Laurea Magistrale in Scienze per l'Ambiente
MArino e Costiero (SAMAC)

Anno accademico 2023-2024

Gestione delle risorse alieutiche

Parte - Simone Libralato
(slibralato@ogs.it)

Lezione 7

i) Introduzione alla gestione dello sfruttamento delle risorse alieutiche, problematiche generali, stato delle risorse, targets internazionali.

ii) Massimo rendimento sostenibile, sforzo di pesca, mortalità da pesca, costi, rendimento economico. *esercizi*

iii) (continua) Massimo rendimento sostenibile, sforzo di pesca, mortalità da pesca, costi, rendimento economico. *esercizi*

iv) Le specie ittiche: crescita, riproduzione, mortalità: esercizio modelli e dati.

v) Stock assessment basi: dalla cohort analysis e virtual population analysis ad oggi (*esercizi*).
Le attività di pesca: selettività, catturabilità, impatto sugli habitat. Dati fishery dependent e fishery independent per la gestione: uso, limitazioni, problematiche.

vi) Pesca e interazioni con altri fattori: approccio multispecifico integrato. Modelli di ecosistema per la gestione della pesca: Ecopath with Ecosim (*esercizio EwE*). Sintesi problematiche, approcci, limitazioni, gaps e aree di sviluppo

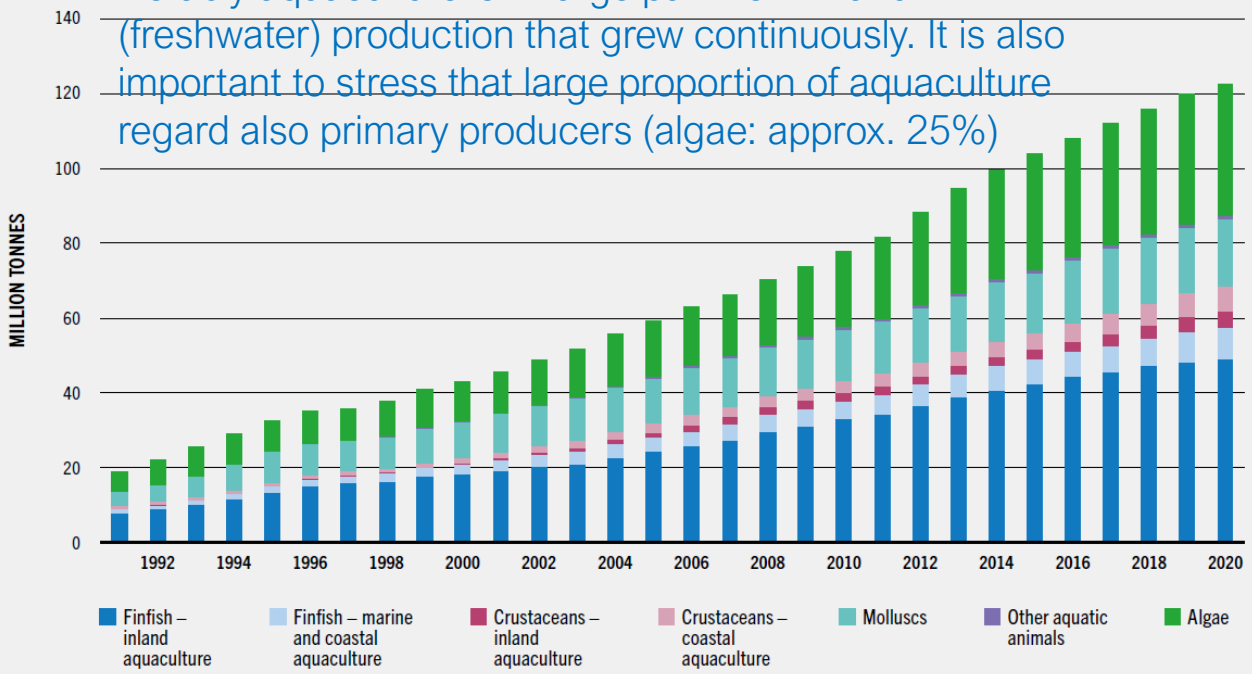
vii) Prodotti ittici da acquacoltura: sistemi di produzione, problematiche generali, sostanibilitá, soluzioni. Gestione integrata pesca e acquacoltura. Target di pesca sostenibile, approcci alla gestione, problematiche: il caso del mediterraneo. Gestione spaziale della pesca, essential fish habitats, regolamenti comunitari ed internazionali. Sforzo di pesca, gestione dello sforzo di pesca, misure tecniche, misure economiche.

Growth of aquaculture worldwide

Production of seafood is stagnant from wild fisheries while aquaculture is growing at worldwide scale: is farming a sustainable solution?

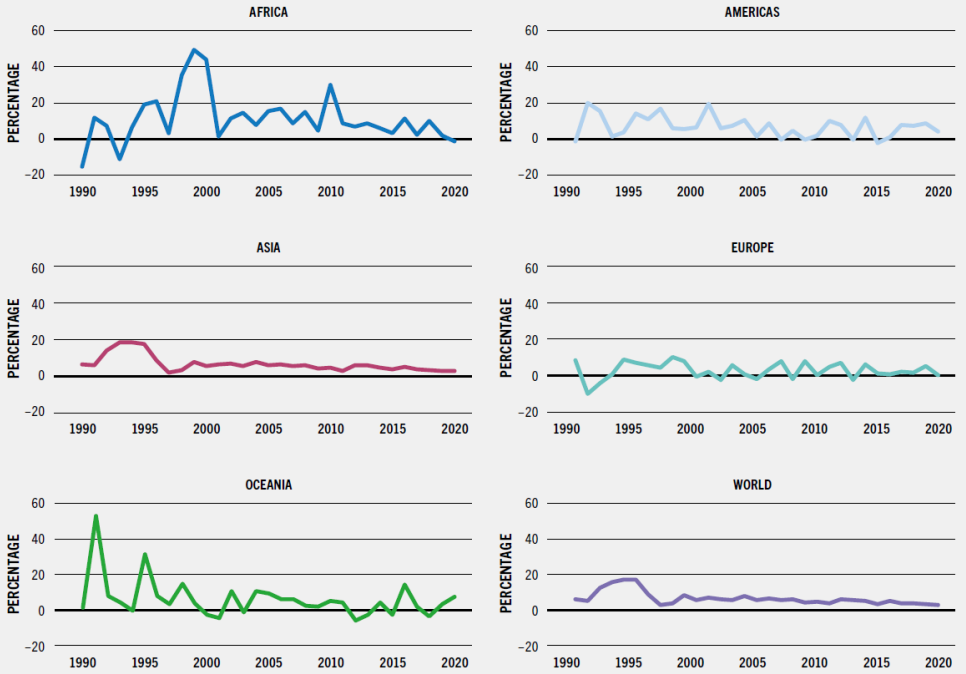
FIGURE 13 WORLD AQUACULTURE PRODUCTION, 1991–2020

Notably aquaculture is in large part from inland (freshwater) production that grew continuously. It is also important to stress that large proportion of aquaculture regard also primary producers (algae: approx. 25%)



NOTES: Data exclude shells and pearls. Data expressed in live weight equivalent.
SOURCE: FAO.

FIGURE 14 ANNUAL GROWTH RATE OF AQUATIC ANIMAL AQUACULTURE PRODUCTION BY CONTINENT, 1990–2020



SOURCE: FAO.

Although aquaculture is still a growing sector the growth (in terms of production) is lowering in all continents.

World capture and aquaculture production
Source: FAO, State of world Fisheries and Aquaculture (SOFIA), 2022

(1) Extensive farms

Aquaculture from extensive farms use natural highly productive environments (coastal lagoons and deltas) as nursery and fastening areas for some marine-breakish species (*Sparus aurata, Dichentrarchus labrax, Anguilla anguilla, Mugil spp., Liza aurata, etc*). These species when they are juveniles go into the lagoon systems and are trapped there for growing there taking advantage of a protective and productive environment. Usually feeding and recruitment is naturally controlled.

Some issues:

Low productivity; Dependent on natural recruitment; high costs of maintenance

(2) semi-intensive farms inshore/offshore (filter feeders)

Some issues:
Correct Placement (MSP)
Exposure to weather conditions
Exposure to toxicant from water

Semi-intensive farms are based on natural feeding of species in which the recruitment is controlled by farmers (placement of juveniles).
Typical system for example for farming filter feeders off-shore (*Mytilus spp, Ostrea spp*).

Strongly dependent on oceanographic natural variability on currents and waves, on temperature, productivity but also esposure to harmful algal blooms or toxins.

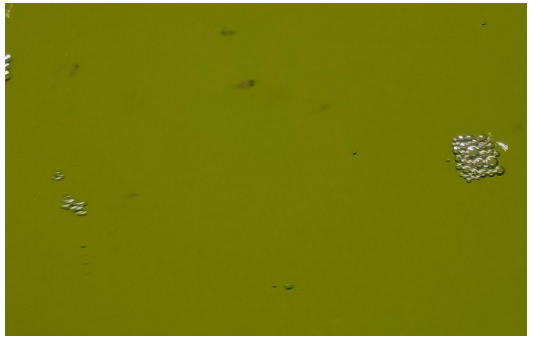
(3) intensive farms inshore/offshore (fish)

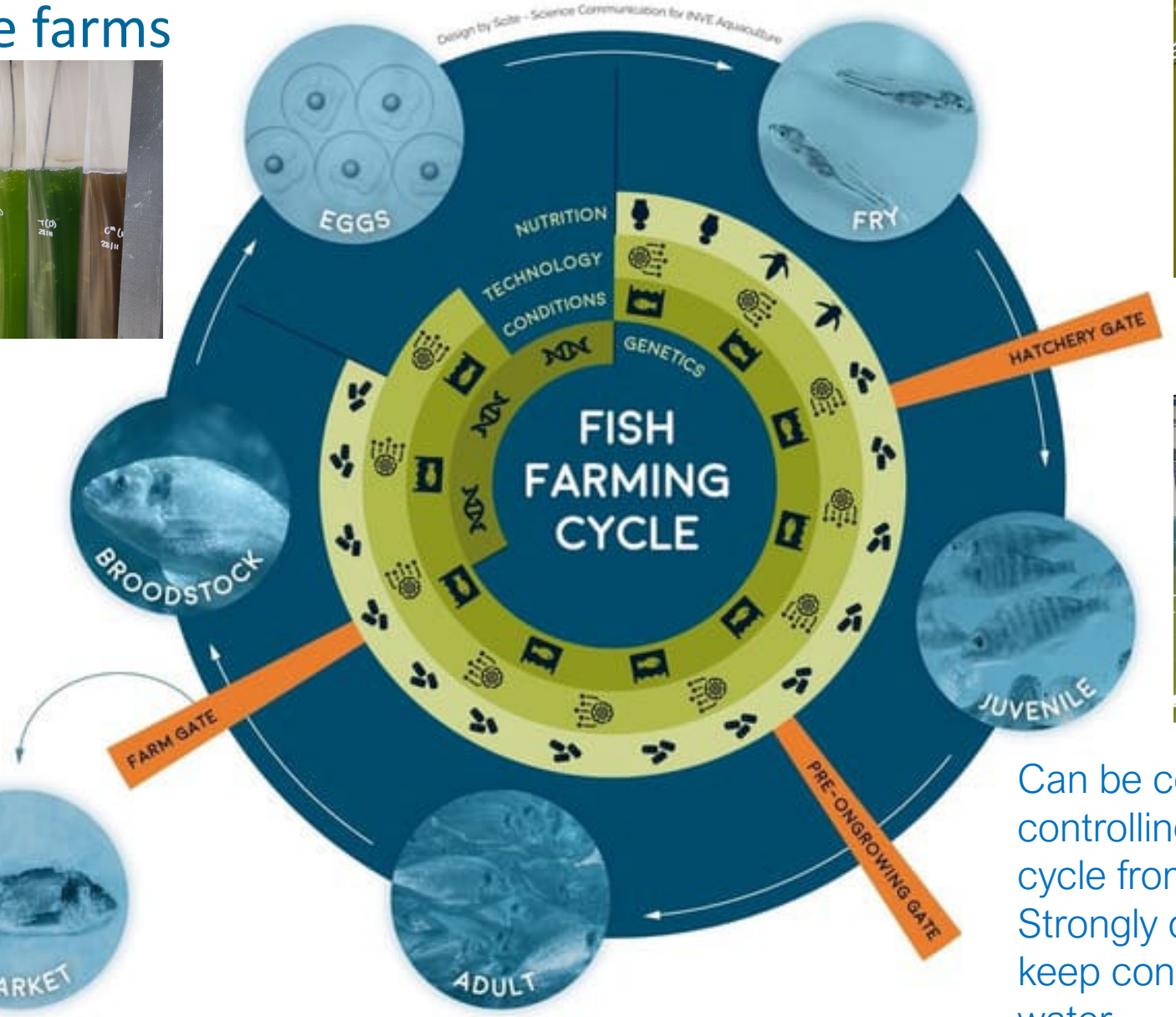
Can be completely inshore or offshore and it is characterized by complete dependence from farmers for both recruitment (fingerlings) and feeding.
Several species (the most important ones usually) are grown in this way of farming (*seabream, seabass, salmon, etc)*

Strongly dependent on the availability of the reproductive adults or of the fingerlings, the process is usually very controlled from conditions in the ponds/cages to feed provided.

Some issues:
Correct Placement (MSP)
Feed & faeces dispersal
Exposure to weather conditions

(4) inland intensive farms





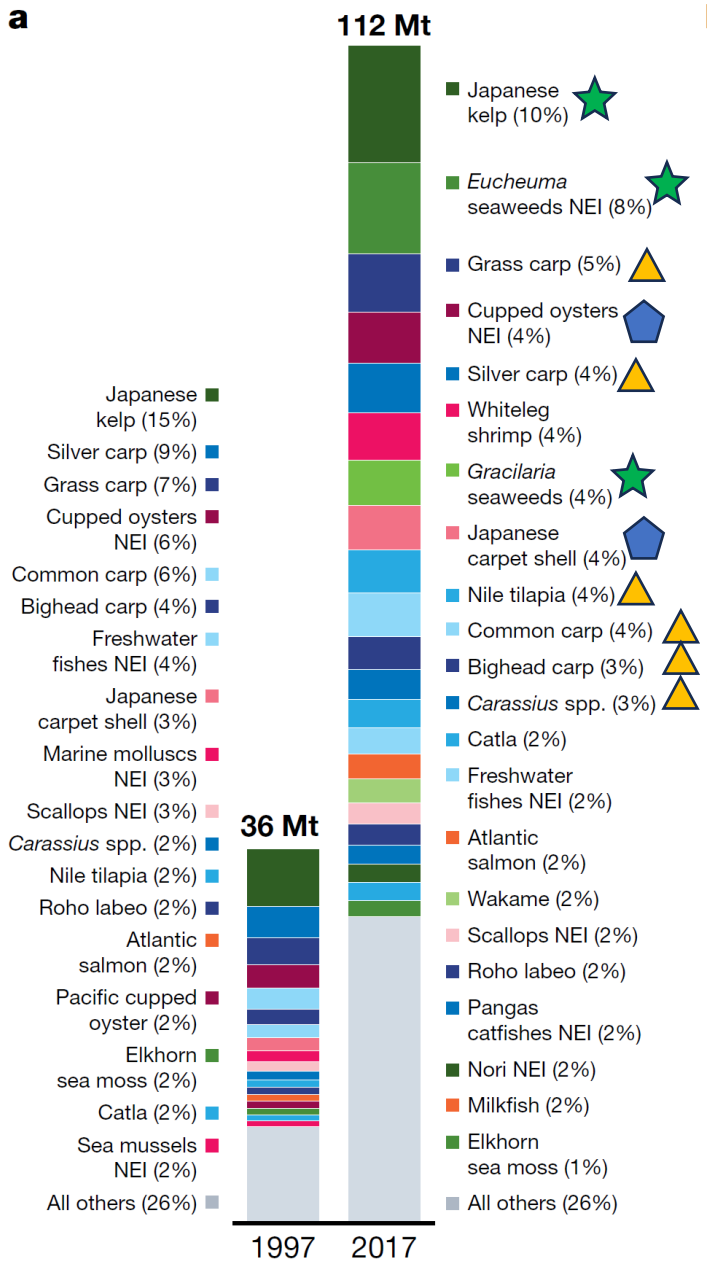
Some issues:
Marine water inputs
Used water discharge
Environmental conditions

