XII International Conference on Science, Arts and Culture
CLIMATE CHANGE:
marine and mountain ecosystems in the Mediterranean region
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Impacts of climate and anthropogenic forcings on the Adriatic Sea fishing community

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Forcings on marine ecosystems

important drivers (stressors) of the marine ecosystems have many effects

Pollution

- accumulation in living organisms;
- effects on species production and mortality;

Nutrient input

- eutrophication;
- modification species composition;
- ipoxia and benthic anoxia (Justic et al., 2005);
- high mortality benthic species (Stenseth et al., 2003);

Habitats modification

Fisheries Aquaculture

- depletion of target species (Myers & Worm, 2003);
- increase mortality of non-target species (by-catch);
- decrease in biodiversity (Robert et al., 2000);
- modification of habitats (Jennings & Kaiser, 1998);
- induced changes in the communities (Pauly et al., 1998);
- indirect effects of biological & physical changes (Yodzis, 2001);
- direct & indirect propagation of effects (Springer et al.,2003);

Climate changes

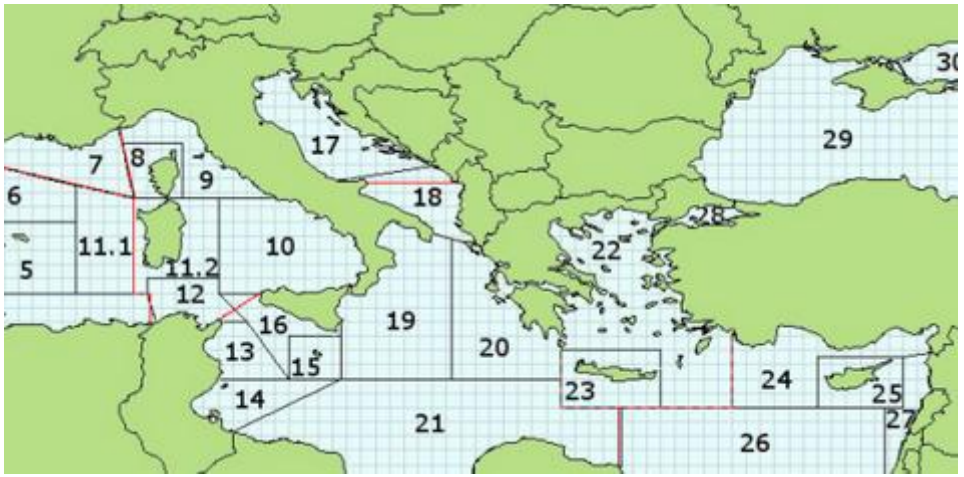
Natural variability
Global warming

- modification of habitats;
- modification species distribution (Loukos et al., 2003);
- effects on physiology & behaviour (Maury & Lehodey, 2003);
- influences on recruitment (Stenseth et al., 2003);
- impacts on trophic interactions (Hunt et al., 2002);
- direct & indirect propagation of effects;

Changes in fisheries resources in Italian seas (1994-2008)

COMUNITA'							
Indicatore	GSA9	GSA10	GSA11	GSA16	GSA17	GSA18	GSA19
Telostei							
Selaci							
Cefalopodi							
Crostacei							
Totale catture							
Diversità							
Lmedia comunità							

legenda	Tendenze degli Indicatori
	tendenza negativa
	stabile
	tendenza positiva
	non calcolato



Source: Annuario delle Risorse, SIBM (2008)

Understanding role of forcings on ecosystem changes in the past

A) Analysis of long time series of biological community data:

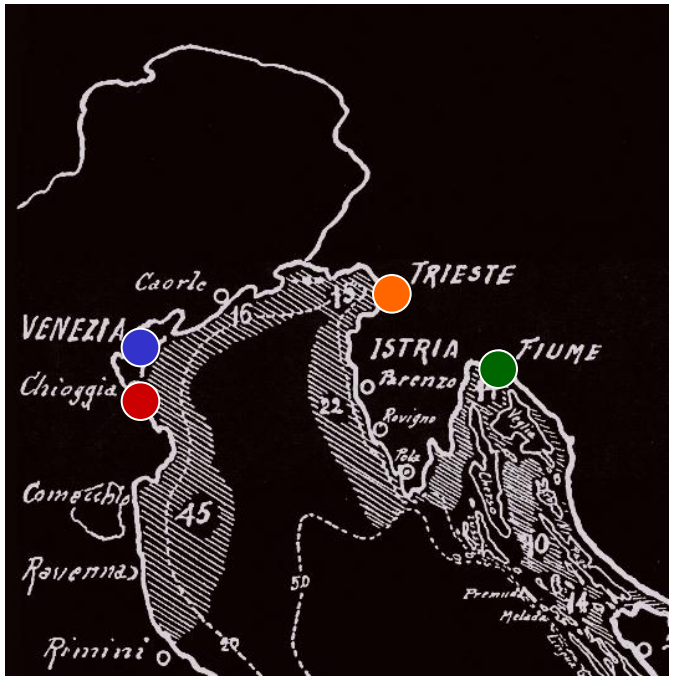
- **Reconstruct fish at sea for 2 century**
- **Analysis of fisheries landings in the last 50 years**

