# Developing ecosystem understanding for Ecosystem-Based Fisheries Management (EBFM) of fish resources

AFS Webinar 2: 24th September 2024

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Murdoch University

# Acknowledgement of Country

We acknowledge that Murdoch University is situated on the lands of the Whadjuk and Binjareb Noongar people.

We pay our respect to their enduring and dynamic culture and the leadership of Noongar elders past and present.

The boodjar (country) on which Murdoch University is located has for thousands of years, been a place of learning. We at Murdoch University are proud to continue this long tradition.

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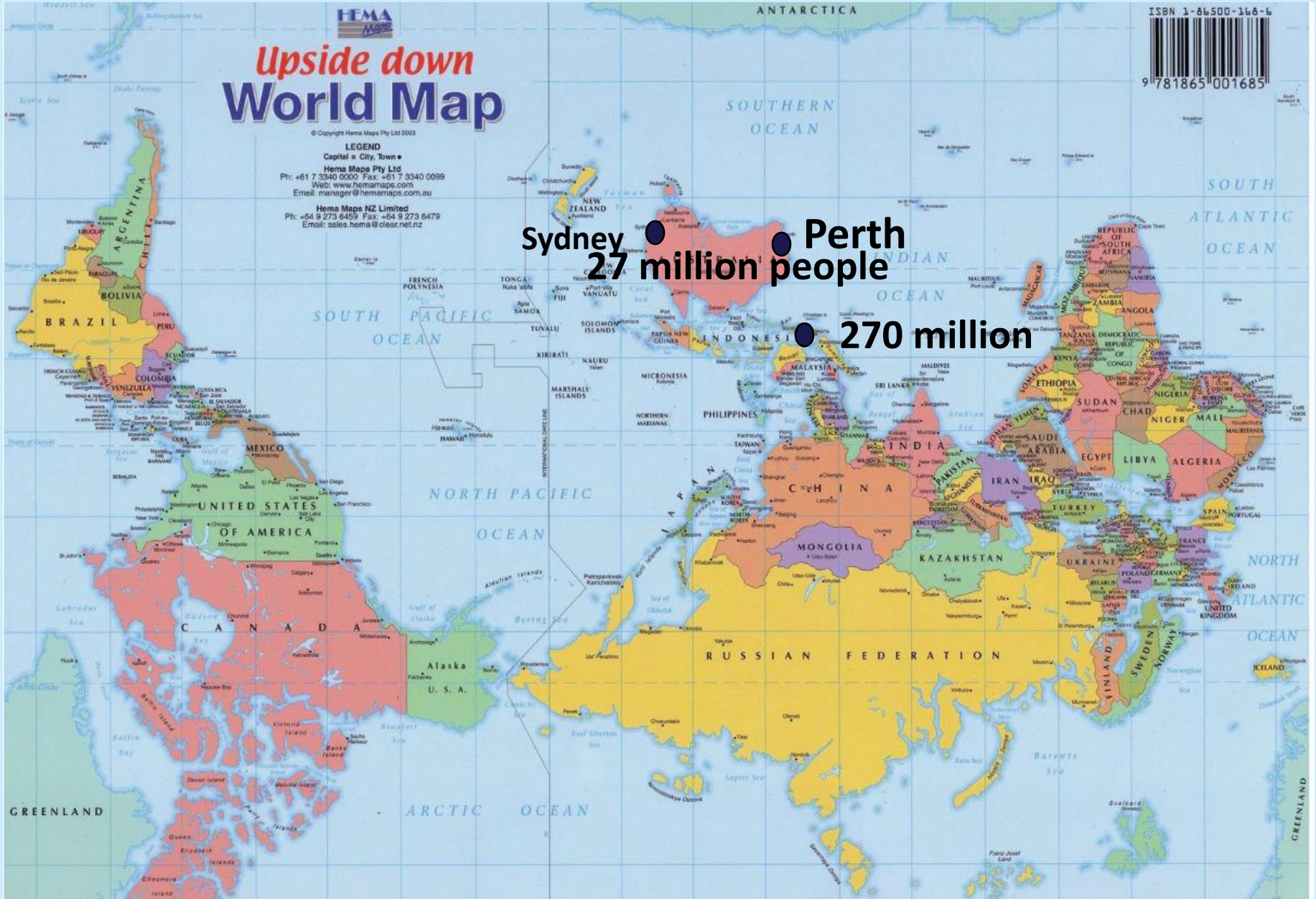
Free your think

# Outline

1. Global, Asian and Australian fisheries
2. Assessment of Asian Fish stocks and the importance of a strong Asian Fisheries Society
3. Evolution of Fisheries Management to reach Ecosystem Based Fisheries Management
4. Developing ecosystem understanding using models – conceptual, qualitative, quantitative models
   a) Example of fished species and a habitat (Australia)
   b) Example of grouper species in Asia (Saleh Bay, Indonesia)

# An Australian perspective




2015 Fisheries assessment workshop
IBP ICC

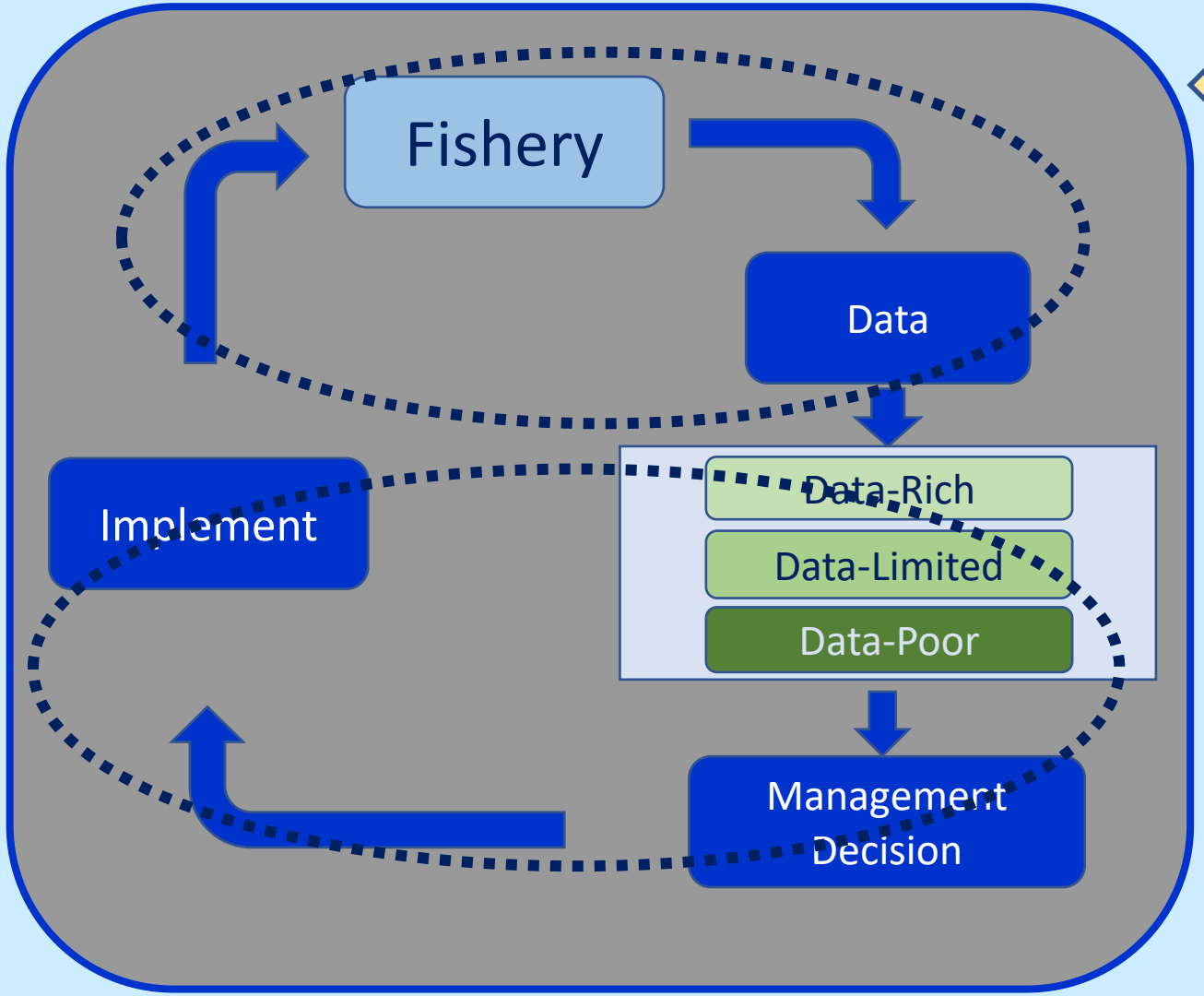

2023 Ecosystem modelling (Lenfest) Bogor


2019 Data-limited fisheries workshops
IBP Techno Park

Murdoch UNIVERSITY
UBC
ACIAR
THE CRAWFORD FUND
KFW
WCS

LENFEST OCEAN PROGRAM

# Fisheries Management System




Objectives

Ecological Economic Social



## Trans-disciplinary approach

- People, culture & fisheries
- Biology and ecology
- Data, statistics & models
- Communication

(design by Dr Adrian Hordyk)

# World Fisheries and Aquaculture production of aquatic animals

(FAO, 2024)

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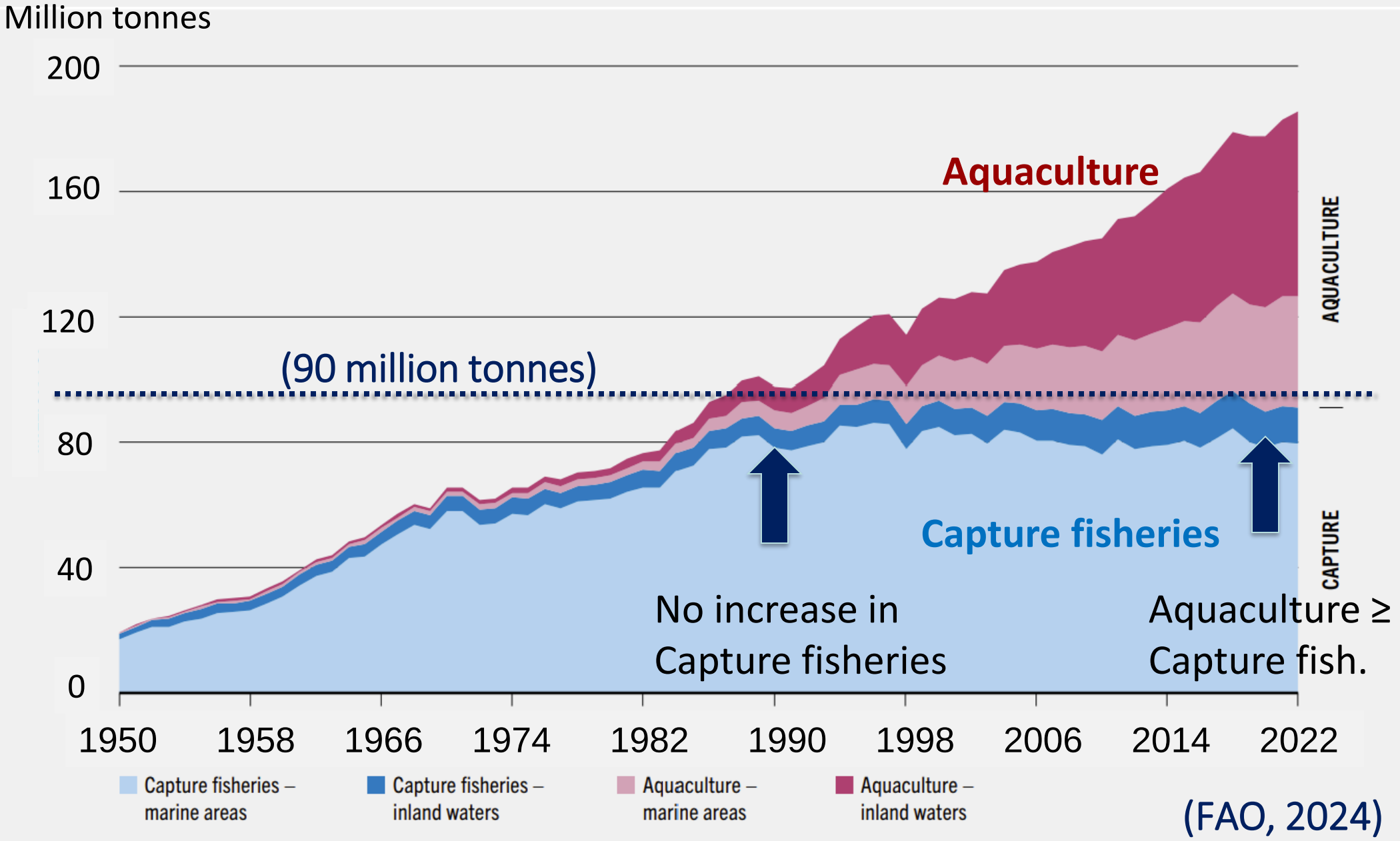
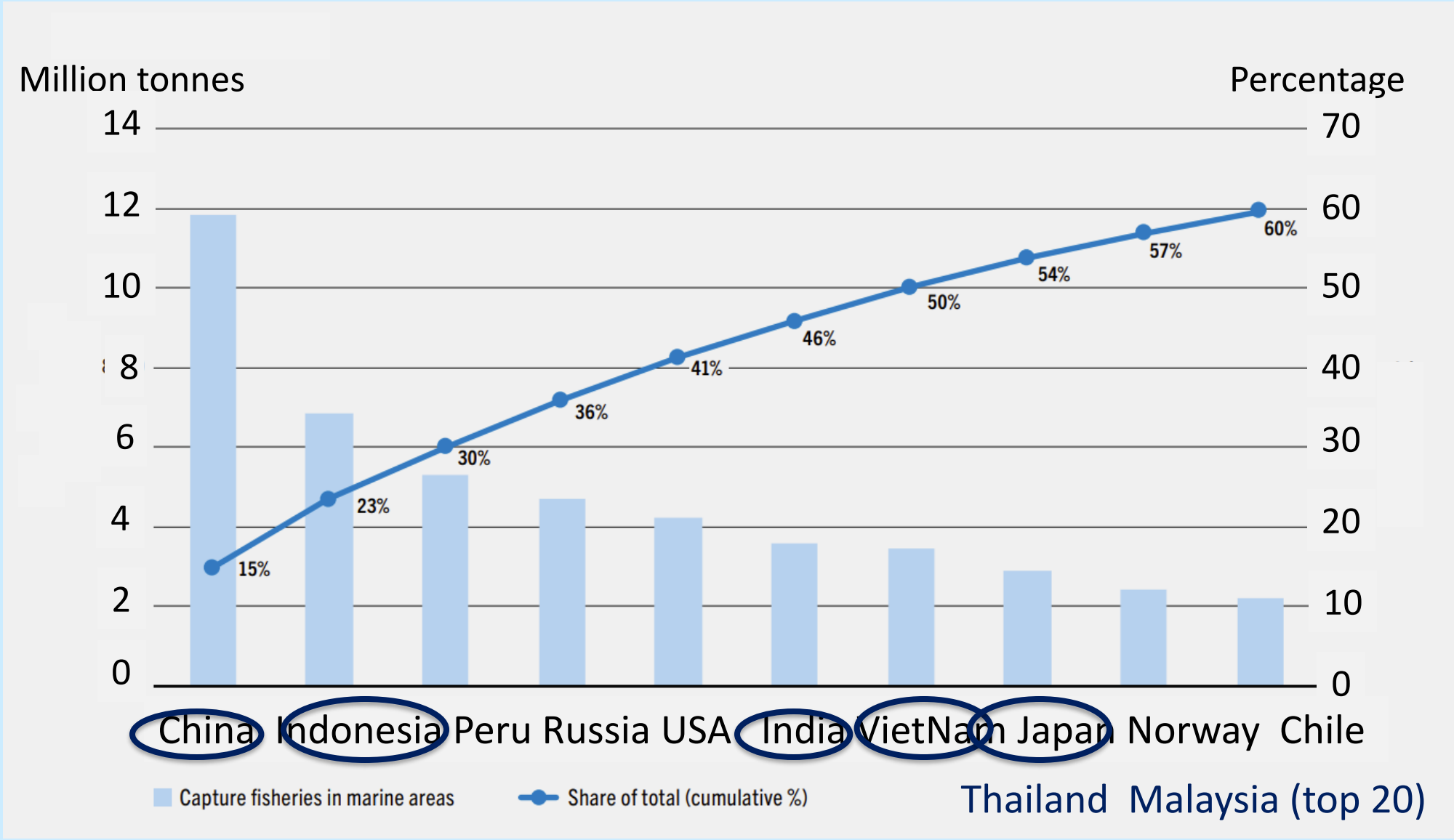



