Bioeconomics of ocean acidification effects on fisheries targeting calcifier species: qualitative and quantitative risk analysis

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Fishing communities targeting calcifier species

Ocean acidification (OA)

an additional fisheries stressor

Atmospheric CO_2

$$CO_2 + H_2O \Longrightarrow H_2CO_3$$

Carbonic acid

$$H_2CO_3 \Longrightarrow HCO_3^{2-}$$

Bicarbonate ion

$$H_2CO_3 \Longrightarrow H^+ + CO_3^{2-}$$

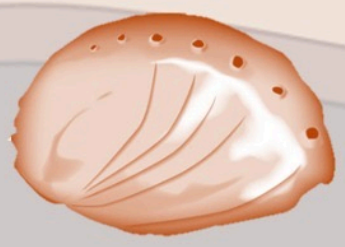
Hidrogen ion Carbonate ion

$$H^+ + CO_3^{2-} \Longrightarrow HCO_3^{2-}$$

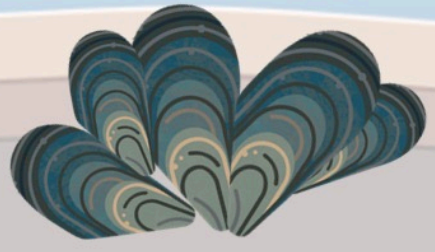
Bicarbonate ion

$$CaCO_3 \Longrightarrow Ca^{2+} + CO_3^{2-}$$

Calcium carbonate Calcium Carbonate ion



Abalone



Mussels

Queen conch

Ocean acidification

- ✓ Diminishing carbonate concentrations in seawater can lead to a decrease in the "saturation state" Ω.
- ✓ Ω is defined as the product concentrations of dissolved calcium and carbonate ions divided by calcium carbonates (i.e solubility of aragonite in seawater)
- ✓ several groups of marine organisms build shells and skeleton structures which generally occurs when $\Omega > 1$. Species stress occur when $\Omega < 3$.

The effect on calcifier species…

- ✓ Dissolution occurs when $\Omega < 1$, (Doney *et al*., 2009).
- ✓ Therefore, through changes in the saturation state values, OA could affect calcifier organisms in several ways

Effect of small changes in pH

(Langdon and Atkinson, 2005; Reynaud *et al.,*2003; Hoegh-Guldberg *et al* 2007; Kurihara *et al.,* 2008; Veron *et al.,* 2009; Liu, 2021).

- ✓ small increments in concentrations of CO_2 in oceanic waters can cause negative impacts in calcifier organisms like:

- ○ mollusks, echinoderms and crustaceans,
- ○ ecologically valuable critical habitats such as corals

- ✓ Impacts may include reductions in individual growth rates and increases in natural mortality

Some of questions

- Which are the possible effects of OA and associated risk perception in small-scale fishing communities targeting calcifying species in different latitudes, and possible measures to mitigate them?

- How to assess the bioeconomic quantitative risks of associated effects of OA on fisheries of calcifying species in temperate, tropical and sub-tropical areas?

Calcifying species in heterogeneous latitudes

- ✓ Galicia Mussel (*Mitilus galloprovincialis*), Isla Arousa, Spain
  K = 1.1 and M = 0.6; Latitude: 42° 33’ 16’’ N
- ✓ Green abalone (*Haliotis corrugata*), La Bocana, BCS
  k = 0.35 and M = 0.37 ; Laltitude: 26° 47’ 48’’ N
  (Vargas et al. 2022; Ponce et al.).
- ✓ Queen conch (*Aliger gigas*), k_1 = Pedro Bank, Jamaica
  k = 0.37 and M_1 = 0.31; Latitude: 17° 58’ 17’’ N
  (Stoner and Appeldoorn, 2021; Morris et al. 2022)

Qualitative risk

Fletcher (2005, 2015) qualitative risk analysis is a useful option to:

- Estimate risks of coastal activities in the marine environment and on marine biodiversity. Also on climate change perception by coastal inhabitants (Astle 2006, Boa 2012, Astle 2015).

