Economic uncertainty in trade-off analyses for fisheries management

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AMURE – CENTRE DE DROIT ET D'ÉCONOMIE DE LA MER

UBO Université de Bretagne Occidentale · Ifremer · CNRS · CSIRO

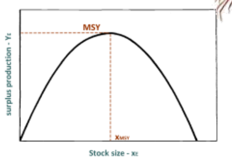
19 January, 2024 – 3 days MESSH (Mathematics for bio-Economics and Sustainability of fiSHeries), Brest

Presentation outline

- General context
- Case study
- Ecoviability
- Discussion and Perspectives

GENERAL CONTEXT

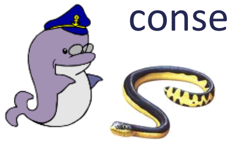
Biological



Political

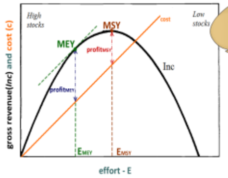
Multiple objectives

Non- target species conservation



Social

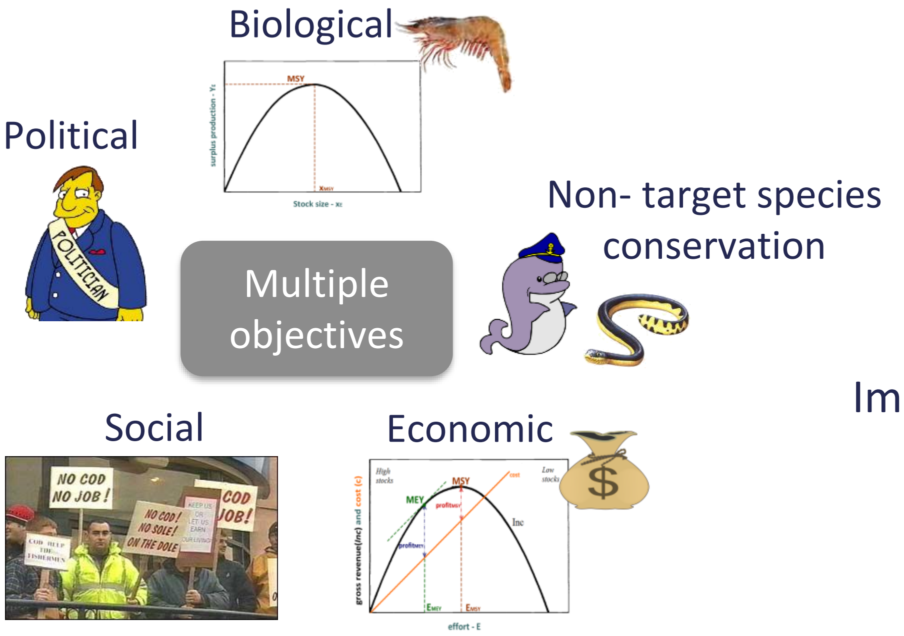
Economic



Many stakeholders are involved in fishery management
=> multiple objectives that might be conflicting

Important to understand the trade-offs among management objectives

GENERAL CONTEXT



Many stakeholders are involved in fishery management
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Important to understand the trade-offs among management objectives

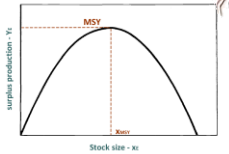
ecoviability approach

Used in: Baumgärtner and Quaas, 2009; De Lara and Martinet, 2009; Cissé et al, 2013; Gourguet et al, 2013; Maynou, 2014; Gourguet et al, 2015; Doyen et al., 2017; Briton et al., 2020…

Respect of multiple constraints (biological, economic, etc.) at a given confidence level

GENERAL CONTEXT

Biological



Political

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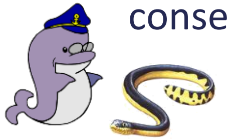
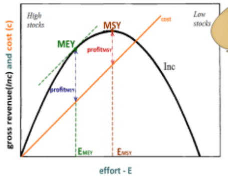
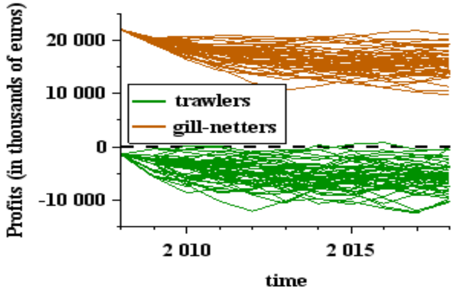


Social

Economic



Uncertainties



Many stakeholders are involved in fishery management
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Important to understand the trade-offs among management objectives

Stochastic ecoviability approach

Used in: Baumgärtner and Quaas, 2009; De Lara and Martinet, 2009; Cissé et al, 2013; Gourguet et al, 2013; Maynou, 2014; Gourguet et al, 2015; Doyen et al., 2017; Briton et al., 2020…

Respect of multiple constraints (biological, economic, etc.) at a given confidence level

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How can the ecoviability approach assist in managing mixed fisheries?

How should we define the thresholds for viability?

CASE STUDY to illustrate

Australian Northern Prawn Fishery (NPF)

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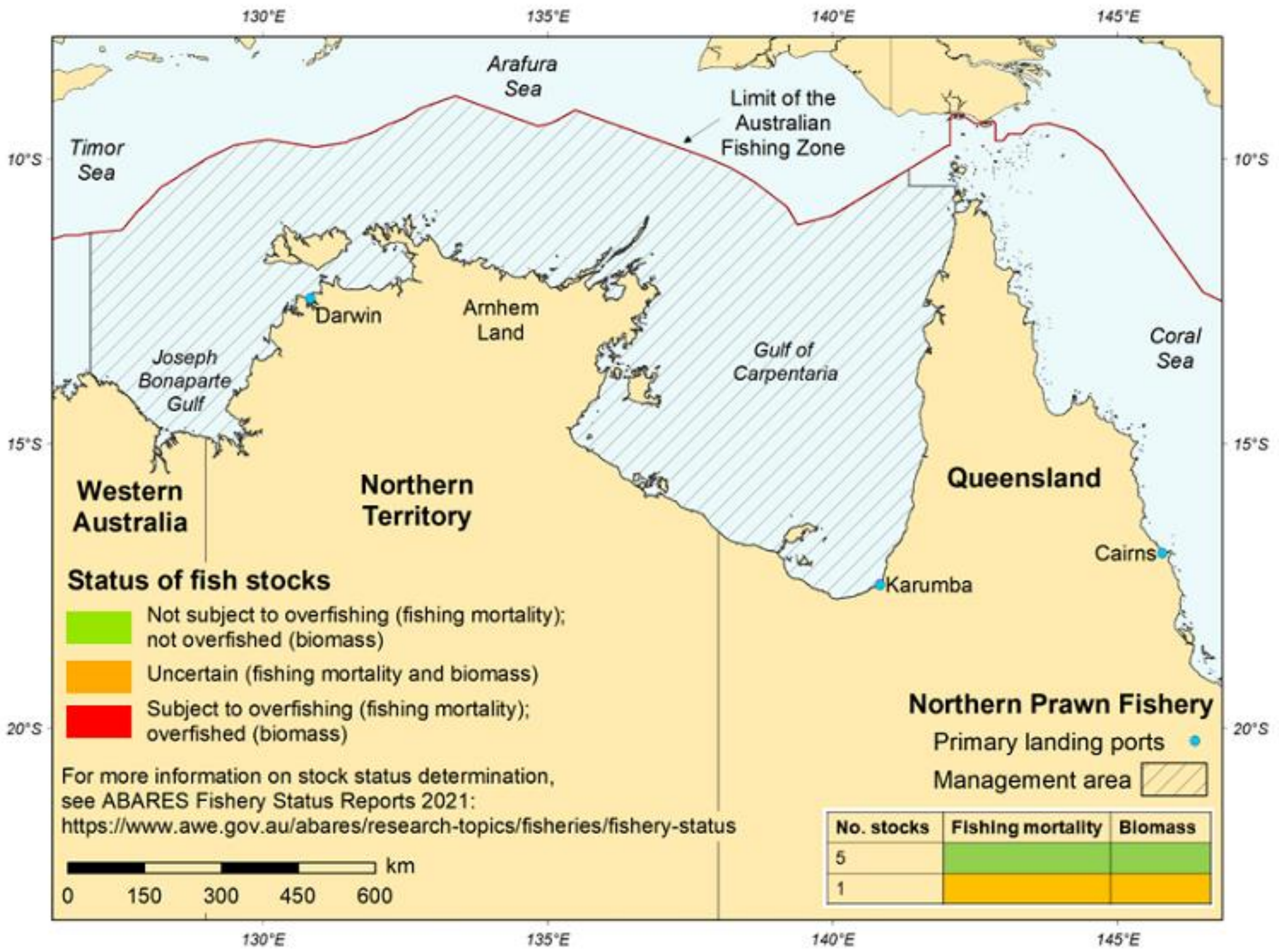
Australian Northern Prawn Fishery (NPF)

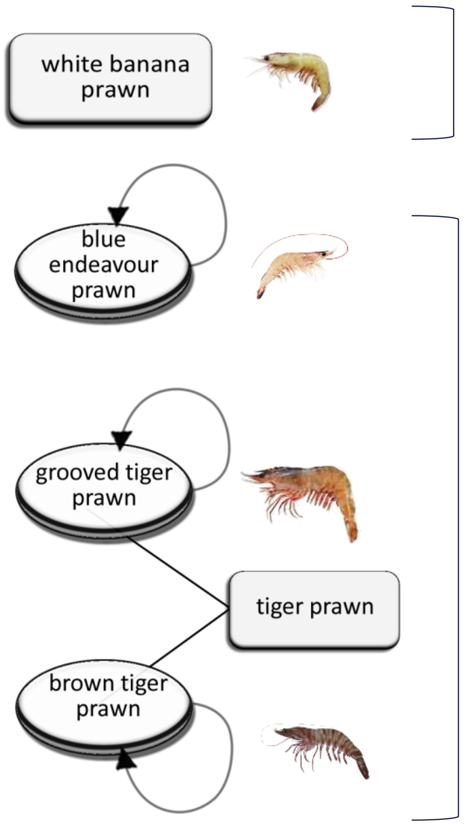


Source: ABARES

Bio-economic model

adapted from Gourguet et al, 2014. *Ecological Economics*

Multi-species trawl fishery



uncertain resource

strong year to year variability

more predictable resources

weekly, size-and sex-structured population dynamic model with Ricker type stock-recruitment function (**integration of uncertainty on recruitment**)