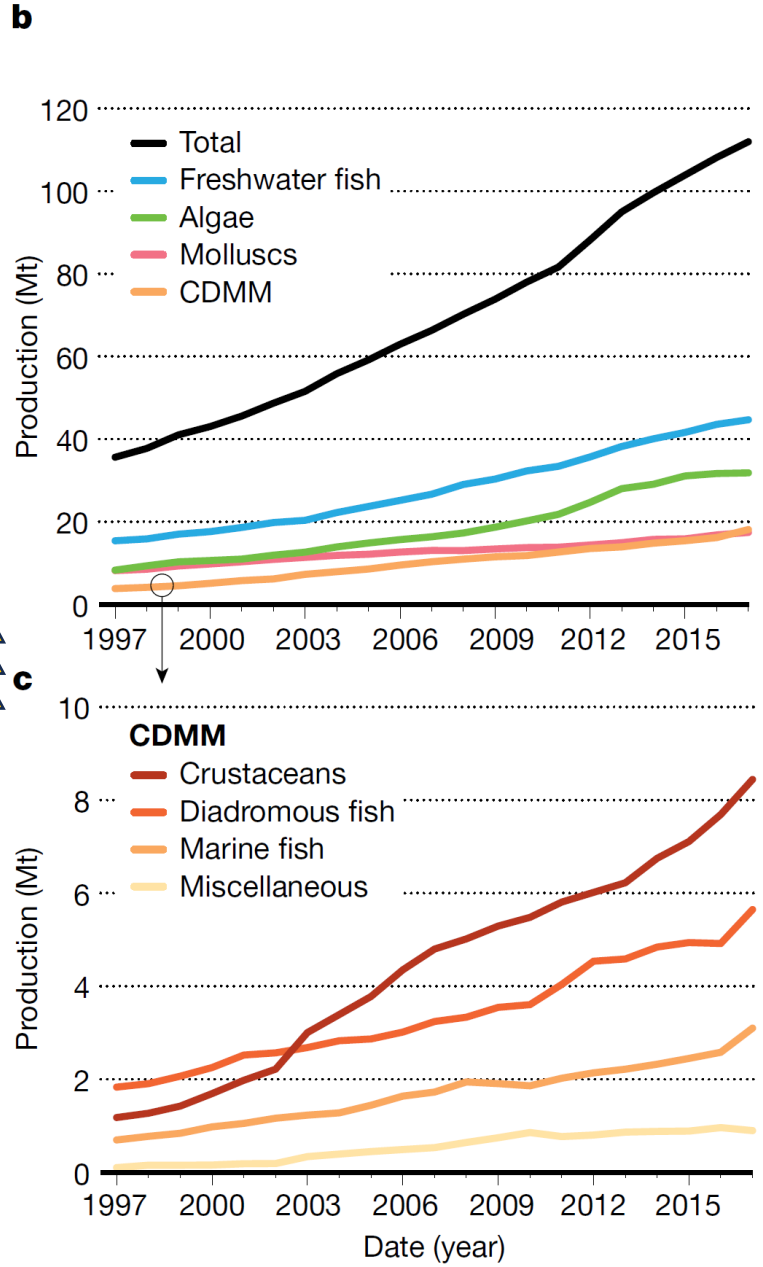
Can be completely inland for better controlling the whole productive cycle from eggs to adults.
Strongly dependent capabilities to keep controlled the recyrculating water

Growth of aquaculture worldwide

What are the species grown? The largest productions nowadays come from

- algae (kelp and seaweeds) ★
- herbivorous/detritivorous fish ▲ (carps)
- bivalves (filter feeders) ⬟





Naylor et al., 2021, Nature

The future is intensive aquaculture: growing over time and with high efficiency.

Generally it is well highlighted the great Efficiency of aquaculture farmed species: far more efficient that terrestrial farmed species, but care need to be placed in a proper evaluation (e.g., water).

Table 1 | Wild fish used in aquaculture feeds for 11 commonly farmed fed fish and shellfish

Farmed fish and crustaceans[a]	Total production (kilotons)[a]	Percentage produced with compound feed (by weight)[a]	Average FCR[b]	Percentage fishmeal in feed (wild)	Percentage fishmeal in feed (trimmings)	Percentage fish oil in feeds (wild)	Net wild fish used (kilotons)	FIFO[c] in 2017
Fed carps	13,986	57	1.7	0.4	0.6	0	0	**0.02**
Tilapia	5,881	92	1.7	0.5	1.5	0	0	**0.03**
Shrimp	5,512	86	1.6	5	5	2	3,034	**0.82**
Catfishes	5,519	81	1.3	0.5	1.5	0	0	**0.02**
Marine fish	3,098	80	1.7	8	6	3	2,528	**1.25**
Salmon	2,577	100	1.3	6	6	6	4,020	**1.87**
Freshwater crustaceans	2,536	60	1.8	5	7	1	548	**0.43**
ODF fish	2,491	43	1.7	3	8	2	728	**0.38**
Milkfish	1,729	55	1.7	2		0	0	**0.07**
Trout	846	100	1.3	5	4	6	1,320	**1.82**
Eel	259	100	1.5	25	10	5	389	**2.98**
Total	44,424						12,566	**0.28**

[a]Categories from Tacon[3], Table 4. ODF, other diadromous and freshwater fish. The calculations by the authors are based on data from the following sources: production, share of production and FCR were obtained from the FAO[2] and Tacon[3]; inclusion of fishmeal and fish oil data were from the National Resource Council report on Nutrient Requirements for Fish and Shrimp[54], Naylor et al.[59], and Ytrestøyl et al.[55]; and analyses of fish trimmings in fishmeal were from Green (SeaFish)[47] and Leadbitter[44]. We use conservative estimates of 24% fishmeal and 10% fish oil recovery from wild fish.
[b]FCR is defined as the estimated average species-group economic FCR (total feed fed/total species group biomass increase). Economic FCR (also known as EFCR)[3,55,59] is defined as total feed fed/total species group biomass increase and includes waste, escapes and other non-ingested feeds[55].
[c]FIFO, wild fish inputs to fed fish output.
See Extended Data Table 3 for more information.

Naylor et al., 2021, Nature

The future is intensive aquaculture: growing over time and with high efficiency.

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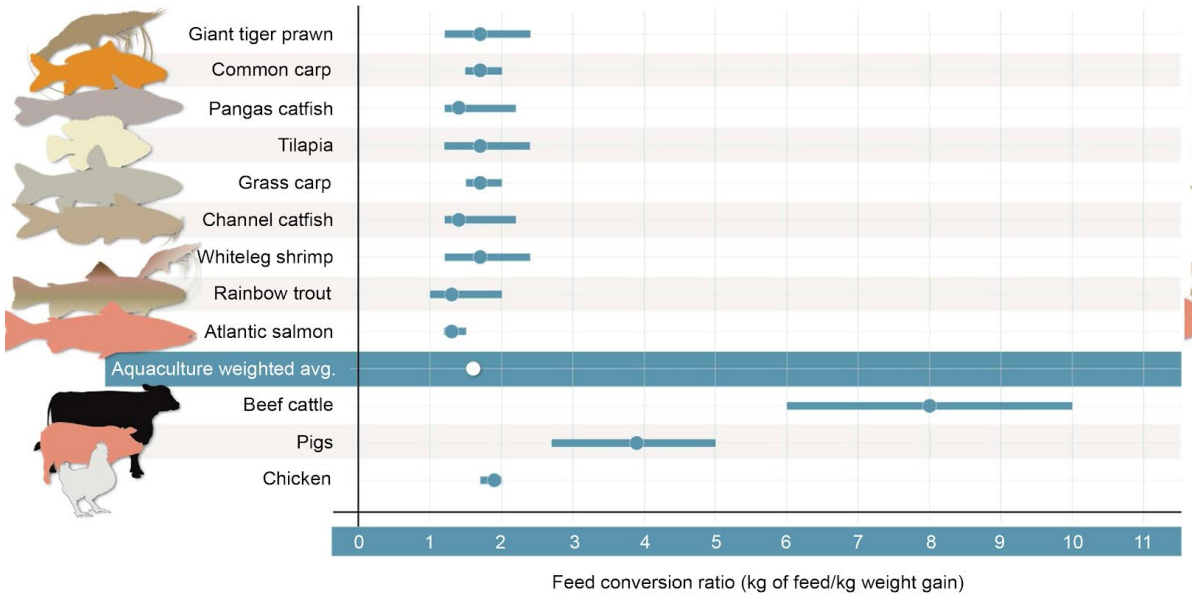
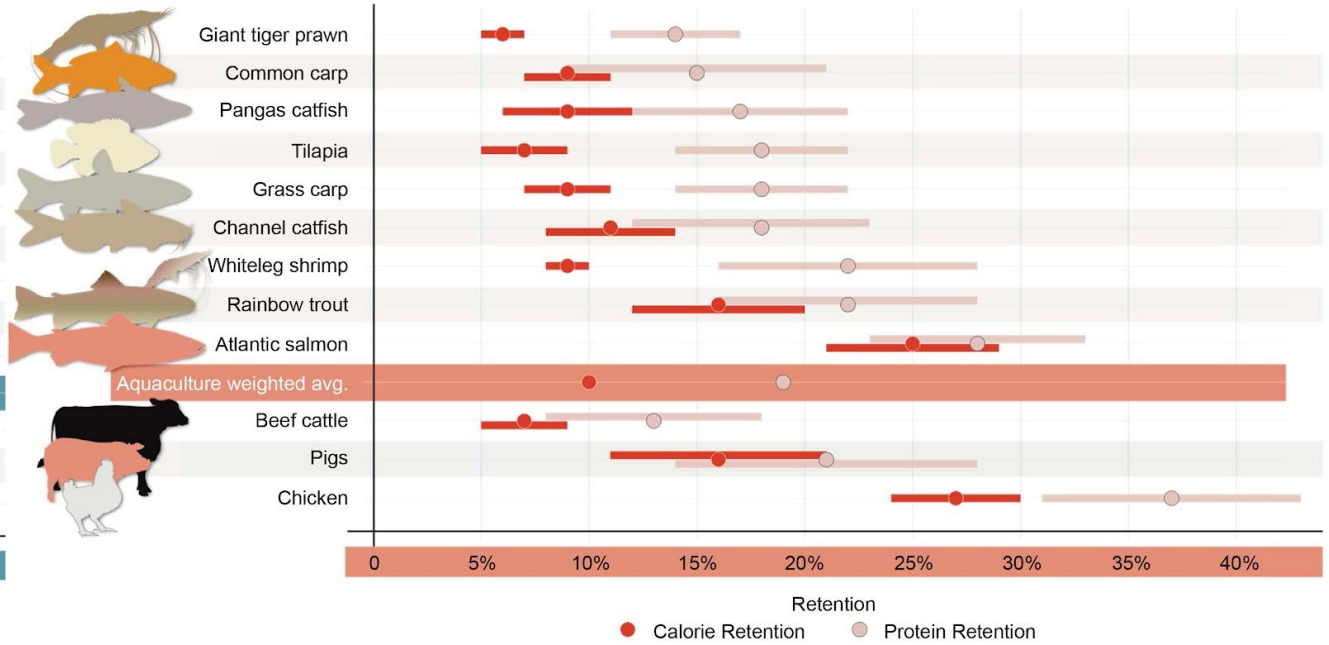




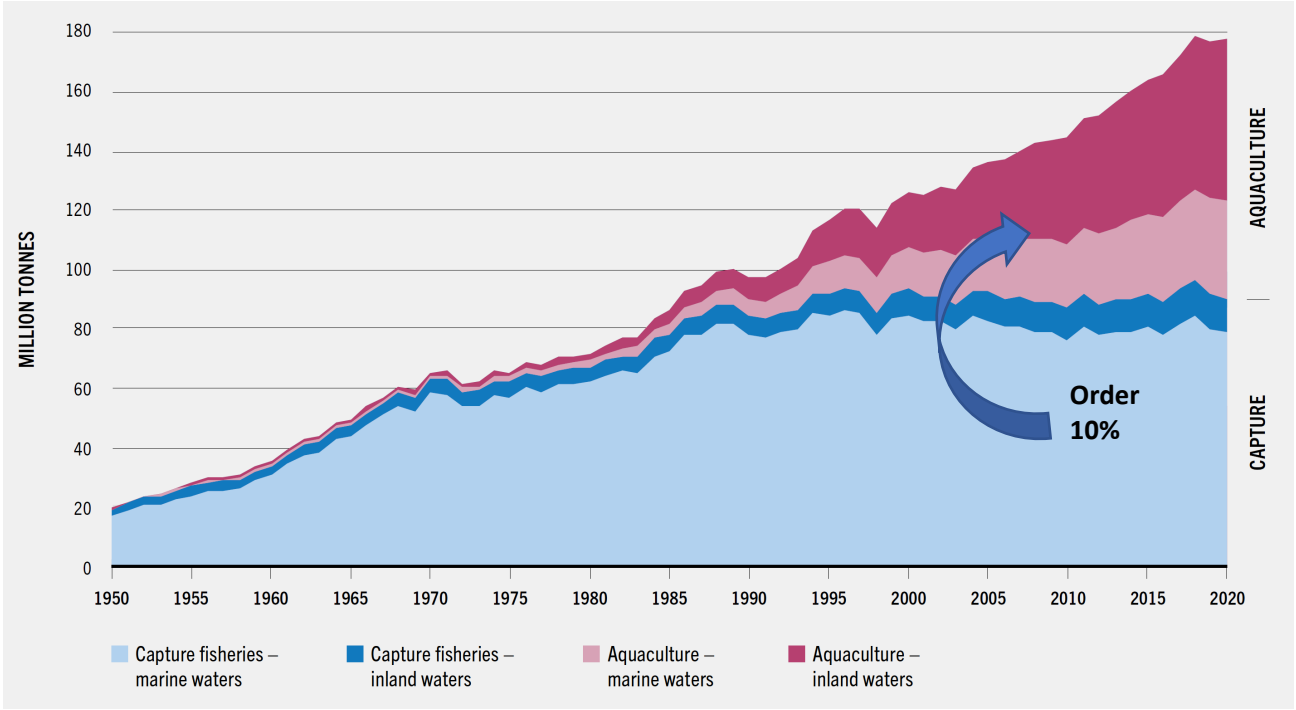
The high feed conversion (kg of feed given/ kg weight gain) fish are proposed to have exceptionally high efficiency, partially due to misconsidering the proportion of water (in feed and live weight of the fish)

Considering retention of proteins and calories the fish and terrestrial species show a more similar range of variability

Fry et al., 2018

Use of fishmeal-fishoil

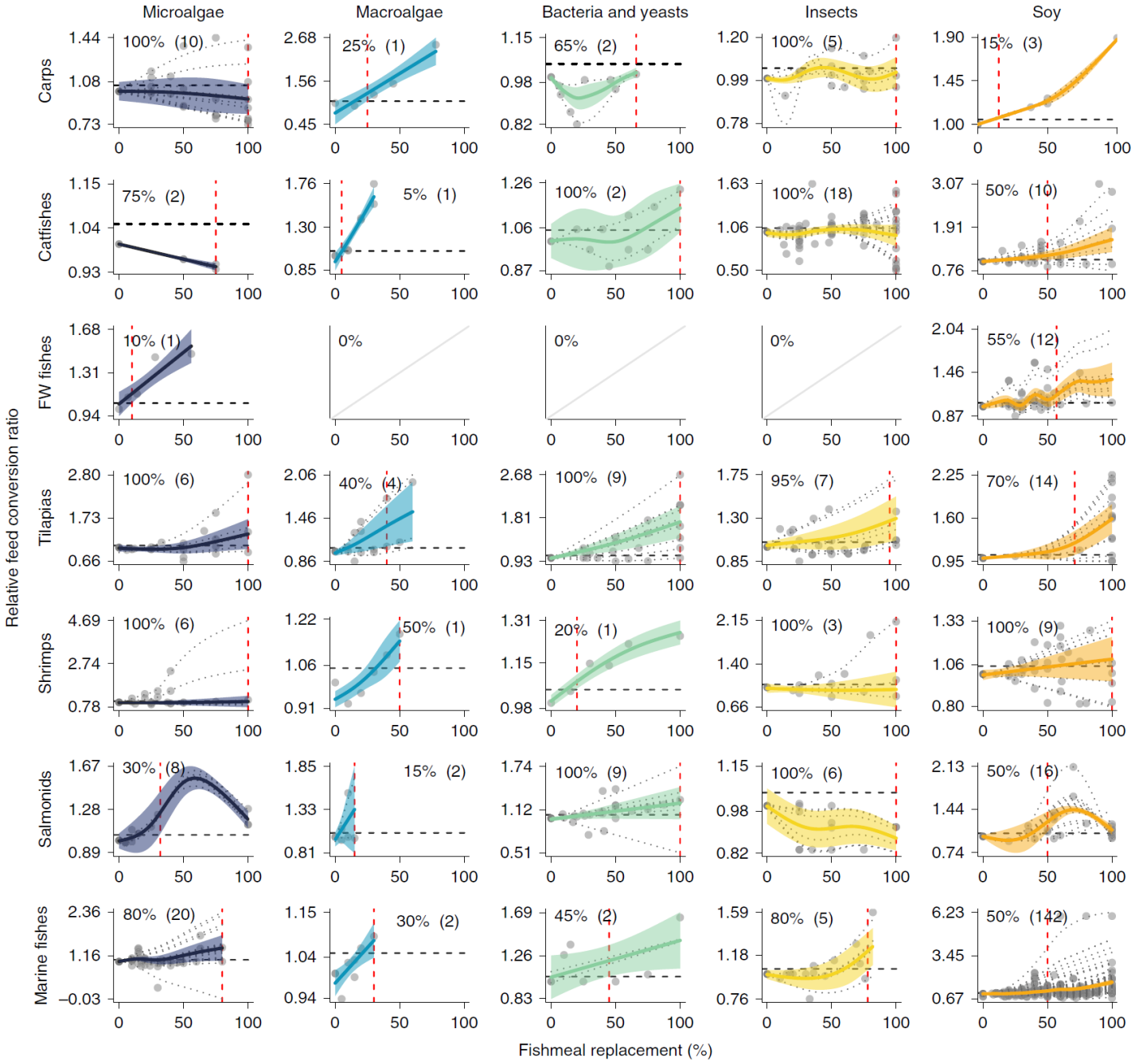
A part of the wild fish capture (approximately 10%) is used as fish meal or fish oil with increasing interest for the farming in the last decades, that also lead to increase in price of fishmeal and fish oil (Naylor, 2021, Nature).