- Identify the degree of awareness of fishing communities concerning possible fishers´ health risks caused by using specific fishing methods and gears (Edvardsson et al. 2011, Booth and Nelson 2014, Huchim and Seijo 2018).

- Know the risk perception fishers of bivalve mollusks and gastropods associated to an additional environmental stressors like OA.

Qualitative risk: procedure

The following steps were undertaken in this study:

(i) Identifying OA impacts (consequences) for fishers concerning their wellbeing, and the effect on their target species biomass, individual growth, and survival, as well as its price.

(ii) Determination of the fishers' perception of the likelihood of occurrence of undesired events such as OA.

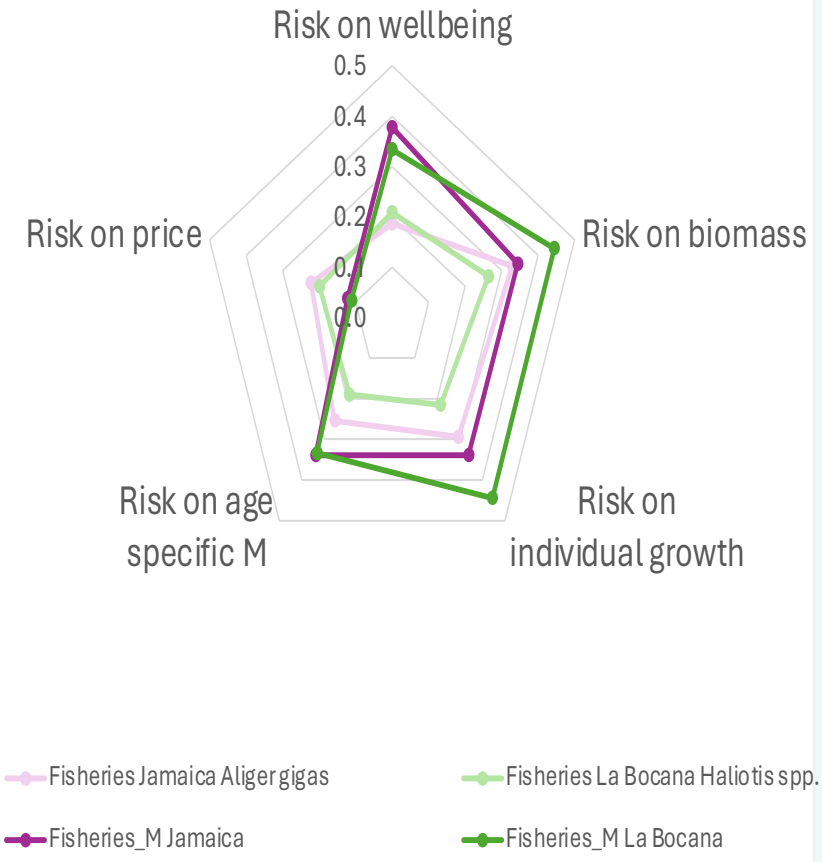
(iii) Building a likelihood-impact matrix,

(iv) Multiplying the likelihood values by the corresponding impact value of socio-bioeconomic variables to estimate the qualitative risk, and