Projecting changes in the future (scenarios):

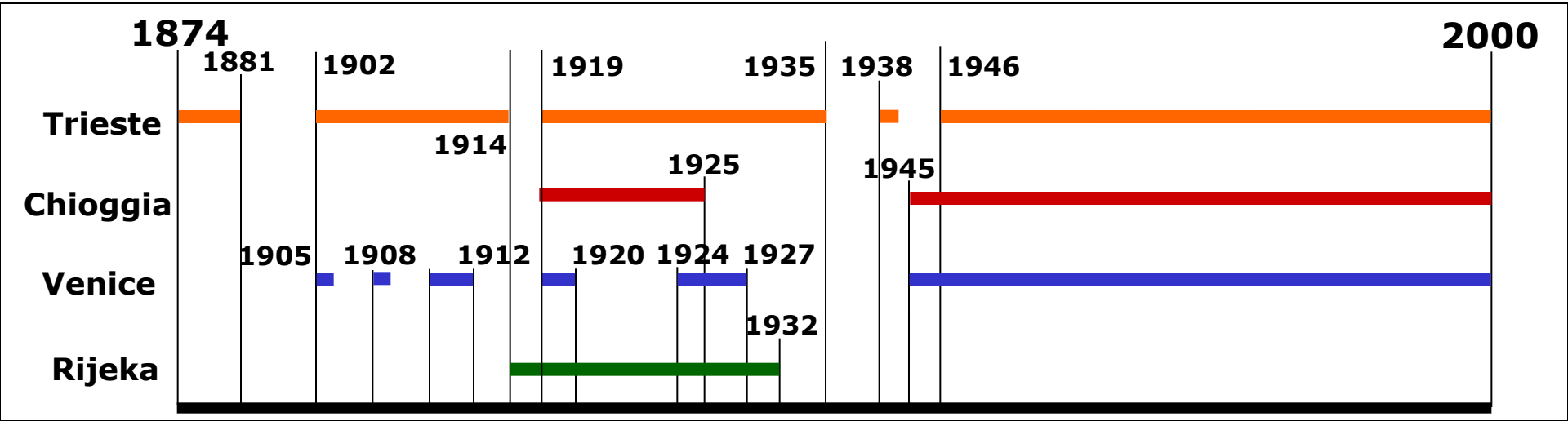
B) by including main forcings (fisheries and climate) into ecosystem models that include physical/biogeochemistry and food web interactions (End-to-End)

Landing statistics

(*quantitative data*)