(FAO, 2024)

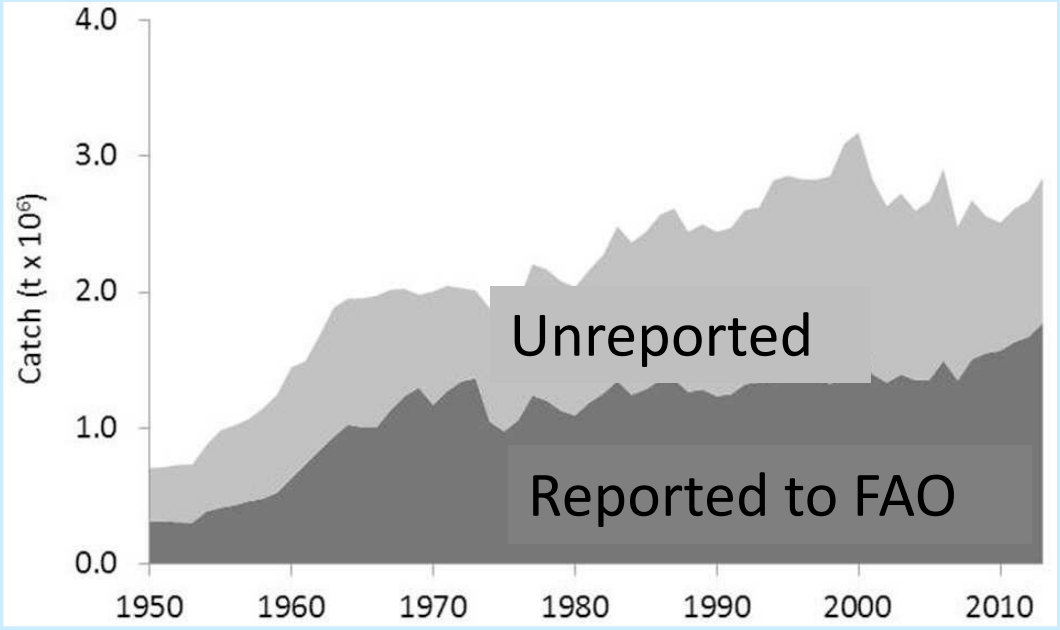
# Top ten marine capture fisheries nations (FAO, 2024)




Asia: largest fleet in the world – 3.5 million vessels, 75% of the global fleet

# Small scale fisheries

- These fisheries are very significant for livelihoods and nutrition - many fishers, many fishing methods
- Catches and fishing effort in SSF are often under-reported



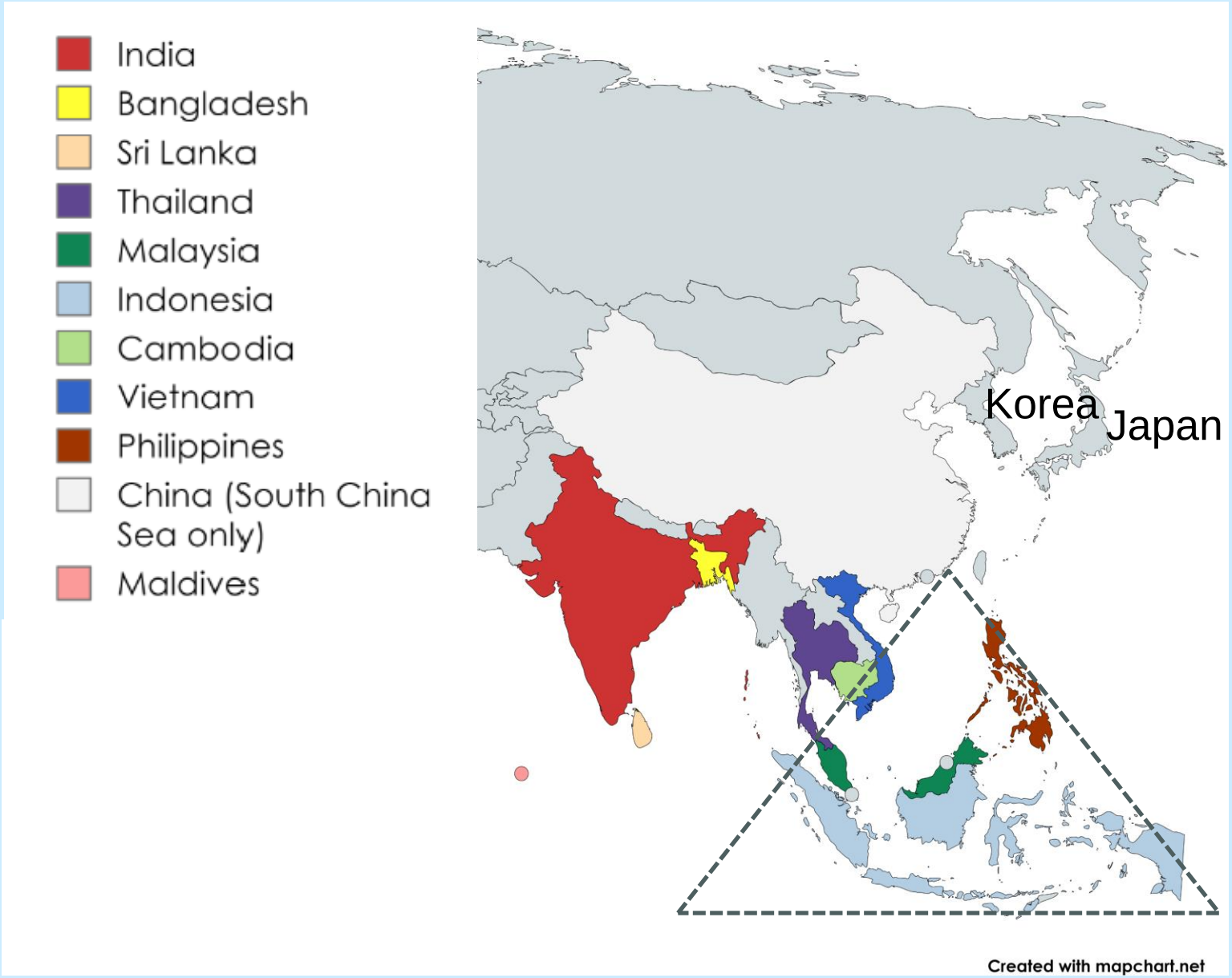

Reconstructed catches for:

Cambodia
Malaysia
Thailand
Vietnam

(Teh and Pauly, 2018)

- Assessment and management of SSF are challenging

# Asian Fisheries and Aquaculture – Asia-Pacific region

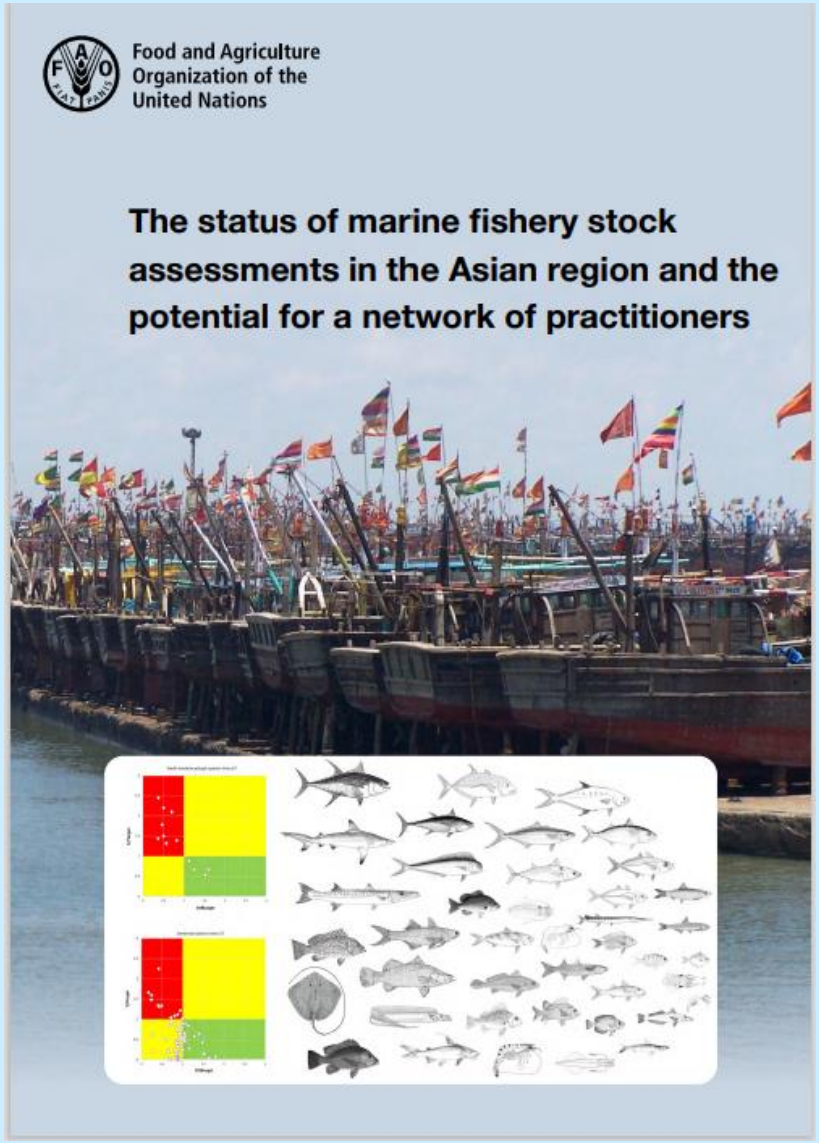


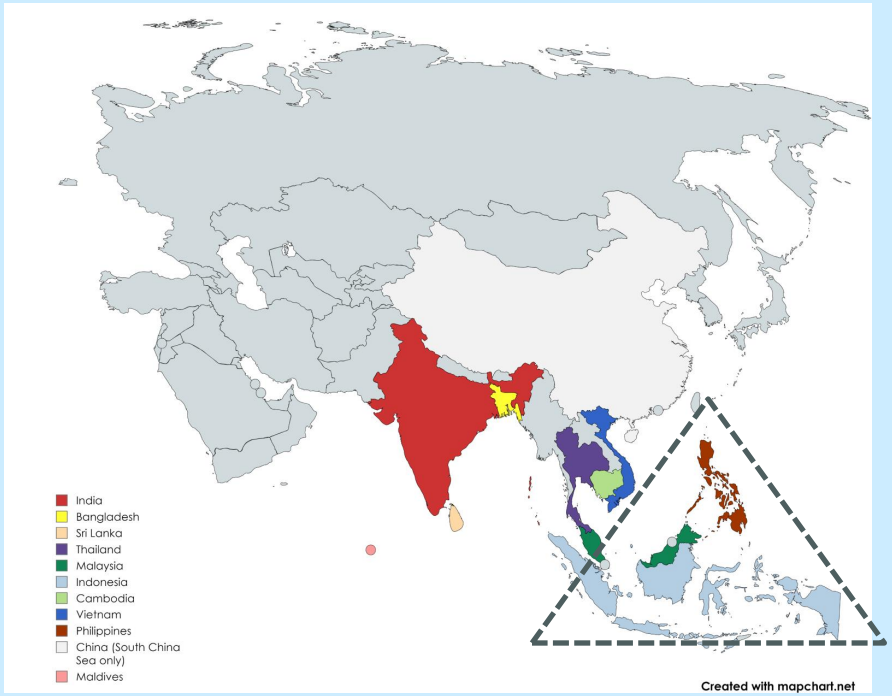

1. Largest marine capture fisheries landings globally
2. Largest aquaculture production globally
3. Millions of livelihoods supported
4. Marine biodiversity hotspot (Coral Triangle)

**>70% of global seafood**

# Asian fish stocks and their assessment

FAO Bangkok workshop January 2023, https://doi.org/10.4060/cc9002en



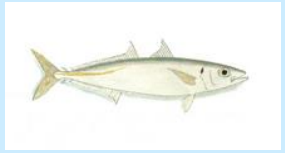




- 10 country assessments
- 10 localized assessments
- Pelagic, reef, and demersal species working groups

# Findings FAO Workshop

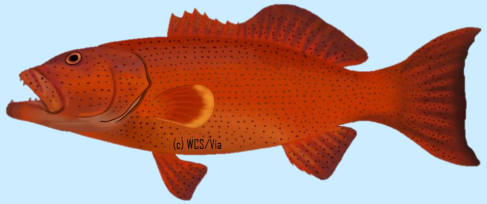
**Small-medium pelagics** **Reef** **Demersal**