World capture and aquaculture production
Source: FAO, State of world Fisheries and Aquaculture (SOFIA), 2022

Replacement of fishmeal-fishoil In the feed for fishfarms

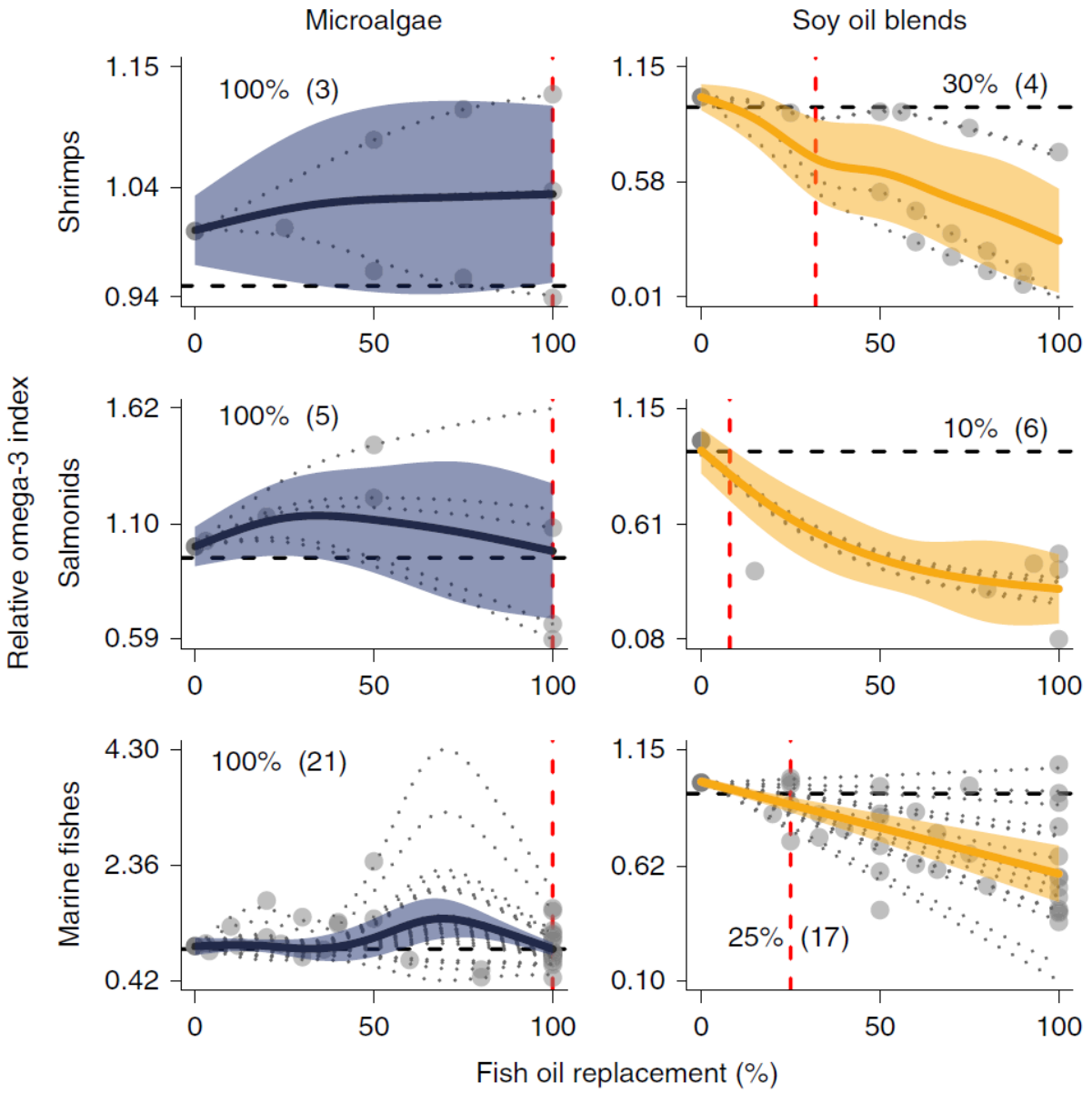
There are growing activities for substituting fishmeal and fishoil into feeds for fishfarms. Generally results show quite good acceptance for medium-low proportion of substitution. Conversion efficiency is not constant with increasing proportion of substitution and in some cases it is evident a negative effect on conversion efficiency.



Cottrell et al., 2020 Nature Food

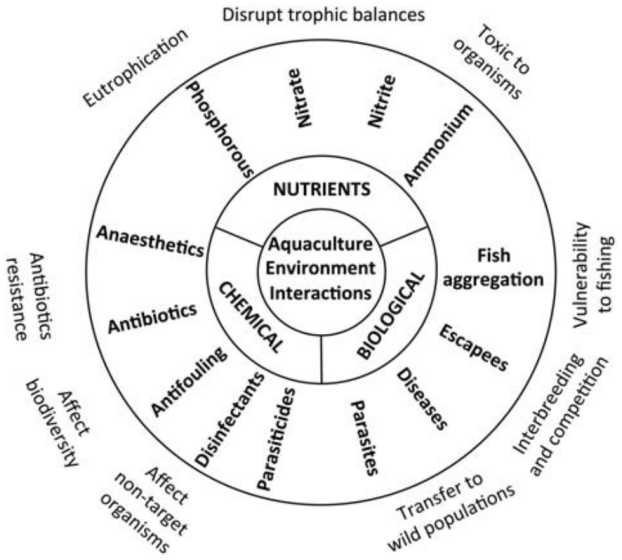
Replacement of fishmeal-fishoil In the feed for fishfarms

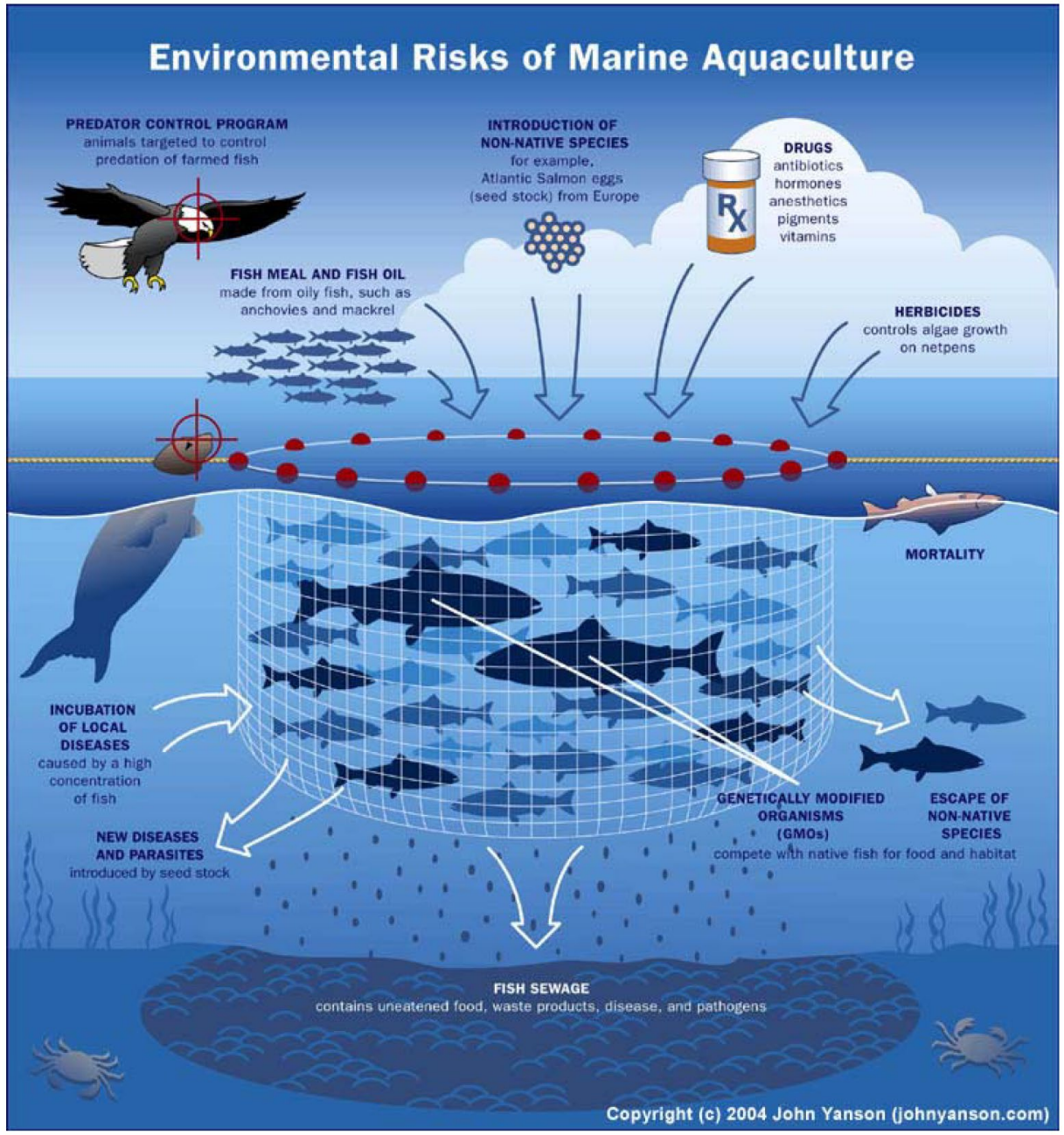
One problem is related to the possibility to retain omega-3. Since species are only accumulating omega-3 it is important that replacement of fish-meal contains omega-3 in order to avoid depletion in the fish produced.