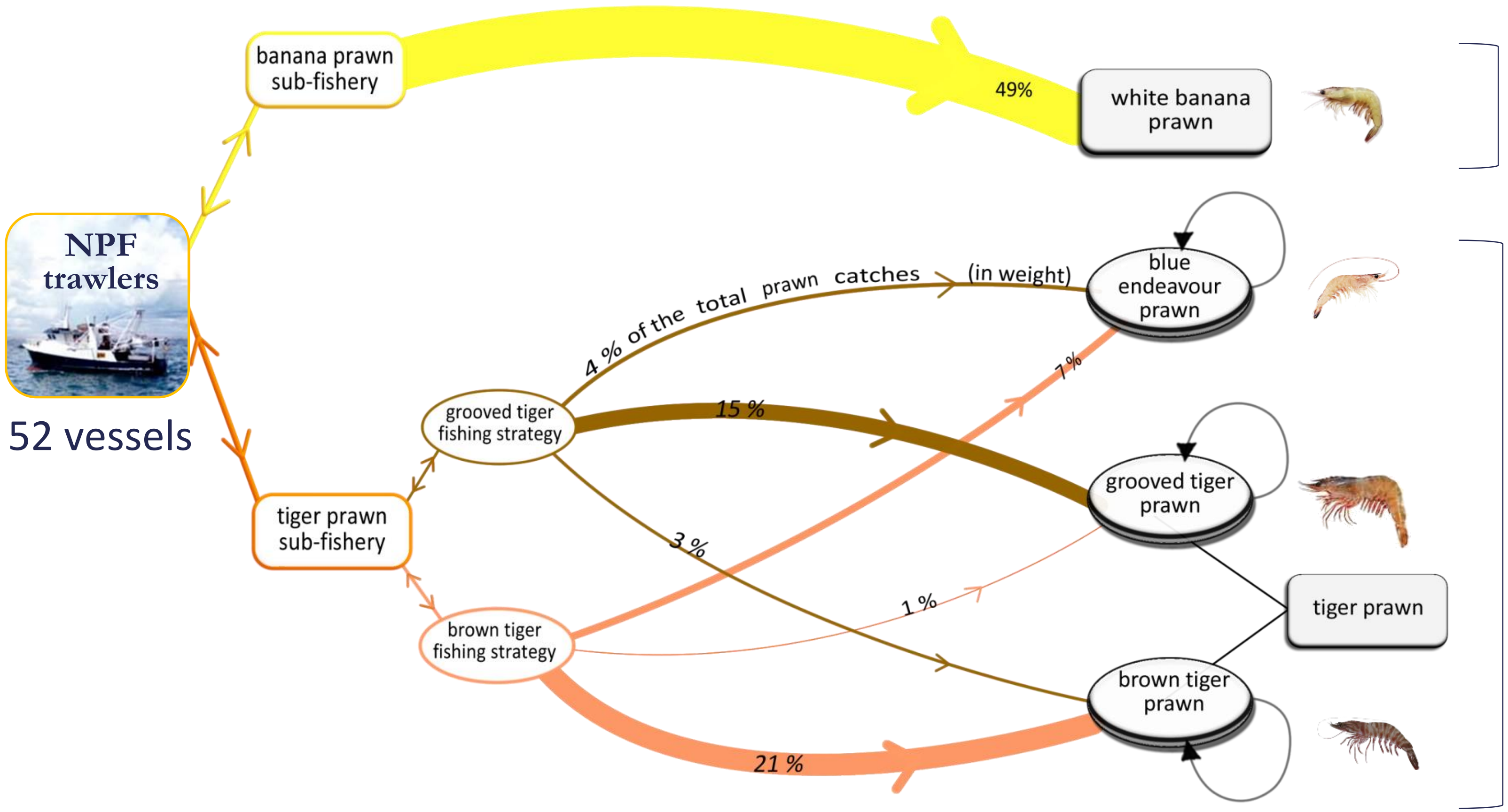
Bio-economic model

adapted from Gourguet et al, 2014. *Ecological Economics*

Multi-fishing strategies

Multi-species trawl fishery

managed by input controls



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weekly, size-and sex-structured population dynamic model with Ricker type stock-recruitment function (with uncertainty)

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Multi-fishing strategies

managed by
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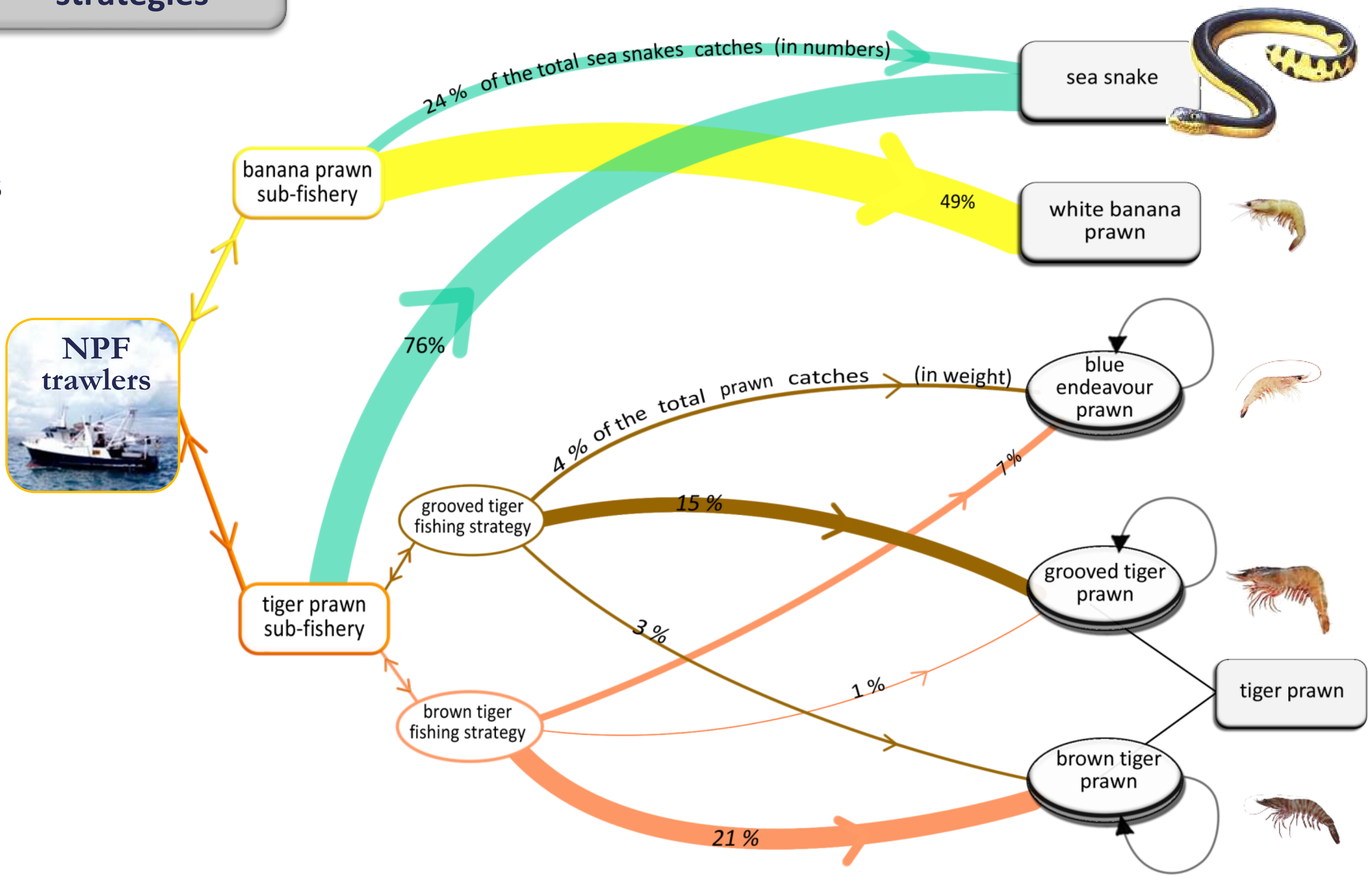
Multi-species trawl fishery



By-catch issues

non-target species (part of TEP – threatened, endangered and protected - species)