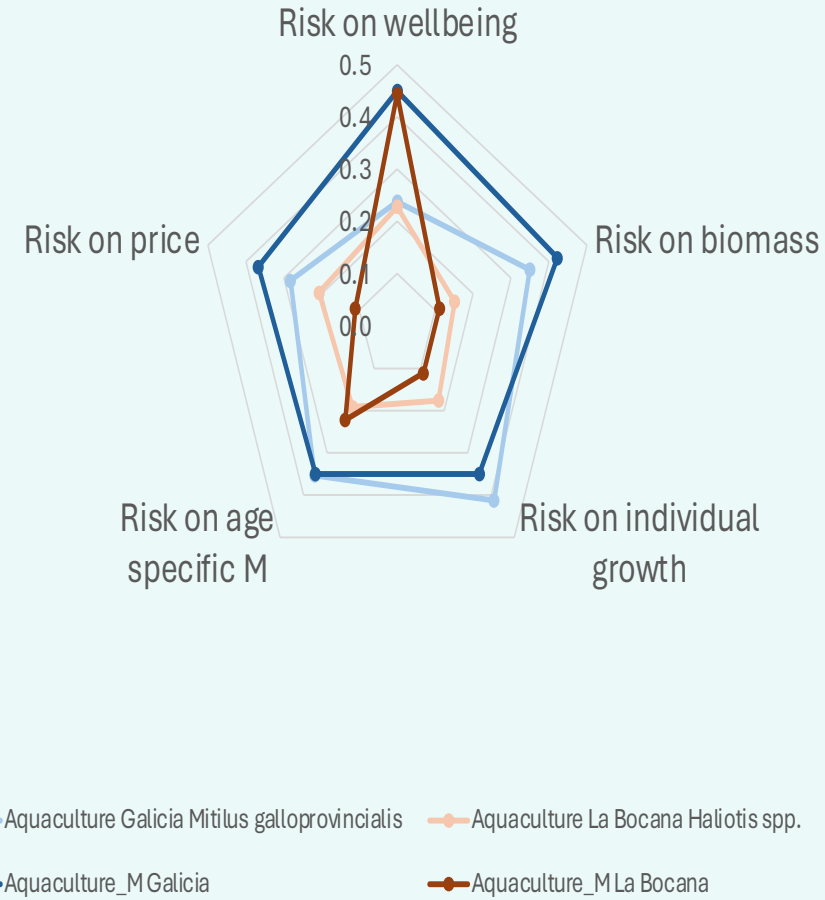
(v) Categorization of risk values for the relevant variables considered .

Risk perception of OA effects on fisheries and aquaculture of calcifier species in different latitudes