Cottrell et al., 2020 Nature Food

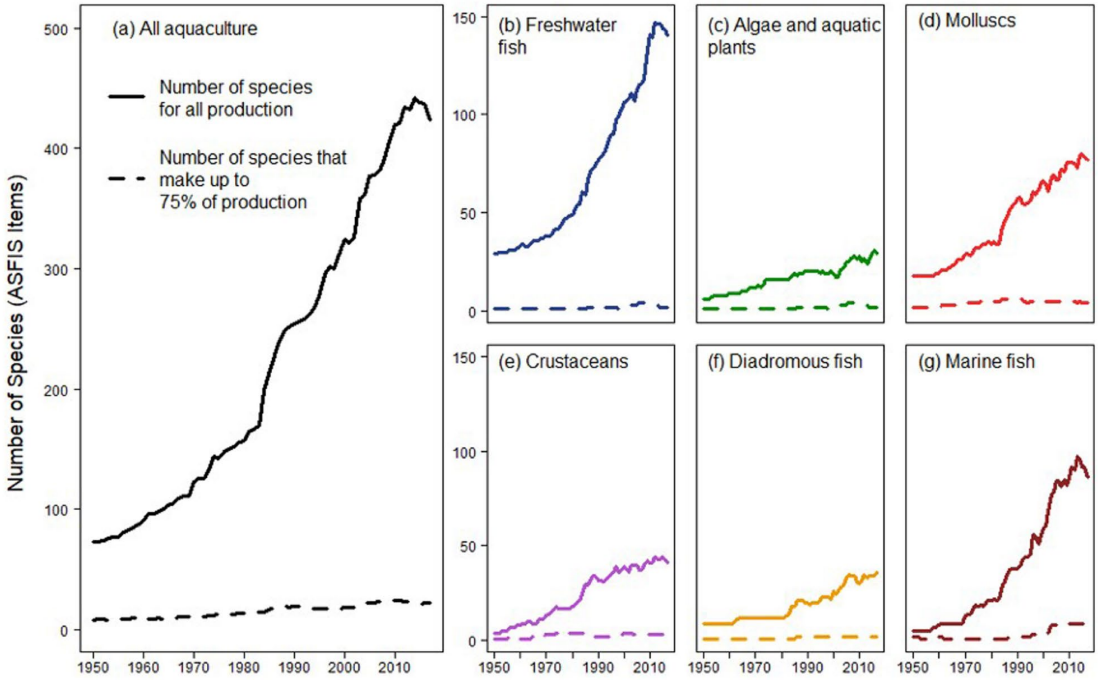
Issues in aquaculture



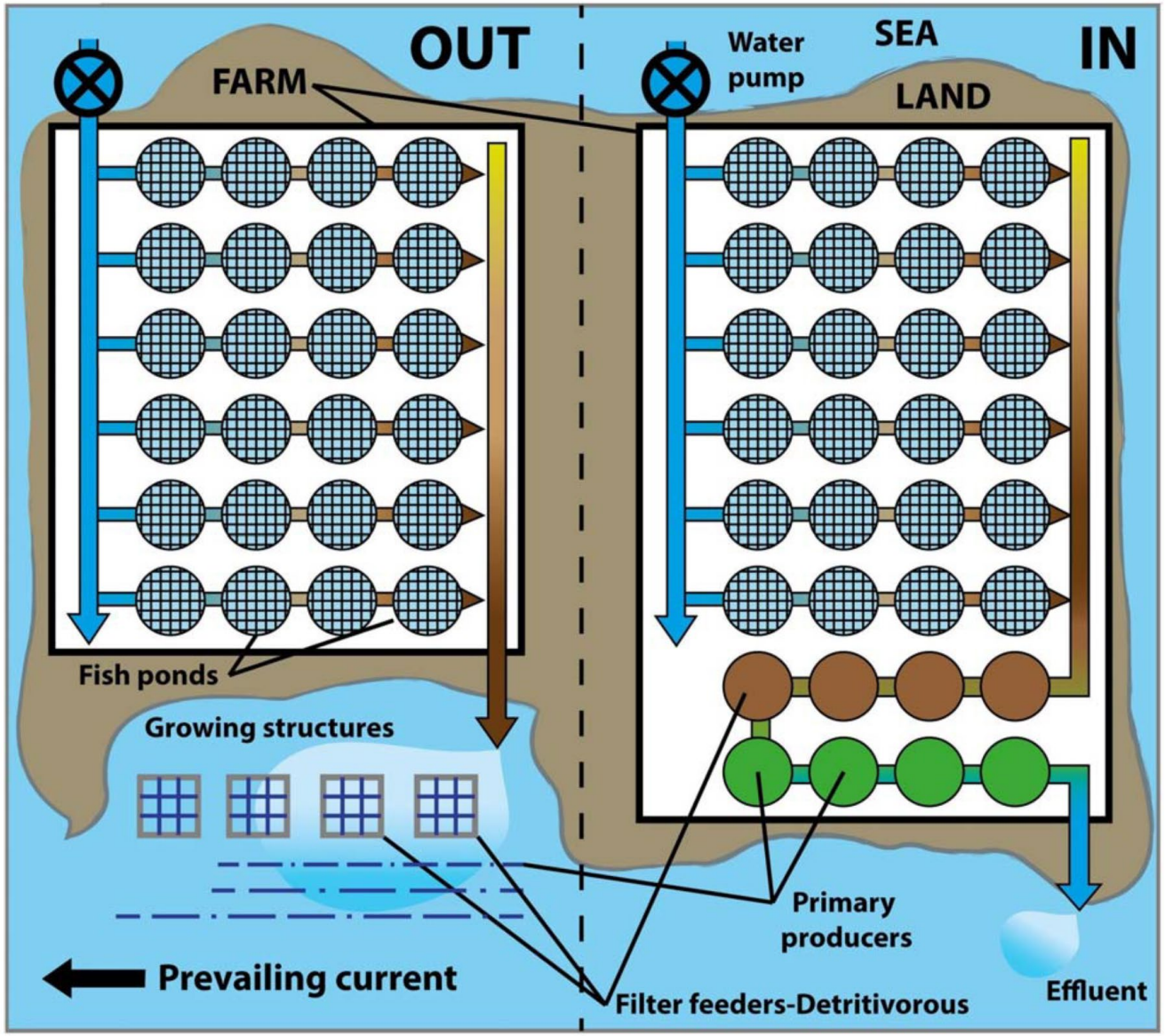


Brana et al., 2021 FMARS

Integrated multitrophic aquaculture and diversification of aquaculture products

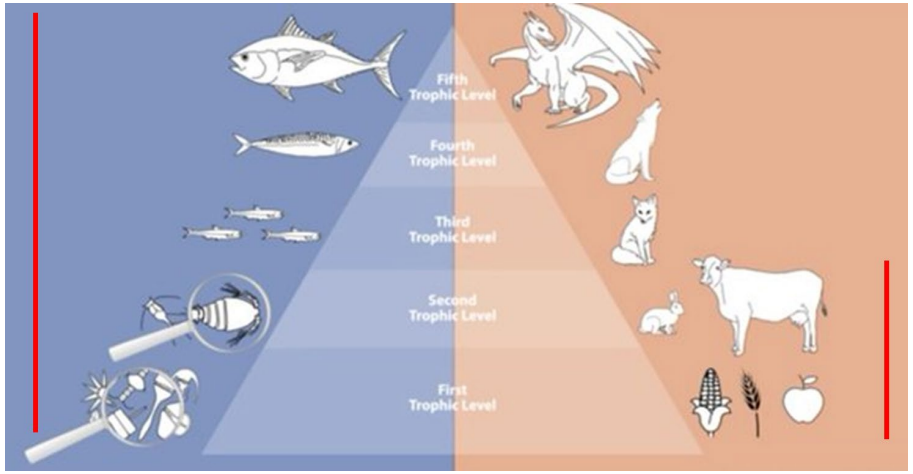


Naylor et al., 2021, Nature

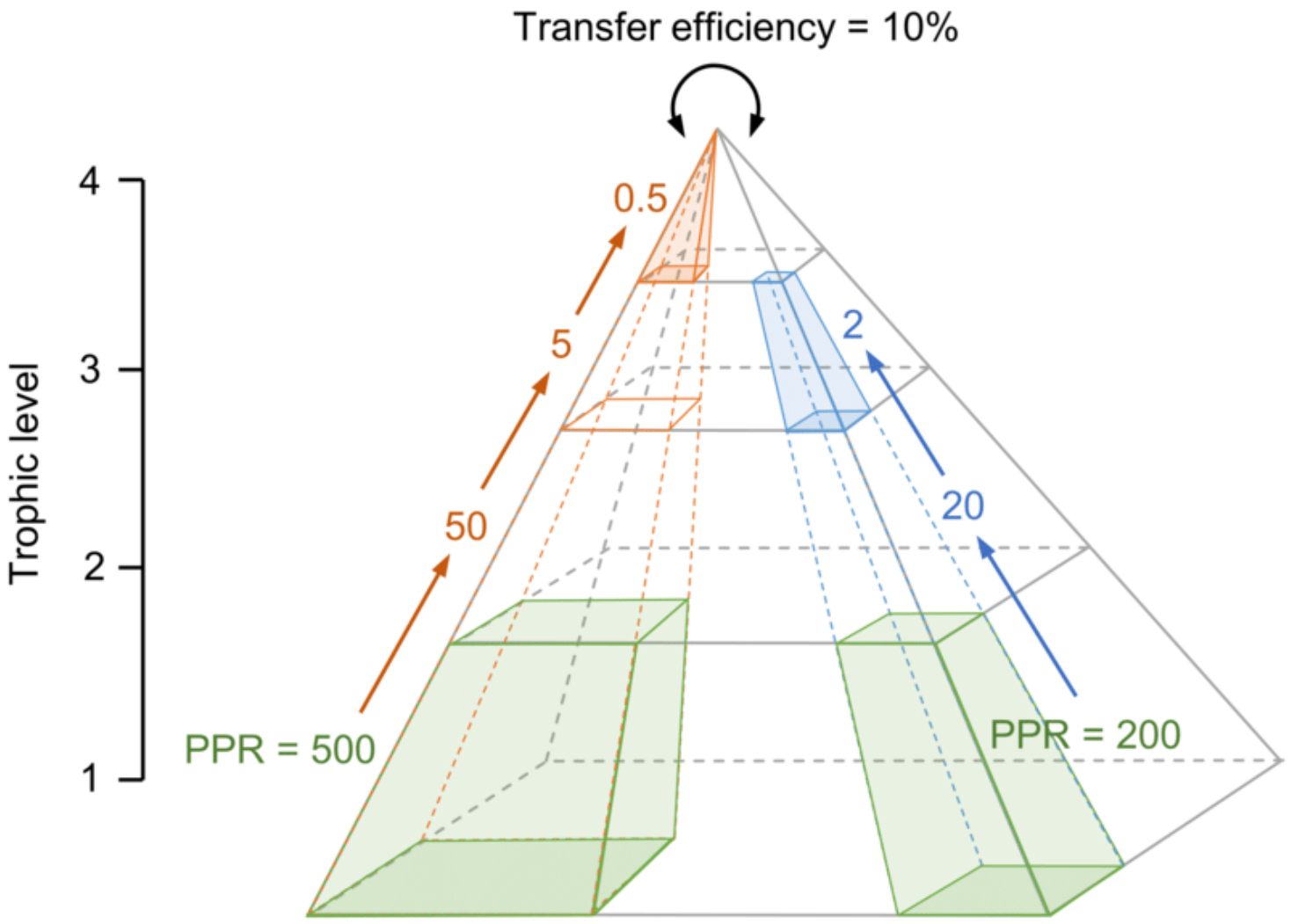


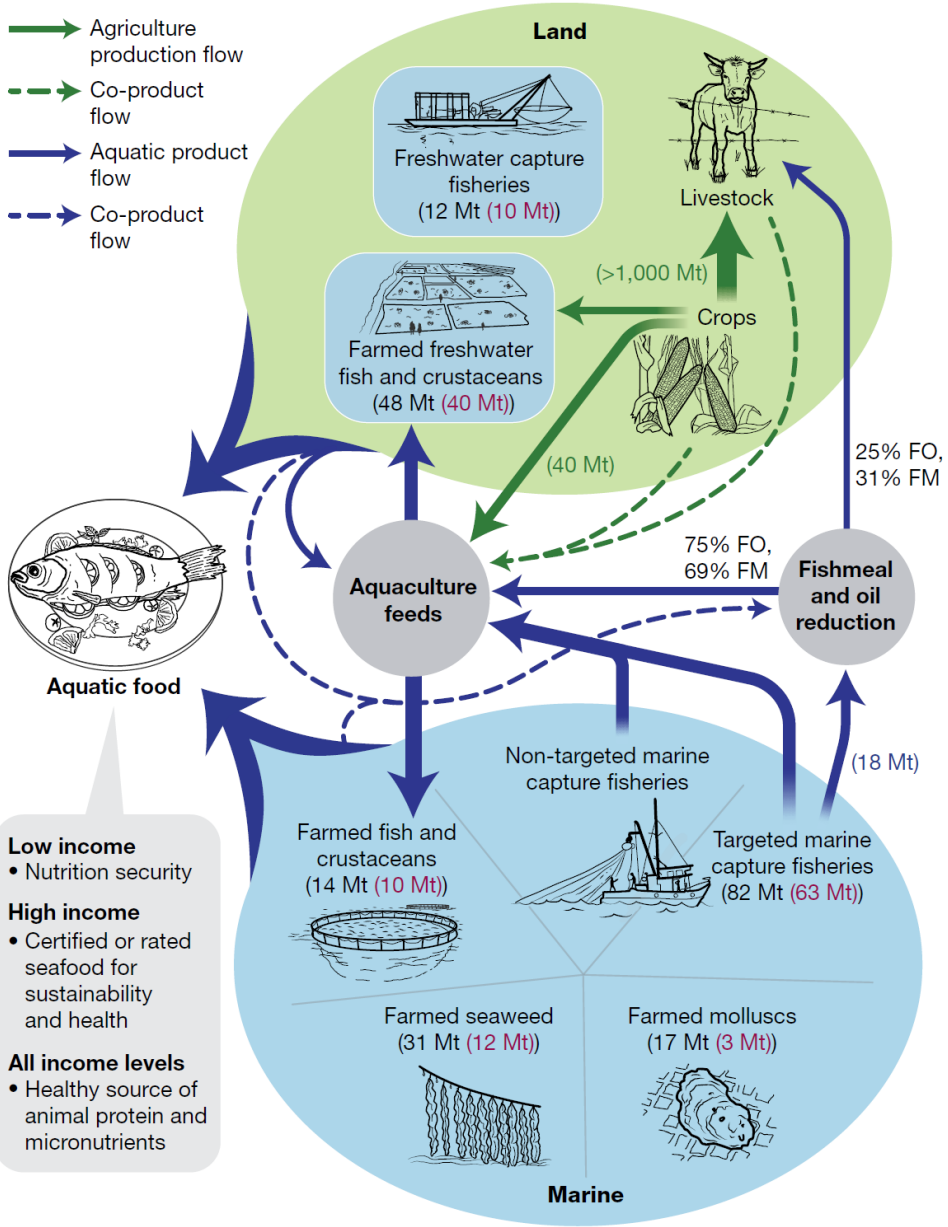
Brana et al., 2021 FMARS

A sustainable solution: avoid «dragon for dinner»!



Balanced consumption across the trophic levels: comsume proportionally higher quantities of lower trophic level organisms. This is particularly true for the aquaculture products (farming of low trophic levels) but regards also wild catches: **«balanced exploitation»** proportional to production at each trophic level (Garcia et al., 2015 IUCN)





Persistent stressors to aquatic food systems

- Pathogens, parasites and pests
- Climate change and ocean acidification
- Harmful algal blooms
- Pollution

Key areas for governance

Spillovers between and within sectors

- Technology transfer from agriculture and livestock farming to aquaculture

Negative externalities

- **Land:** Land-use change, biodiversity loss, GHG emissions, nutrient and chemical wastes and/or effluent (pollution), and antibiotic and antimicrobial resistance
- **Oceans:** Habitat change, biodiversity loss, GHG emissions, nutrient and chemical wastes and/or effluent (pollution), and antibiotic and antimicrobial resistance

Positive externalities

- **Oceans:** Ecosystem services (for example, nutrient uptake and habitat from mollusc and seaweed farming)

Naylor et al., 2021, Nature

Fisheries management action options

Fisheries are managed by controlling either the INPUT (for example, access to grounds, number of vessels, seasonal closures) or the OUTPUT (for example, catches), or using other technical measures

$$C(t) = F(t) \cdot B(t) = q \cdot E(t) \cdot B(t)$$

Management options

-LIMIT TO NUMBER OF FISHING VESSELS, DIMENSIONS AND POWER (LICENCES)

-LIMIT TO CATCH (TAC)

-TIME CLOSURES (BIOLOGICAL AND TECHNICAL)

-MINIMUM LANDING SIZE

-TECHNICAL MEASURES (GEAR PROPERTIES)

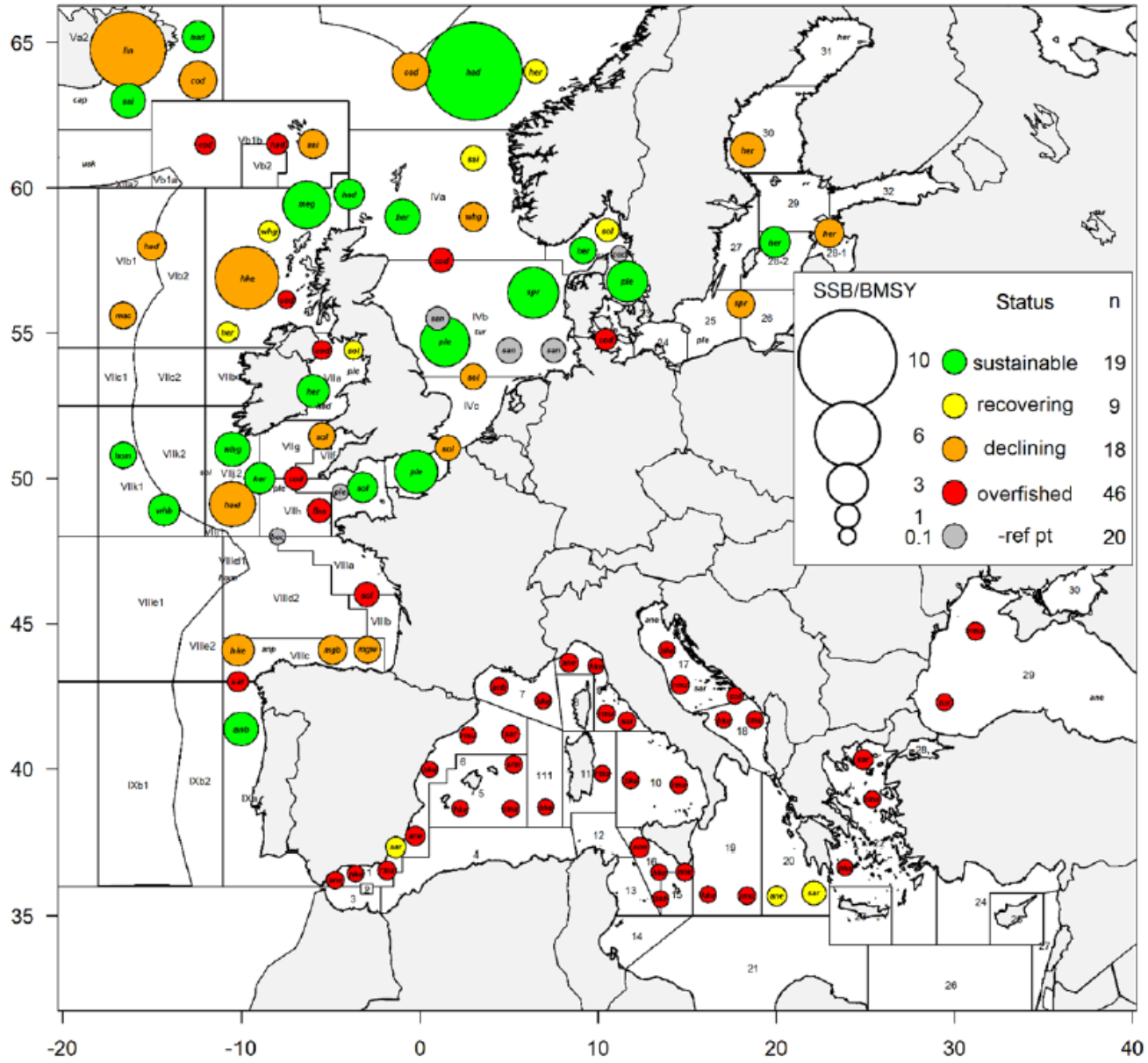
-SPATIAL RESTRICTIONS(COASTAL AREA, MPAs, ARTIFICIAL REEF, Etc.)

Status of european stocks

Stocks in European seas are under same control and management structure, although sounthern European countries started later with an organized stock assessment (2007).

Moreover while Mediterranean fisheries are managed mainly through technical measures and control of input (effort), the northern european Seas are managed in several cases using control of output (quota system).