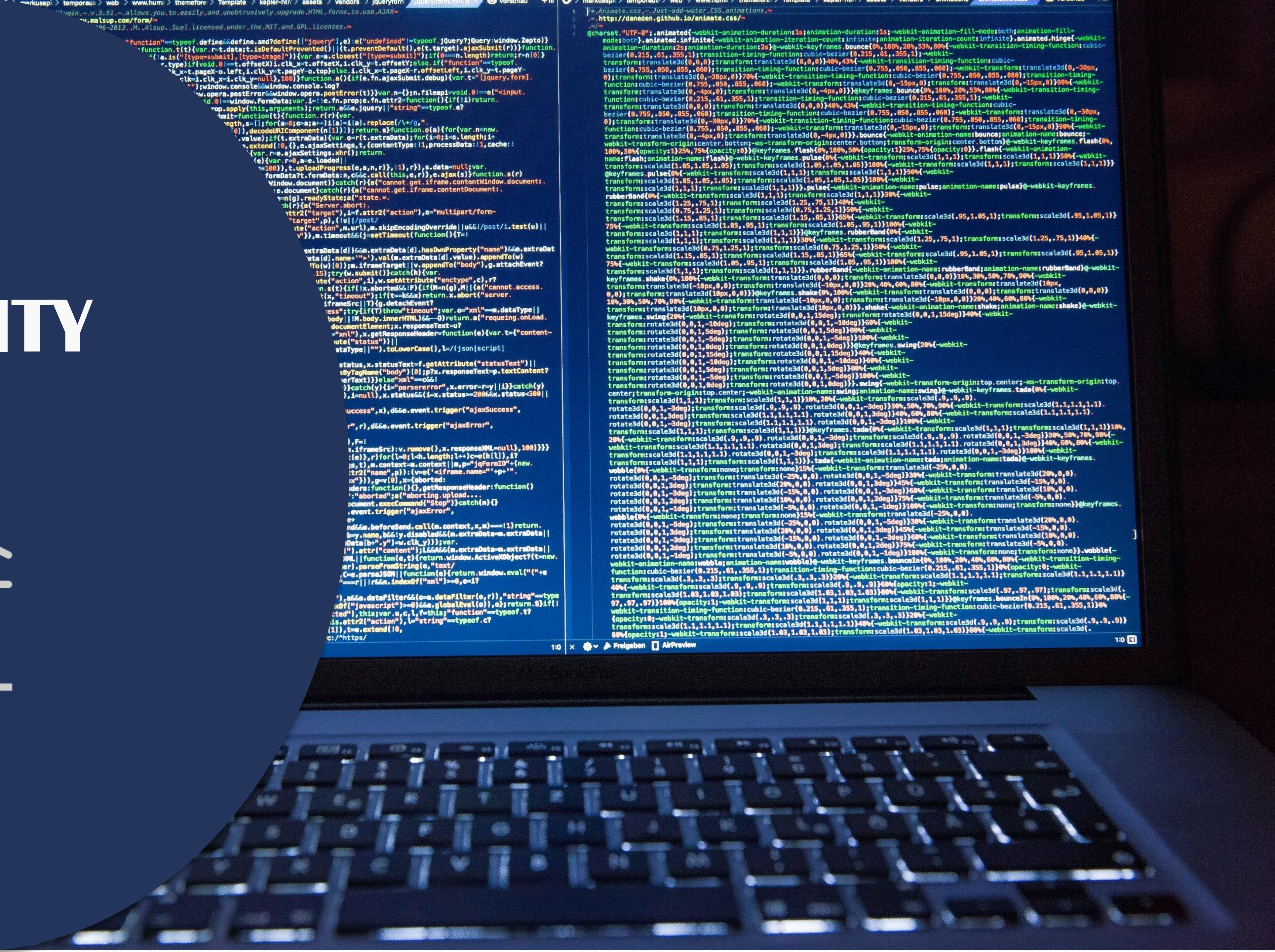
uncertain resource

strong year to year variability

more predictable resources

weekly, size-and sex-structured population dynamic model with Ricker type stock-recruitment function (with uncertainty)

ECOVIABILITY



Ecoviability constraints

The number of vessels is found as to maximize the probability of respecting multiple constraints at each time (i.e. ecoviability probability => **CV**)

Control => fleet size of the fishery

Constraints:

Biological: spawning stock size index (S) of prawns are above a precautionary threshold

$$S_s(y(t)) \geq S_s^{\text{min}}$$

Economic: annual profit of the fishery is above an economic viability threshold

$$\pi(y(t)) \geq \pi^{\text{min}}$$

Sea snake conservation: annual sea snake catch is below a sea snake viability threshold

$$C_{\text{snake}}(y(t)) \leq C_{\text{snake}}^{max}$$

CV = likelihood of respecting these constraints at each time of the simulation

Gourguet et al, 2016. *Environmental Modeling & Assessment*

Ecoviability thresholds

Controls (i.e. management strategies based on) : The number of vessels for the entire fishery

Constraints:

Biological: spawning stock size index of prawns are above a precautionary threshold

$$S_s(y(t)) \geq S_s^{\text{min}}$$

50% of the spawning stock size index of the first year of simulation (based on precautionary approach, FAO 1996)

Economic: annual profit of the fishery is above an economic viability threshold

$$\pi(y(t)) \geq \pi^{\text{min}}$$

50% of the annual profit of the first year of simulation (AU$5.95 million)

Sea snake conservation: annual sea snake catch is below a sea snake viability threshold

$$C_{\text{snake}}(y(t)) \leq C_{\text{snake}}^{max}$$

11 000 individuals (based on max value of catches with status quo management strategy)

Ecoviability results

Status quo: 52 vessels

Controls (i.e. management strategies based on) : The number of vessels for the entire fishery

Constraints:

Biological: spawning stock size index of prawns are above a precautionary threshold

$$S_s(y(t)) \geq S_s^{min}$$

→ No real trade-offs with other objectives

Economic: annual profit of the fishery is above an economic viability threshold

$$\pi(y(t)) \geq \pi^{min}$$

50% of the annual profit of the first year of simulation (AU$ 5.95 million)

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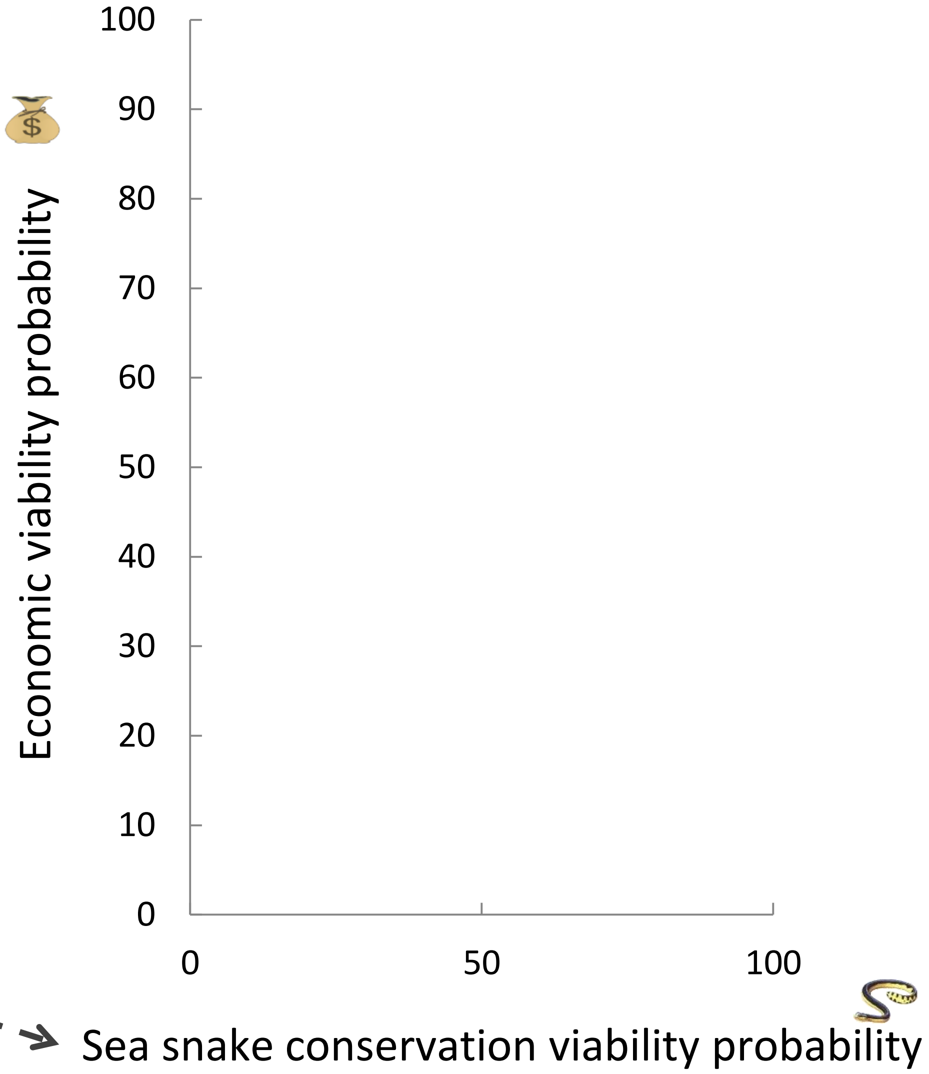

Ecoviability results

Status quo: 52 vessels CV = 80.51 %

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Controls (i.e. management strategies based on) : The number of vessels for the entire fishery

CV=91.2% (biological viability = 96.3%)

Constraints:

Biological: spawning stock size index of prawns are above a precautionary threshold

