Universidad Marista
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Modeling a small-scale sea cucumber fishery in Yucatan

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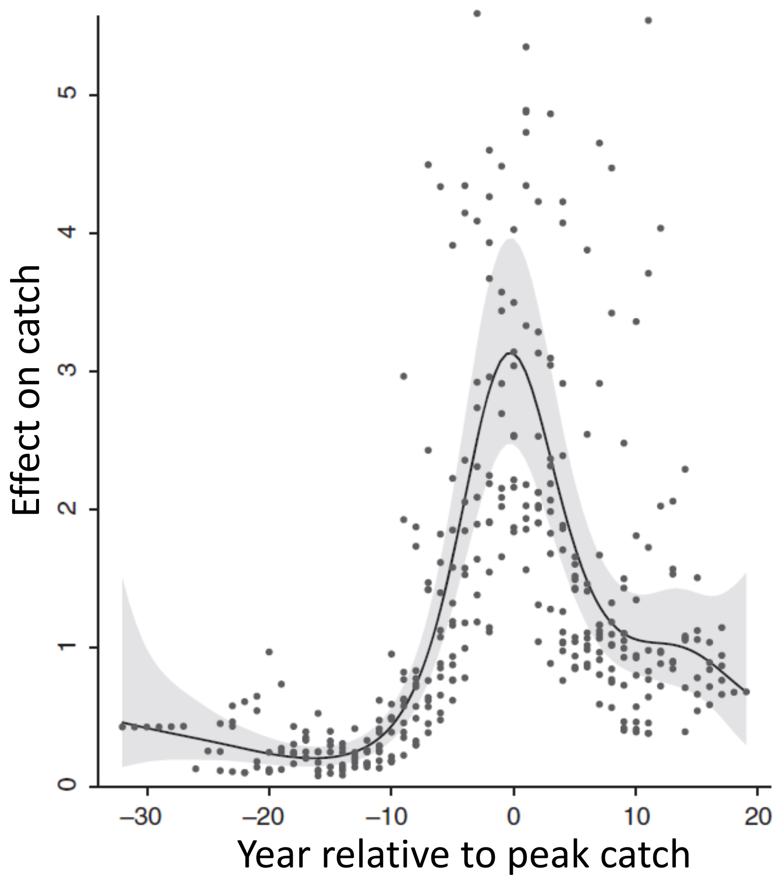
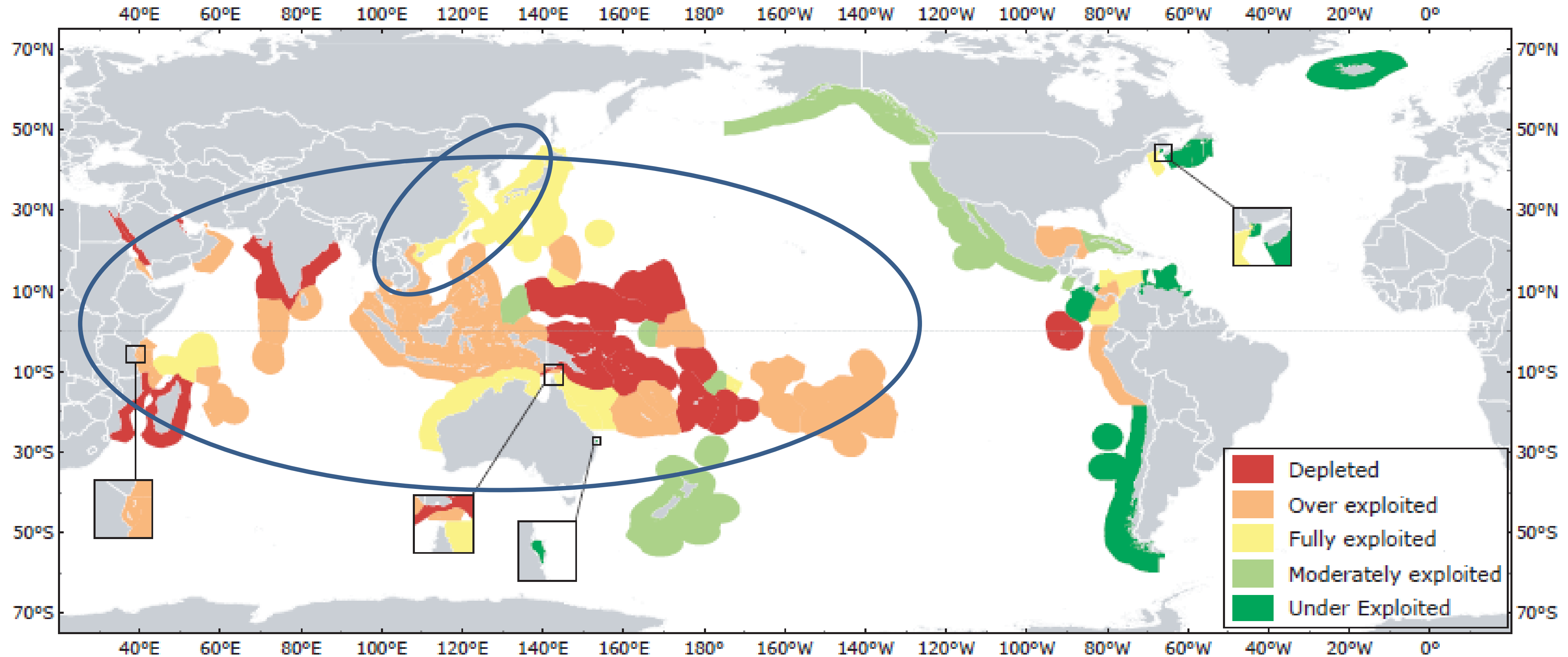
Catch trajectory of global sea cucumber fisheries



Generalized additive model.
Dots - residuals of catch per country (n= 23)
Line - fitted smooth function
Shaded region - 95% confidence interval