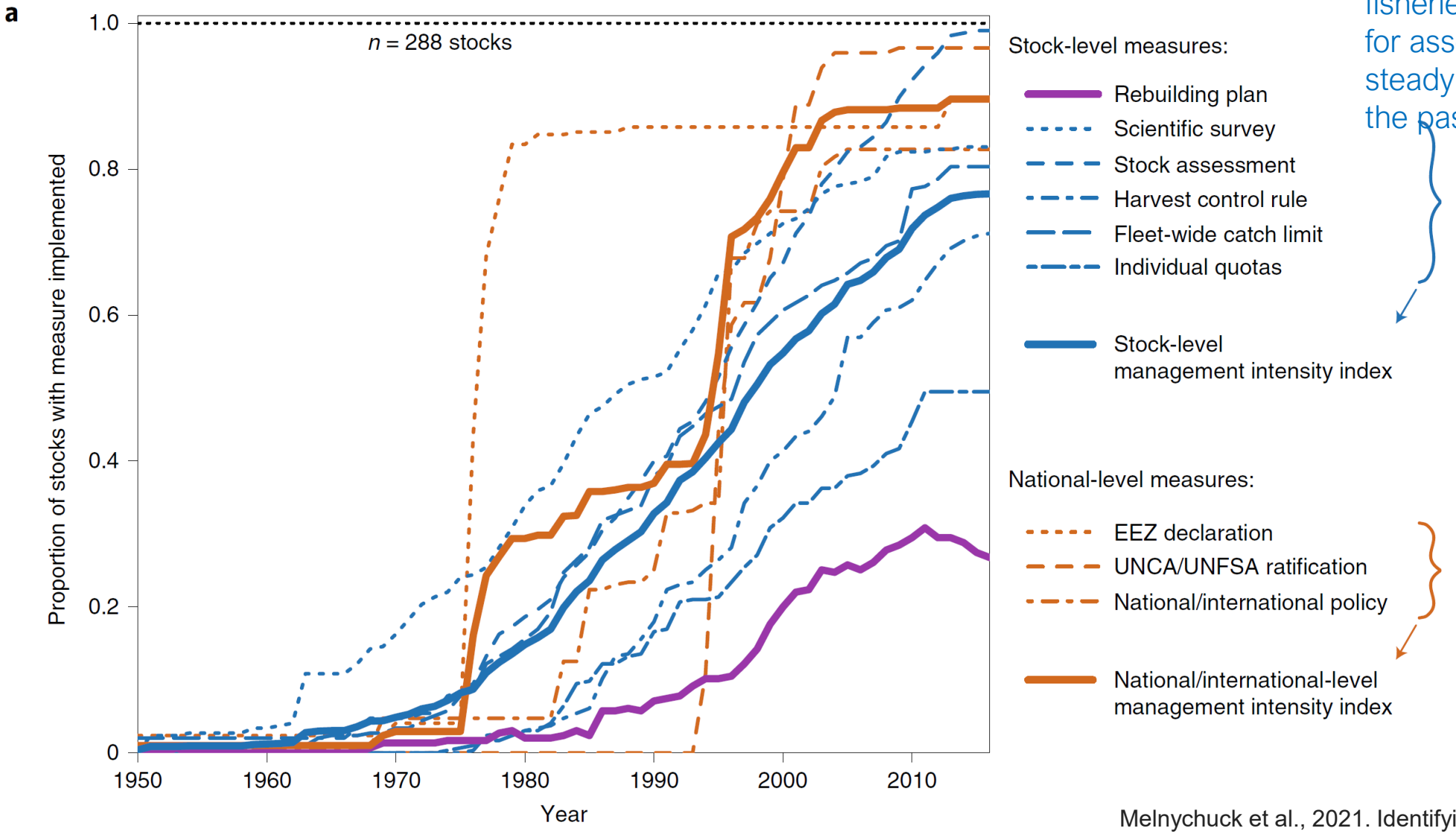
The quota system, however, to be practicable needs high quantitative knowledge and monitoring of the stocks (stock assessment)



Fernandez et al., 2017

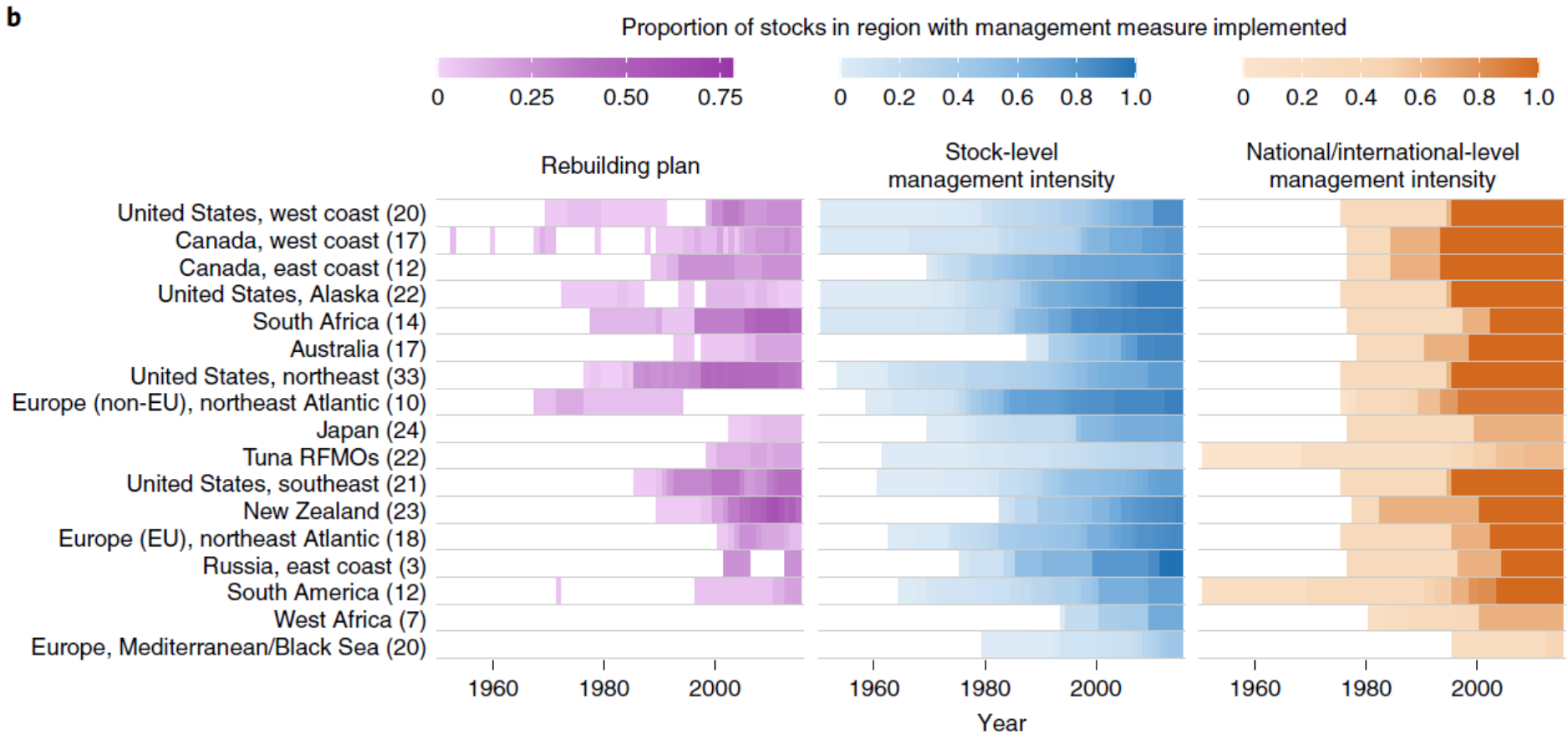
Development of fisheries Management actions worldwide

Implementation history of fisheries management measures for assessed stocks, showing steady increases globally over the past half century.



Melnychuck et al., 2021. Identifying management actions that promote sustainable fisheries. Nature sustainability

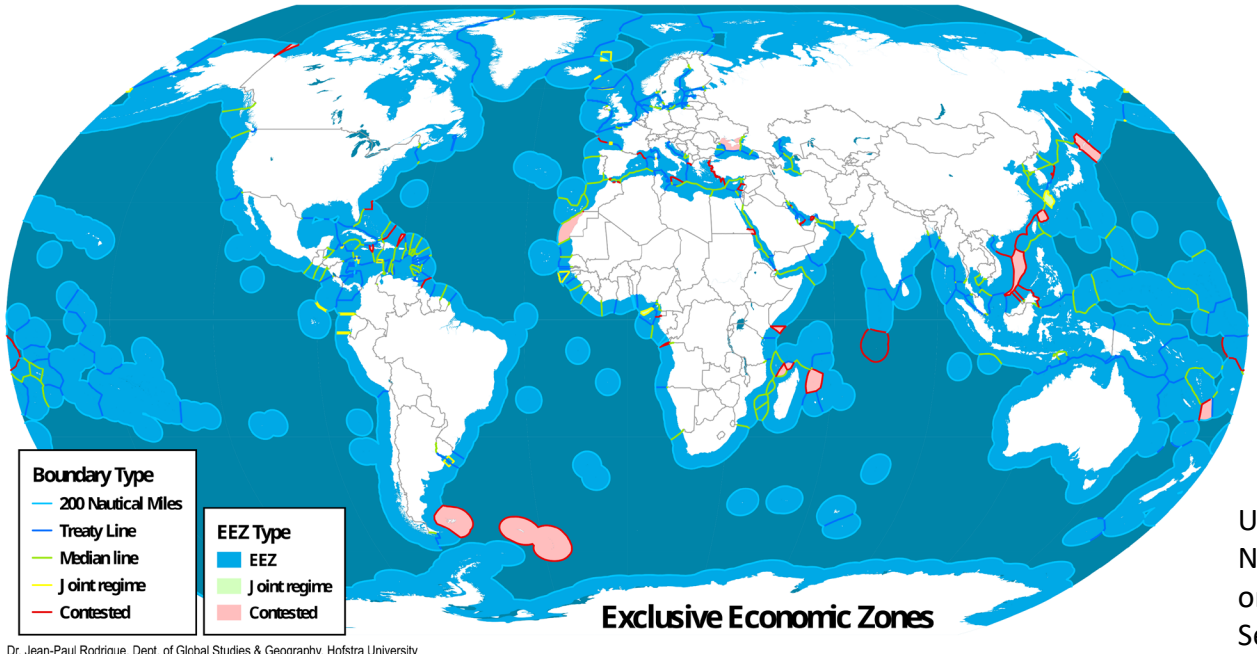
Development of fisheries Management actions worldwide



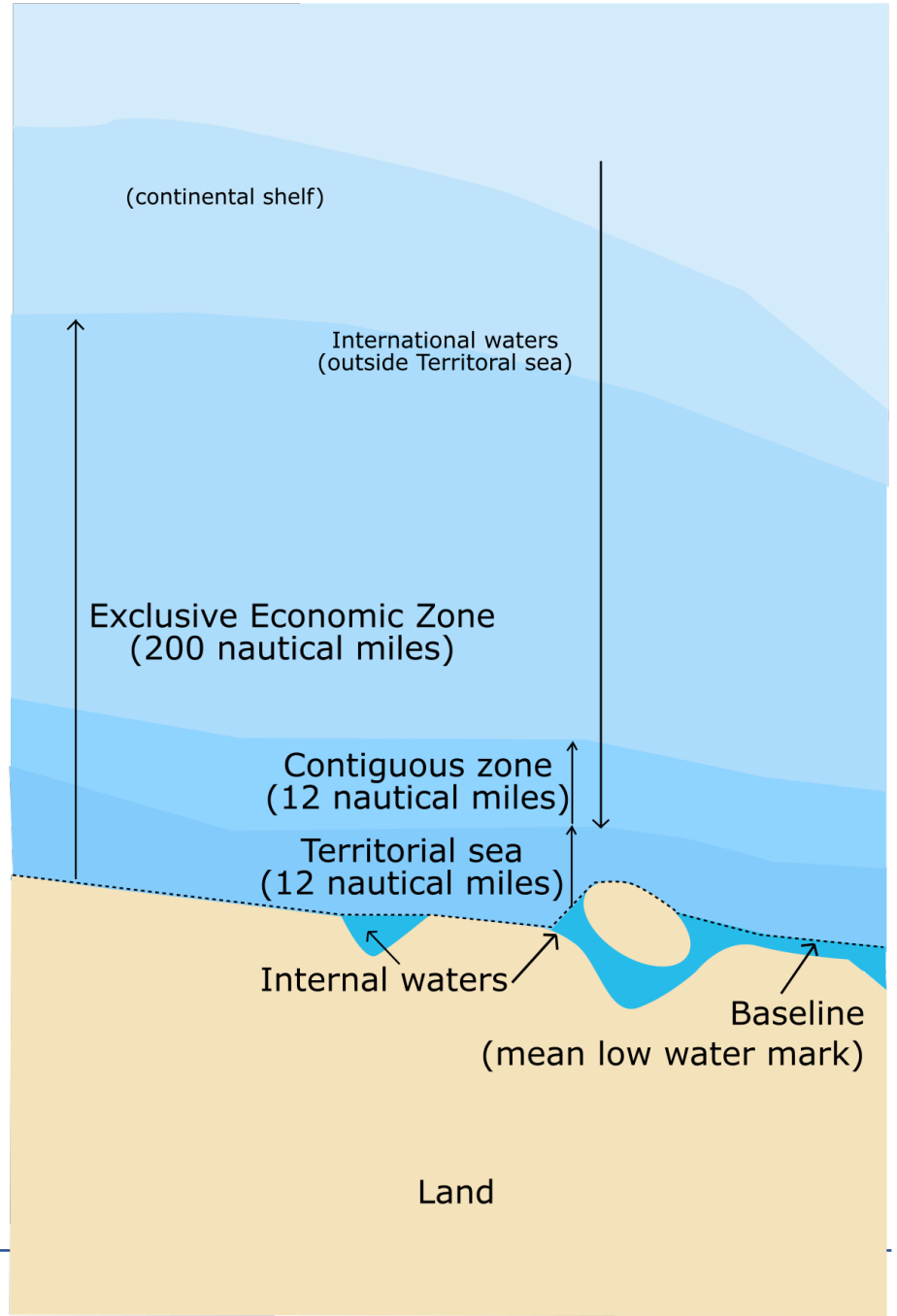
Implementation history of fisheries management measures for assessed stocks, showing steady increases globally over the past half century. But not hevenly distributed across areas.

Melnychuck et al., 2021. Identifying management actions that promote sustainable fisheries. Nature sustainability

Exclusive Economic zones



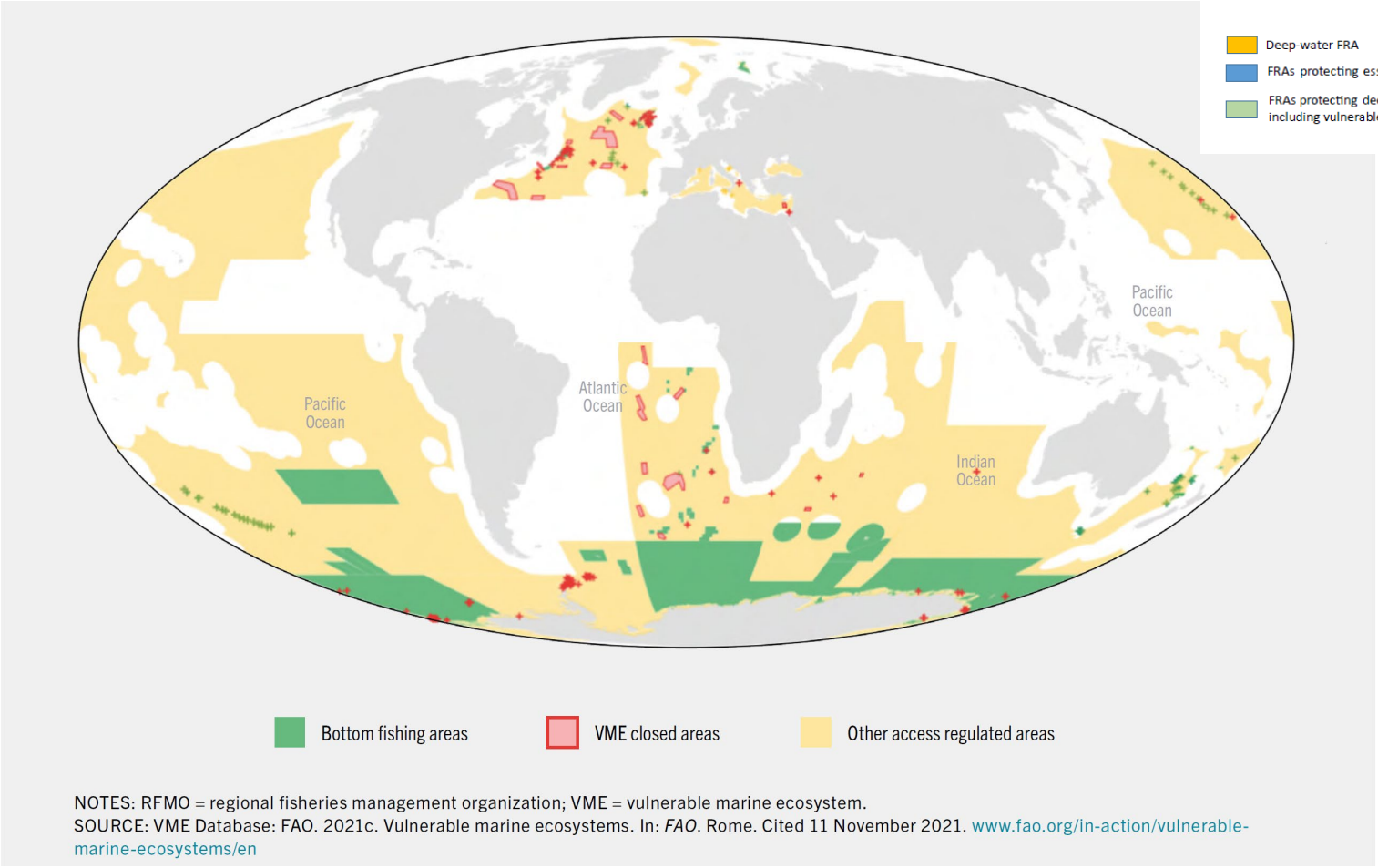
UNCLOS (United Nations Convention on the Law of the Sea)