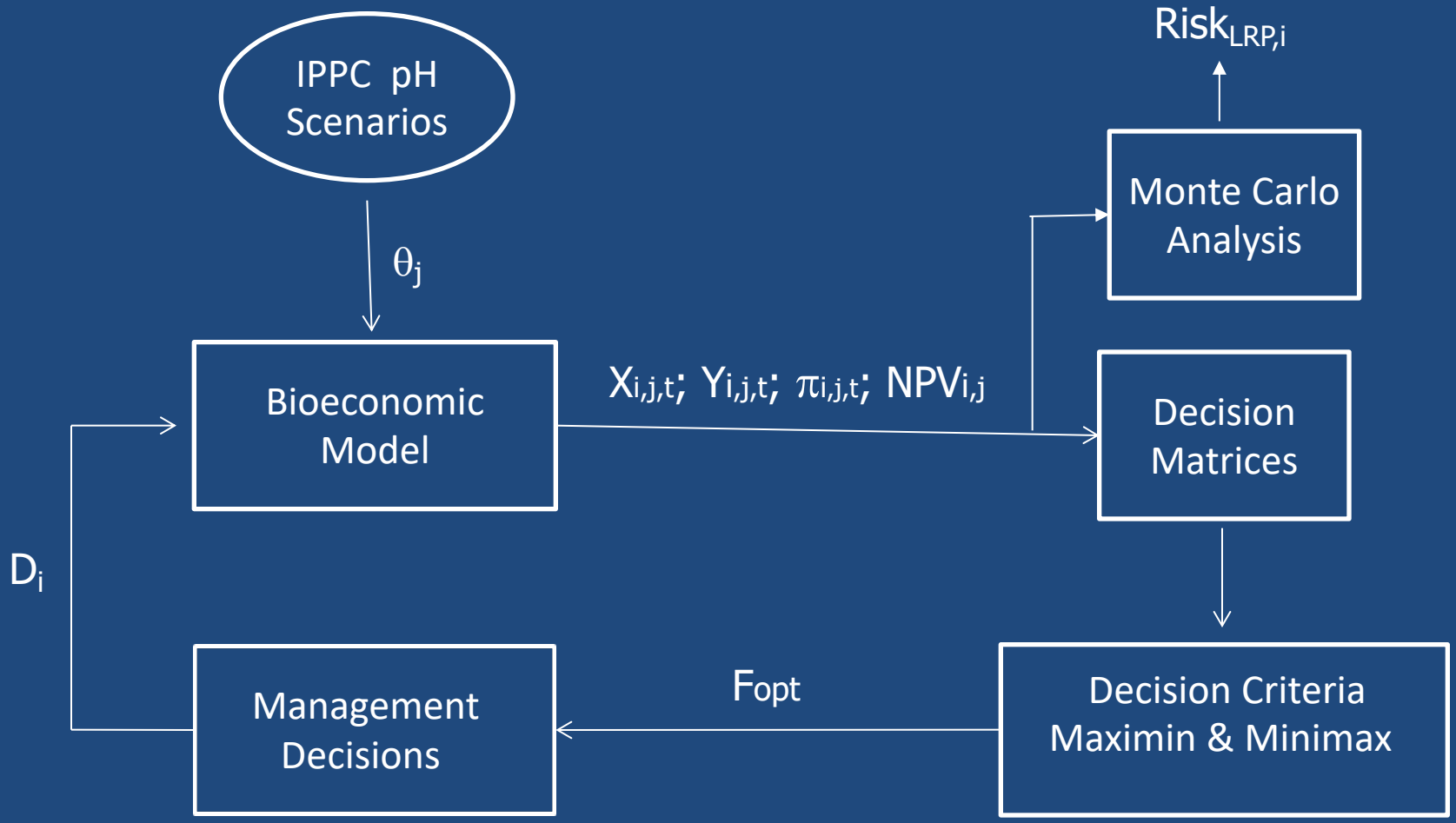
Fisheries targeting calcifier species



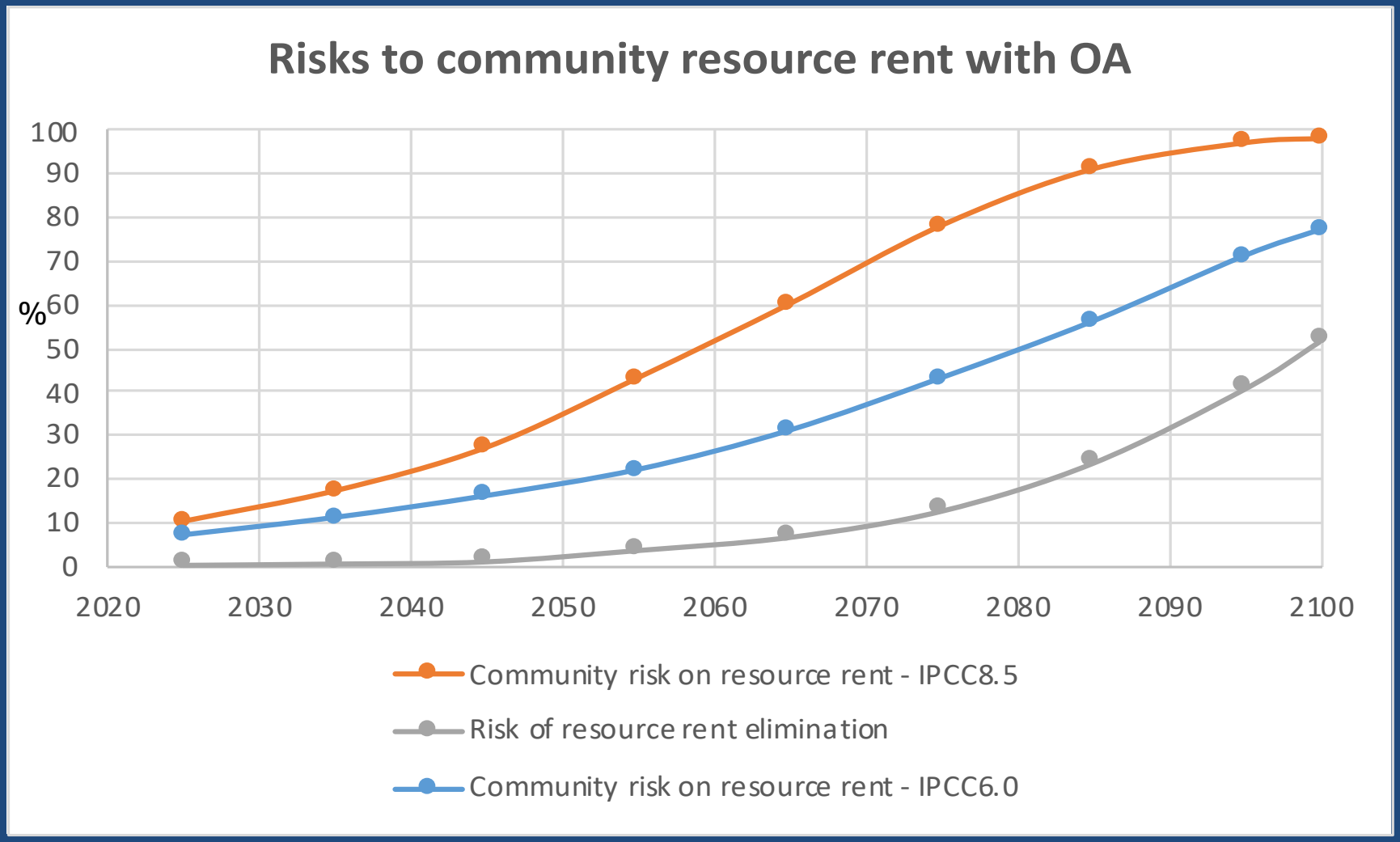
Aquaculture of calcifier species

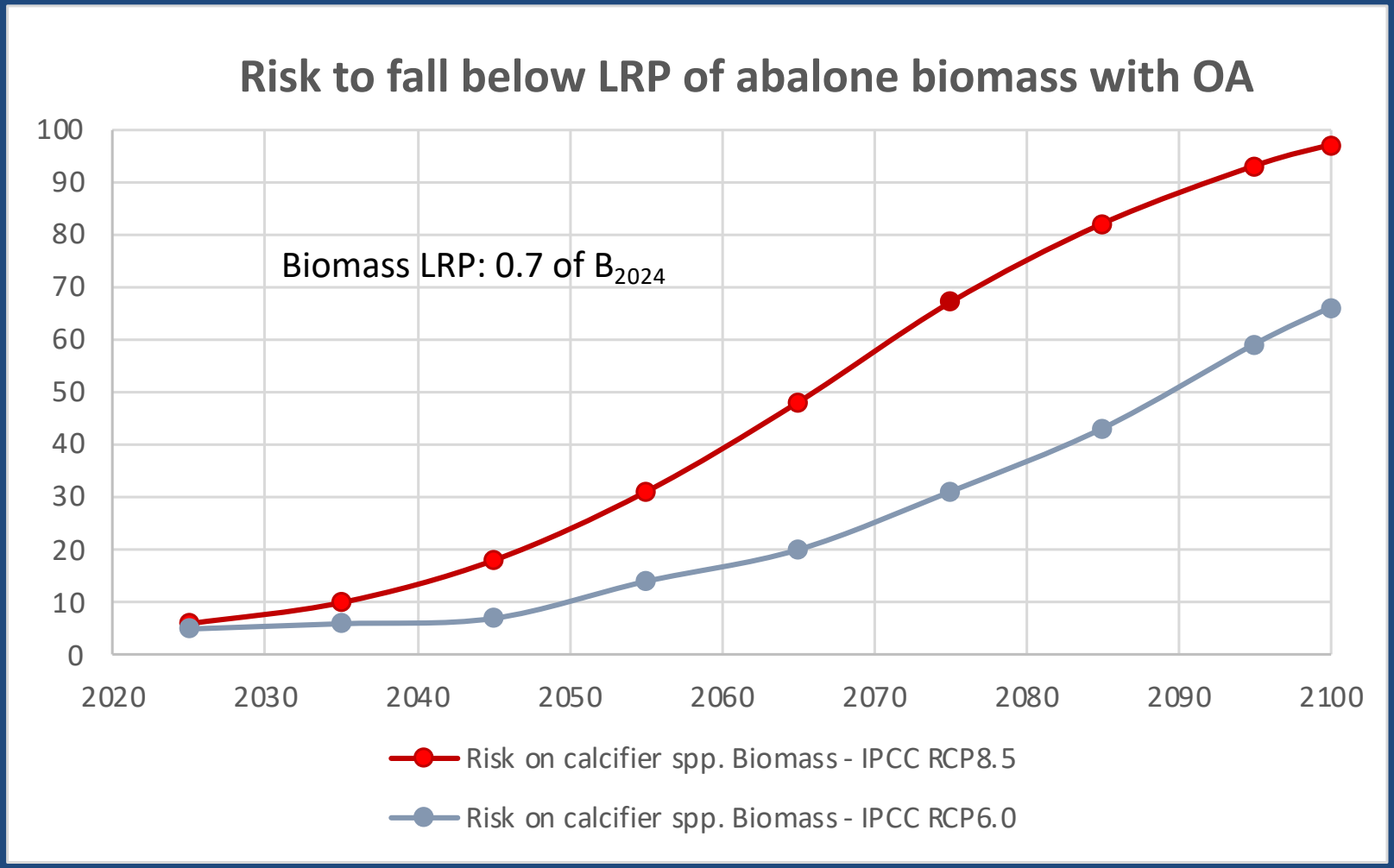


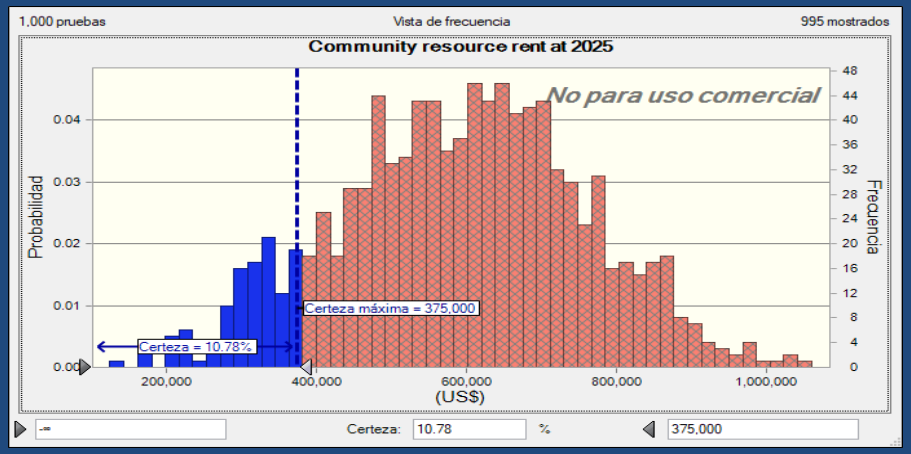
Quantitative risks with OA

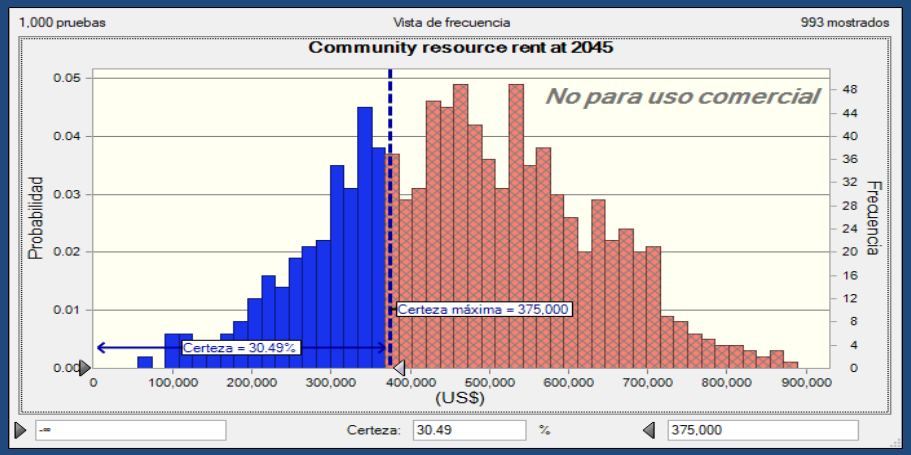


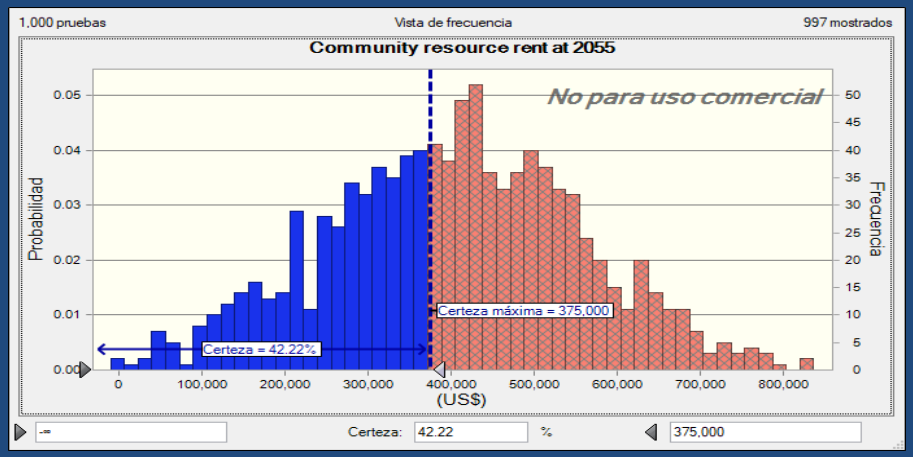
(Adapted de Seijo *et al*. 2016, Seijo and Villanueva 2018)


Risks to community resource rent with OA
100
90
80
70
%60
50
40
30
20
10
0
2020
2030
2040
2050
2060
2070
2080
2090
2100
Community risk on resource rent - IPCC8.5
Risk of resource rent elimination
Community risk on resource rent - IPCC6.0


Risk to fall below LRP of abalone biomass with OA
Biomass LRP: 0.7 of B_{2024}
100
90
80
70
60
50
40
30
20
10