Anderson et al., 2011

The status of sea cucumber fisheries in the world



20% of fisheries were found to be depleted

38% over-exploited

14% fully exploited

27% moderately or underexploited

n = 69

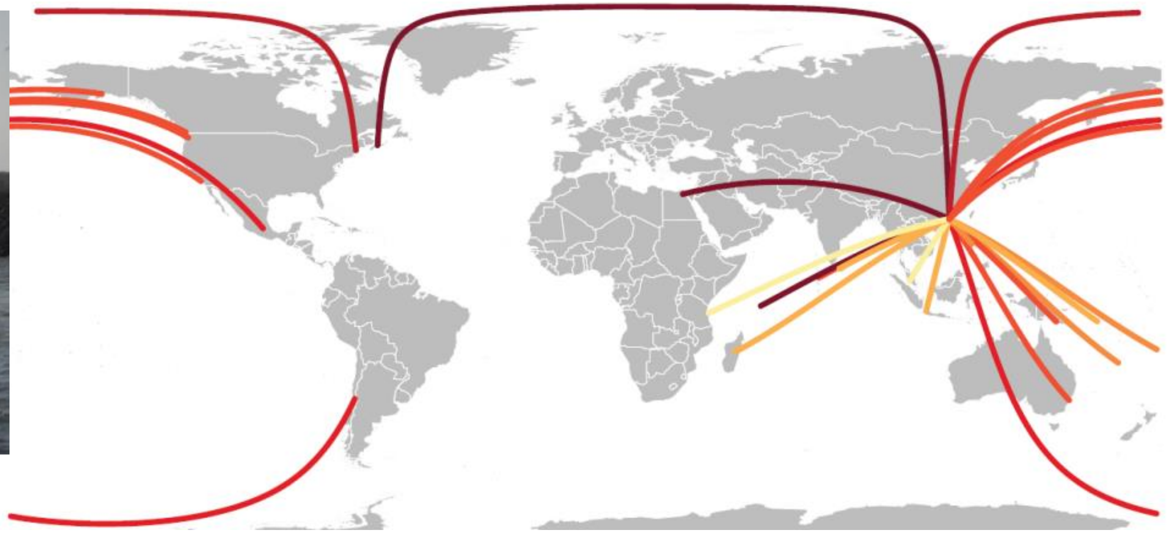
Purcell et al., 2013

Causes of the systematic over-exploitation of sea cucumbers

1) Expansion of the Hong Kong market

2) Distance of fishing areas to Asia

3) Increase in the rate of fishery development



Anderson et al., 2011

Causes of overfishing at local level

- **Economic pressure exceeds the capacity of authorities**
- **Lack of scientific knowledge (stock and ecosystem impact)**
- **Lack of regulations**
- **Failures in management strategies**
- **Poor monitoring and reporting of catch and abundance**




OBJECTIVE:

- **To illustrate how a tropical sea cucumber small-scale fishery operates in the short term at local level under open access, threatening the stock in a short period, despite traditional management restrictions.**

RESEARCH QUESTIONS:

- **What are the main biological and economic factors that interact in the development of these fisheries?**
- **What are the factors that threaten the sustainability of the stock?**
- **What possible strategies could overcome these threats?**

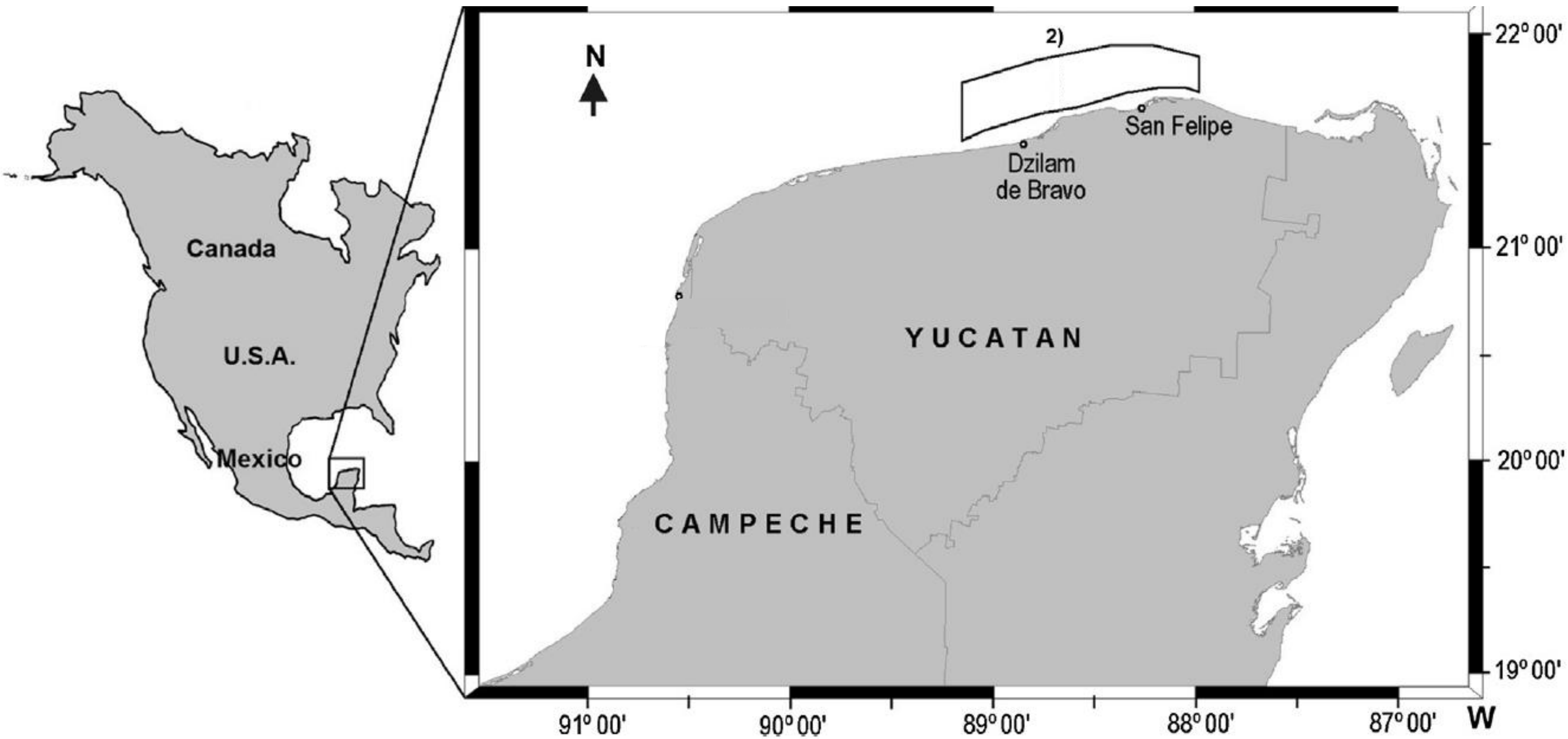
Sea cucumber fishery in Yucatan, Mexico

- **No commercial fishing before 2012**
- **2010 – 2011: traders arrived to Yucatan**
- **2011 – 2012: different sites of high abundance**
- **2012 – first stock assessment was carried out**
- **2012 – fishing licenses issued to 250 hundreds fishers for 30 days open for fishing, from April 1st to 30th**
- **2012 – 2016 Continuous monitoring of density and abundance**
- **2012 – 2016: every new patch discovered is exploited**