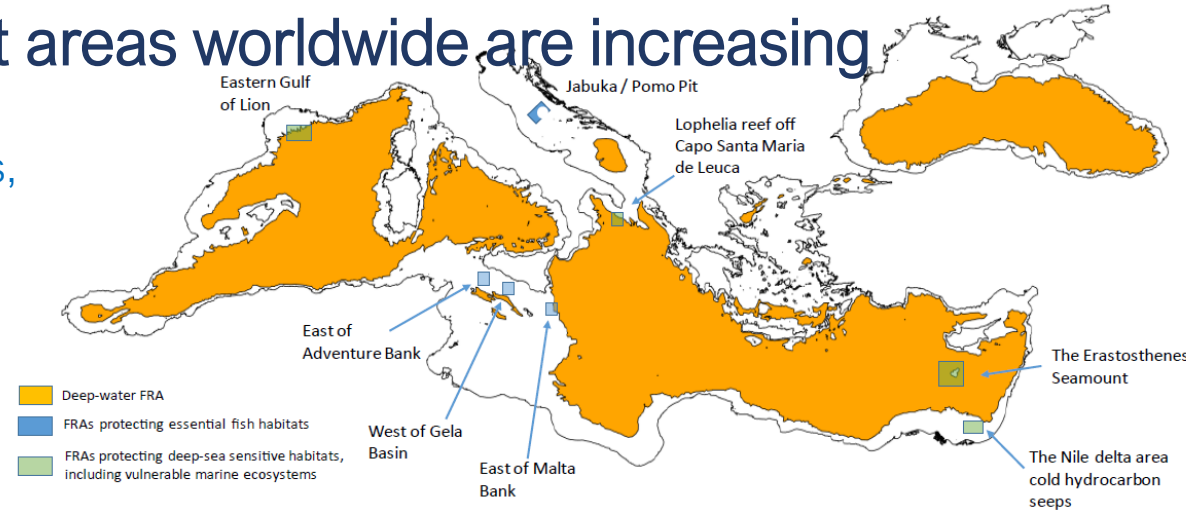
- If the **exclusive economic zone** (EEZ) is defined (declared and ratified to UNCLOS; since 1982): also the fisheries resources are of the country on the shores
- **up to the continental shelf**: the bottom and the organisms that live on the bottom can be exploited by the country;
- outside 12 NM: **international waters** free to pass;
- Contiguous zone: some restrictions to
- **Territorial waters:** up to 12 NM from the coasts: complete soverhegnity by the country on shore;

Agreements for defining fisheries management areas worldwide are increasing

Protecting **vulnerable marine ecosystems** (i.e., areas of the ocean floor where habitat-forming animals such as deep-sea sponges, stony corals, etc..) & **essential fish habitats** (where fish lives and reproduce).
Forbidding bottom fishing or providing other frameworks for controlling the access to fisheries.



NOTES: RFMO = regional fisheries management organization; VME = vulnerable marine ecosystem.
SOURCE: VME Database: FAO. 2021c. Vulnerable marine ecosystems. In: *FAO*. Rome. Cited 11 November 2021. www.fao.org/in-action/vulnerable-marine-ecosystems/en



GFCM-FAO (2018) The State of Mediterranean and Black Sea Fisheries.

In the Mediterranean sea it is forbidden to fish with trawling in areas with depth greater than 1000m (in discussion to adopt 800m).
Some exceptional fish habitats are also protected.
One of the largest fisheries restricted area is in the Adriatic Sea (Pomo pit, since 2017).

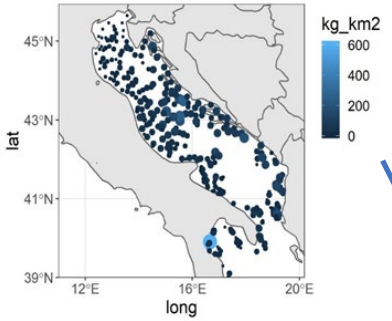
FAO, State of world Fisheries and Aquaculture (SOFIA), 2022

https://www.fao.org/in-action/vulnerable-marine-ecosystems/vme-database/en/vme.html

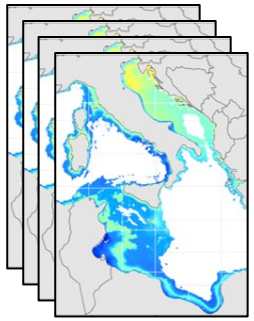
Quantitative tools to support improved management: set best protected/managed areas

areas where multiple species have their hotspots. Values in the figures refer to the number of species having their hot spot in the grid cell (6x6km).

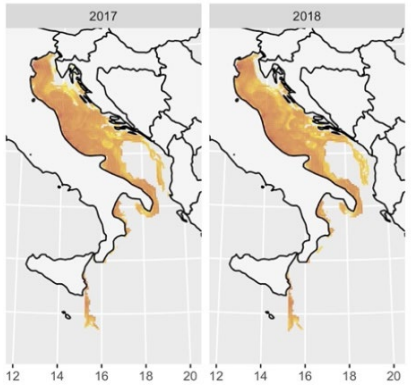
Trawl survey data on species abundance



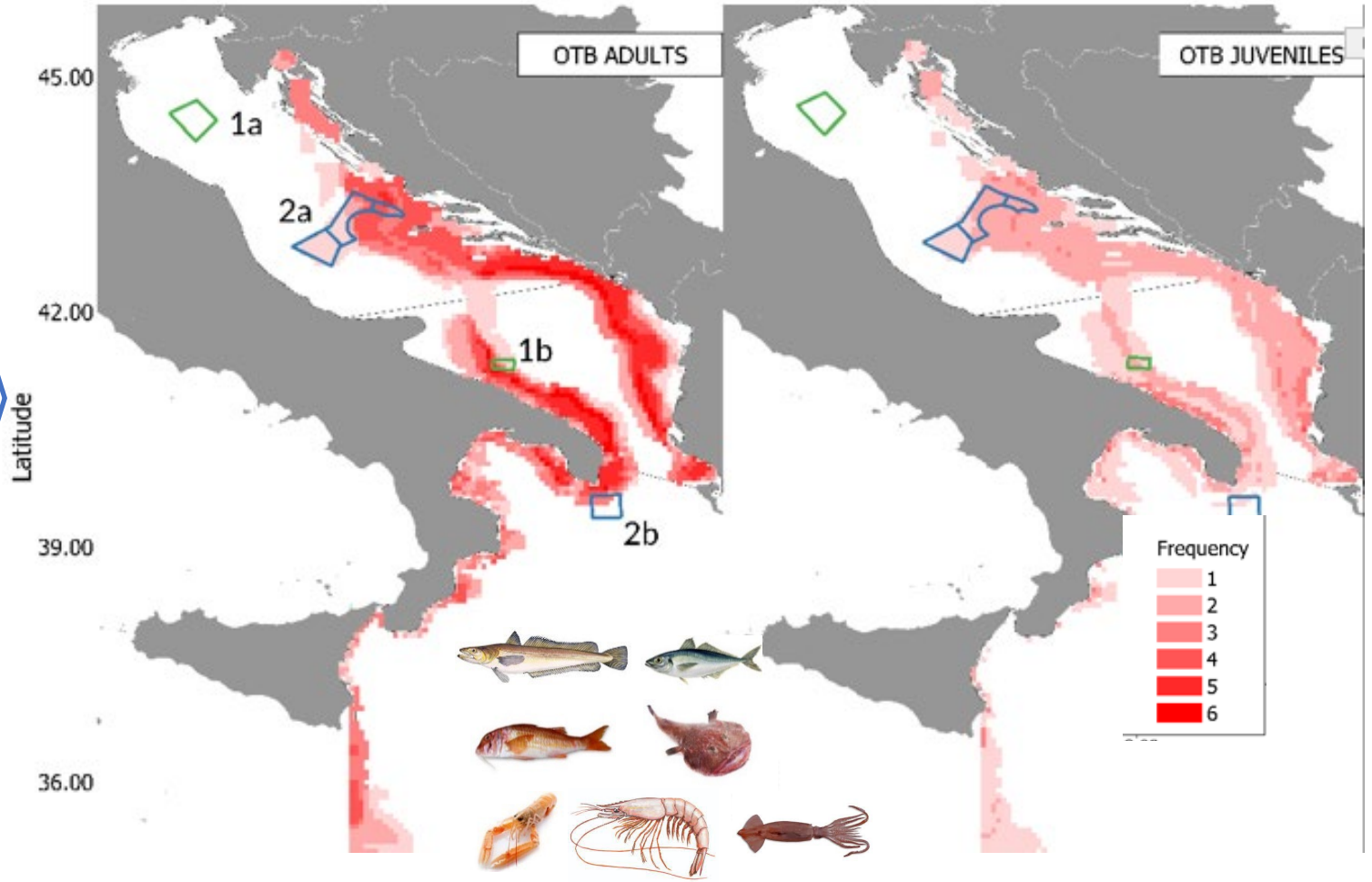
3D oceanographic variables



Fishing vessel position



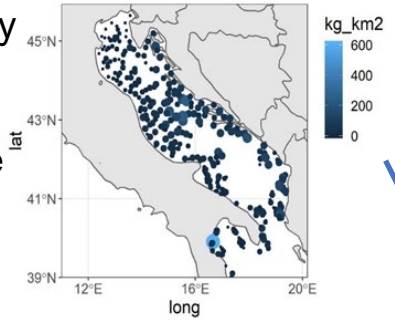
Ensamble of models
Integrating data



Panzeri et al., 2023 Fish and Fisheries

Quantitative tools to support improved management: set best protected areas

Trawl survey data on species abundance (once per year)



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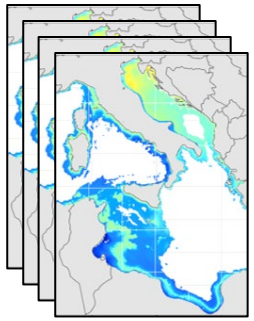

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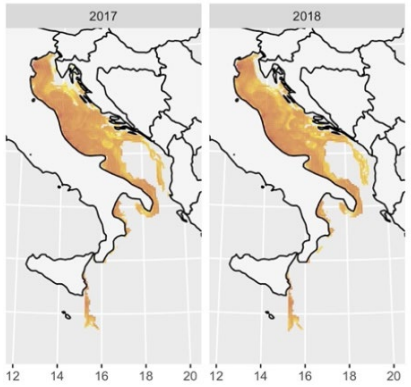
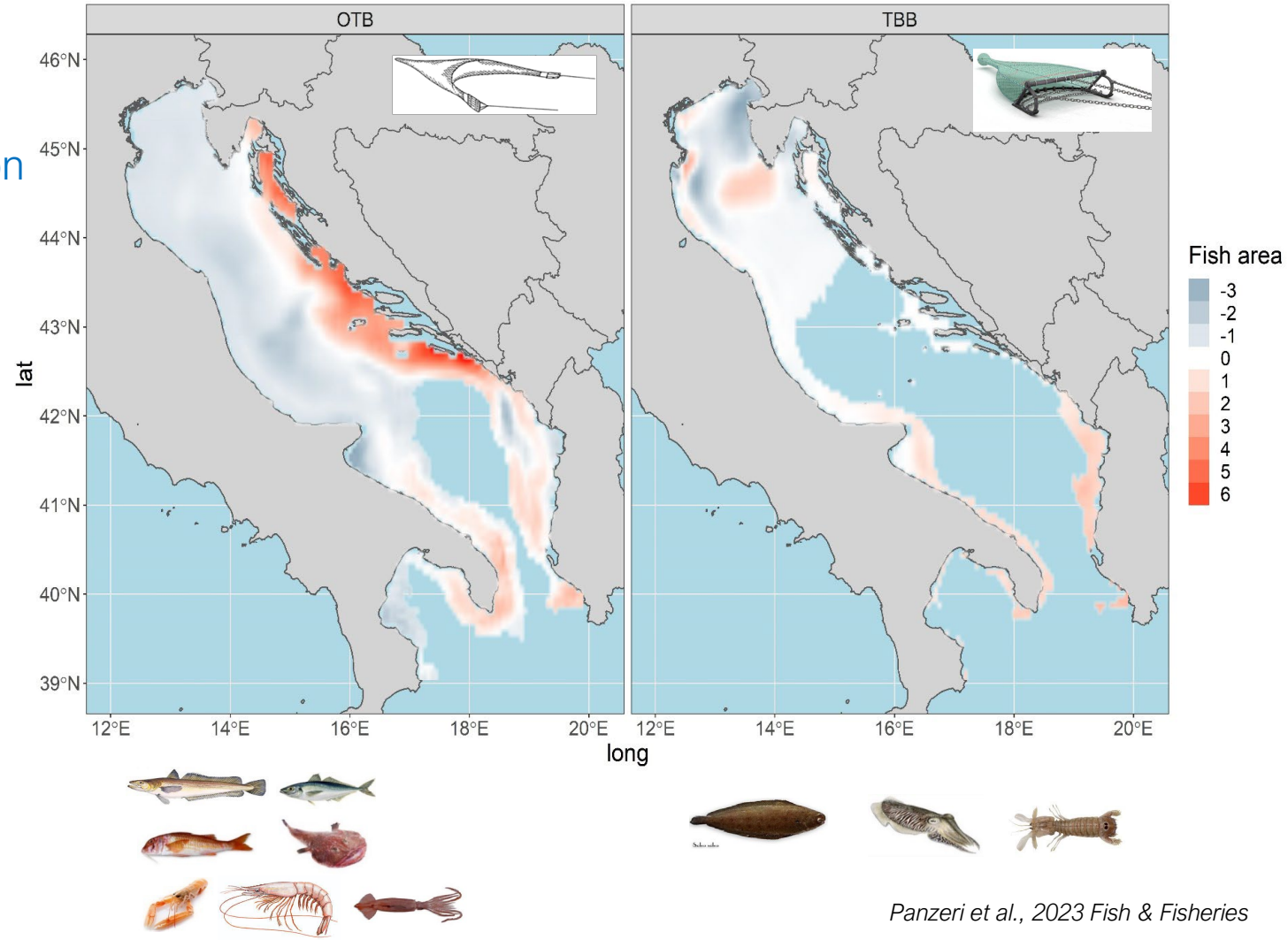


Match/mismatch between adult aggregation and juvenile aggregation areas as maps to support selective fisheries.

Ensamble of models
Integrating data

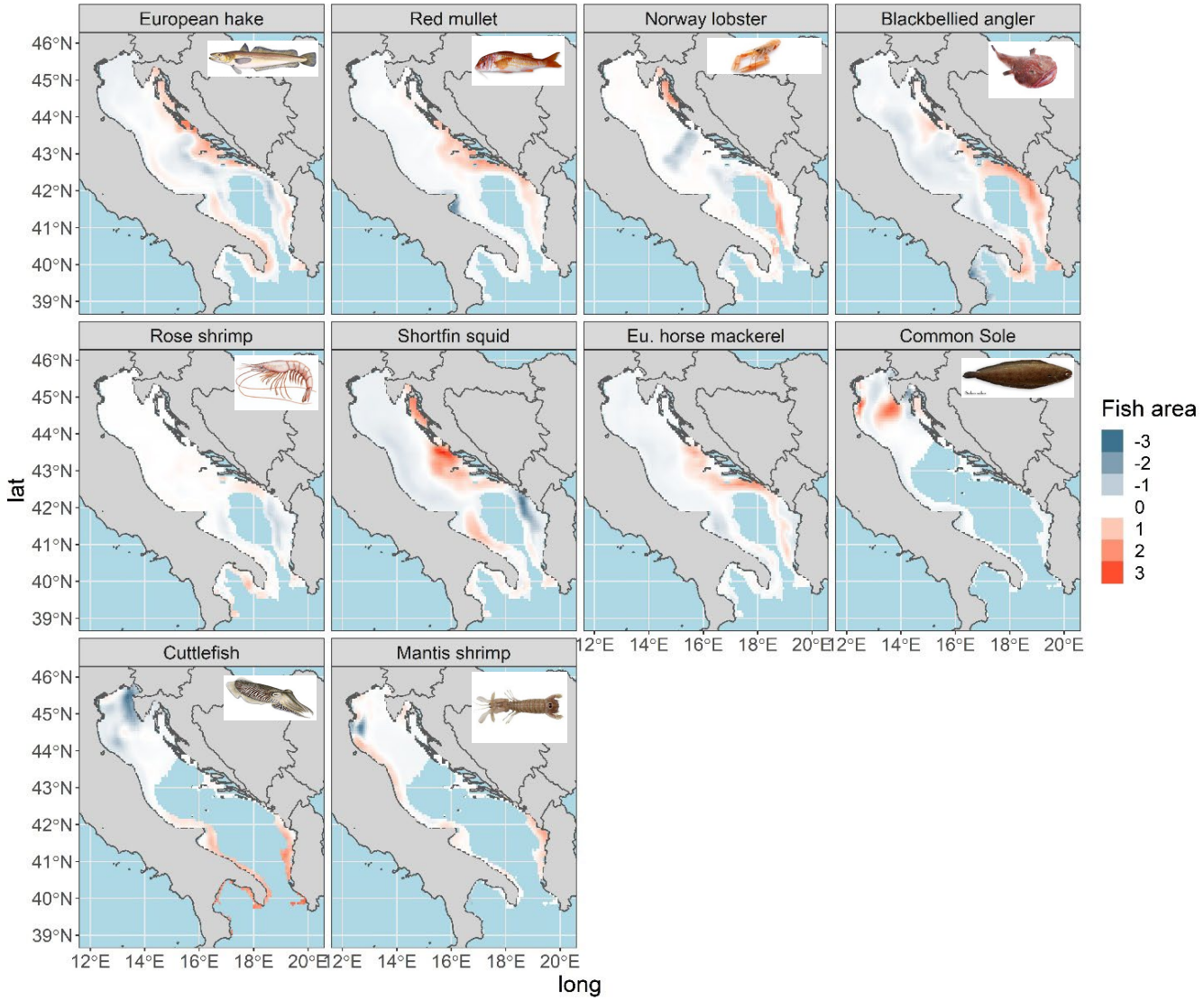


Panzeri et al., 2023 Fish & Fisheries

New technologies and tools can make this more effective and more accurate!