0
2020
2030
2040
2050
2060
2070
2080
2090
2100
Risk on calcifier spp. Biomass - IPCC RCP8.5
Risk on calcifier spp. Biomass - IPCC RCP6.0


1,000 pruebas
Vista de frecuencia
995 mostrados
Community resource rent at 2025
No para uso comercial
Probabilidad
Frecuencia
Certeza máxima = 375,000
Certeza = 10.78%
(US$)
Certeza: 10.78 %
375,000


1,000 pruebas
Vista de frecuencia
993 mostrados
Community resource rent at 2045
No para uso comercial
Probabilidad
Frecuencia
Certeza máxima = 375,000
Certeza = 30.49%
(US$)
Certeza: 30.49 %
375,000


1,000 pruebas
Vista de frecuencia
997 mostrados
Community resource rent at 2055
No para uso comercial
Probabilidad
Frecuencia
Certeza máxima = 375,000
Certeza = 42.22%
(US$)
Certeza: 42.22 %
375,000

Some considerations for the mitigation of OA effects in small-scale communities

- Identify the degree of vulnerability of the coastal community to OA
- Foster capacity building necessary to produce calcifier species under control conditions in small-scale communities
- Community capacity building to increase adaptability to increasing OA affecting their target calcifier species

Vulnerability to ocean acidification in local fishing communities

Vulnerability of fishing communities to OA could depend on:

(i) Local ecosystem pH level and saturation state (Ω)

(ii) Degree of dependence of local economy with respect to their harvest of calcifying species

(iii) Fishing community adaptive capacity to changing OA conditions and offset its impacts

Where we may need to increase resilience to climate change and OA?

- In marine ecosystem where calcifier species occur by reducing exploitation rates
- In human communities harvesting calcifier species, by diversifying target species
- In fisheries management institutions by acting proactively towards possible climate change and OA effects, and
- In socio-economic structure of the community by fostering their social capital and sense of solidarity

Planning an effective adaptation to OA

(Allison *et al.*, 2005; 2009, Seijo et al. 2016)

Planning an effective adaptation to OA requires identifying:

- ✓ who and what is vulnerable to OA and
- ✓ which is the capacity of fishing communities to confront potential effects OA

Thank you…

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