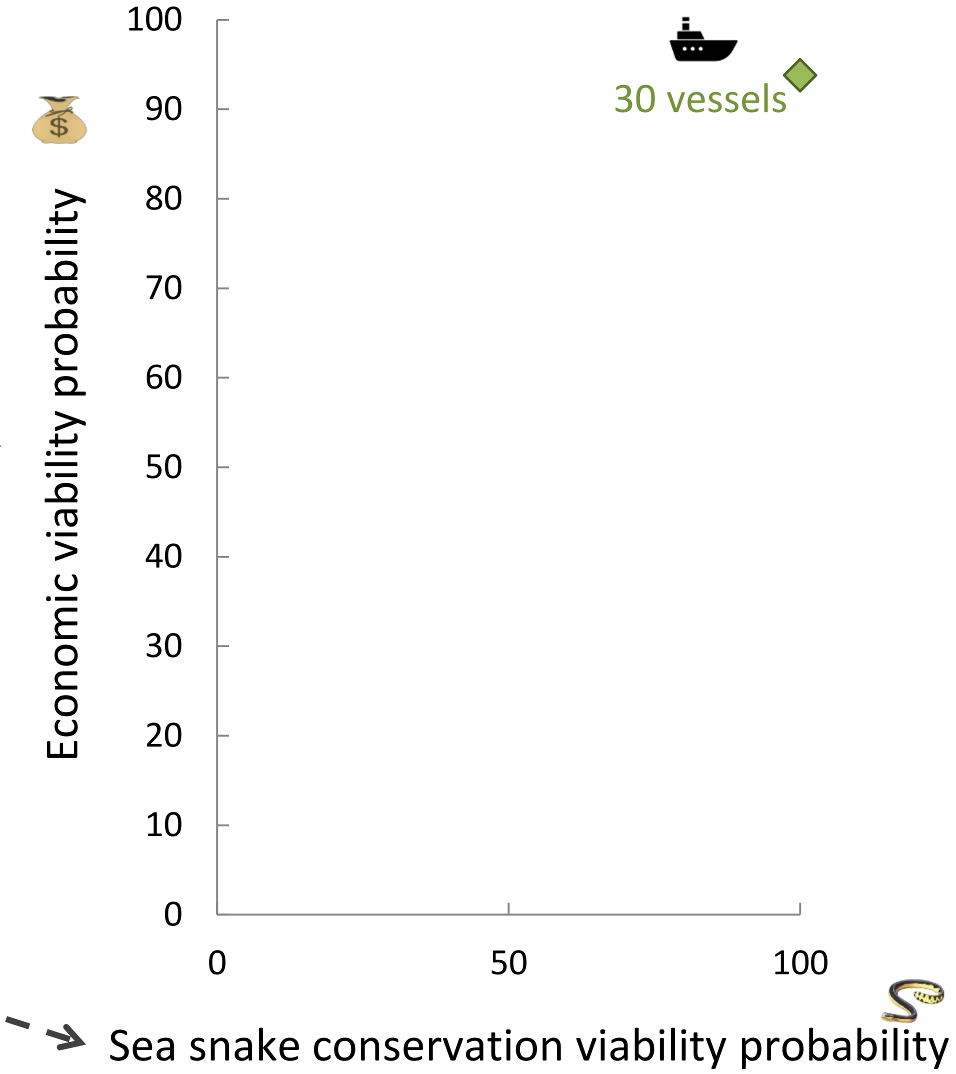
$S_s(y(t)) \geq S_s^{\min}$ → No real trade-offs with other objectives

Economic: annual profit of the fishery is above an economic viability threshold

$\pi(y(t)) \geq \pi^{\min}$ *50% of the annual profit of the first year of simulation (AU$ 5.95 million)*

Sea snake conservation: annual sea snake catch is below a sea snake viability threshold

$C_{snake}(y(t)) \leq C_{snake}^{max}$ *11,000 individuals (based on max value of catches with status quo management strategy)*



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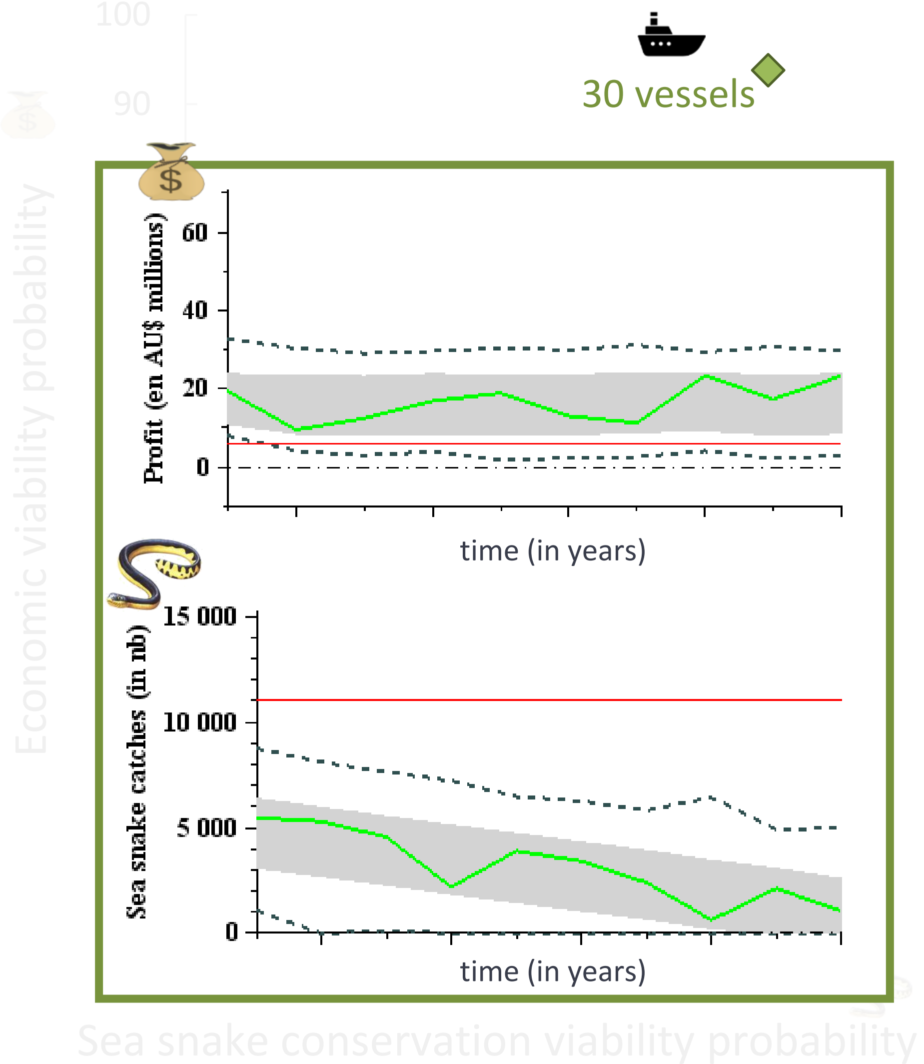


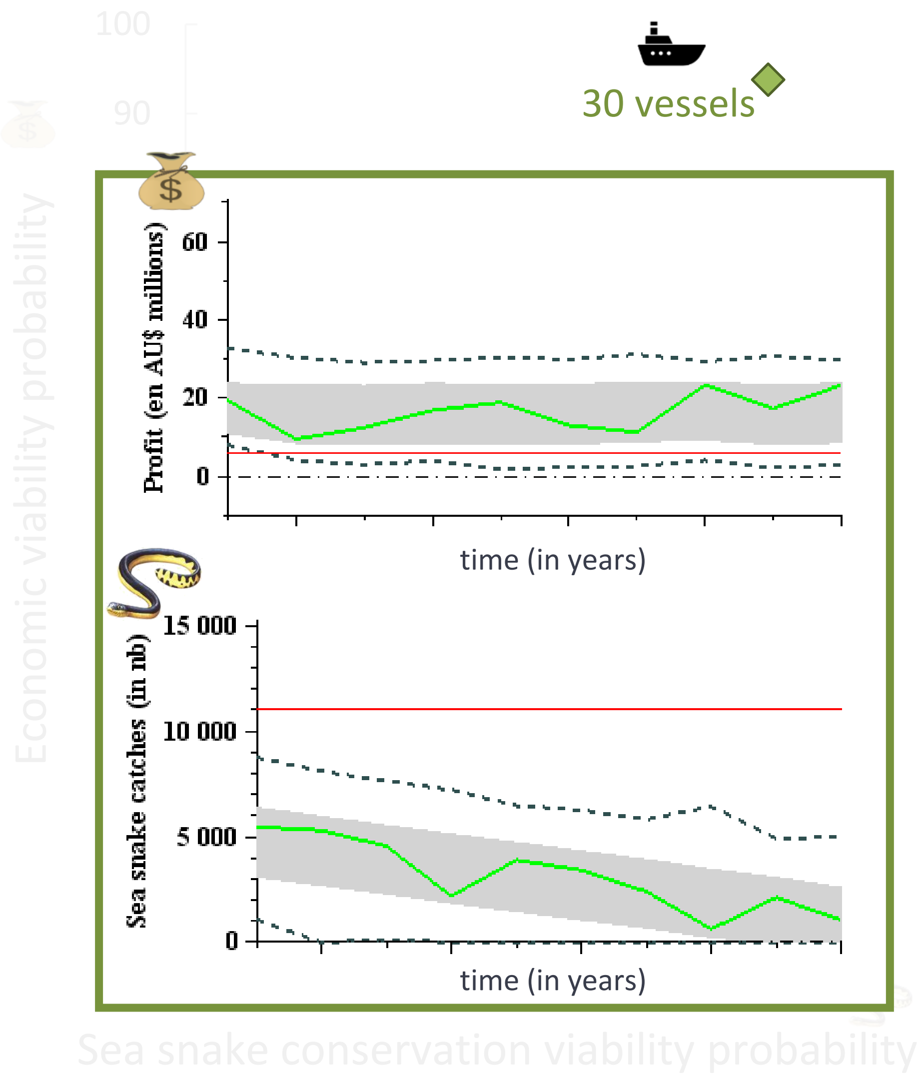
Ecoviability results

Status quo: 52 vessels

CV = 80.51 %

CV=91.2% (biological viability = 96.3%)