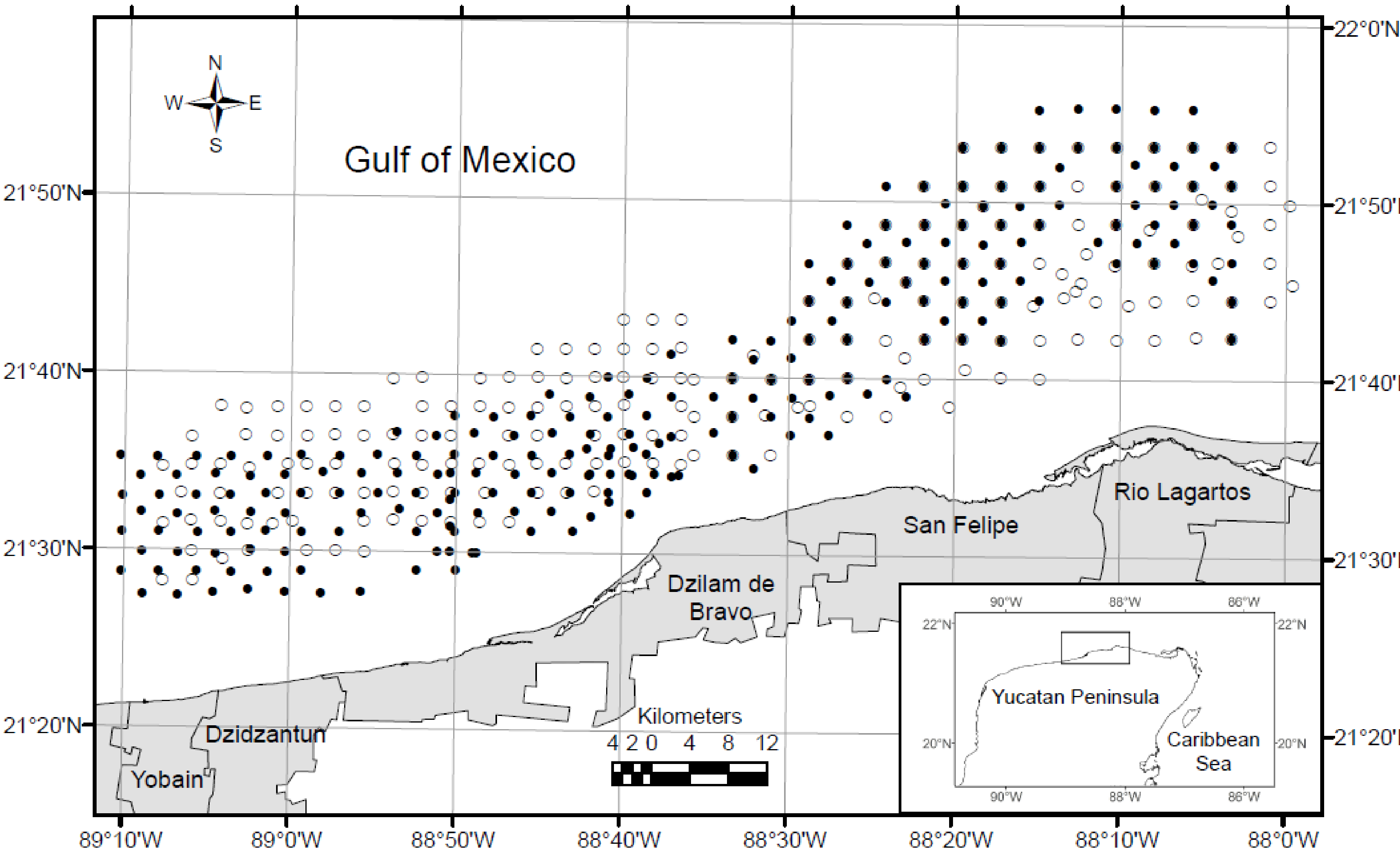
Three-rowed sea cucumber (*Isostichopus badionotus*)

- **Tropical species widely distributed in the Caribbean Sea (Pawson et al., 2010)**
- **Very abundant between 12 and 60 m depth**
- **High demand and value in the Asian market (US$30 per kilo, gutted weight)**
- **Length: 45 cm**
- **Weight: 750 g (wet weight)**