Hilsa



Mackeral Scad

Bali sardine



Coral leopard Grouper

Blue Swimmer Crab (BSC)

- Virtually all stocks fully or over-exploited (similar to FAO assessments)
- Data collection and measurement programs are impressive
- People are applying past, current and emerging methods – good technical capacity, some success stories – BSC in Sri Lanka

**Gaps, areas where assessments can be enhanced**

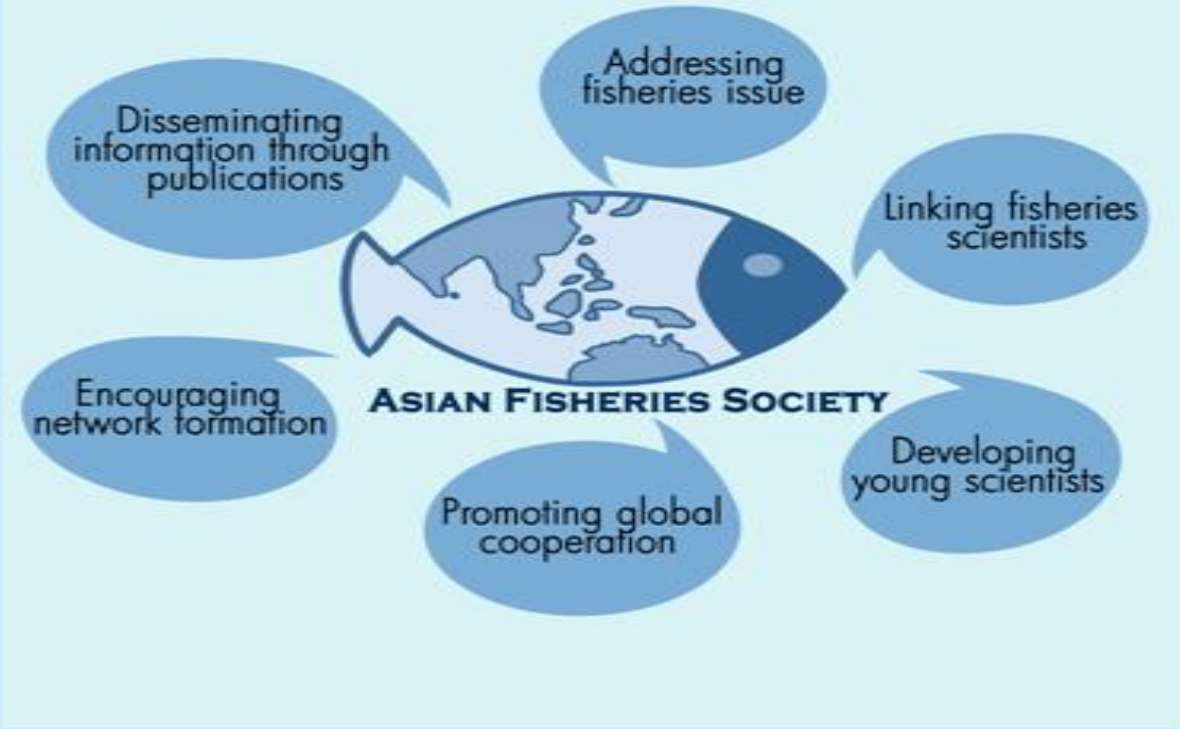
- No ecosystem assessments, No social indicators for fisheries
- Little discussion on sampling design, data limitations, model assumptions …
- Improved communication is needed with:
  managers, policy makers, politicians, fishers, …

# The Asian Fisheries Society

## Established in 1984 – now 40 years old

### Vision

"A vibrant Asia-Pacific society of researchers and other stakeholders that is valued by members for its ability to provide **opportunities** for **communication**, **collaboration** and **capacity development** in fisheries and aquaculture science."

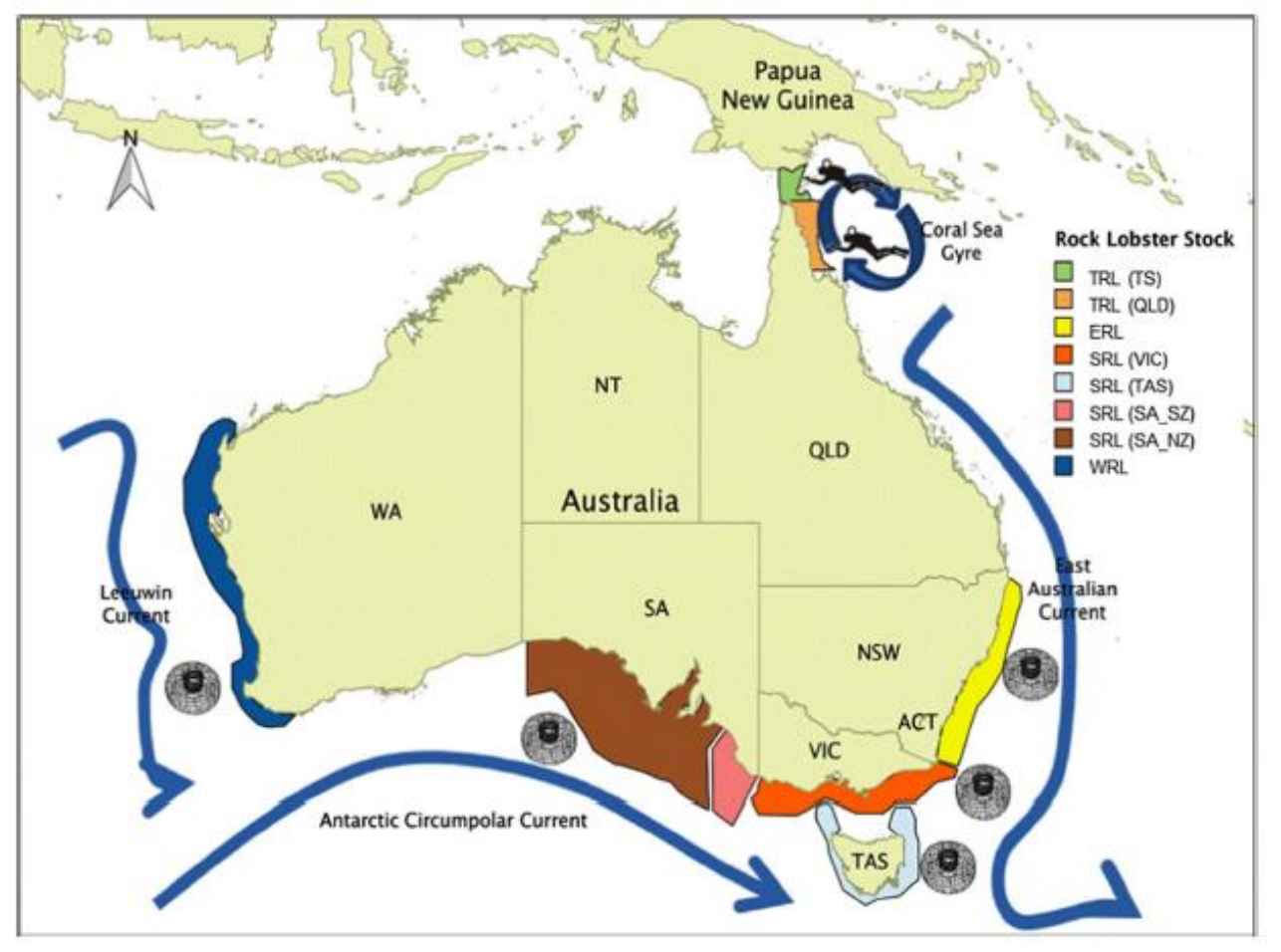



### Council

- 14 Councillors (max. of 2 per country)
- 7 Countries
- Secretariate at University Putra Malaysia

# Australian /West Australian fisheries

# Fisheries and marine environment of Australia




(Figure 1, Plaganyi et al., 2017)

EEZ covers 10 million $km^2$
3rd largest EEZ (Indonesia ~#6)

Fisheries rank by weight < top 50 (IND. #2), very high value

Employment = 21,000 (direct)
(Indonesia 3-6 million, SSF)

Low nutrient environment
Low fisheries productivity

# Commercial Fisheries – Australia

total capture fisheries ~175,000 tonnes

*Panulirus cygnus*

**Northern Prawn Fishery**

6,000 km of coastline (3 states)

~ **50** trawlers in 2023

6 to 10,000 tonnes of prawns (export)

US ~$70 million

**Western rock lobster fishery**

800 km of coastline, WA (1 state)

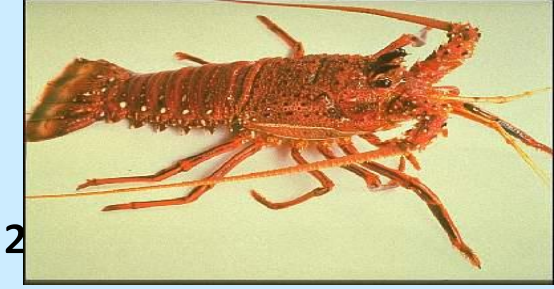
230 boats

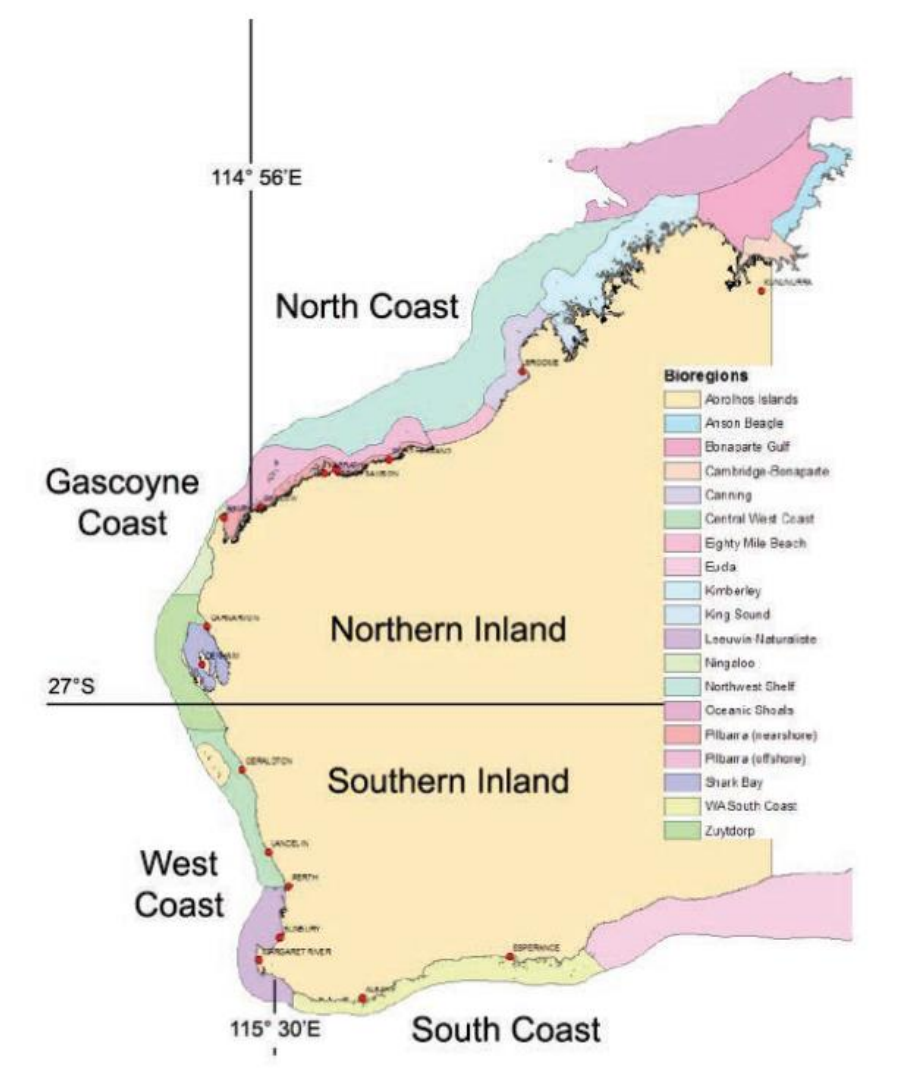
~6,800 tonnes 2023 (export)

US ~$200 million


Data Rich; Fisheries cover large areas, **few boats**, **small catch** but **high value**

# Data-limited fisheries in Western Australian






(Figure 2, Fletcher et al. 2017 www.fish.wa.gov.au )

1/3 of Australia 2,500,000 km$^2$
population ~3 million people

Extensive geographic region –
~ 12,800 km of coastline, 568,677 km$^2$ shelf

~50 managed fisheries, 40 assessed,
some are data-limited
- estuaries, remote regions, some non-target species, **recreational fisheries**

~30% of people in WA fish at least once/year

~900,000 fishers

# Goals of fisheries management

Maximum sustainable yield (MSY)

"any species each year produces a harvestable surplus, and if you can take that much, and no more, you go on getting it for ever (AMEN!)"

(Larkin 1977, 1978)

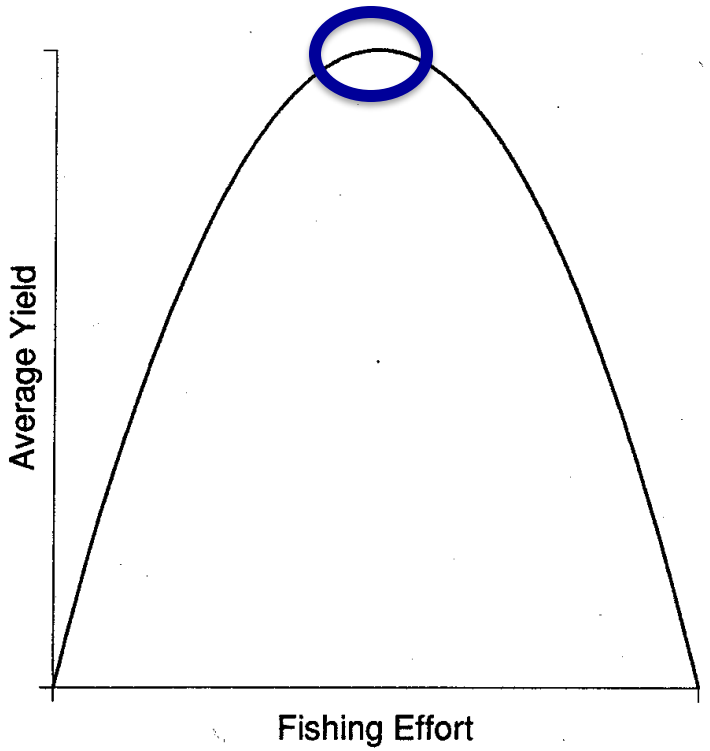



*Figure 1.2.* The assumed relationship between fishing effort and average catch. Perhaps the most commonly printed illustration in fisheries textbooks, and the most dangerous.