Ecoviability results depend on the viability thresholds defined

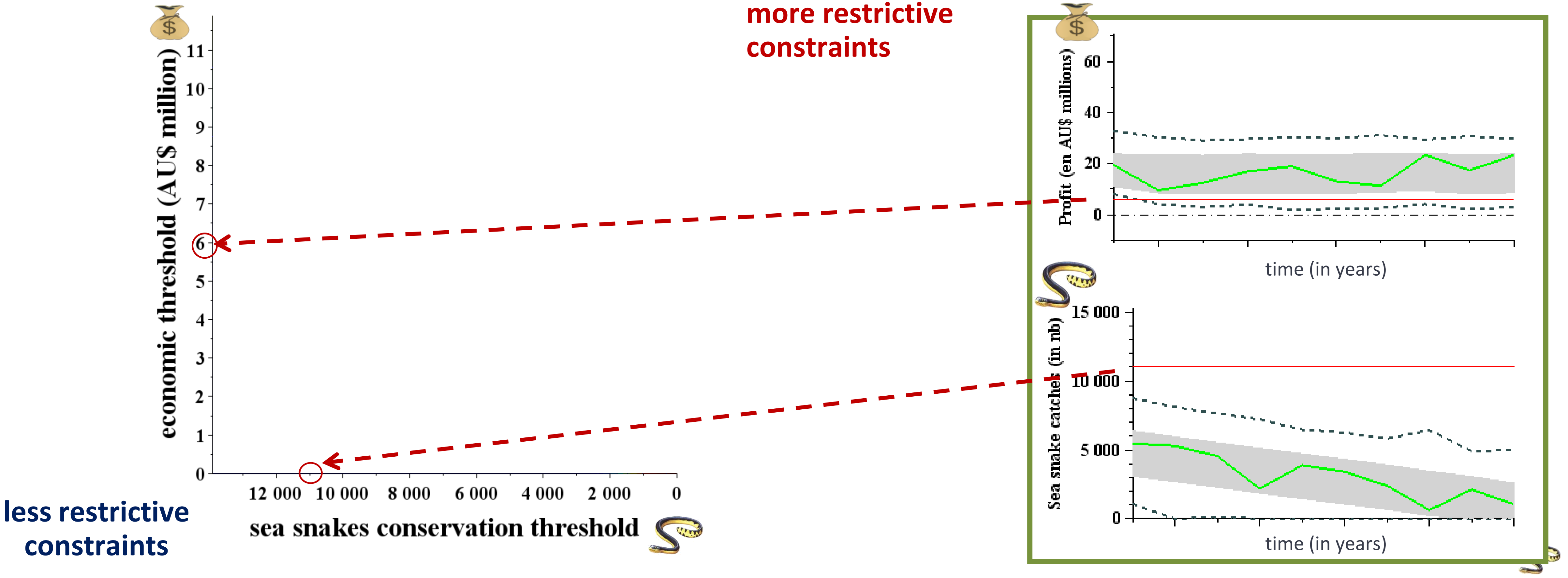


Sensitivity analysis on viability thresholds

Different values of economic viability threshold and sea snake conservation viability threshold

CV=91.2% (biological viability = 96.3%)

30 vessels

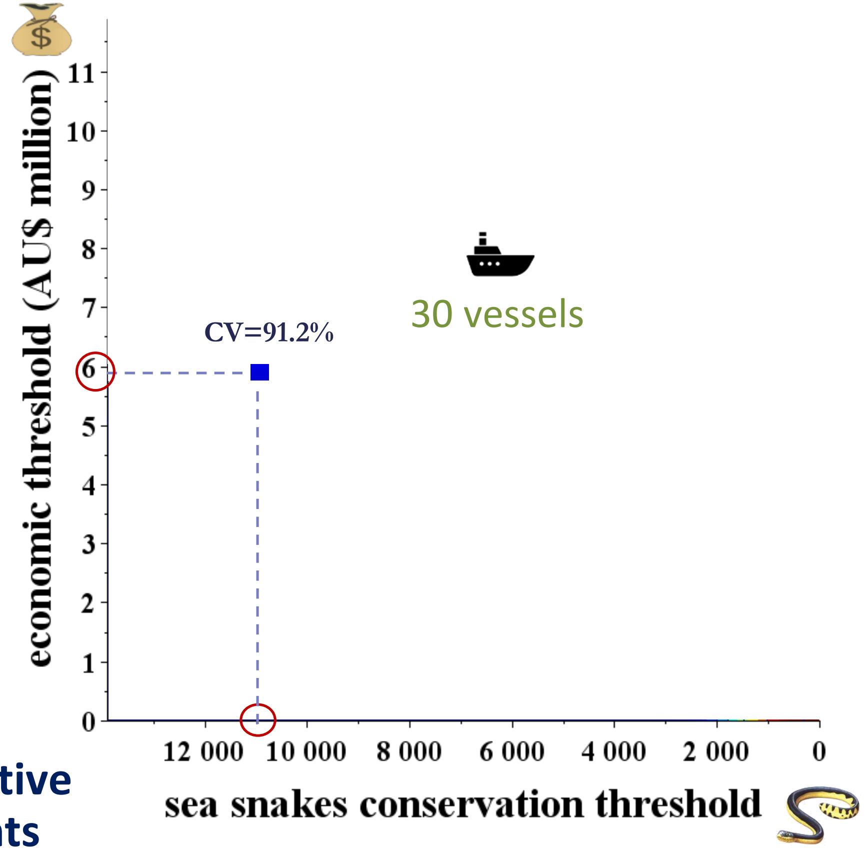


Gourguet et al, 2016. *Environmental Modeling & Assessment*

Sensitivity analysis on viability thresholds

Different values of economic viability and sea snake conservation viability thresholds

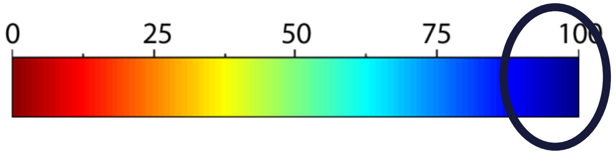
for each combination of threshold values: identify the number of vessels that maximizes the ecoviability probability (probability of satisfying all defined constraints)



more restrictive constraints

less restrictive constraints

Ecoviability probability (probability of satisfying all defined constraints)



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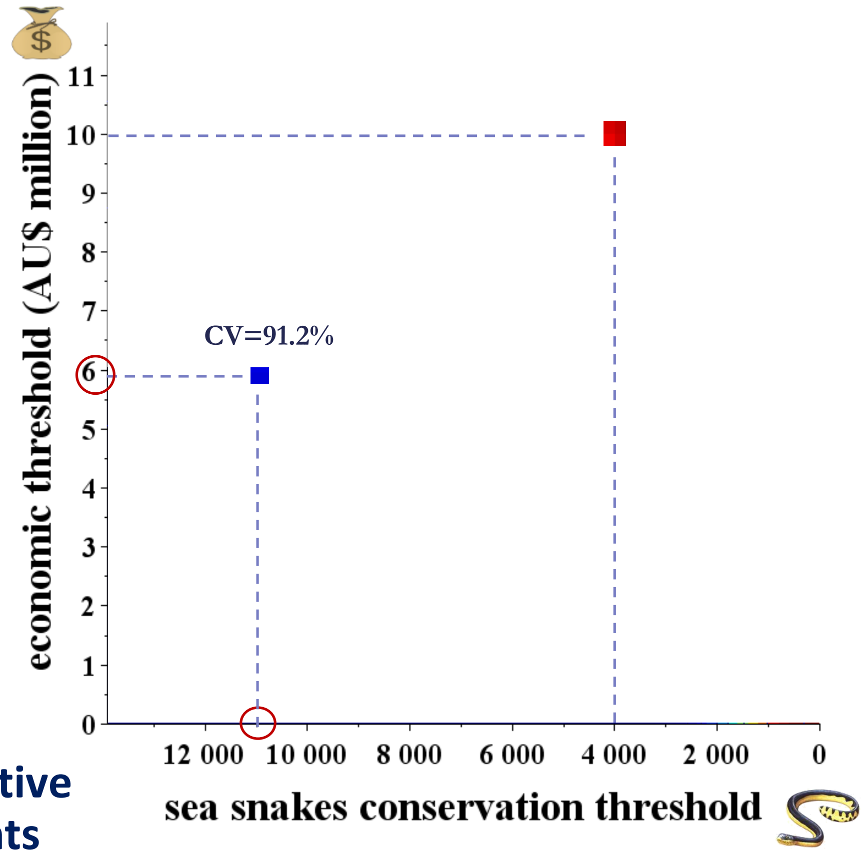
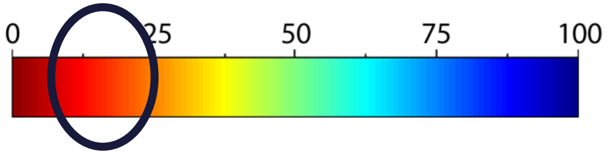


less restrictive constraints

Ecoviability probability (probability of satisfying all defined constraints)



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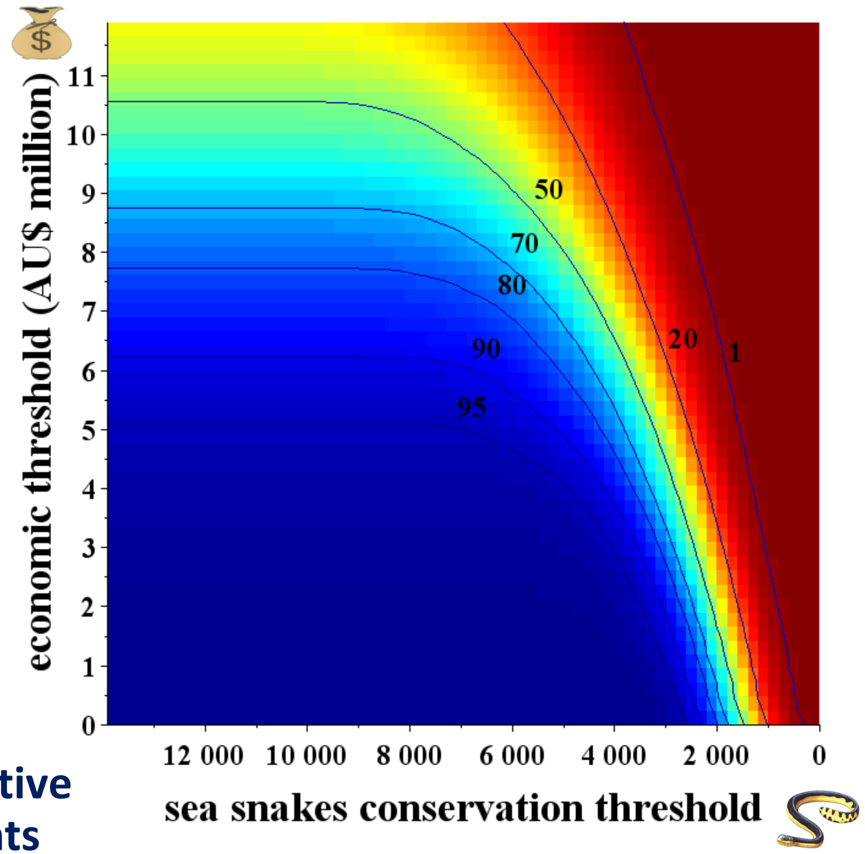
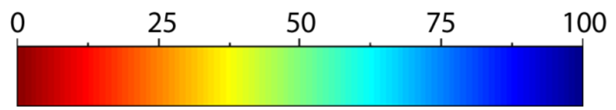


more restrictive constraints

less restrictive constraints

Ecoviability probability (probability of satisfying all defined constraints)