AREA OF STUDY



GEOSTATISTICAL STOCK ASSESSMENT: SAMPLING

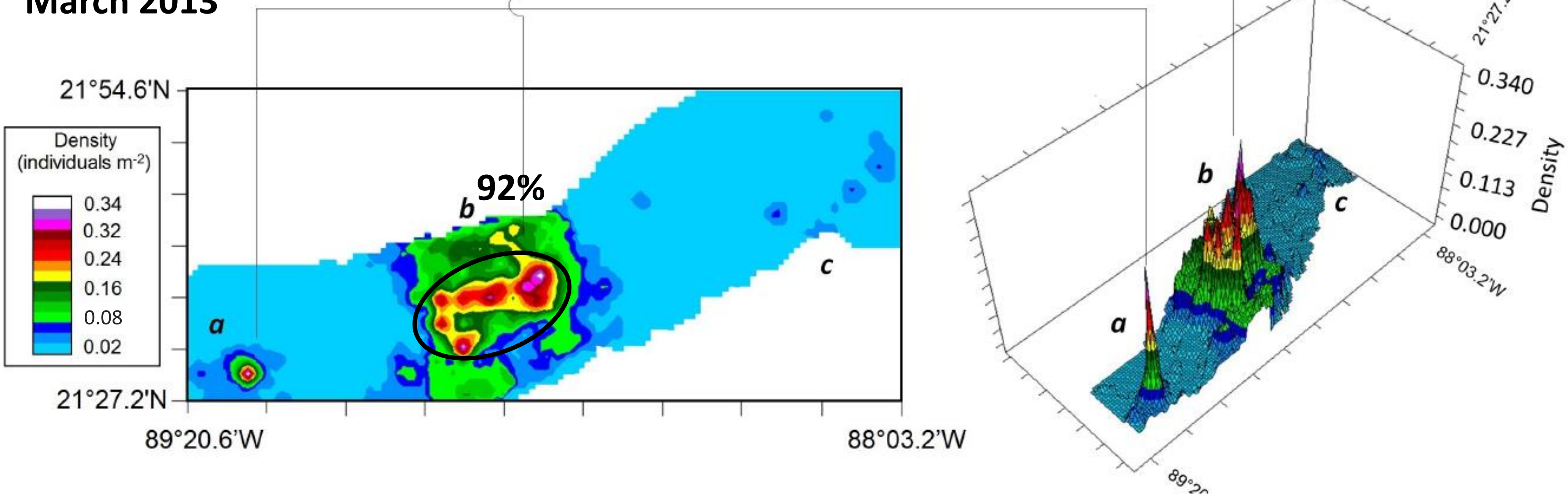


● **March 2013**
n = 236

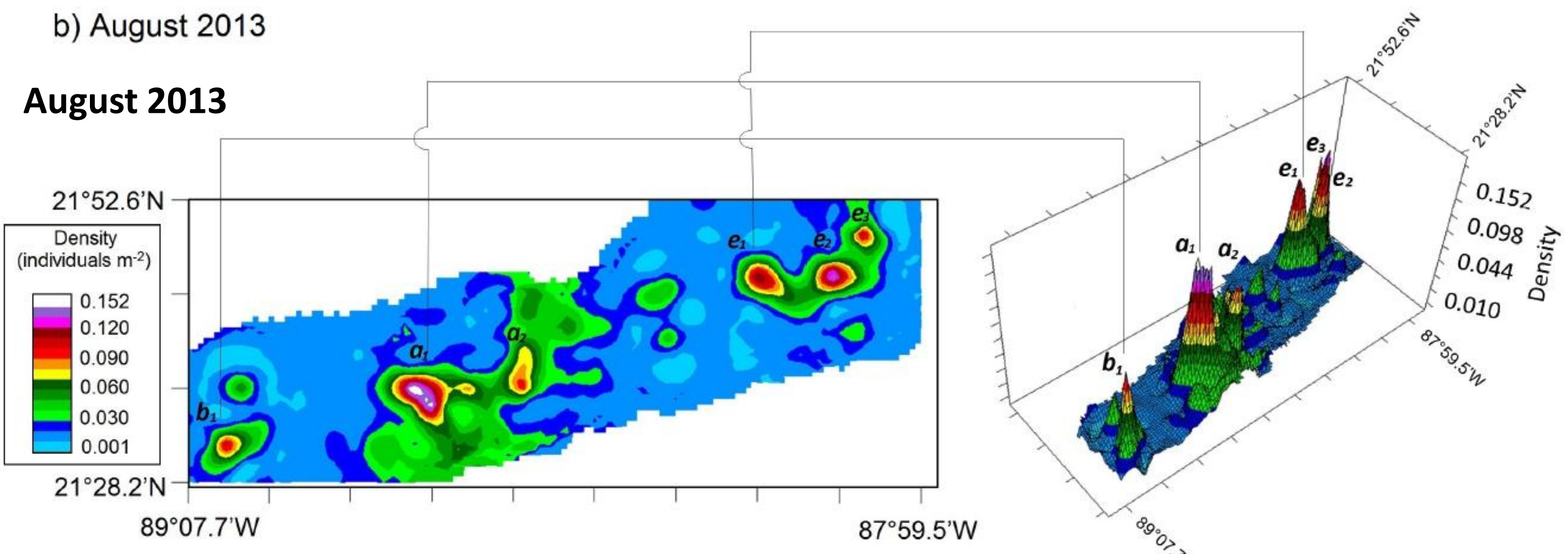
○ **August 2013**
n = 200

GEOSTATISTICAL STOCK ASSESSMENT:
KRIGING INTERPOLATION

March 2013

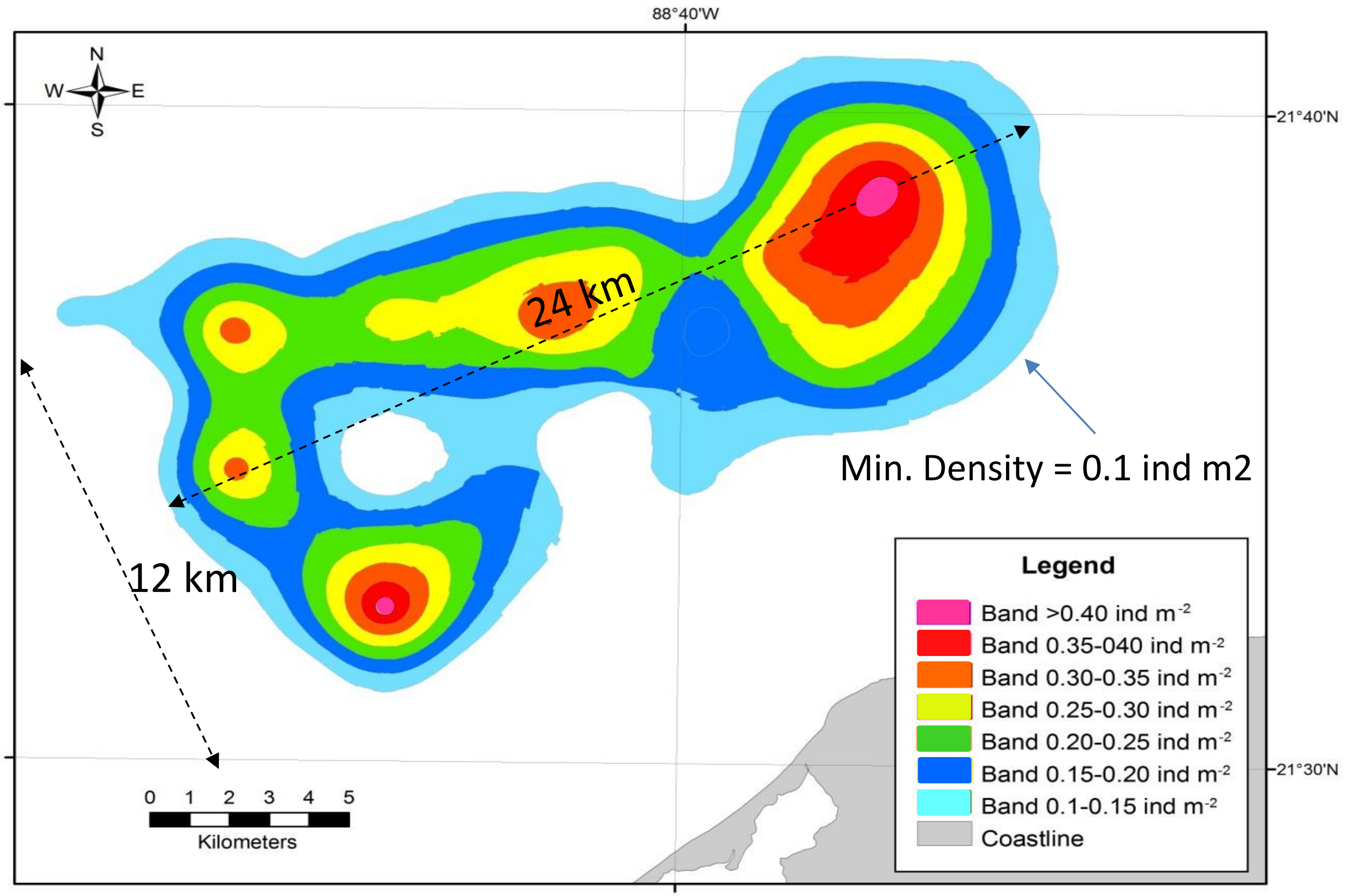


August 2013



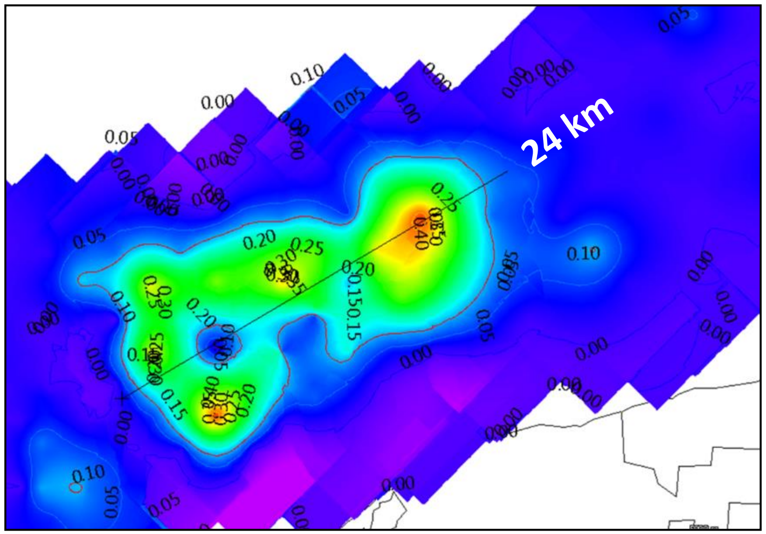
GEOSTATISTICAL STOCK ASSESSMENT: PATCH B STRUCTURE

Detailed interpolation of density in the patch b in March 2013. The colors represent different ranges of density (7 density bands)



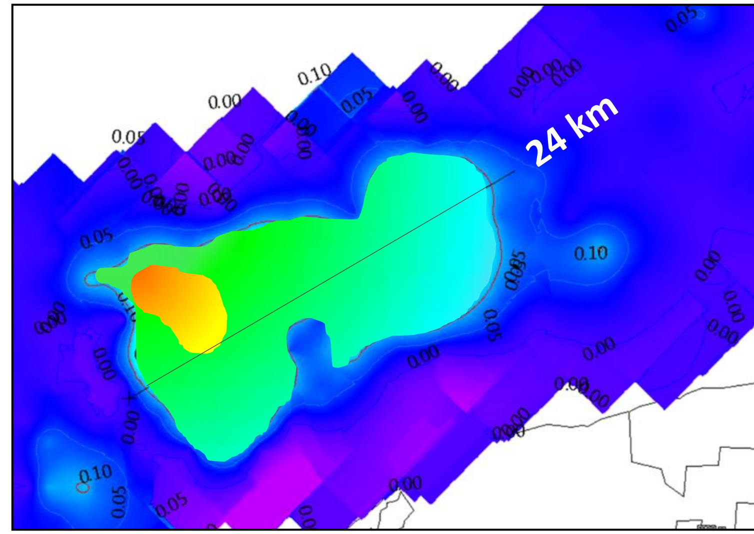
Geostatistical stock assessment in Patch B

March 2013



Abundance: 44,144,538
Area: 221 Km^2
Biomass: 23,816 tons
Quota: 2,400 tons (10%)
Avg. Density: 0.19 ind m^{-2}

August 2013



Abundance: 12,798,342
Area: 221 Km^2
Biomass: 6,905 tons