(from Hilborn and Walters 1992)

# Goals of fisheries management

Maximum sustainable yield (MSY)

"any species each year produces a harvestable surplus, and if you can take that much, and no more, you go on getting it for ever (AMEN!)" (Larkin)

Goal of fisheries management

"to ensure sustainable production over time from fish stocks, preferably through regulatory and enhancement actions that promote economic and social well-being of the fishermen and industries that use the production"

(Hilborn and Walters, 1992)

Ecologically sustainable development (ESD) in Australian Fisheries (1991/92)
"using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased"

Now - Ecosystem Based Fisheries Management (EBFM)

# Goals of fisheries management

1960s: Maximising harvest – Maximum Sustainable Yield (**MSY**)

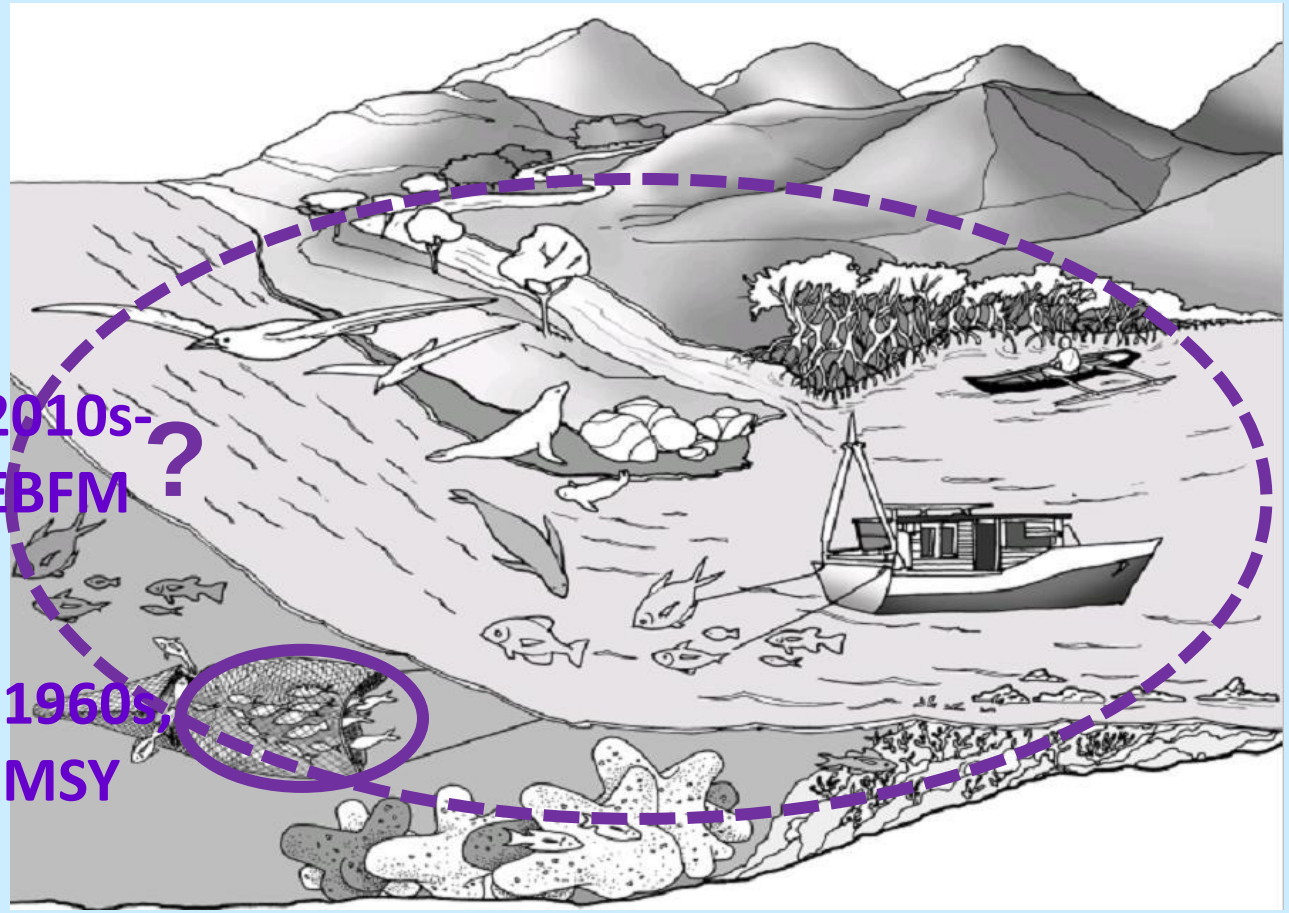
1980s: Sustainable production – fisheries and fishing industry

1990s: Ecologically sustainable development – sustainable fisheries extending to ecology (**ESD**)

2000s Ecosystem approaches to fisheries and Ecosystem Based Fisheries Management (**EBFM**)

# Ecosystem based fisheries management (EBFM)

- Requirement for certification e.g. Marine Stewardship Council
- Fishery improvement plans
- UN Sustainable Development Goals 14:
  Conserve and sustainably use the oceans, seas and marine resources for sustainable development

# Ecosystem based fisheries management (EBFM)

- Requirement for certification e.g. Marine Stewardship Council
- Fishery improvement plans
- UN Sustainable Development Goals 14: Sustainably use the oceans, seas and marine resources



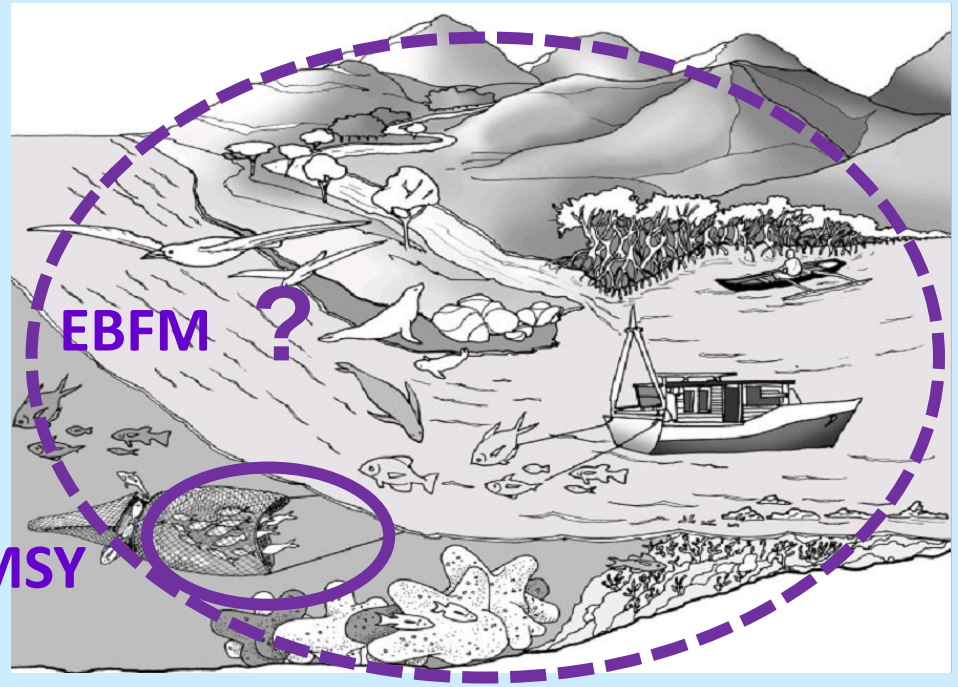
## Components of EBFM

1. **Ecological**
   a) Target b) non-target, ecosystem
2. **Socio-economic outcomes**
3. **Governance –** ability to achieve

# Ecosystem approaches to fisheries/EBFM

## (EBFM, also Ecosystem approaches to fisheries)

- Requirement for certification e.g. Marine Stewardship Council
- Fishery improvement plans
- UN Sustainable Development Goals 14: Sustainably use the oceans, seas and marine resources


## Components of EBFM

**1. Ecological**

a) Target b) non-target, ecosystem

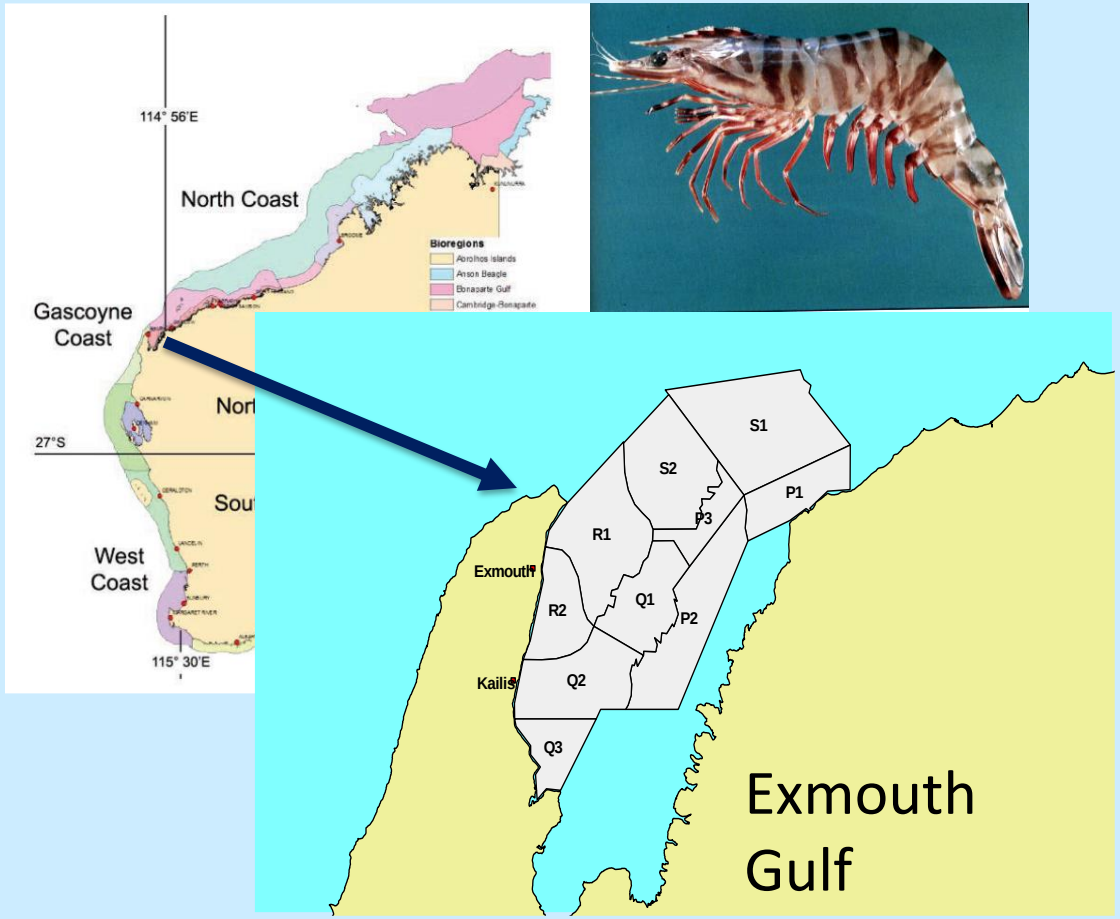
**Stock assessment biology**

**2. Socio-economic**

**3. Governance**

Ecology, Ecological Modellers, Social Science, Economics, Policy and Law

# Shifting to EBFM
# Targeted fish species and habitats






## Exmouth Gulf Prawn Fishery

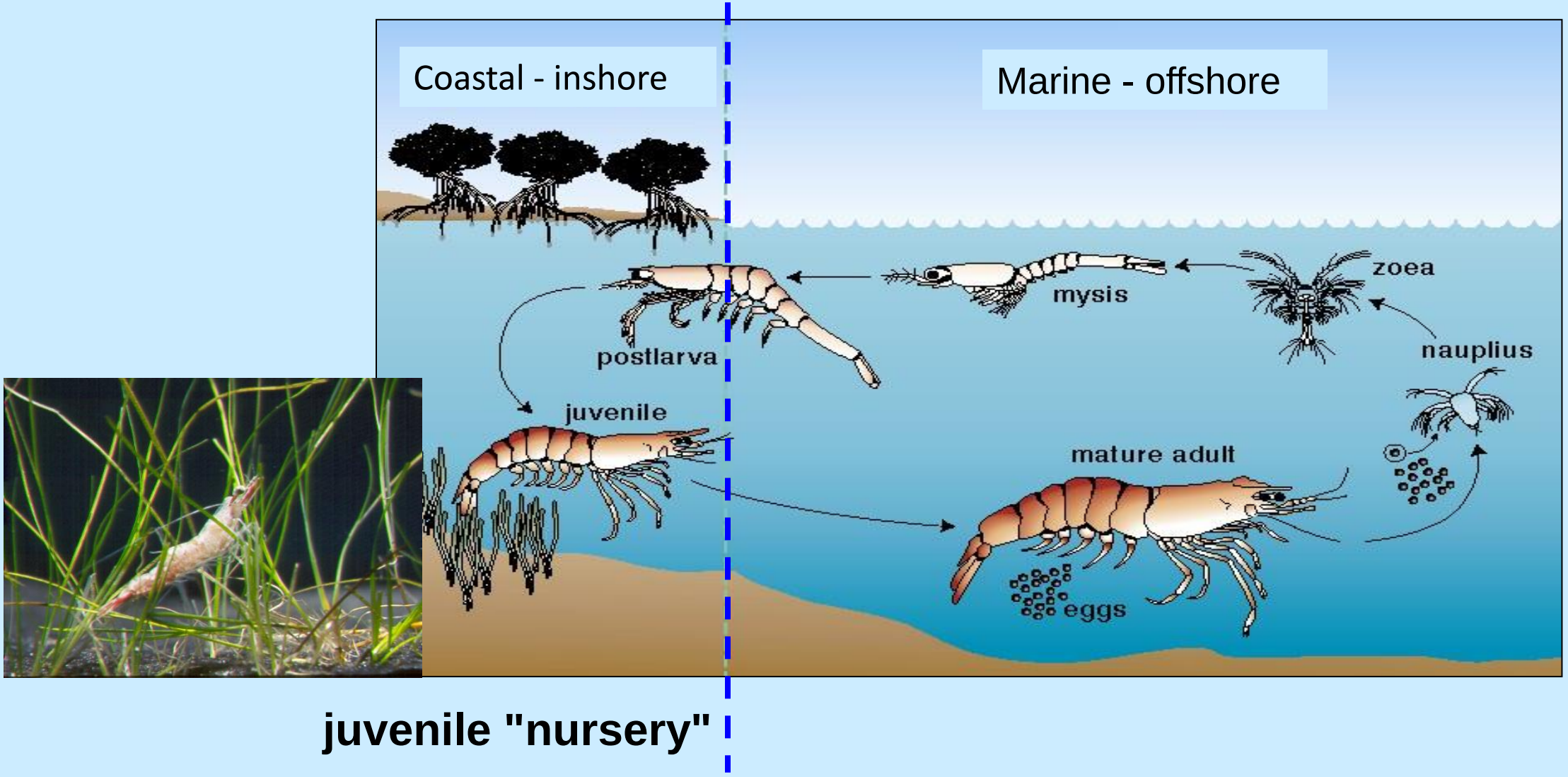
- Limited entry – licenses
- Gear – trawl mesh size
- Closed areas recruits (small prawns)
- Closed seasons to protect spawners