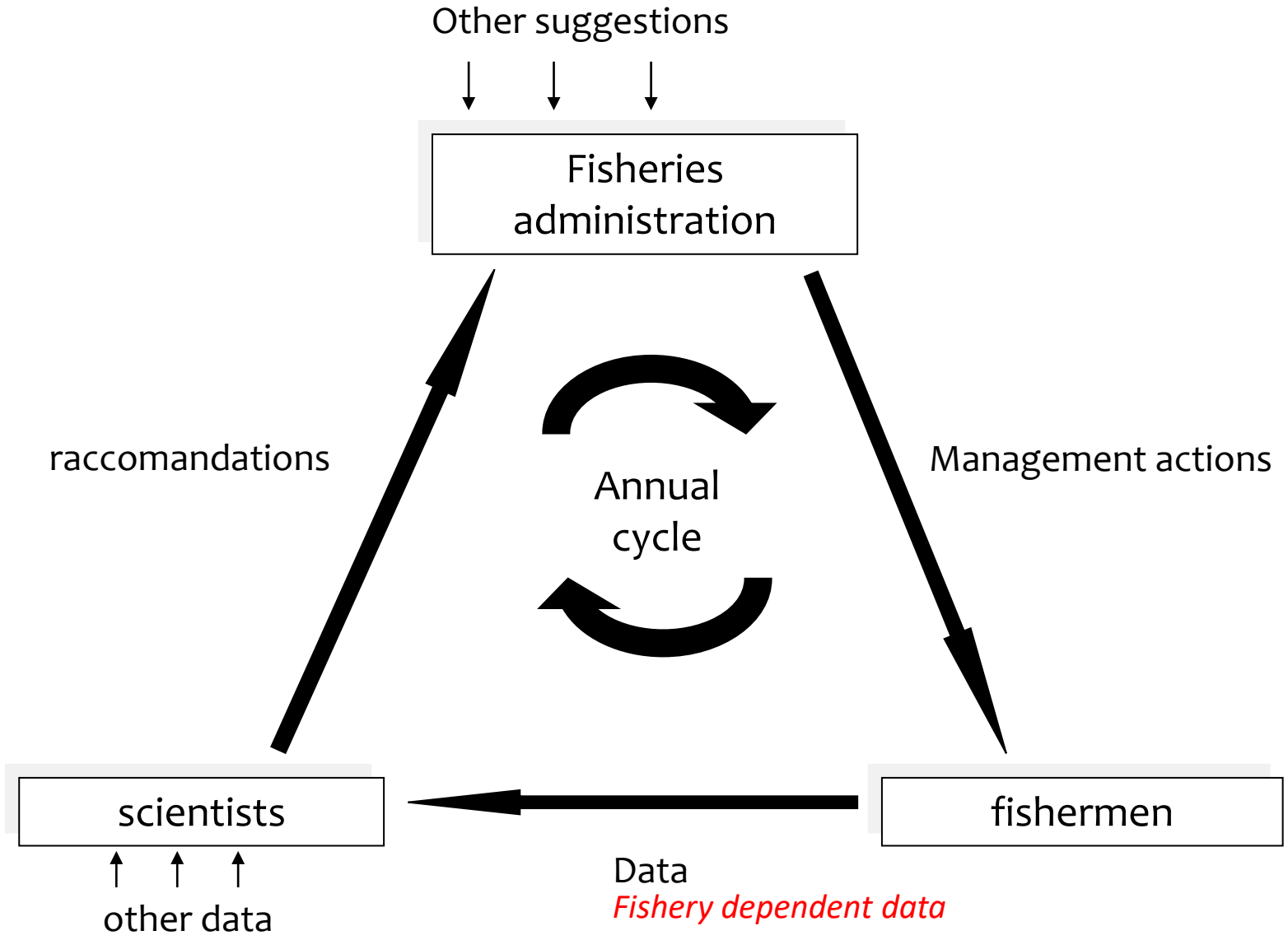
Increasing selectivity not changing gear but changing area of exploitation

Differenza tra aree di aggregazione adulti e aree aggregazione giovanili:
In red the areas with prevalence of adults byspecies
In blues the areas with prevalence of juveniles by species



Management of fisheries

The theory of fisheries management involve interactions among scientists that provide assessment and raccomandations to policy makers; these transfer management actions to fishermen; theoretically these one provide information useful to scientists

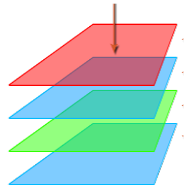


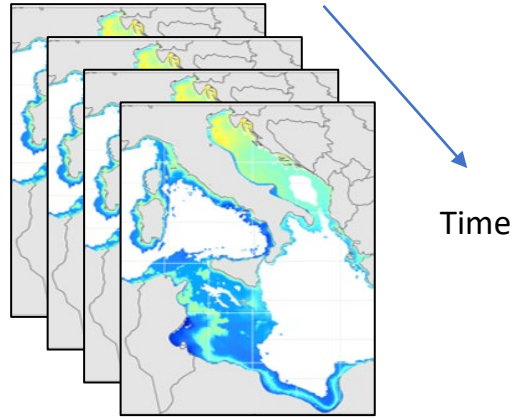
Courtesy: S. Raicevich

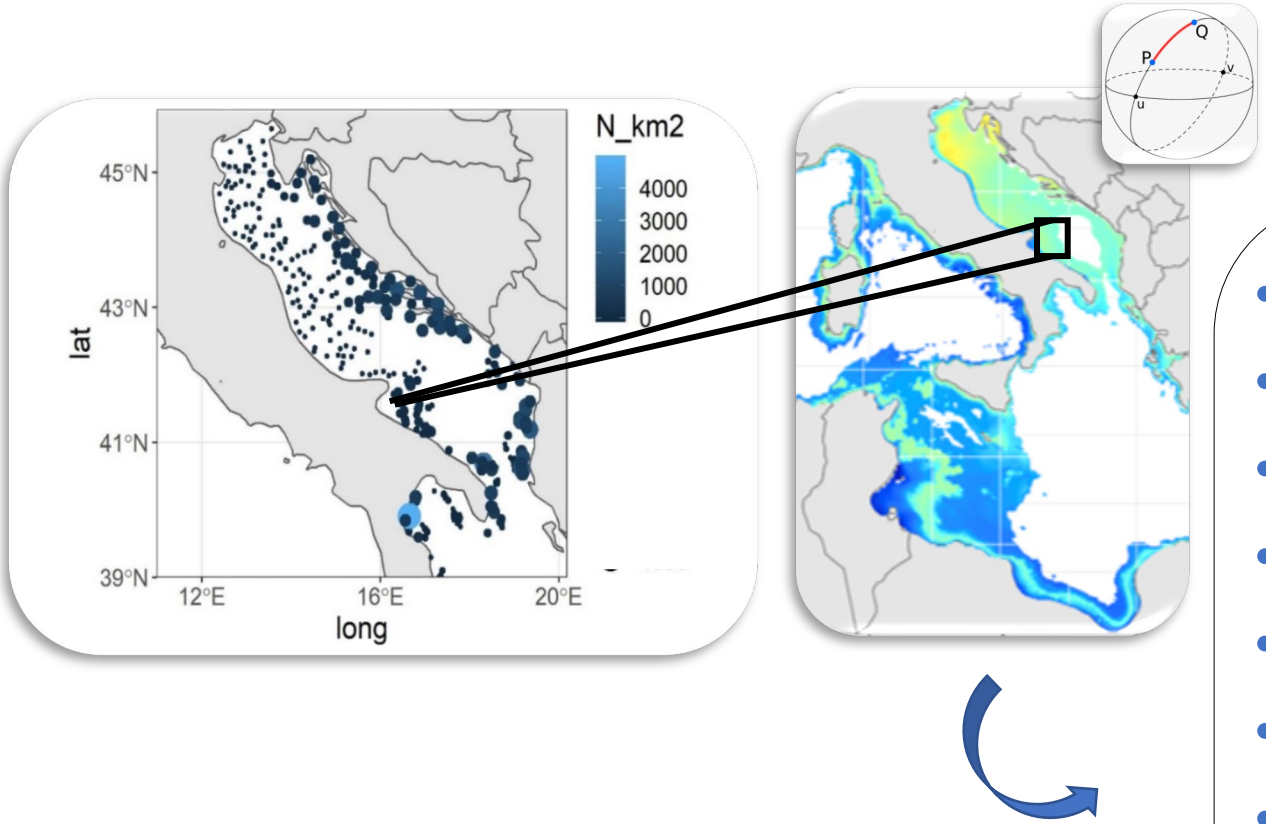
Scientific Data : oceanographic variables

Physical and biogeochemical datasets were developed within the Copernicus Marine Environment Monitoring Service (CMEMS, https://marine.copernicus.eu/access-data) and covered the available time series of data with a spatial resolution of 1/16°(approx. 6x6 km). These information are 3D!

Copernicus Grid:
For each
- month
- year
- Variable
- depth
- 1/16° (~6km)

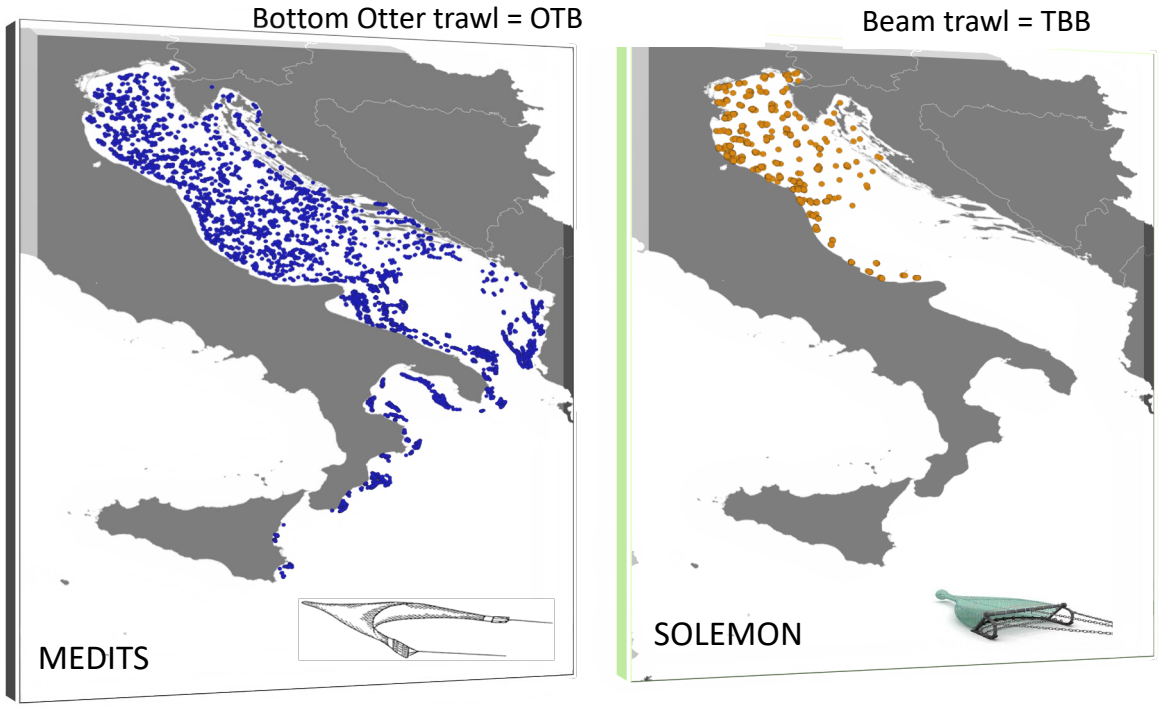




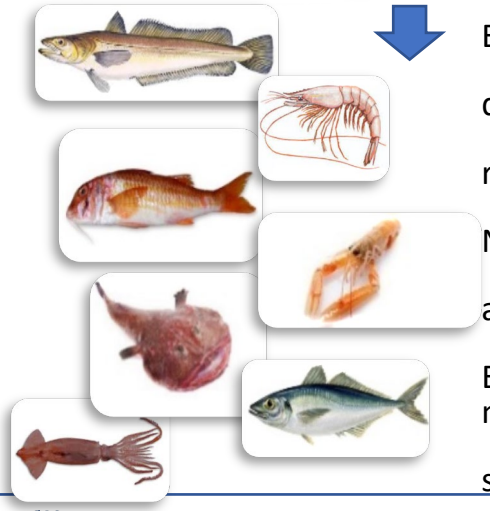


- Temperature: surface & bottom in degC
- Dissolved molecular oxygen(dox): millimolm-3
- Nitrate (nit): millimolm-3 (mean)
- Phosphate(pho): millimolm-3 (mean)
- Salinity: 1e-3 (mean)
- pH (mean)
- Particulate Organic Carbon mg/m3 (mean)
- Chlorophyll (CHL): milligramm-3 (mean until 200m)

Fishery independent data



- Each point is a haul location, let' say a fishery survey conducted in that 'site' (haul)
- Data for all years (1994-2018 for MEDITS) and 2005-2018 for SOLEMON only for Northern Adriatic).
- From each point we obtained a index of number of individuals per km^2 or kg for km^2 (standardized data).



European hake,

deep rose shrimp,

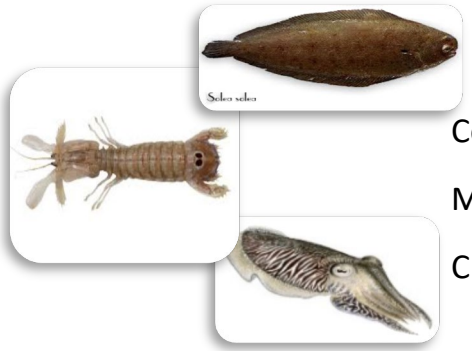
red mullet,

Norway lobster,

anglerfish,

European horse mackerel,

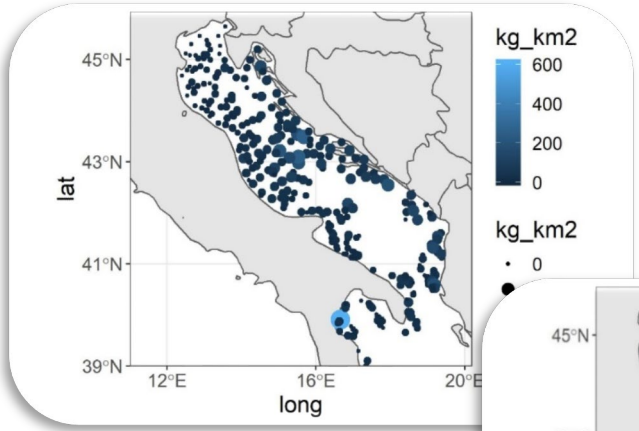
southern squid.