Avg. Density: 0.05 ind m^{-2}

Spatial dynamic bioeconomic model

Depletion dynamic model:

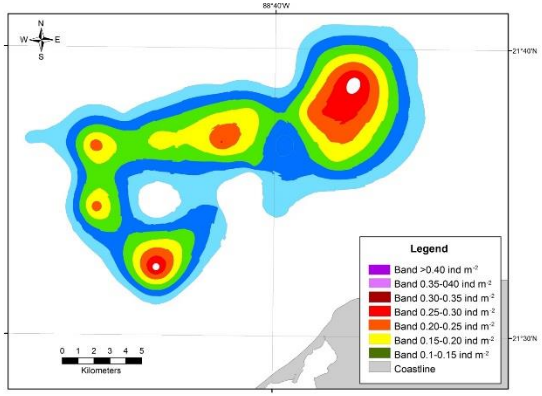
$$N_t = N_0 - K_{t-1}$$

Where: N_t **is the abundance at time** t
N_0 **is the initial abundance**
K_{t-1} **is the cumulative catch from** $t = 0$ **to** t-1

Assumptions: Closed population (the patch), no recruitment and no natural mortality

Catchability coefficient: density-dependent

$$q_i = a_i' - \frac{b}{c_i D_{i,}}$$



Where: $q_{i,}$ **is the catchability coefficient at density** i
a_i , b, and c_i **are the parameters of the equation**
D_i **is the denisty**

Catch at density *i* and time *t*

$$Y_{t,i} = q_{t,i} f_{t,i} B_{t,i}$$

Where: $Y_{t,i}$ **is the catch at time** t**, density** i
$f_{t,i}$ **is the effort at at time** t**, density** i
$B_{t,i}$ **is the biomass at at time** t**, density** i