**A Data Rich Fishery**

- Data from fishery - logbooks
- Fishery-independent data
  - Recruits (small prawns)
  - Spawners (large prawns)
  - Habitats (juveniles)

# Shifting to EBFM, an example

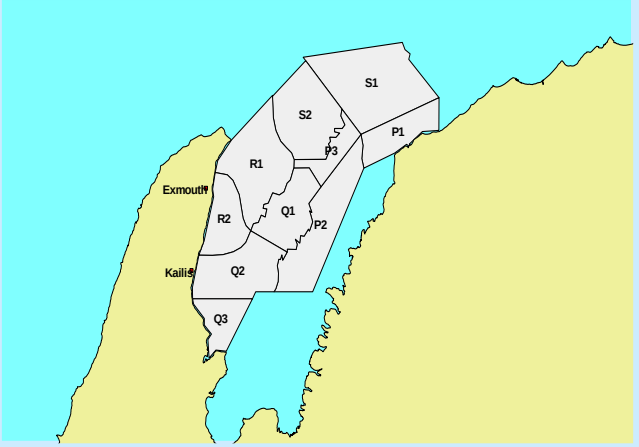
## Life cycle of Tiger prawns *Penaeus esculentus*




**juvenile "nursery"**

(Graphic design by Louise Bell, CSIRO Hobart)

# Data Rich Fishery
# Exmouth Gulf Trawl

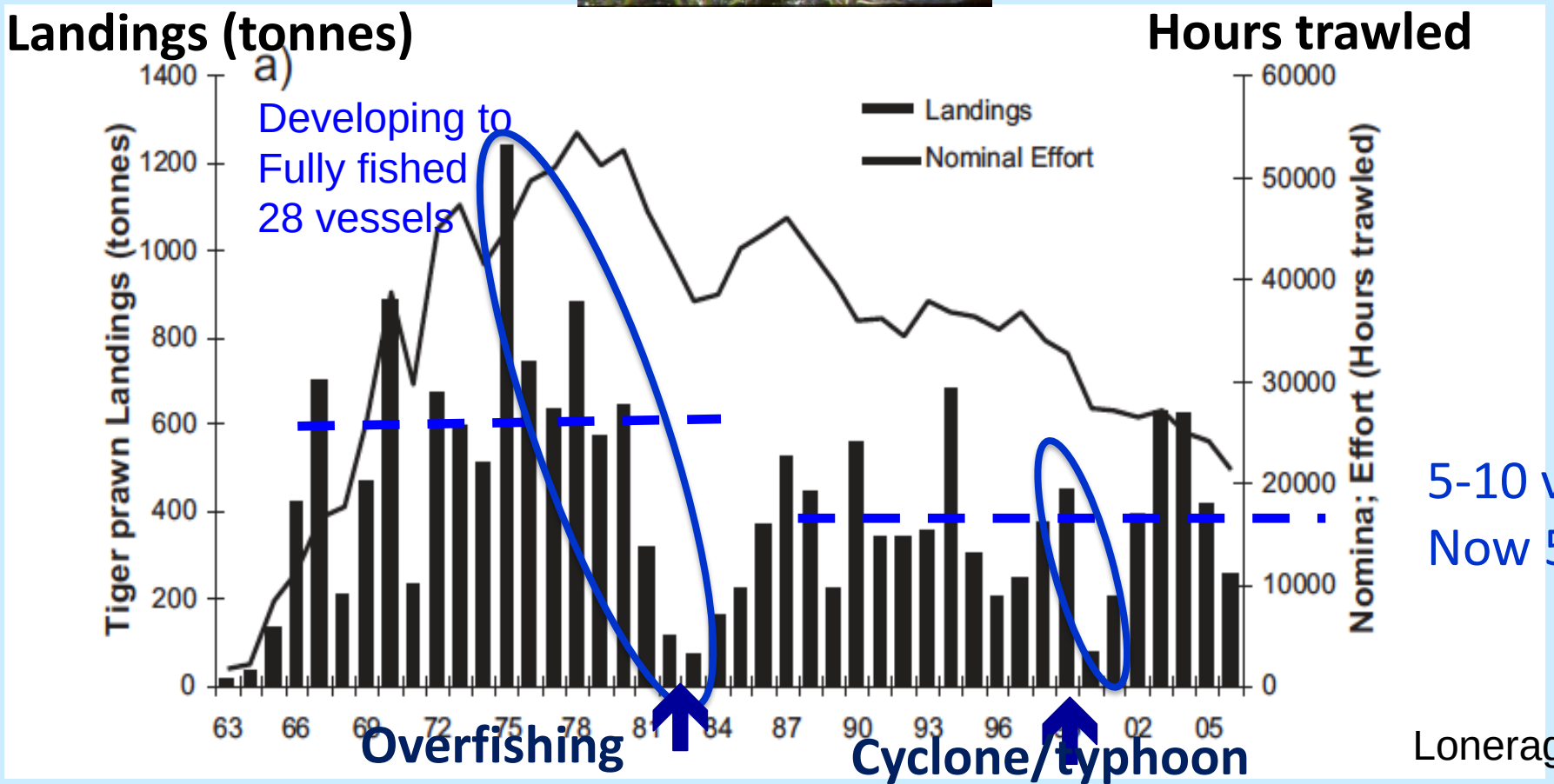



**Fishery Dependent Data**

**Landings (tonnes)**

**Fishing Effort**

**Hours trawled**

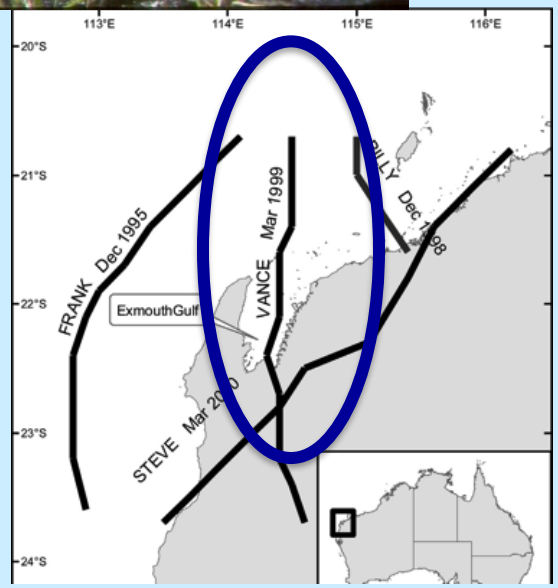



5-10 vessels,
Now 5

Loneragan et al., 2013

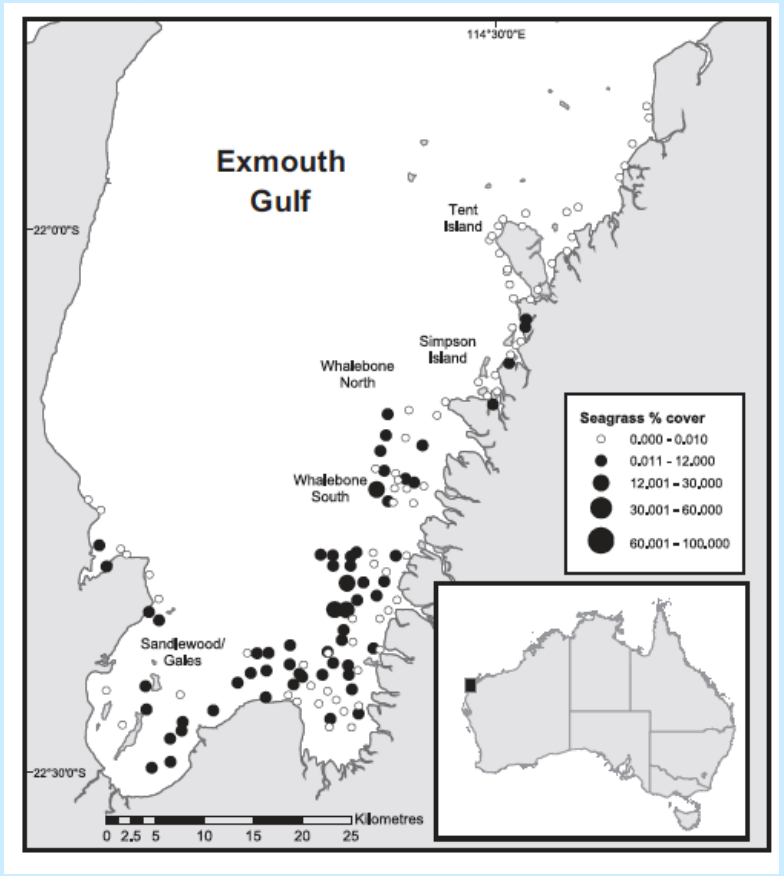
# Seagrass cover (% cover)

Loneragan et al. 2013

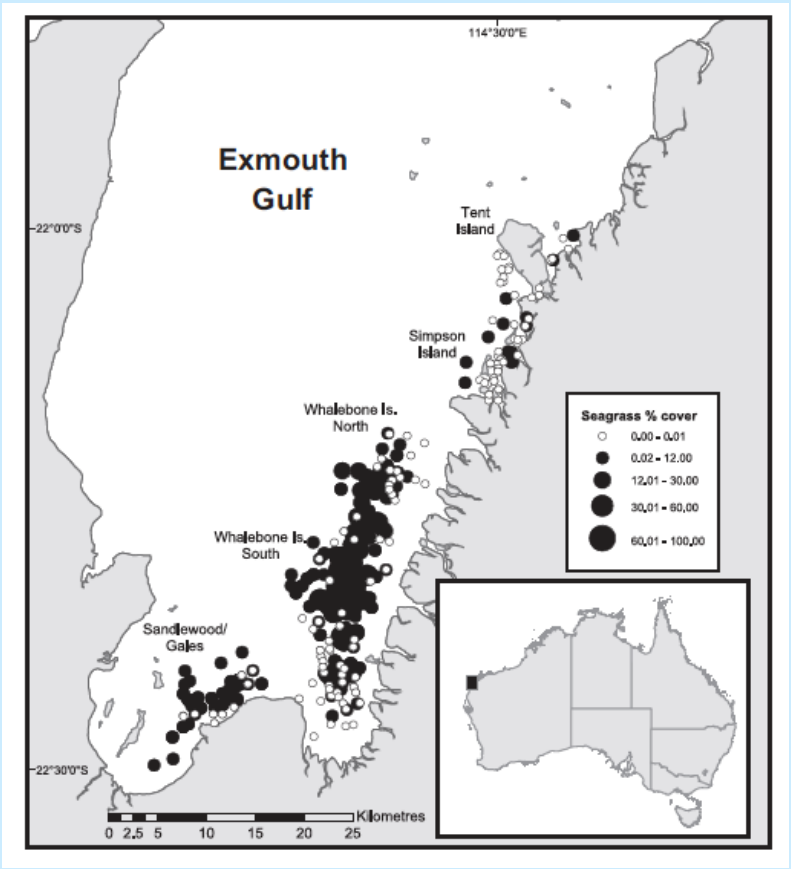



Cyclone paths
Exmouth Gulf

Cyclone Vance
270 km $h^{-1}$ winds

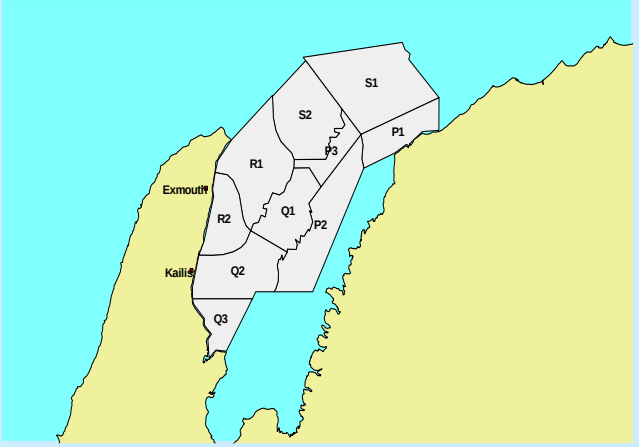



November 1999 **<2%** cover
7 months post-cyclone




November 2000 **>20%** cover
19 months post-cyclone

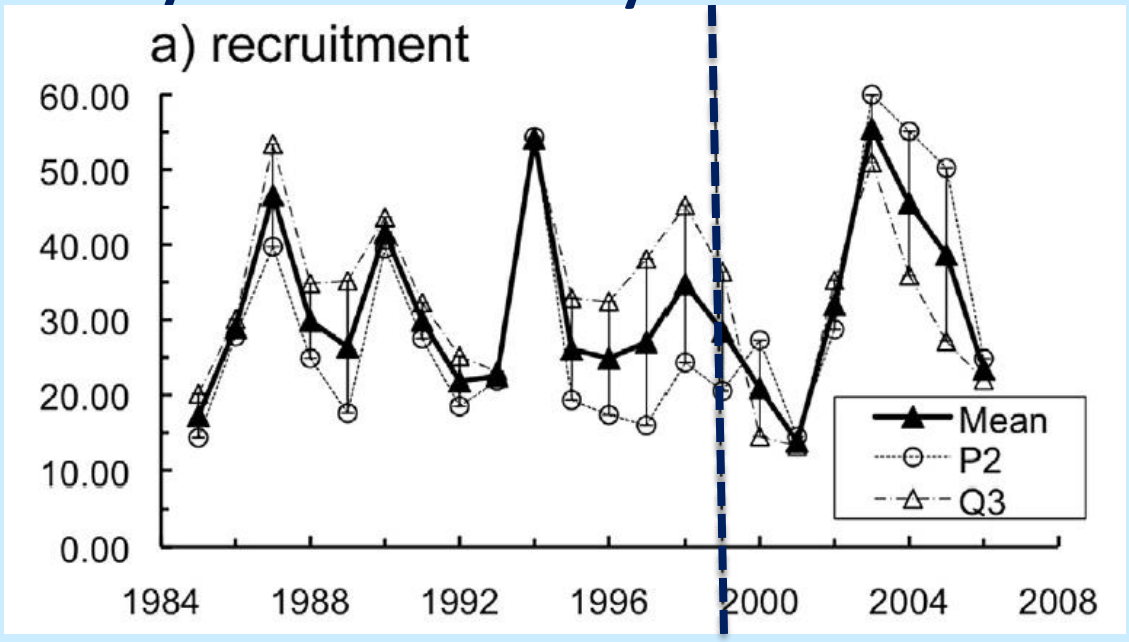
# Data Rich Fishery
# Exmouth Gulf Trawl




