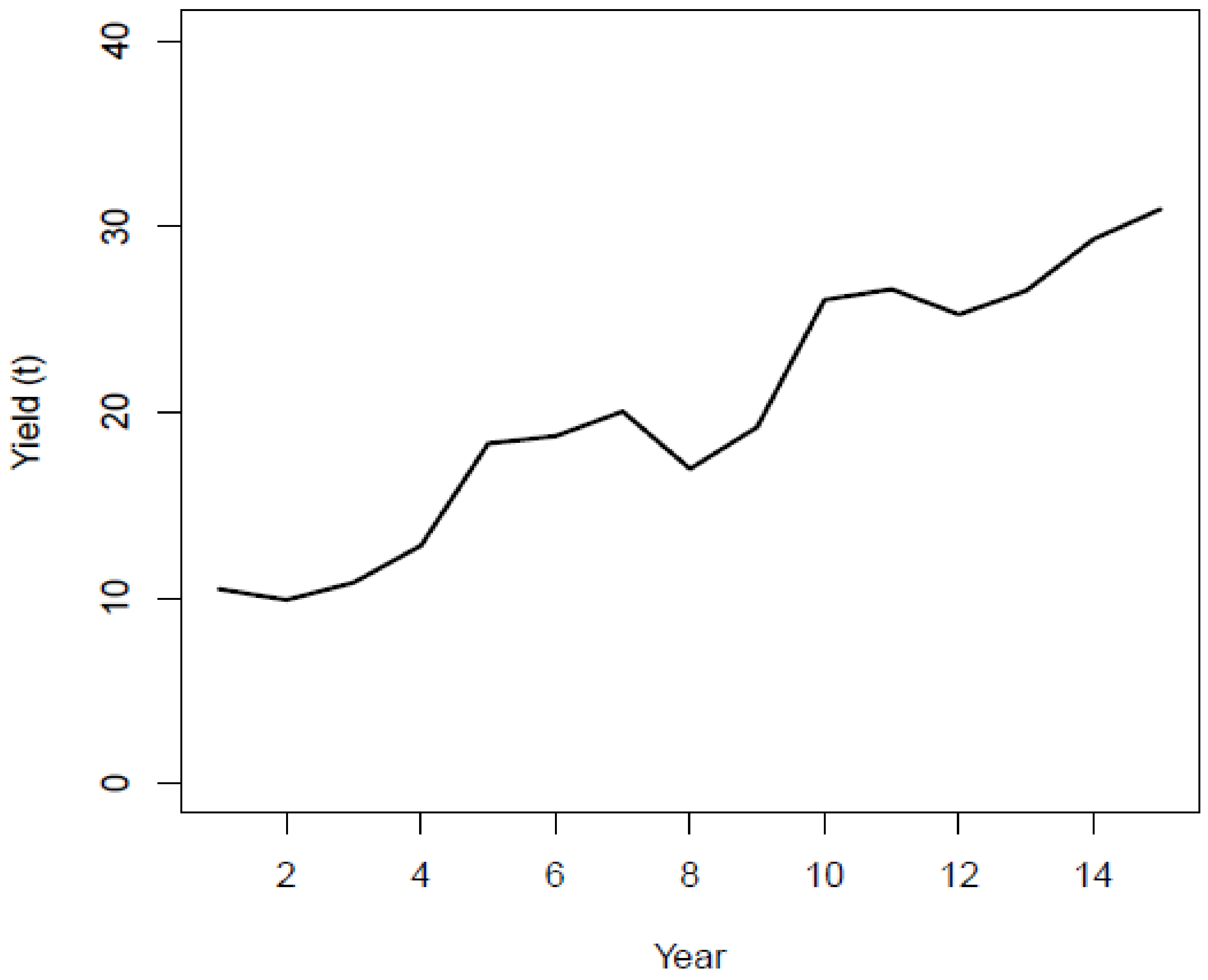
15 areas

(f) Fluctuations of sea cucumber yield for 15 years

Conditions

- 90% larval dispersal rate
- 6 contiguous MPA's in 10-25 m

It is expected 3 times increase in current yield at the end of 15 years



Conclusions

- Spatial management through marine reserves is seen to have potential to rebuild the sea cucumber populations in the east coast of Sri Lanka

- Biomass recovery is mainly related to the larval dispersal rate

- Potential to gain high stock biomass when large number of closures are existed

- This model application provides the basis for planning MPA's.

Limitations

- Multi-species interaction and the habitat preference of sea cucumber species were not considered in this model.

- The dispersal potential of sea cucumber larvae and their behavior in water column is still questionable

- As sea cucumbers are sedentary organisms, movement of adults from MPA's to open areas was neglected

Hydrographic studies coupled with population genetics of sea cucumbers will be useful to resolve this problem in the future.

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