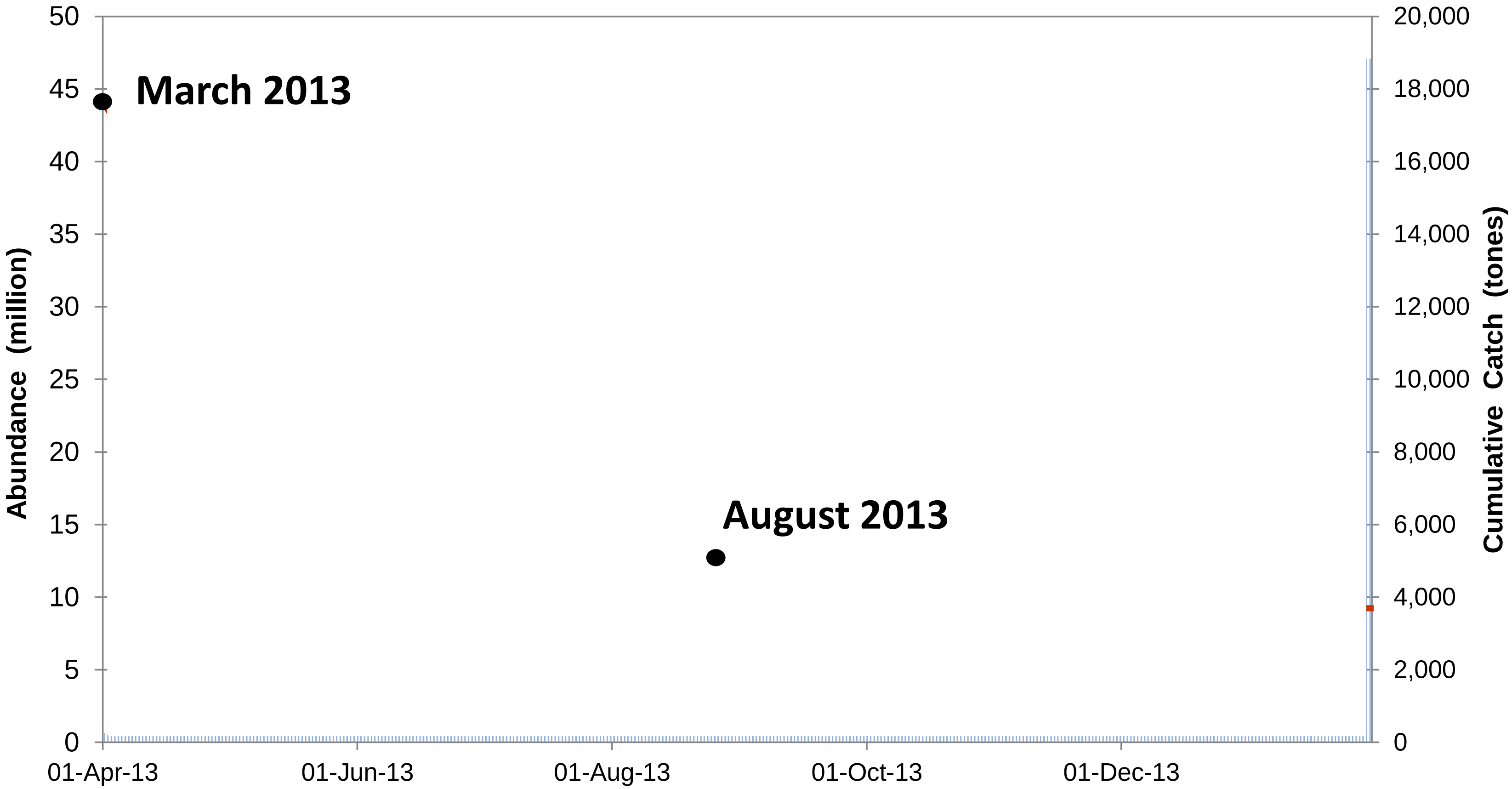
Effort at site i and time t

$$E_{t+1,i} = \phi\left[E_t\left(p_{t,i} q_{t,i} B_{t,i} - c_i\right)\right]$$

Where: $E_{t,i}$ **is the effort at time** t**, density** i
p_t **is the price at time** t
c_i **is the cost to fish in a density** I
ϕ **is the entry-exit parameter**

SPATIAL DYNAMIC BIOECONOMIC MODEL

The model predict the trajectory of catch, abundance and other bioeconomic variables



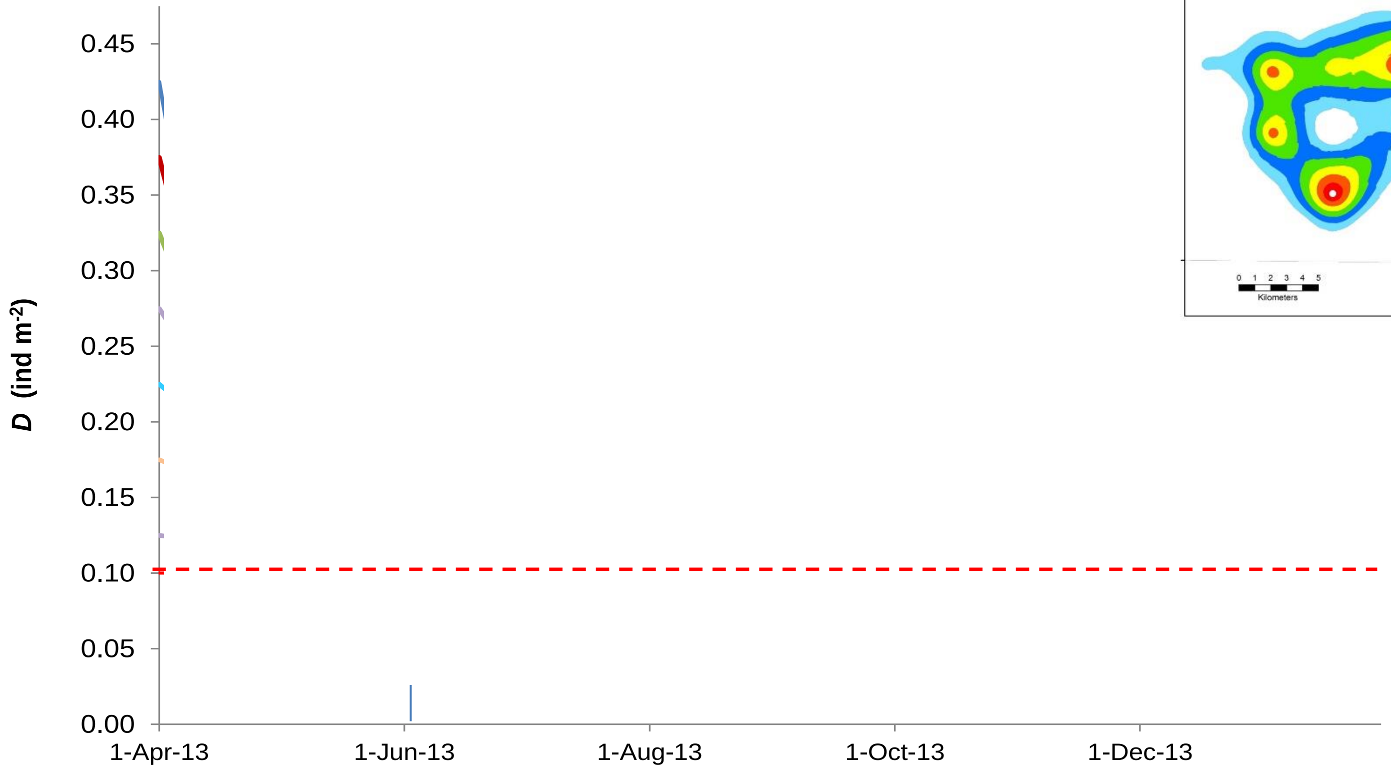
Simulation period: April 1st 2013 to January 26th 2014