How to help decision making

Ecoviability probability (probability of satisfying all defined constraints)

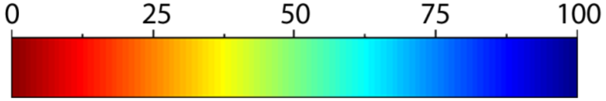
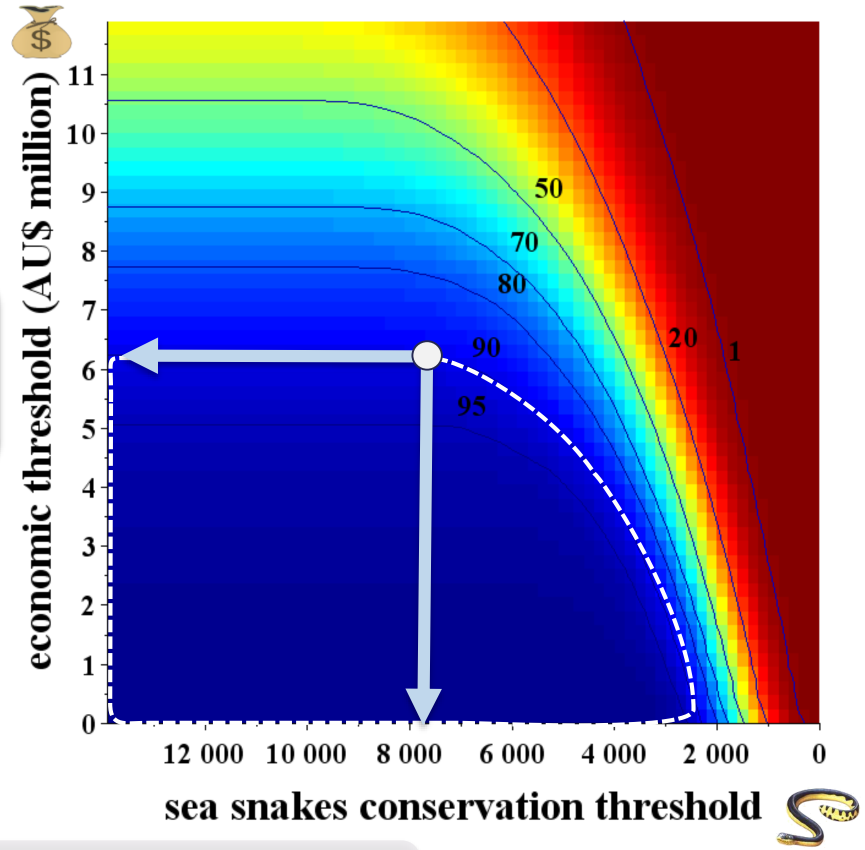


Illustration of how the results can aid in selecting a set of viability thresholds and making related management decisions



max economic threshold: 6.2 AU$ million

min sea snake catch threshold: 7 700 indv.

1- select a minimum confidence level to guarantee for ecoviability probability => e.g. 90%

2- within the defined "sustainable space" => identify the maximum economic viability threshold

3- then among the various possibilities : minimizes the sea snake catch viability threshold

Identification of the **"Trade-Off Point" (TOP)**

=> associated fleet size: 30 vessels

Economic uncertainty

Bio-economic models used for fisheries management often overlook economic uncertainty, in contrast with biological uncertainties that are most of the time taken into account

Results I showed: when considering a base case economic scenarios (fuel price and prawn market prices considered constant over the time of the simulation)

⇒ Are the results sensitive to economic scenarios? Which implication in terms of management?

Assessing and comparing results from viability analyses when accounting for various economic scenarios

CV

0 25 50 75 100

PRAWN PRICE SCENARIOS

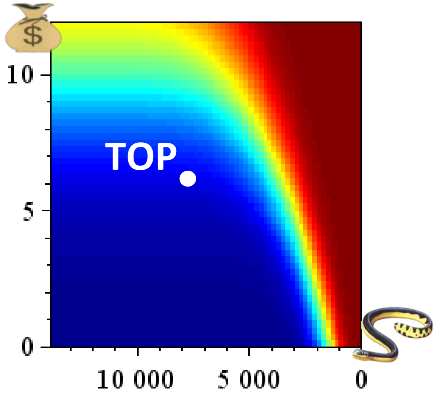
P decrease by 3 % | P decrease by 2 % | P BASE CASE | P increase (as in Punt et al, 2011)