## Fishery independent data

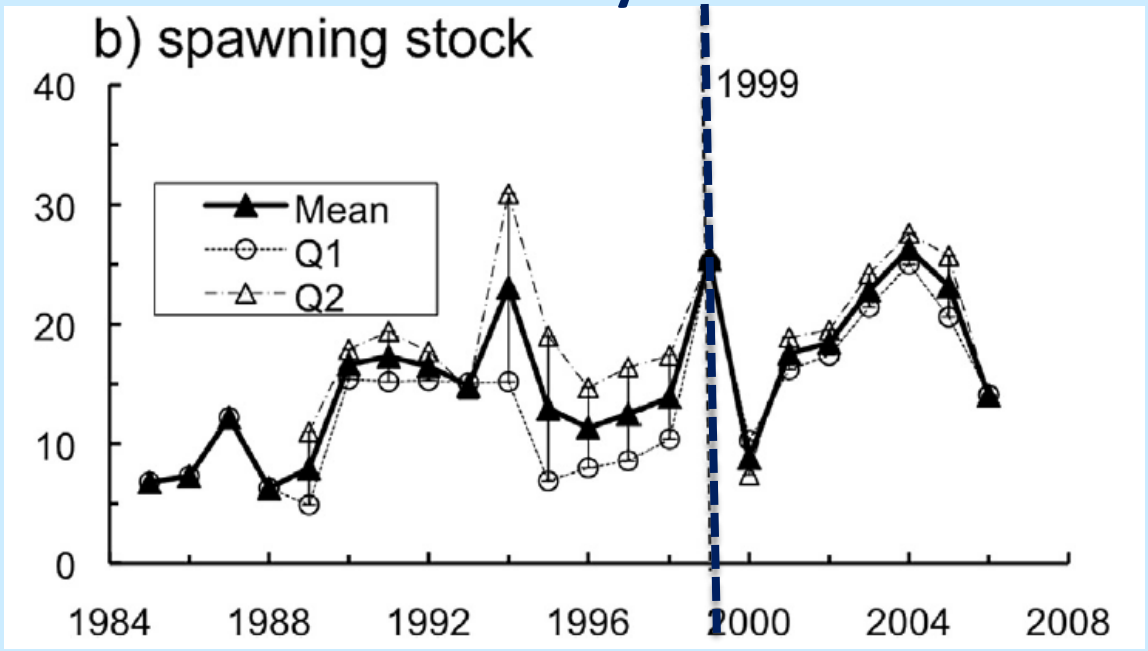
### Surveys

### Cyclone Vance




March/April - Opening of season

### Cyclone Vance




August - Closing of season

Loneragan et al., 2013

# Extending to food webs and ecosystem understanding

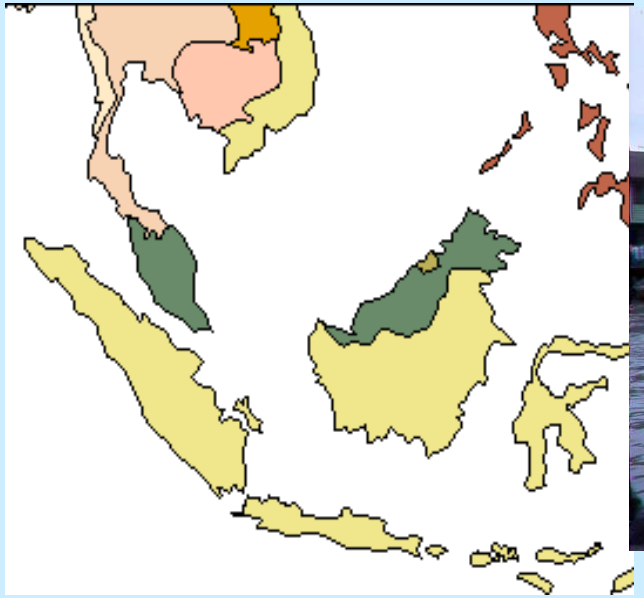
**Exmouth Gulf example**

- Focus on the fishery, and significant habitat for postlarvae and juveniles
- Data sources
  - Commercial catch log book
  - Fishery independent indices of recruits and spawners
  - Research data on seagrass

How do we gain an understanding on food webs in the ecosystem?

What other information is needed for EBFM of this fishery?

# Fishing – Asia – the people dimension



**Malaysia**

Western Peninsular Malaysia **WPM**

Eastern Malaysia

**Trawlers – 2,000 boats**

**200 km of coastline WPM**

**Push nets -illegal**

**Nets set on tide**

**“bag nets” –**

**10,000 fishers**

# The Indonesian Archipelago - ~18,000 islands

# Fishers, fishing industry and community knowledge

Shark fishers – data collection

Shark fisher knowledge – interviews

Shark fisheries of eastern Indonesia

**Dr Vanessa Jaiteh**

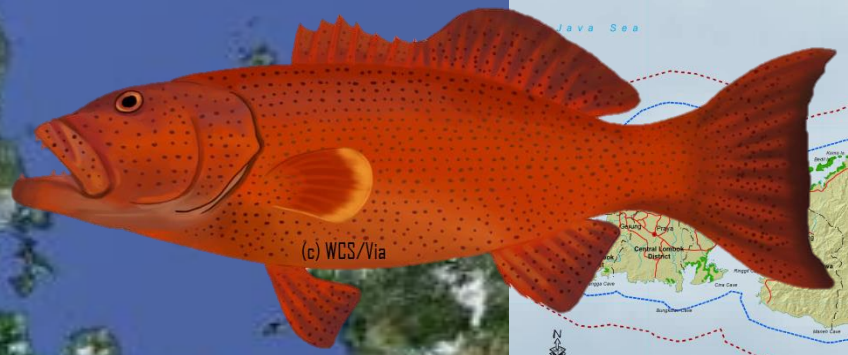
Processor Sumbawa Besar

Fisher cooperative Saleh Bay

Small-scale grouper and snapper fisheries

**Dr Abdul Halim**

# Saleh Bay – demersal and reef fisheries





Jakarta

Handlines, speargun, longlines … 8 gears

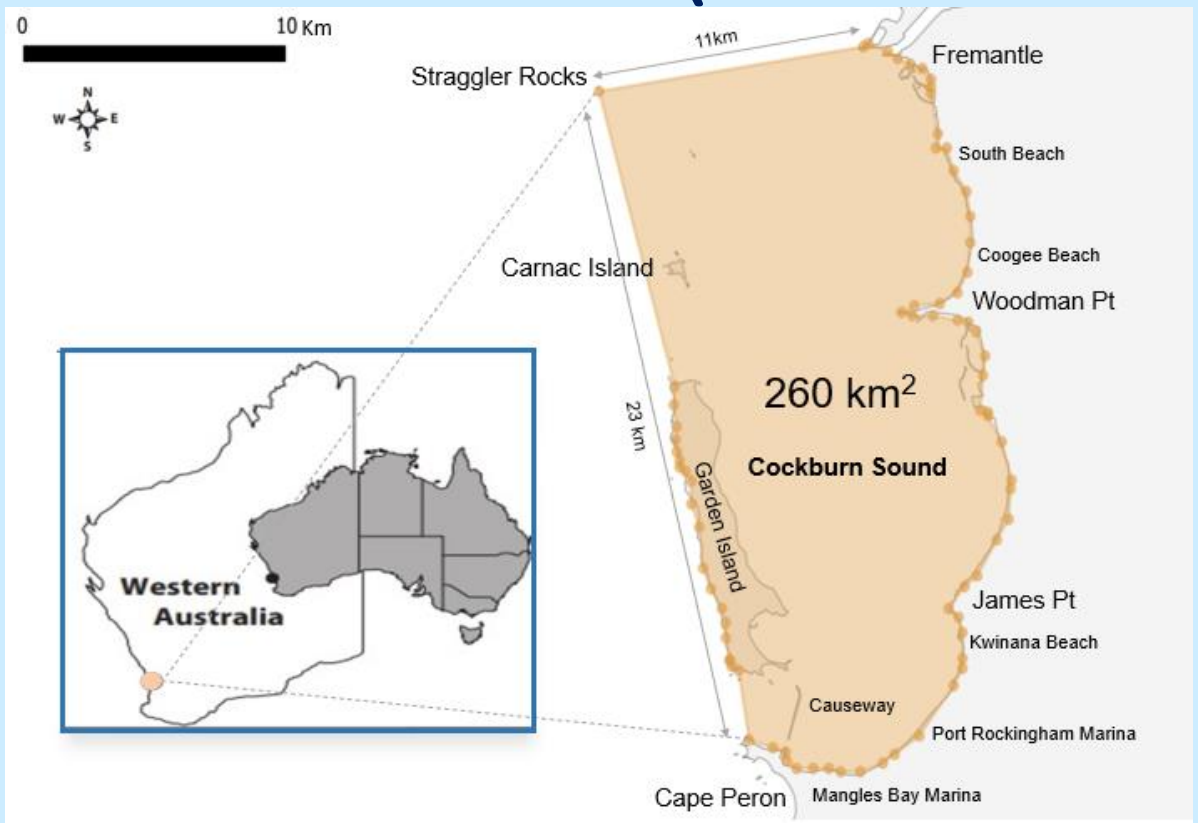
Bali

# What is the Ecosystem status of grouper/snapper fisheries in Saleh Bay?

How do we build ecosystem understanding?
What data and information for we need for EBFM?


An Example: Cockburn Sound, Western Australia

# Cockburn Sound (Derbal Nara)




- Area for industrial development e.g. cement plant, oil and nickel refineries, grain port, ….
- proposed new container port

- **Valued for its aquatic resources** - fisheries and recreation

Hector Lozano

Beth Fulton

Jeff Dambacher

# Conceptual and qualitative models

- Fished species –

*Chrysophrys auratus*
Snapper

*Portunus armatus*

*Sardinella lemuru*
Scaly Mackeral

- Conservation species –

Little Penguin
*Eudyptula minor*

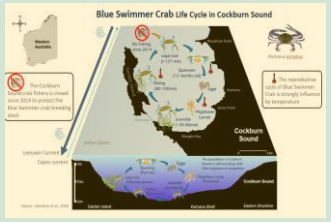
Seagrass – *Posidonia sinuosa*

- Major influencing factors
  – climate, dredging, fishing, low oxygen, increasing temperature
- Ecosystem processes

# Building Conceptual and Qualitative models

## Conceptual models (3 workshops)

## Qualitative models

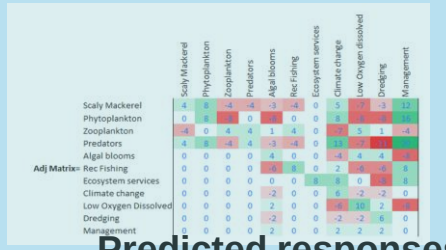



Development of conceptual models

Workshops

Concept harmonisation

Qualitative model building




[-A] Predicted responses (Adjoint matrix

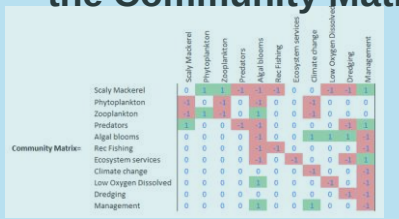
Implications for Management

Selection of conceptual models

Meetings with ecologist and stakeholders

Review of model structure

Qualitative Analysis of the Community Matrix




[A] Community Structure

"Weighted-Predictions' Matrix


[W] Reliability of response signs

Researchers, managers, fishers, other interest groups

Predictions of directions of change

# Blue Swimmer Crab - Conceptual Model


The Cockburn Sound crab fishery has been closed since 2014. Recreational fishing has been allowed to continue north of Woodman Point (legal size is 127mm CW)






*Portunus armatus*

The reproductive cycle of Blue Swimmer Crab is strongly influenced by temperature