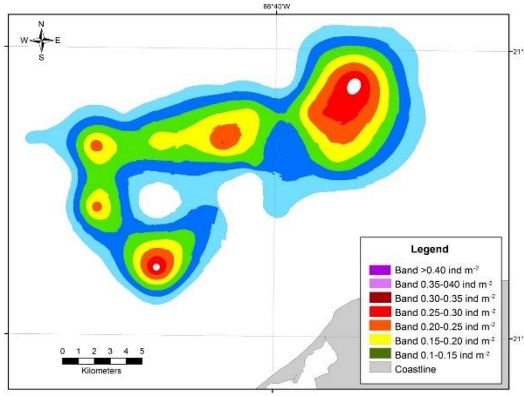
Total abundance
Cumulative catch

Spatial dynamic bioeconomic model

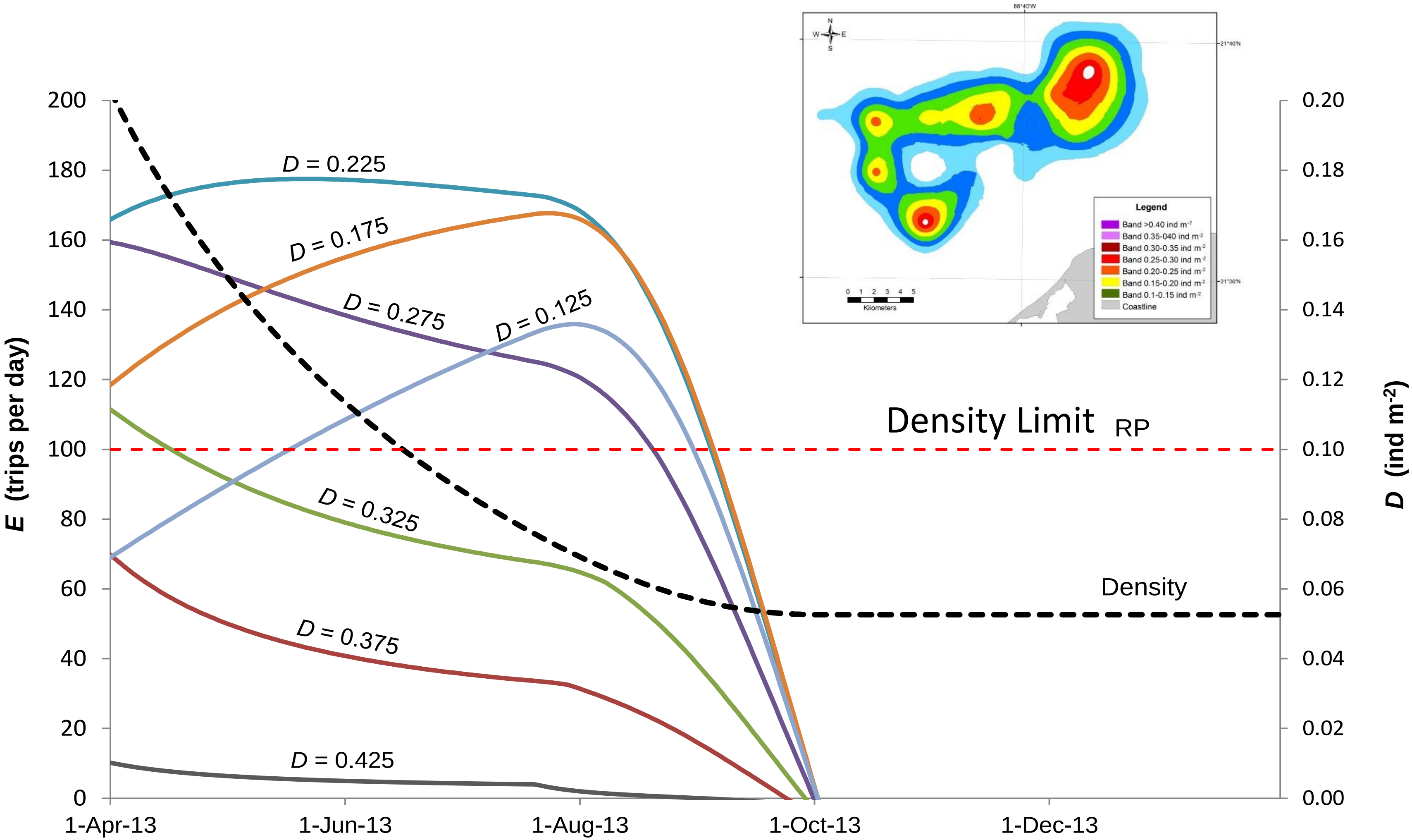
Patch *a* divided in seven sub-areas (density bands of March 2013)

Trajectories of density (*D*) per density band

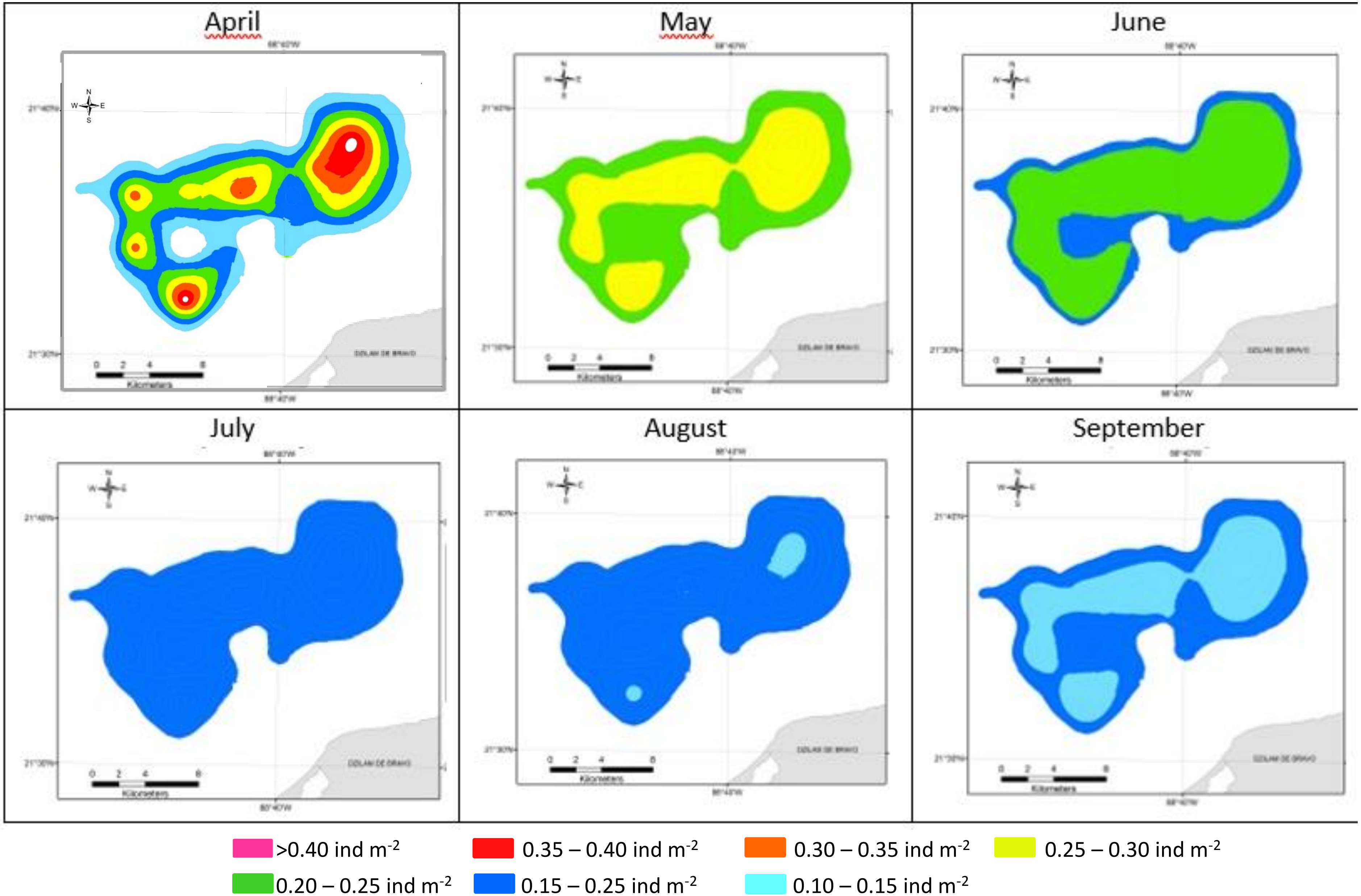




Spatial distribution of fishing effort (*E*) per density band. The trajectory of density (*D*) intersects the reference point (*RP*) on July 14th, 2013



Distribution of the density from April to September (first day of the month)




Pepin

What alternatives could be applied to overcome this situation?