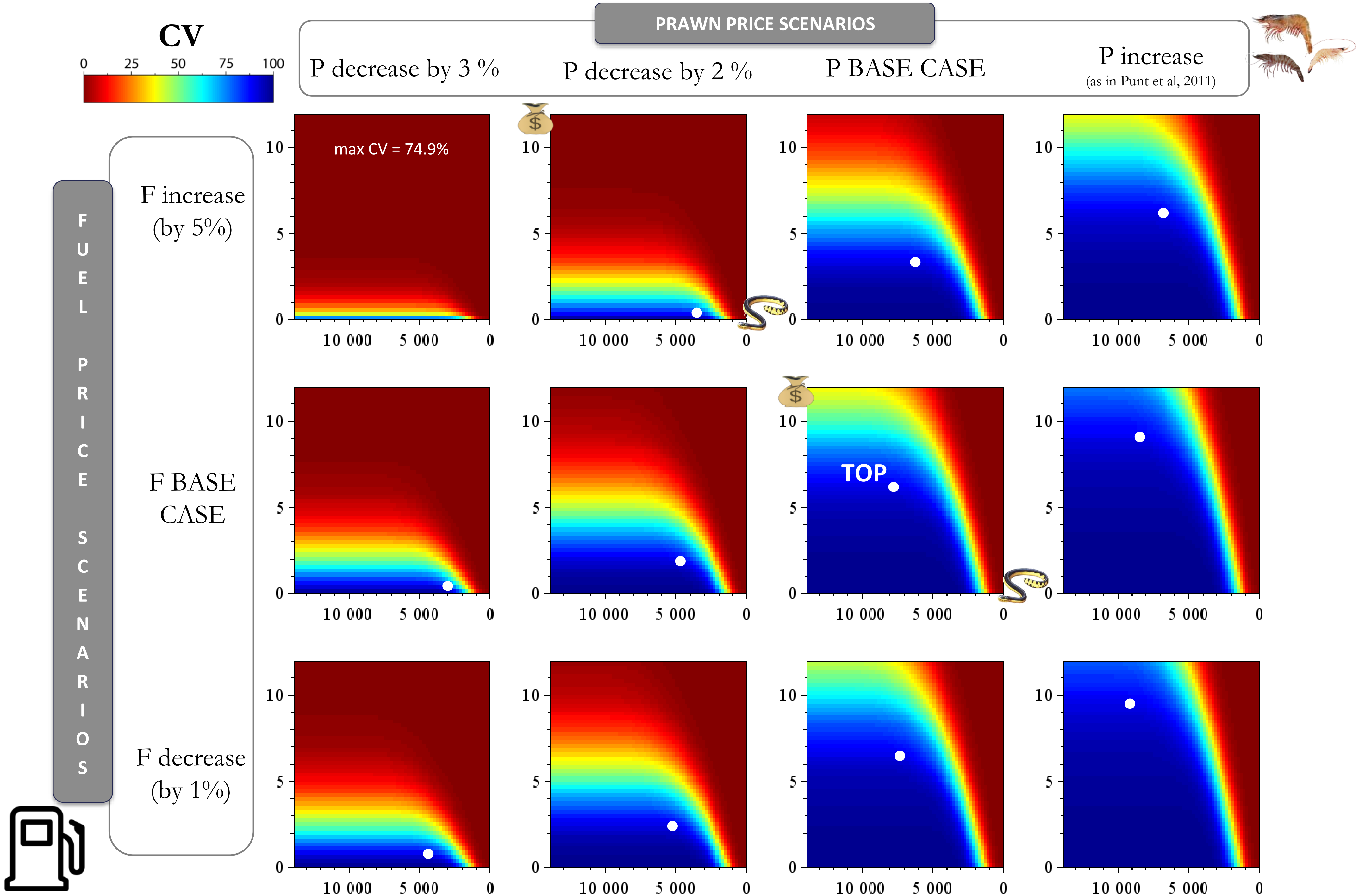
FUEL PRICE SCENARIOS

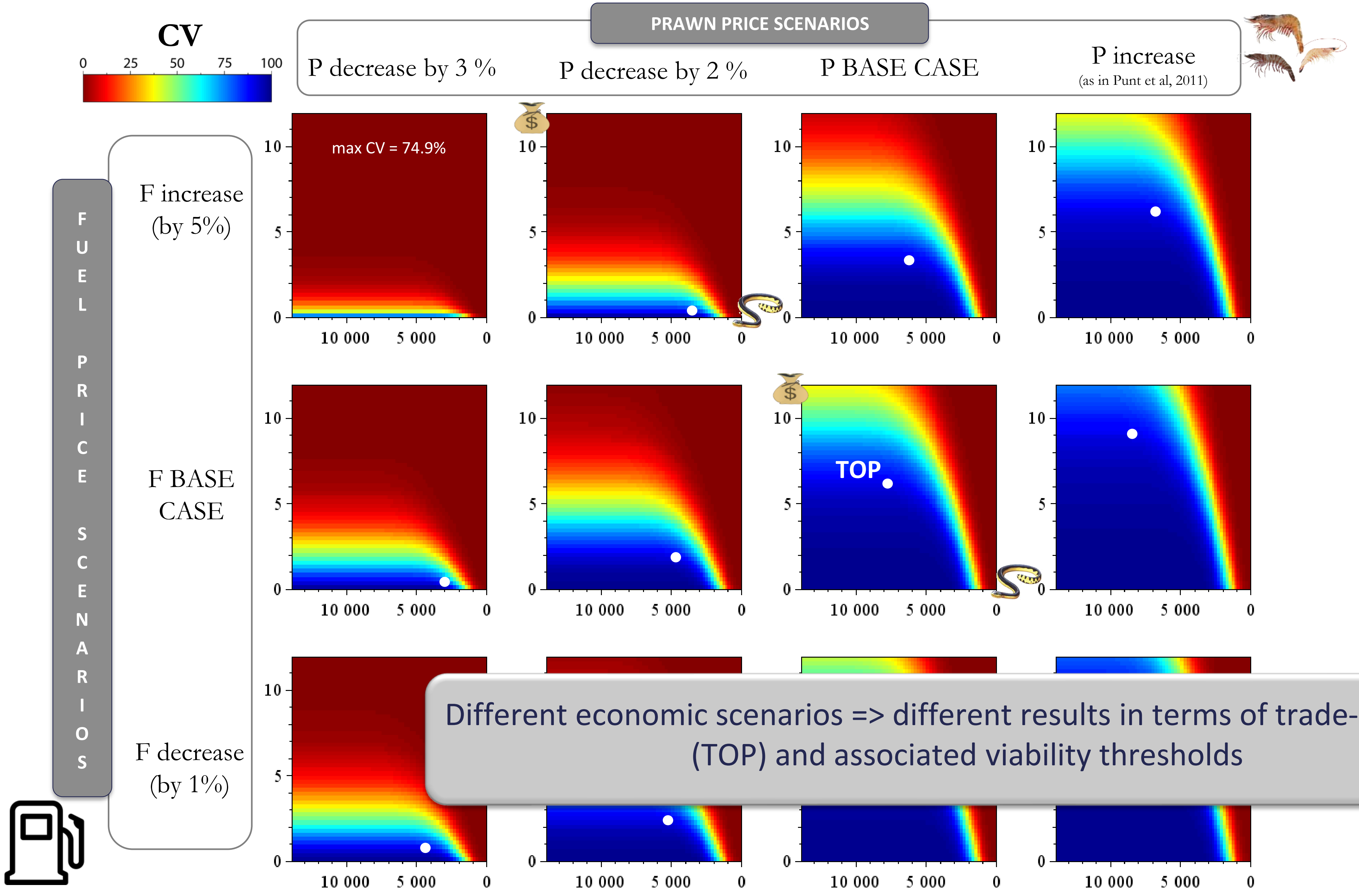
F increase (by 5%)

F BASE CASE

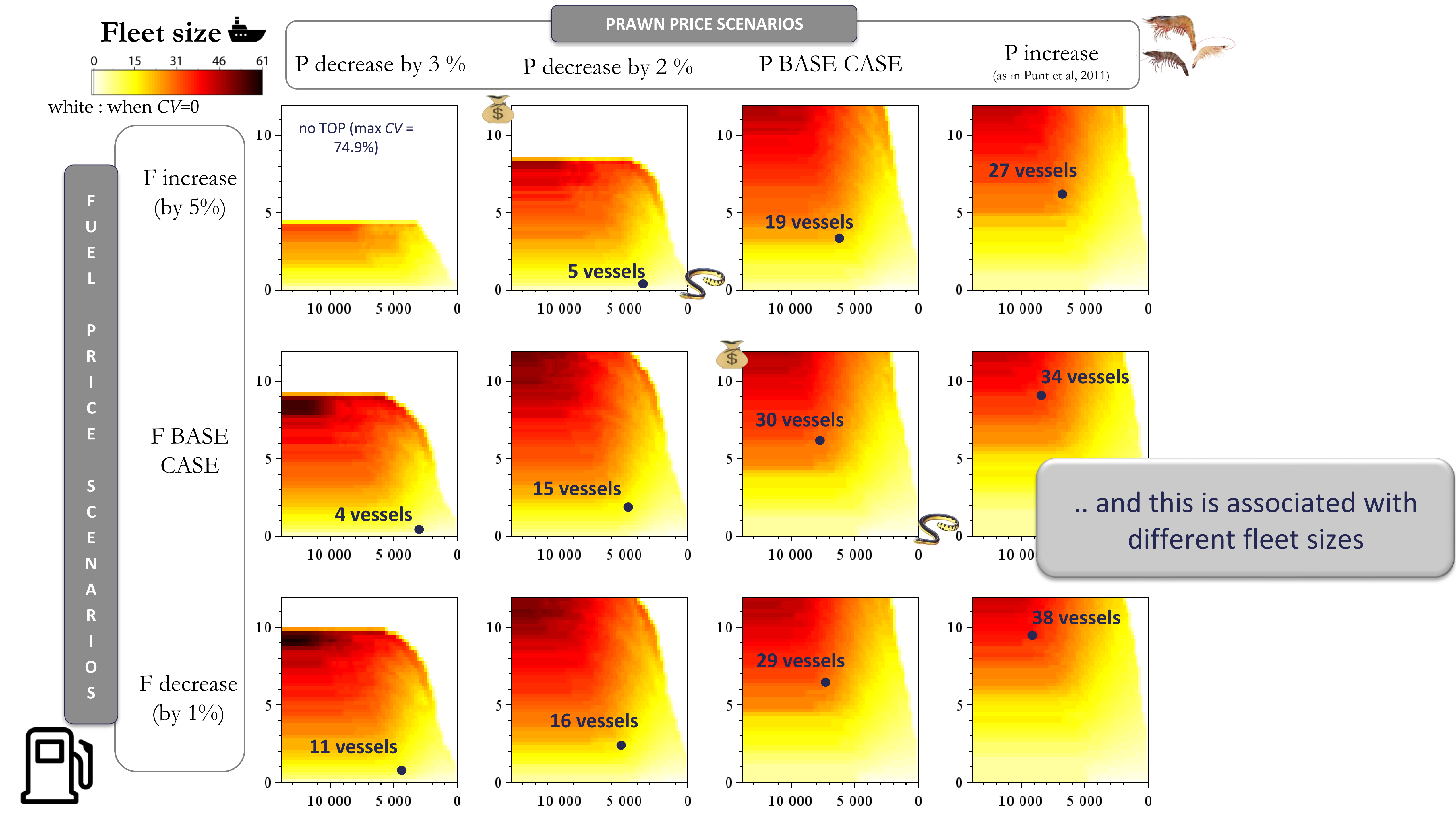
F decrease (by 1%)




CV
0 25 50 75 100
PRAWN PRICE SCENARIOS
P decrease by 3 %
P decrease by 2 %
P BASE CASE
P increase
(as in Punt et al, 2011)
FUEL PRICE SCENARIOS
F increase
(by 5%)
F BASE CASE
F decrease
(by 1%)
max CV = 74.9%
TOP
10 000
5 000
0
10
5
0



Different economic scenarios => different results in terms of trade-off points (TOP) and associated viability thresholds



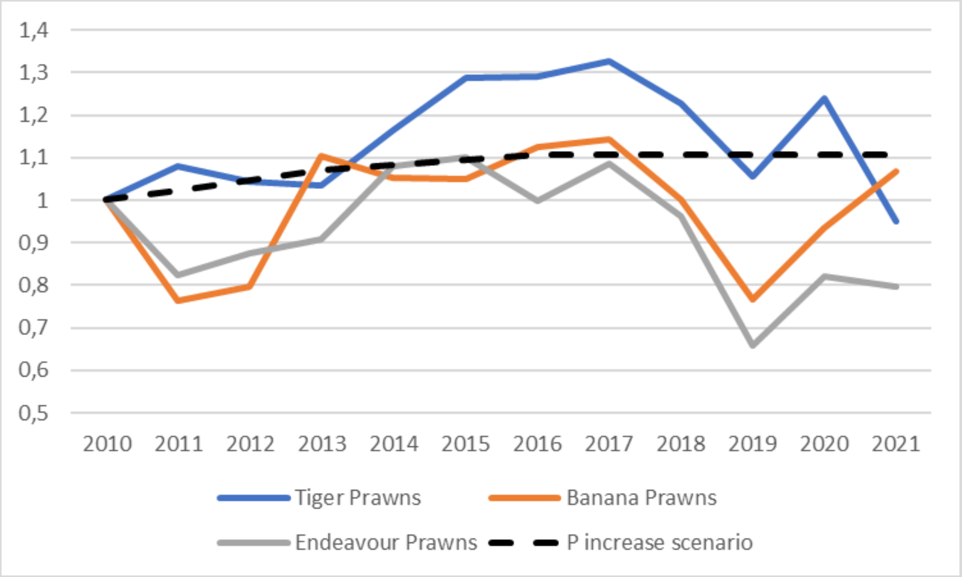
Fleet size
0
15
31
46
61
white : when CV=0
PRAWN PRICE SCENARIOS
P decrease by 3 %
P decrease by 2 %
P BASE CASE
P increase
(as in Punt et al, 2011)
FUEL PRICE SCENARIOS
F increase (by 5%)
F BASE CASE
F decrease (by 1%)
no TOP (max CV = 74.9%)
5 vessels
19 vessels
27 vessels
4 vessels
15 vessels
30 vessels
34 vessels
11 vessels
16 vessels
29 vessels
38 vessels
10
5
0
10 000
5 000
0
.. and this is associated with different fleet sizes

Historical evolution of the economic parameters

"Old" simulations here: from 2010 to 2020 ! → We know what really happened for prawn and fuel prices

Economic scenario => based on evolution between 2010-2020 of prawn prices and fuel prices (in real value)