## Life stages

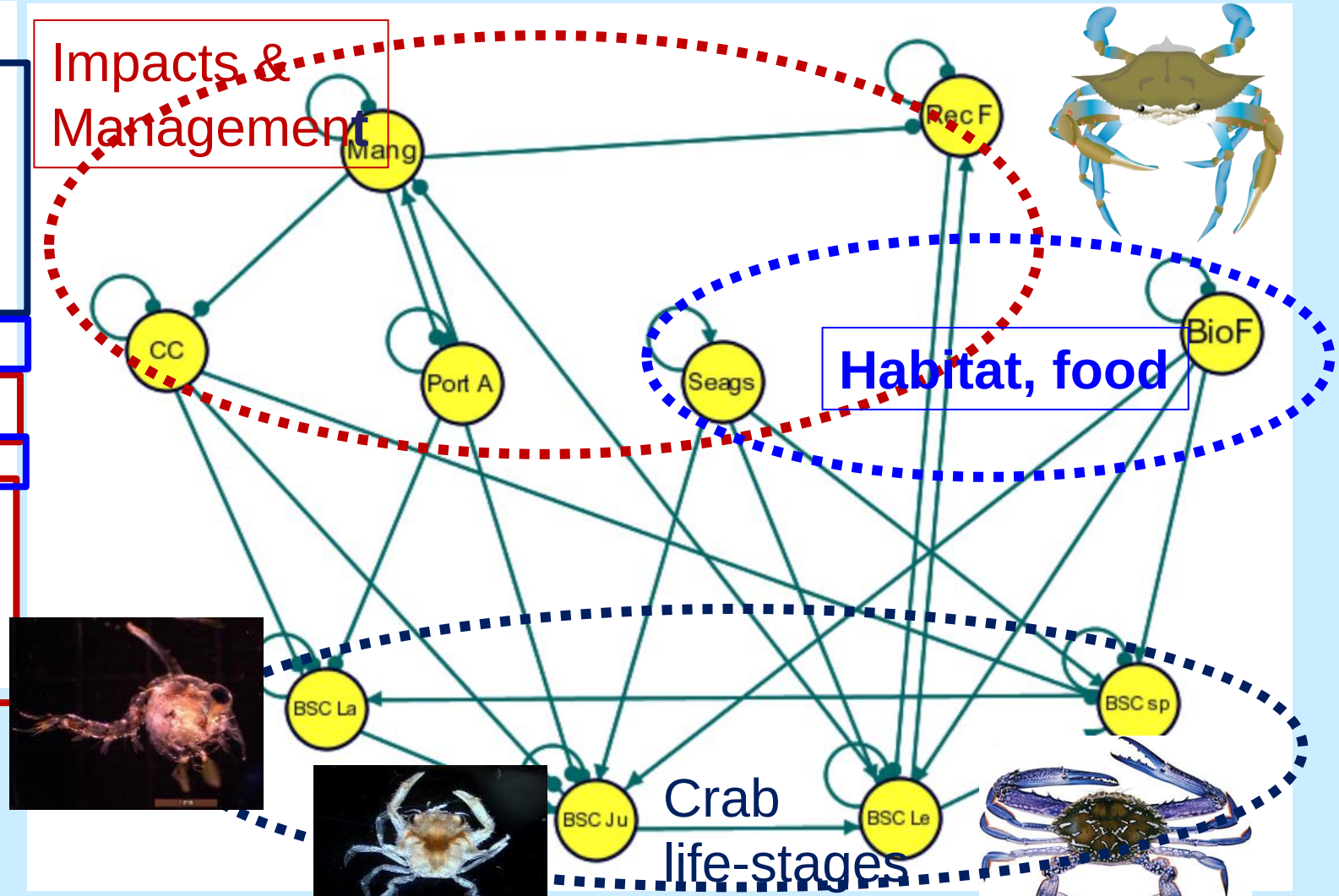
1. Larvae
2. Juveniles
3. Spawners
4. Legal size

# Nodes and signed digraph for BSC (Powerplay)

**10 Nodes**

→ = positive effect; •= negative effect

| Node | Group |
|---|---|
| BSC Leg | BSC Legal Size |
| BSC Spw | BSC spawners |
| BSC Juv | BSC Juvenile |
| BSC L | BSC larvae |
| BioF | Biofouling community |
| Rec F | Rec Fishing |
| Seags | Seagrass meadows |
| CC | Climate change |
| Port A | Port activities |
| Mang | Management |

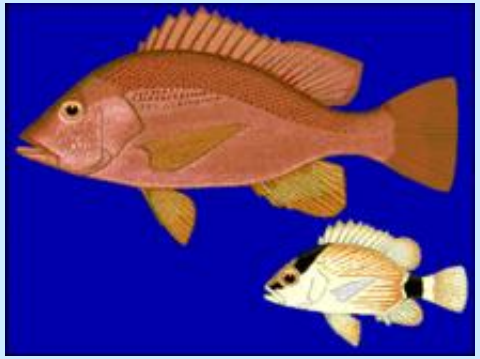


# Ecosystem status of fisheries in Saleh Bay?

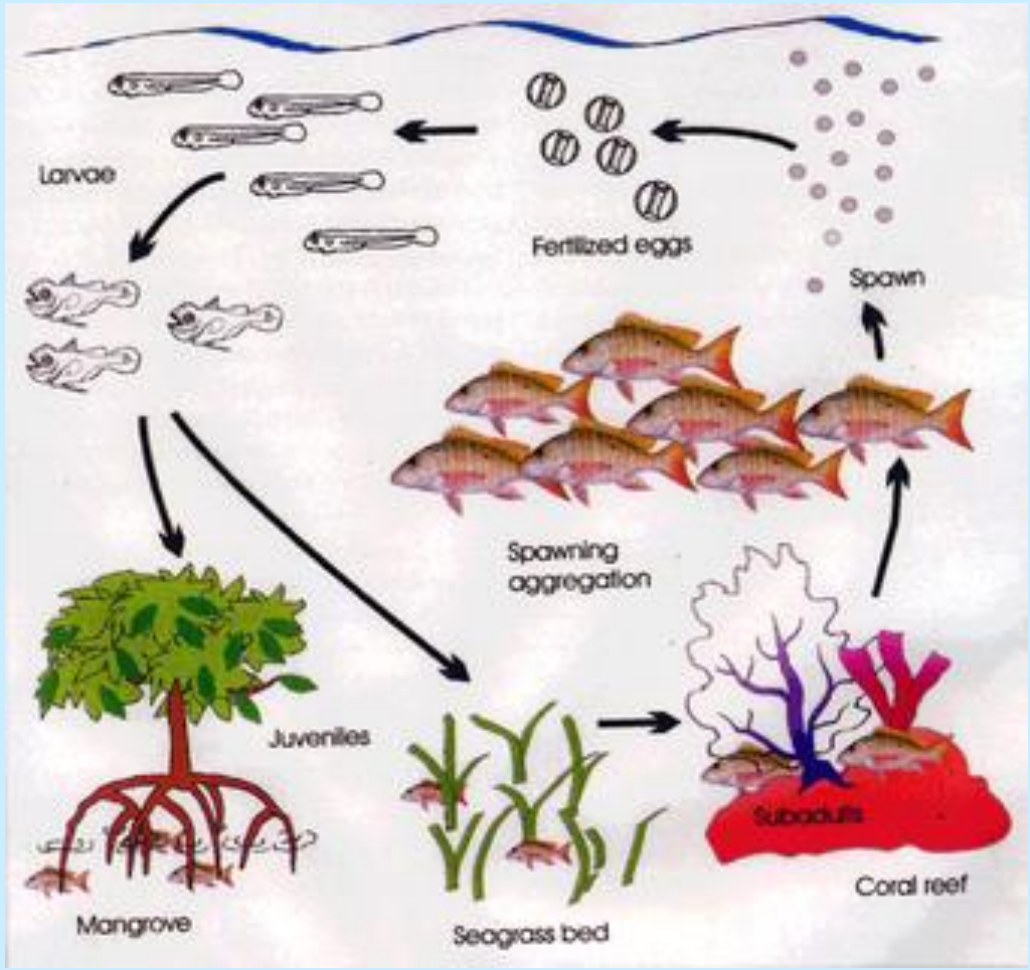

1. What are the key species, key groups of species, habitats and processes?
2. What are the sources of data and knowledge?
3. What management is in place and what might be possible?
4. How have the fisheries and ecosystem changed over time?
5. What information do we need for an EBFM approach?

# Saleh Bay conceptual/qualitative models for: fish, habitats and processes


Leopard Coral Grouper
*Plectropomus leopardus*



Malabar Blood Snapper
*Lutjanus malabaricus*




FSU Coastal and Marine Laboratory
http://emilymarinescience.weebly.com/grouper-life-cycle.html

Which species, what behaviour?

What is the life-cycle?

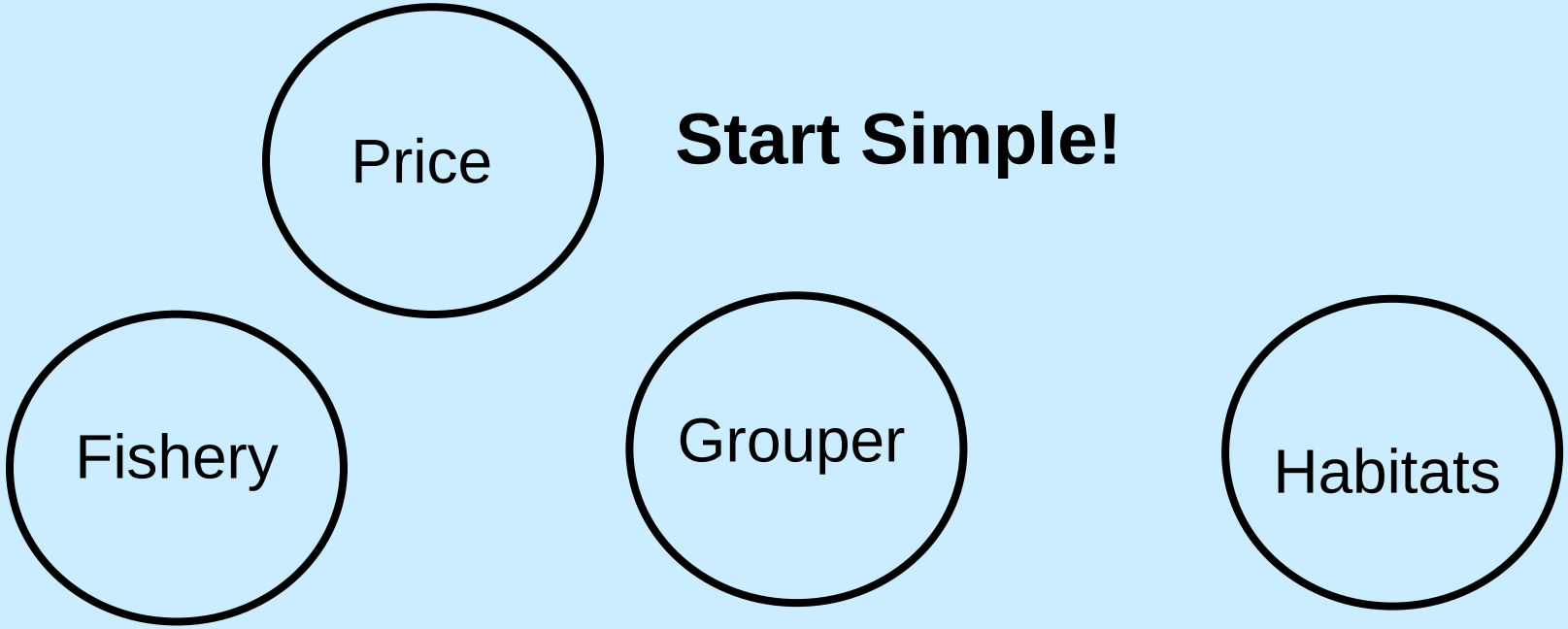
Which habitats are important?

What are the threats to species and habitats?

Changes with time?

# Conceptual and qualitative models

**1.** Develop the conceptual model of the focus species
2. Identify Nodes (components) of interest
3. Relationships between Nodes




Price and grouper fisheries system:
$H_0$: Price affects fishing and grouper stocks