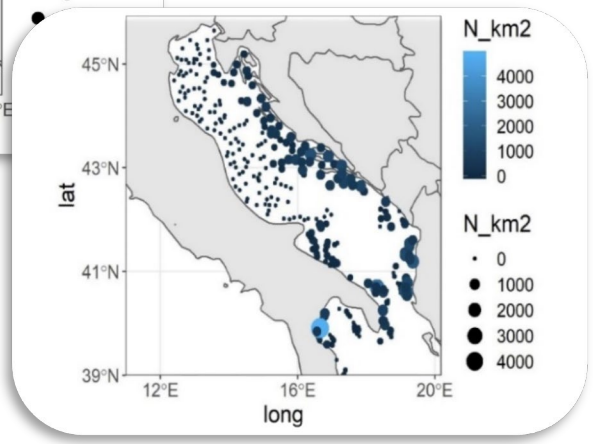


Common sole

Mantis shrimp,

Cuttlefish

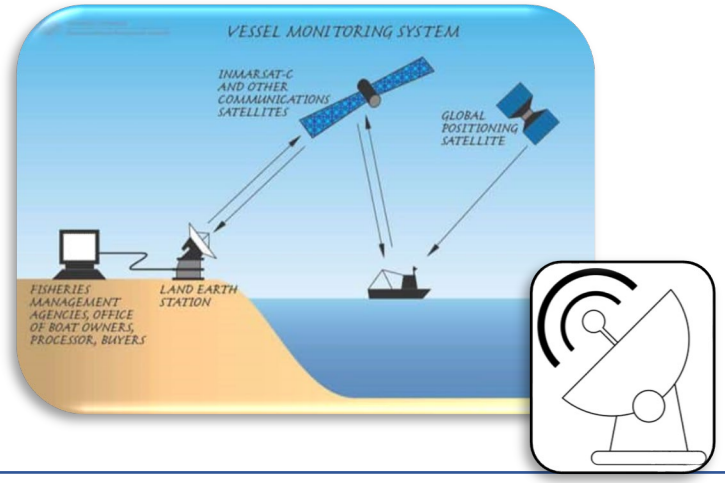




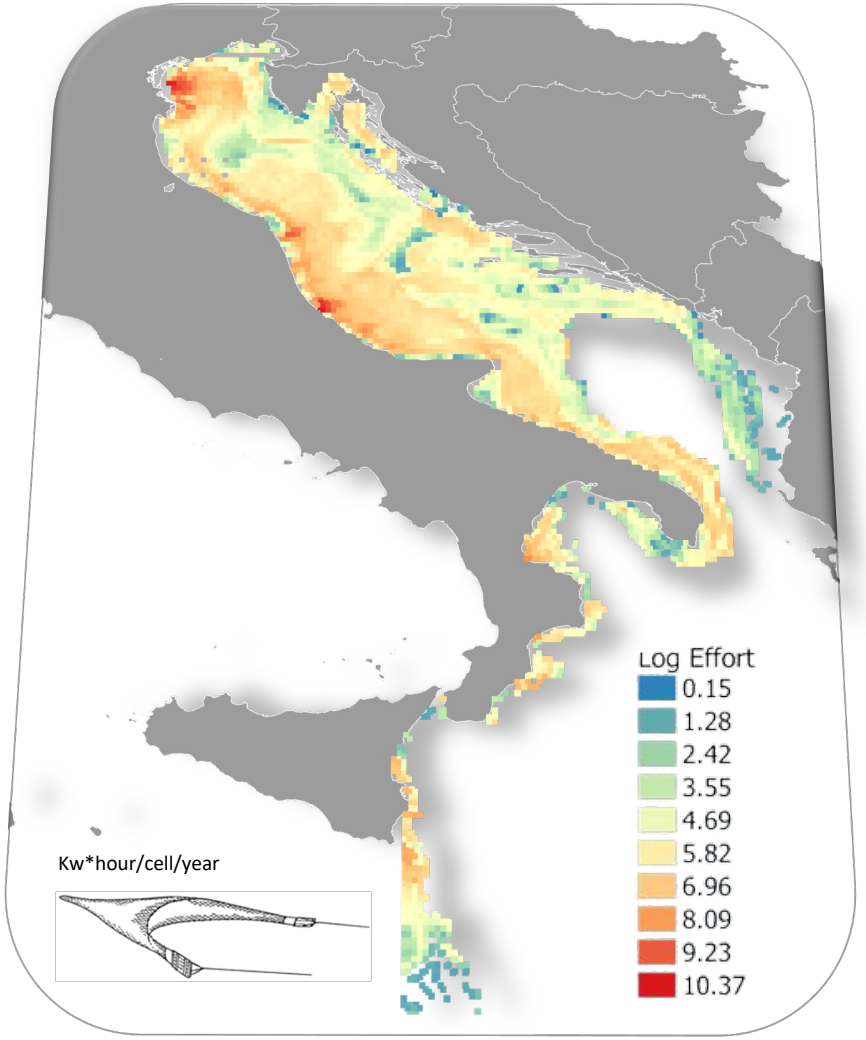
Effort - fishery dependent variable

- Effort data derived from Vessel Monitoring System (VMS) by gear: OTB and TBB. From tracks of vessels it is possible to reconstruct where effective fishing was carried out. Knowing the size of the vessel these data can support determination of swept area

Temporal coverage	2008 – 2018
Data sources	VMS
Gears	OTB (Bottom otter Trawl) TBB (Beam Trawl
Unit	Kw*hour/cell (Each year)



Bottom Otter trawl = OTB 2018



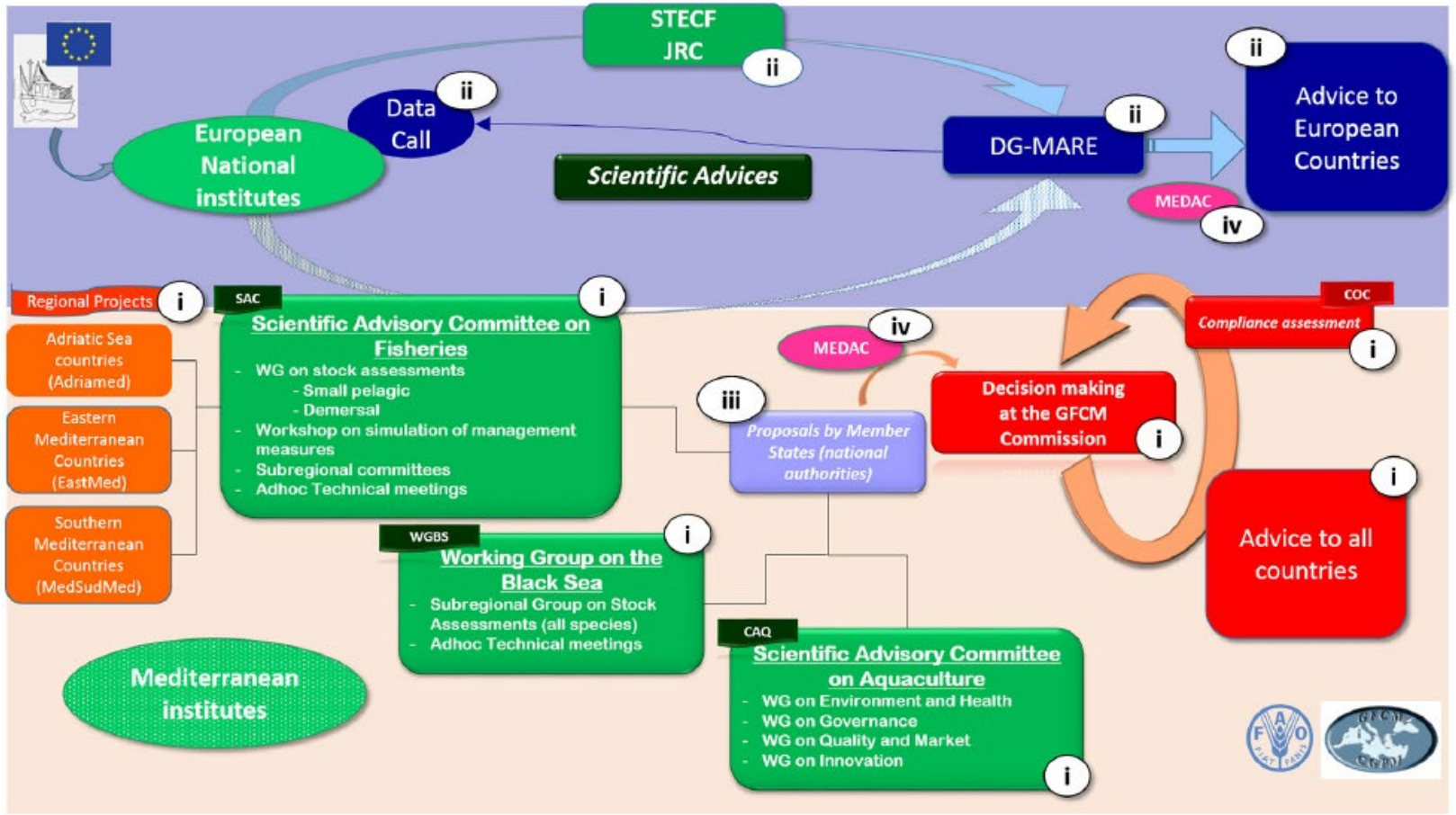
Management of fisheries in the Mediterranean Sea

The management system, however, can be relatively complex for the presence of several actors:

(i) The Food and Agriculture Organization (FAO) with its own Regional Fisheries Management organization (RFMO), the GFCM (General Fisheries Commission for the Mediterranean and Black Sea) [emit binding reccomandations], as well as its Scientific Advisory Committee on Fisheries (SAC) [stock assessment & scientific independent advice] and regional projects.

(ii) the European Commission (EC) and its commission dedicated, DG MARE [implementation of EU marine policies] and its bodies (i.e., STECF and JRC) [stock assessment & scientific independent advice]

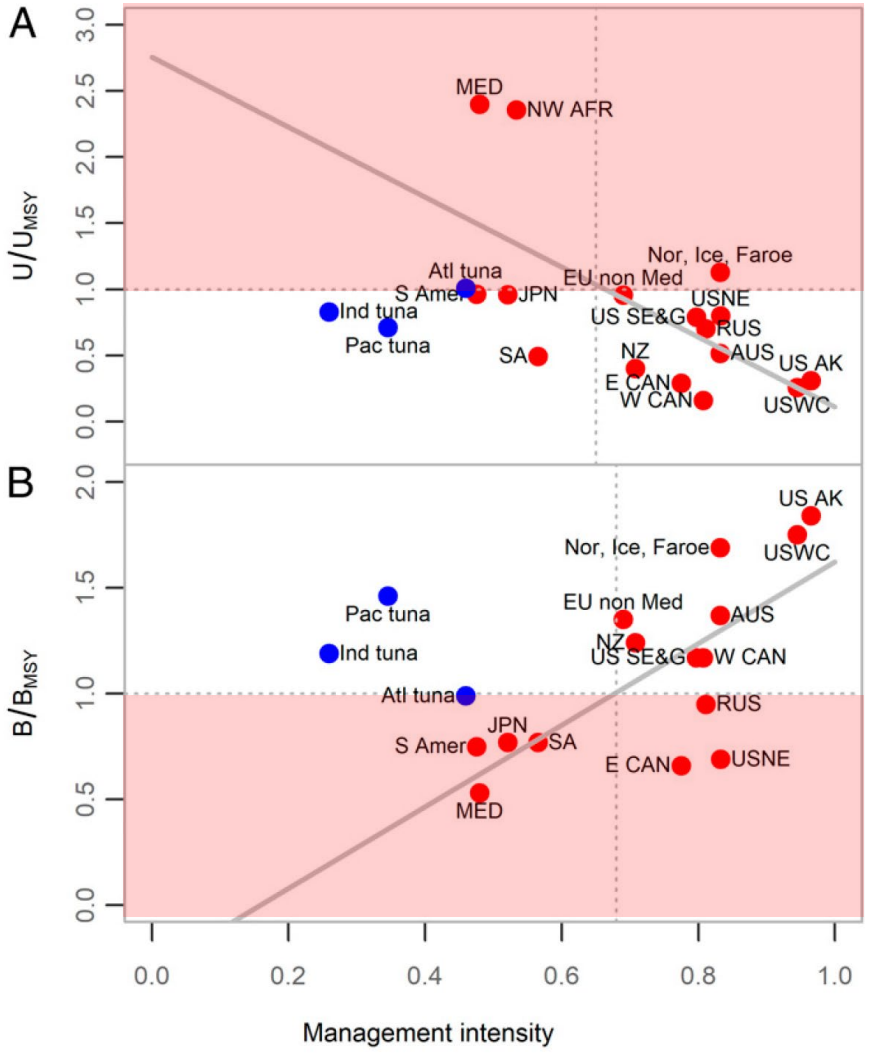
(iii) the national authorities [implement regulations emitted by GFCM and EC/DG MARE]



(iv) fisheries and NGOs associations coordinated by the MEDiterranean Advisory Council (MEDAC) which is representing the whole fisheries sector and other interest groups (such as environmental organizations, consumer groups, and sports/recreational fishery associations) [opinions on fisheries management and socio-economic aspects]

Carpi et al., 2017 Frontiers in Marine Science

Management is effective in improving and maintaining sustainable exploitation



Effective fisheries management instrumental in improving fish stock status

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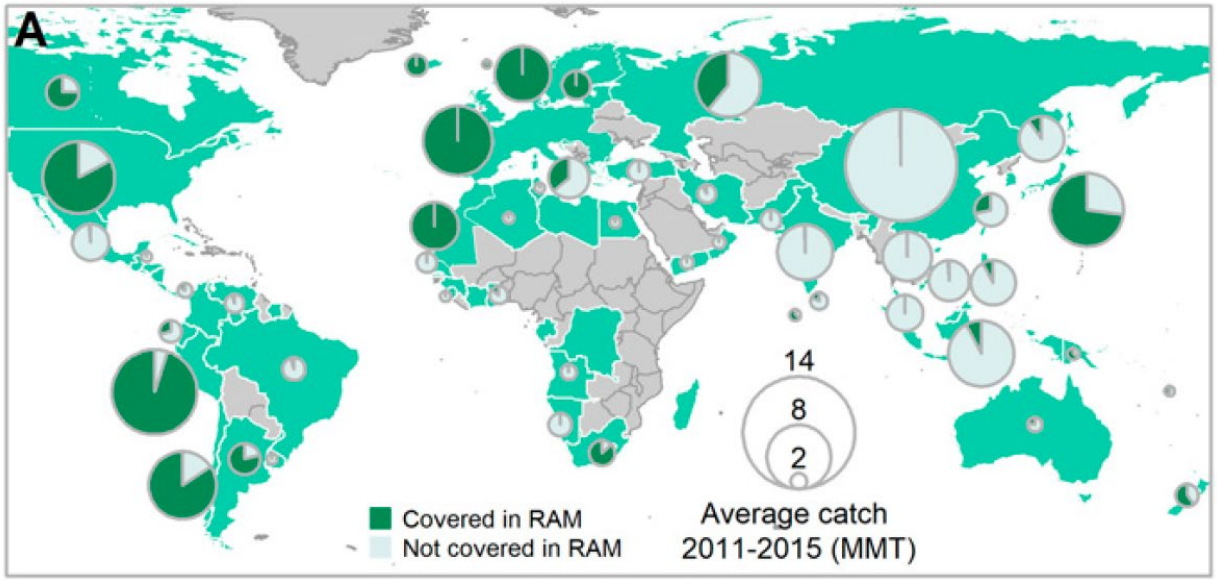

countries

The areas where fisheries management is mature the exploited stocks appears to be in better conditions: management is effective!
By management here we consider a wide set of actions!

Hilborn et al., PNAS, 2020

Collegamenti tra lezioni svolte ed il libro di riferimento «Marine Fisheries Ecology»

i) Introduzione alla gestione dello sfruttamento delle risorse alieutiche, problematiche generali, stato delle risorse, targets internazionali. **(Chapters 1, 12.4, 14)**

ii) Massimo rendimento sostenibile, sforzo di pesca, mortalità da pesca, costi, rendimento economico. *Esercizi* **(Chapter 7.3)**

iii) (continua) Massimo rendimento sostenibile, sforzo di pesca, mortalità da pesca, costi, rendimento economico. *Esercizi* **(Chapter 7.3)**

iv) Le specie ittiche: crescita, riproduzione, mortalità: esercizio modelli e dati. **(Chapters 3.4 and 4)**

v) Stock assessment basi: dalla cohort analysis e virtual population analysis ad oggi (*esercizi*). Le attività di pesca: selettività, catturabilità, impatto sugli habitat. Dati fishery dependent e fishery independent per la gestione: uso, limitazioni, problematiche. **(Chapter 7.5, 8.4, 10)**

vi) Pesca e interazioni con altri fattori: approccio multispecifico integrato. Modelli di ecosistema per la gestione della pesca: Ecopath with Ecosim (*esercizio EwE*). Sintesi problematiche, approcci, limitazioni, gaps e aree di sviluppo **(Chapter 8.7)**

vii) Prodotti ittici da acquacoltura: sistemi di produzione, problematiche generali, sostanibilitá, soluzioni. Gestione integrata pesca e acquacoltura. Target di pesca sostenibile, approcci alla gestione, problematiche: il caso del mediterraneo. Gestione spaziale della pesca, essential fish habitats, regolamenti comunitari ed internazionali. Sforzo di pesca, gestione dello sforzo di pesca, misure tecniche, misure economiche. **(Chapters 16, 17)**