Limiting the fishing effort to 300 boats per day

Rotation of participants to tackle the equity issue and reduce the "race for fish"

Adopt community agreements to determine the fishing days during the week and the people authorized to fish

Catch limit per trip (up to 300 kilos per trip)

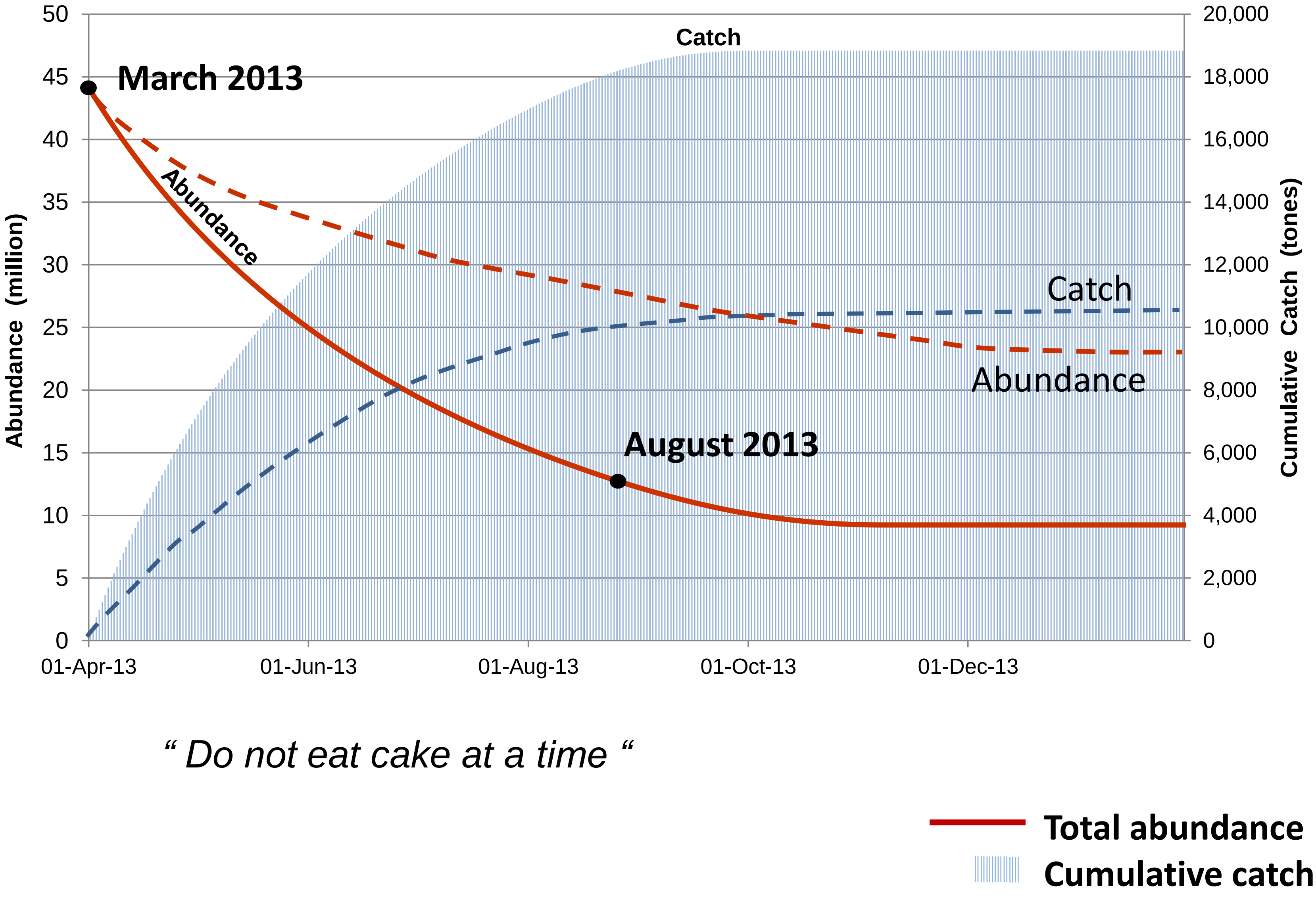
Effective enforcement to control fishing effort

Establish: total allowable catch, season closure to protect reproduction, and minimum legal size, prohibit evisceration on board

Maintain a minimum density of 0.10 individuals m^{-2} in the patches

SPATIAL DYNAMIC BIOECONOMIC MODEL

Limit the fishing effort to 300 boats per day



“ Do not eat cake at a time “

Comparative analysis between the current situation and the strategy to limit the fishing effort to 300 boats per day

	Day 1 of the fishing season		
Number of fishing trips-boat	691		
Remaining Abundance (millions)	43.66		[illegible]
Avg. Density (individuals m^{-2})	0.20	0.06	(83%) 0.11
Cumulative Catch (t)	0	16 986	[illegible]
Cumulative NPV (US$ million)	0		[illegible]
Price (US$ kg^{-1})	2.69	[illegible]	
Avg. income per trip (US$ $trip^{-1}$)	(April 1st) 482.95		4

“ Do not eat cake at a time, do it slowly “

CONCLUSIONS

1. The factors that drove the stock to a very low level were:

   a) patchy distribution

   b) excess of fishing capacity

   c) low opportunity cost of fishers and high discount rate

   d) significantly high quasi-profits per fishing trip at the beginning of the season

   e) density dependent catchability coefficient

CONCLUSIONS

2. The reduction of 71% of the abundance in the patch *"b"*, from March to August 2013 (148 days) is attributable to the fishing impact
3. A new more homogeneous spatial pattern of abundance resulted from the fishing effort that focused on fishing areas with higher densities
4. Under open access, this fishery tends to the collapse in a short time

CONCLUSIONS

5. Limiting the number of trips per day could contribute to avoid the declining of these fisheries
6. To ensure equity, community agreements could include: rotate the participants, establish specific days for fishing, establish a maximum catch per trip and traditional regulations.


Thank you!
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