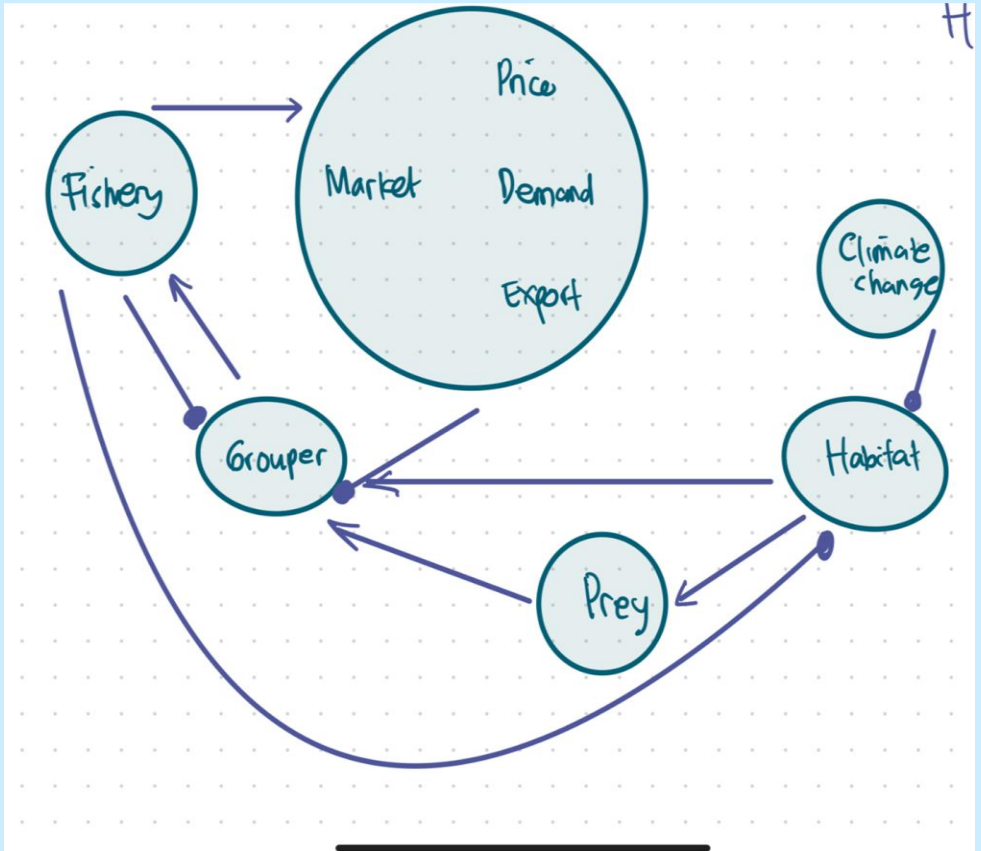
# Grouper Fishery Habitat System

Heidi, Siska, Ika, Ikeu, Neri, ADS, Tasrif, Irfan

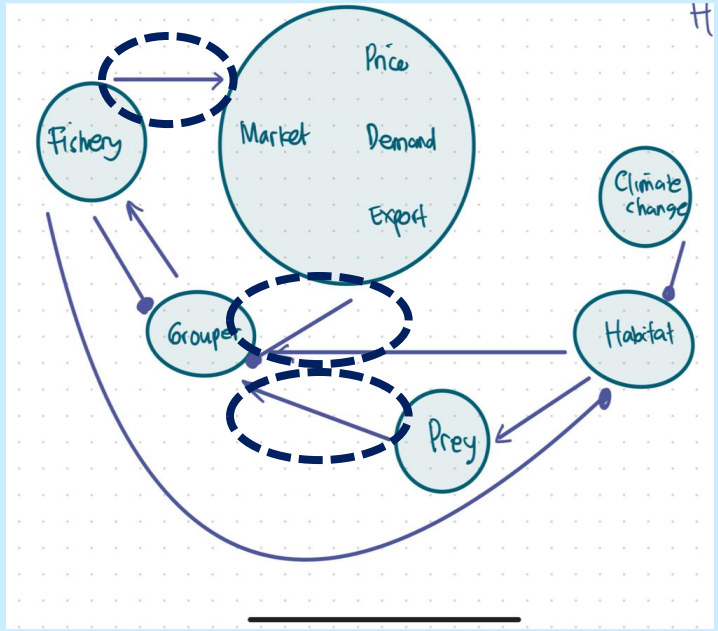
6 Nodes

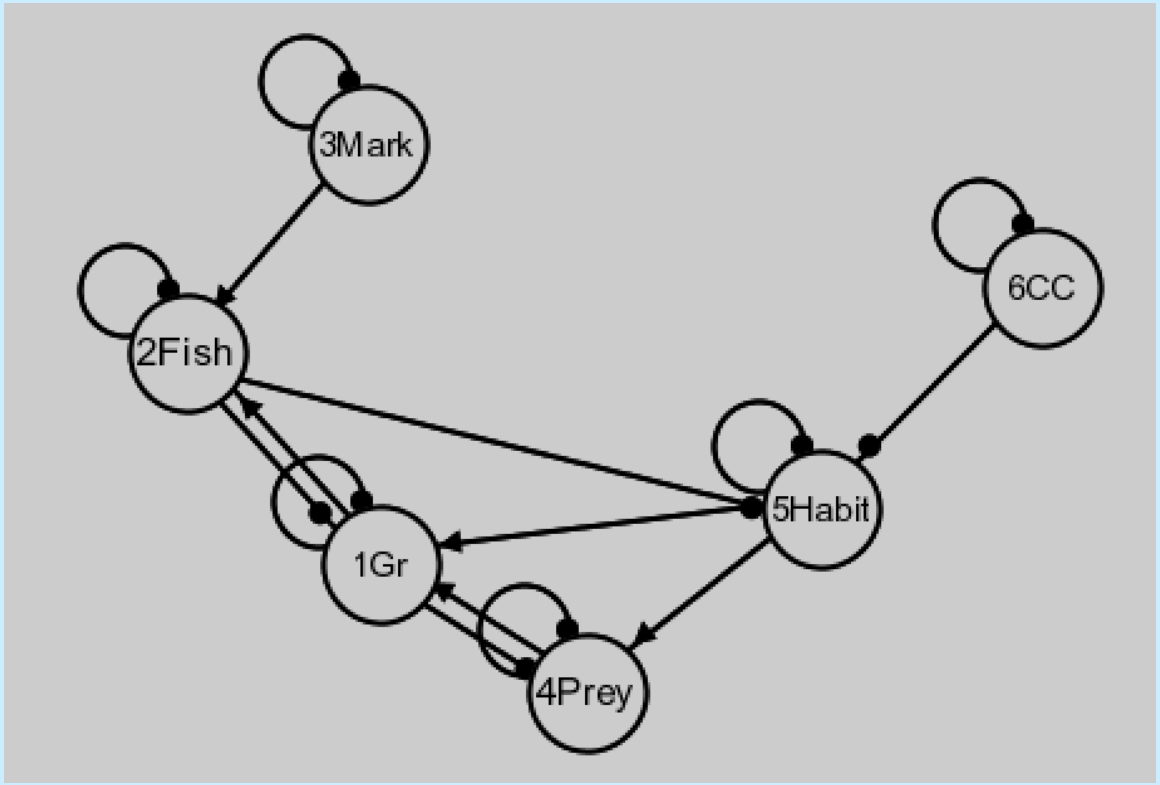
- **Fishery**: (-) affect on grouper & habitat
- **Habitat**: (+) affect on grouper stock, and grouper prey
- **Grouper stock**:

  (-) affect by fishery,
  (+) affect by prey & habitat
- **Market**: (+) affected fishery
- **Prey**: (+) affect on grouper stock
- **Climate change**: (-) affected on habitat



# Signed digraph – Powerplay app




6 nodes 1: 1Gr, 2: 2Fish, 3: 3Mark, 4: 4Prey, 5: 5Habit, 6: 6CC

Interactions [-1,-1,0,1,1,0],[1,-1,1,0,0,0],[0,0,-1,0,0,0],[-1,0,0,-1,1,0],[0,-1,0,0,-1,-1],[0,0,0,0,0,-1]


Community matrix [A]

# Community matrix [A] and stability - Maple

"Community Matrix (°A)"

$$A := \begin{bmatrix} -1 & -1 & 0 & 1 & 1 & 0 \\ 1 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 & 0 \\ -1 & 0 & 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

"Criterion i"

$poly\_coef\_F0\_to\_Fn = [-1, -4, -7, -6, -2]$

$positive\_feedback = [\ 0\ \ 0\ \ 0\ \ 0\ \ 0\ ]$

$negative\_feedback = [\ -1\ \ -4\ \ -7\ \ -6\ \ -2\ ]$

$absolute\_feedback = [\ 1\ \ 4\ \ 7\ \ 6\ \ 2\ ]$

$wFn = [\ -1.\ \ -1.\ \ -1.\ \ -1.\ \ -1.\ ]$

"Criterion ii"

$wD_3 = 0.42$

$ratio\_to\_model\_C = 4.7$

"Class I Model"

| | Gr | Fish | Mark. | Prey | Hab. | CC |
|---|---|---|---|---|---|---|
| Grouper | -1 | -1 | 0 | 1 | 1 | 0 |
| Fishery | 1 | -1 | 1 | 0 | 0 | 0 |
| Markets | 0 | 0 | -1 | 0 | 0 | 0 |
| Prey | -1 | 0 | 0 | -1 | 1 | 0 |
| Habitats | 0 | -1 | 0 | 0 | -1 | -1 |
| Climate ch. | 0 | 0 | 0 | 0 | 0 | -1 |

# Prediction/Adjoint matrix [-A], weights and certainty

"adjoint (-A)"

$$\begin{bmatrix} 1 & -3 & -3 & 1 & 2 & -2 \\ 1 & 2 & 2 & 1 & 2 & -2 \\ 0 & 0 & 5 & 0 & 0 & 0 \\ -2 & 1 & 1 & 3 & 1 & -1 \\ -1 & -2 & -2 & -1 & 3 & -3 \\ 0 & 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

"absolute feedback (T)"

$$\begin{bmatrix} 1 & 3 & 3 & 1 & 2 & 2 \\ 1 & 2 & 2 & 1 & 2 & 2 \\ 0 & 0 & 5 & 0 & 0 & 0 \\ 2 & 3 & 3 & 3 & 3 & 3 \\ 1 & 2 & 2 & 1 & 3 & 3 \\ 0 & 0 & 0 & 0 & 0 & 5 \end{bmatrix}$$

"weighted predictions (W)"

$$\begin{bmatrix} 1. & 1. & 1. & 1. & 1. & 1. \\ 1. & 1. & 1. & 1. & 1. & 1. \\ 1.0 & 1.0 & 1. & 1.0 & 1.0 & 1.0 \\ 1. & 0.33 & 0.33 & 1. & 0.33 & 0.33 \\ 1. & 1. & 1. & 1. & 1. & 1. \\ 1.0 & 1.0 & 1.0 & 1.0 & 1.0 & 1. \end{bmatrix}$$

| | Gr | Fish | Mark. | Prey | Hab. | CC |
|---|---|---|---|---|---|---|
| Grouper | -1 | -1 | -1 | 1 | 1 | -1 |
| Fishery | 1 | 1 | 1 | 1 | 1 | -1 |
| Markets | 0 | 0 | 1 | 0 | 0 | 0 |
| Prey | -1 | 1? | 1? | 1 | 1? | -1? |
| Habitats | -1 | -1 | -1 | -1 | 1 | -1 |
| Climate ch. | 0 | 0 | 0 | 0 | 0 | -1 |

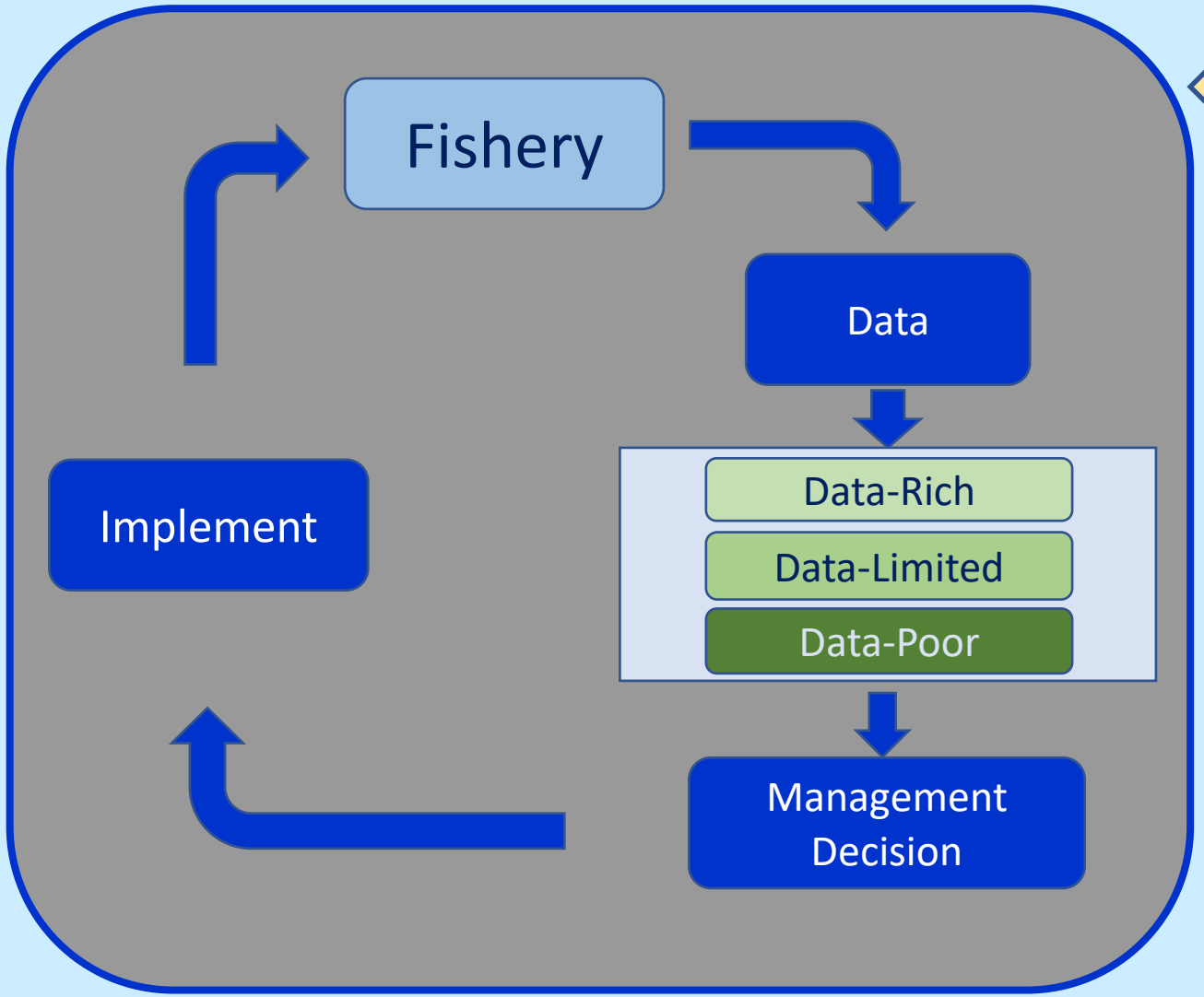
# Ecosystem understanding for sustainable Grouper and Snapper fisheries of Teluk Saleh



- Focus on building a quantitative ecosystem model – Ecopath w Ecosim (EwE - Rekam team with Hector Lozano)
- Completing interviews with fishers and key informants – perspectives of the state of the fishery, management, importance to livelihoods
- Refining the Ecopath w Ecosystem model in technical and stakeholder workshops
- Develop other conceptual and qualitative models

# Fisheries Management System

(design by
Dr Adrian Hordyk)




Objectives

Ecological Economic Social



## Trans-disciplinary approach

- People, culture & fisheries
- Biology and ecology
- Data, statistics & models
- Communication

**Collaboration, partnerships, knowledge sharing**

Government, Universities, NGOs, fishers, fishing industry, fishing communities

# References


Pauly and Zeller (2016) Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications* (**7***,* 10244)

Halim et al. (2017) Concept of fisheries management rights as a management tool for sustainable fisheries in Indonesia. *Jurnal Kebijakan Perikanan Indonesia* **9:** 11-20.

Halim et al. (2019) Developing a functional definition of small-scale fisheries in support of marine capture fisheries management in Indonesia. *Marine Policy* 100: 238-248.

Halim A, **et al.** (2020). Evaluating data-limited fisheries for grouper (Serranidae) and snapper (Lutjanidae) in the Coral Triangle, eastern Indonesia. *Regional Studies in Marine Science* 38: 101388. https://doi.org/10.1016/j.rsma.2020.101388

Hordyk et al. (2015). A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES Journal of Marine Science* 72: 217-231

Jaiteh et al. (2016). Higher abundance of marine predators and changes in fishers' behavior following spatial protection within the world's biggest shark fishery. *Frontiers in Marine Science* http://dx.doi.org/10.3389/fmars.2016.00043

Jaiteh et al. (2017a) Shark finning in eastern Indonesia: Assessing the sustainability of a data-poor fishery. *ICES Journal of Marine Science* **74**: 242-253*.*

Jaiteh et al. (2017b) The end of shark finning? Impacts of declining catches and fin demand on coastal community livelihoods. *Marine Policy* 82: 224-233.

Loneragan et al. 2021. *Proceedings from Workshops on Management Strategy Evaluation of Data-Limited Fisheries: Towards Sustainability – Applying the Method Evaluation and Risk Assessment Tool to Seven Indonesian Fisheries.* Murdoch University, Western Australia, and IPB University, Indonesia, 185 pp.

Prince et al. (2015). Extending the principle of Beverton-Holt Life History Invariants to develop a new framework for borrowing information for data-poor fisheries from the data-rich. *ICES Journal of Marine Science* 72: 194-203.

Teh and Pauly (2018) Who Brings in the Fish? The Relative Contribution of Small-Scale and Industrial Fisheries to Food Security in Southeast Asia. *Frontiers in Marine Science* doi: 10.3389/fmars.2018.00044

Worm and Branch (2012) The future of fish. *Trends in Ecology and Evolution* **11:** 594-599.

# 14th AFAF, 12-15 February 2025, New Delhi (Dr JK Jena/Indian Br.)

## 14th Asian Fisheries and Aquaculture Forum (14afaf.in)

# Developing ecosystem understanding for Ecosystem-Based Fisheries Management

AFS Webinar 2: 24 September 2024

**Thank you**

UPV Visayas for organisation and logistics,
all participants

Colleagues: Prof. Budy Wiryawan, Dr Irfan Yulianto, Rekam team
Beth Fulton, Hector Lozano, Jeff Dambacher