Prawn prices:
different evolution for tiger, banana and endeavour prawns
To note:
- Competition with aquaculture (major arrival on the Australian market => lower prices)
- Ecolabel (MSC) in 2013 => positive impact on (tiger) prawn prices



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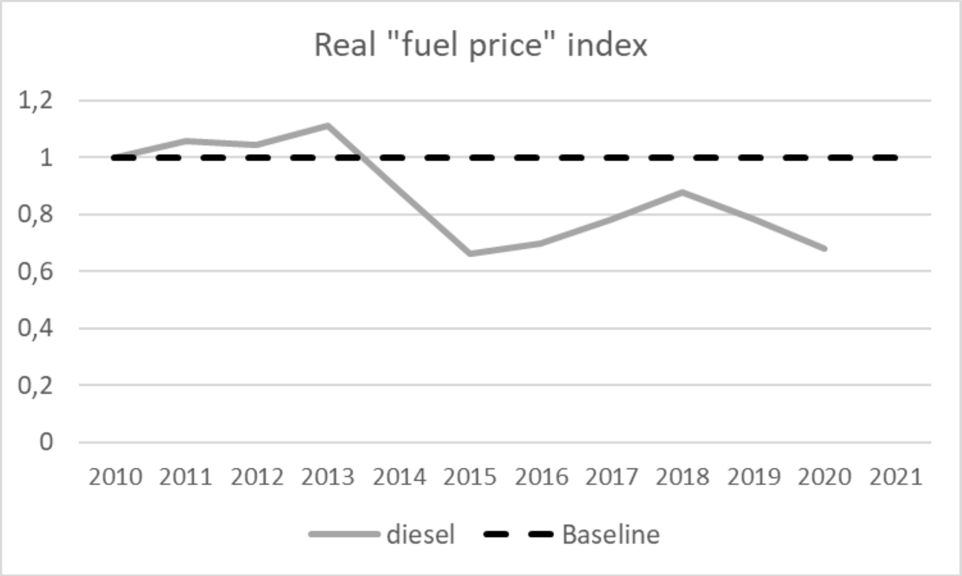
Economic scenario => based on evolution between 2010-2020 of prawn prices and fuel prices (in real value)

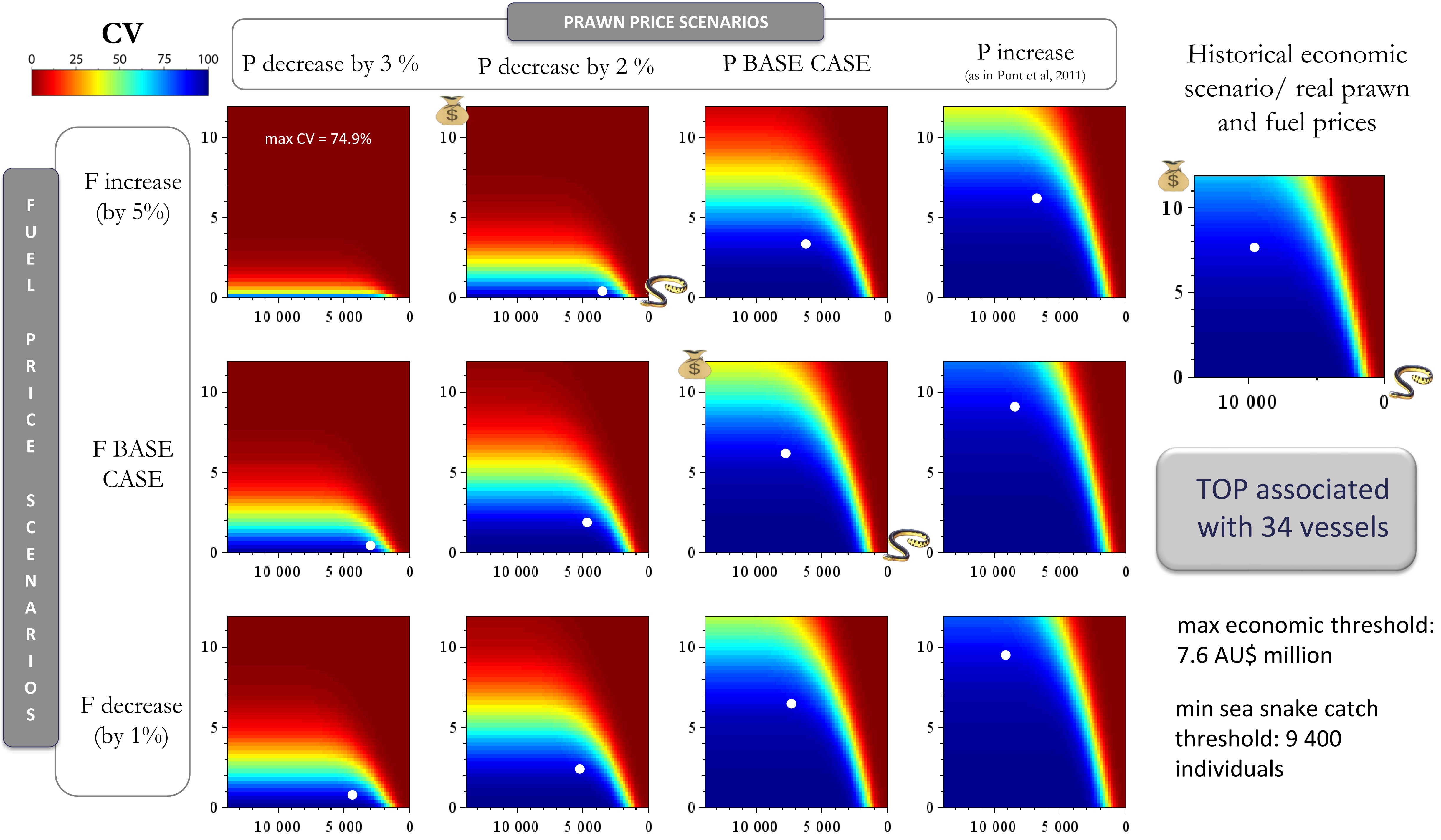
Fuel prices:

Tendency to decrease

Implementation of fuel purchasing strategies to bring prices down => "Bulk" buying



Data source: ABARES



CV
0 25 50 75 100
PRAWN PRICE SCENARIOS
P decrease by 3 %
P decrease by 2 %
P BASE CASE
P increase
(as in Punt et al, 2011)
Historical economic scenario/ real prawn and fuel prices
FUEL PRICE SCENARIOS
F increase (by 5%)
F BASE CASE
F decrease (by 1%)
max CV = 74.9%
10
5
0
10 000
5 000
0
$
TOP associated with 34 vessels
max economic threshold: 7.6 AU$ million
min sea snake catch threshold: 9 400 individuals

Discussion

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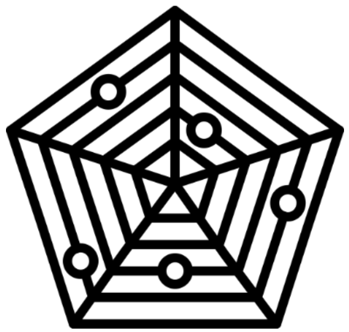
Trade-offs between multiple objectives



⇨ This framework might **help fisheries managers and stakeholders to find consensus** when assessing management strategies

⇨ Identification of the TOP (trade-off point) => might help setting viability thresholds

Discussion

Economic scenario analyses

Results are sensitive to the assumptions made on evolution of prawn market and fuel prices

NPF: under every economic scenarios, we need to reduce the current fleet size to maximize the probability of co-viability (i.e. to have a sustainable fishery)

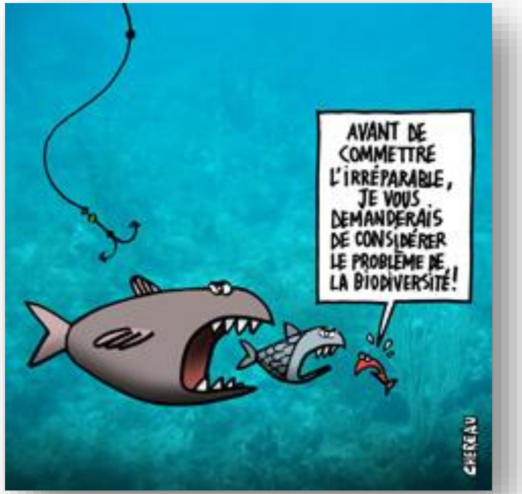
⇒ requires reductions in the fleet size compared to the status quo (i.e. 52 vessels)

Situation today : fishery still with 52 vessels, so assumption of fleet size constant overtime, relevant in this case

Importance of the assumptions we make about the economic parameters when managing a fishery

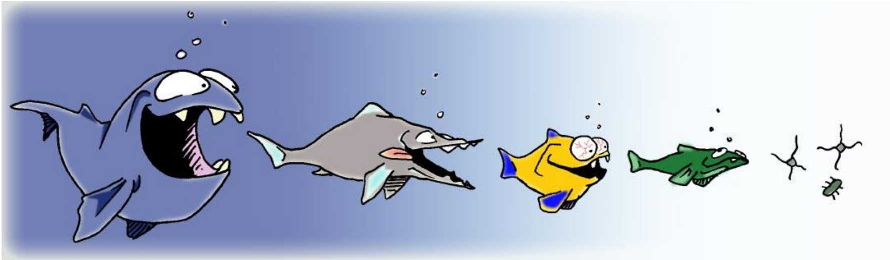
Question: can we predict these parameters better?

Perspectives



Extension toward a biodiversity conservation objective (including a suite of groups, such as rays, sharks, sawfishes, turtles, etc.)

Incorporation of a broader set of objectives (as social dimensions)



Ecological interactions (to better address the needs of ecosystem-based approaches to the sustainable harvesting of marine biodiversity)

Climate change scenarios (especially for banana prawn biomasses)

Thank you for your attention

A prawn trawler returning to Cairns from the Northern Prawn Fishery. Brian Cassey, CSIRO

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