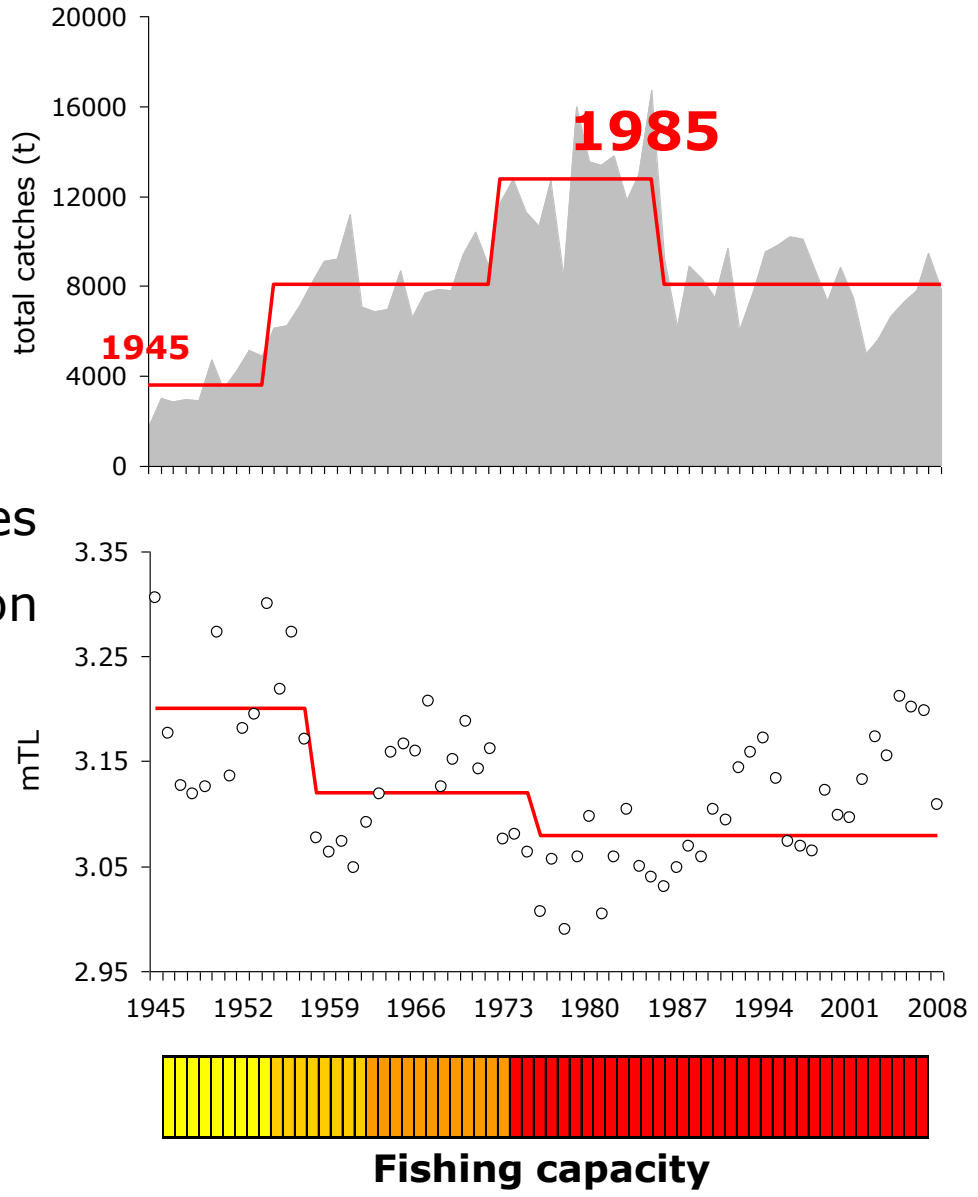


- annual landings per species/group of species
- refer to major fish markets of the area
- 1874-2000, with some gaps
- despite the intrinsic limitations (e.g. not being standardized in terms of fishing effort and gears)
- solely quantitative data available before 1950s
- **the composition of landings may represent a proxy of the structure of the fish community**

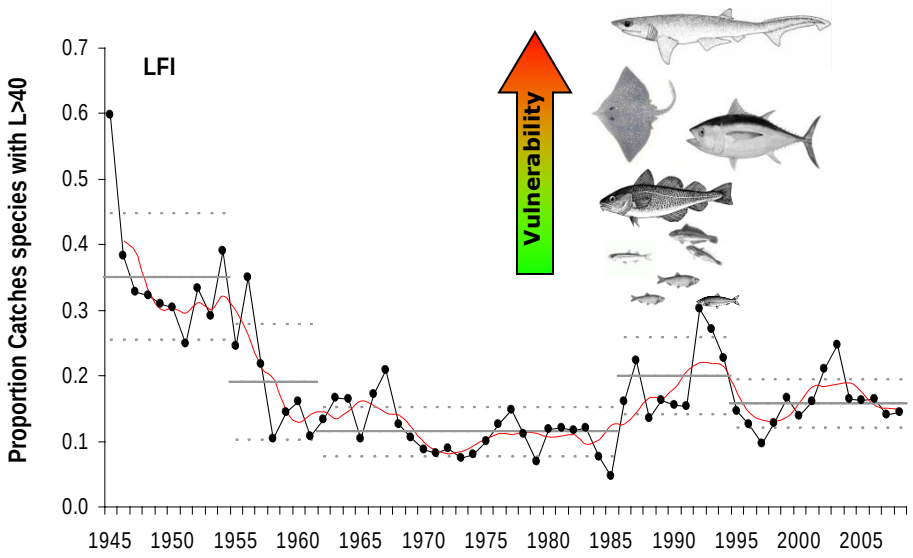


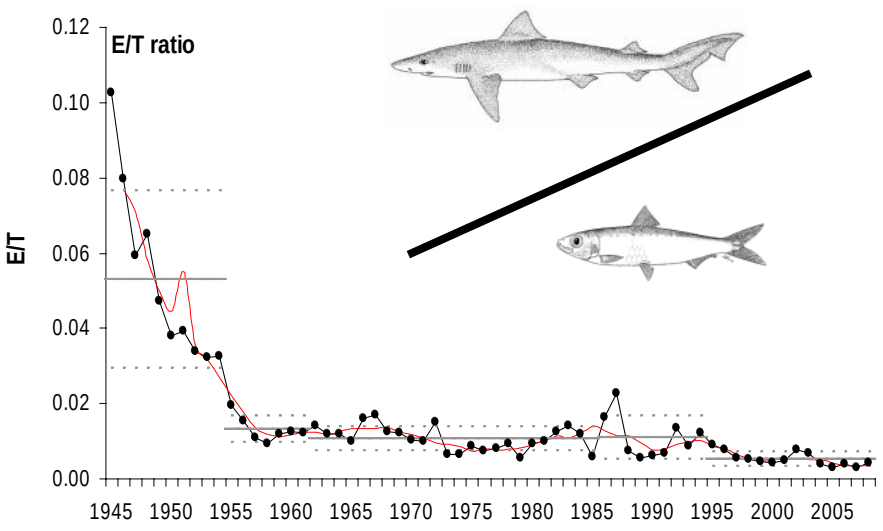
Total Catches and Mean Trophic Level (Pauly *et al.*, 1998)

- 1945-1985: four-fold increase in landings
- '50s and '70s: increase in landings, decrease in *mTL*
- **low *TLs* are more productive**: a decrease of the *mTL* of landings was compensated by an increase of catches
- fishing was expanding its exploitation on low *TL* species
- '80s: collapse of landings, no significant change in *mTL*



Maximum length and Elasmobranch-Teleost ratio





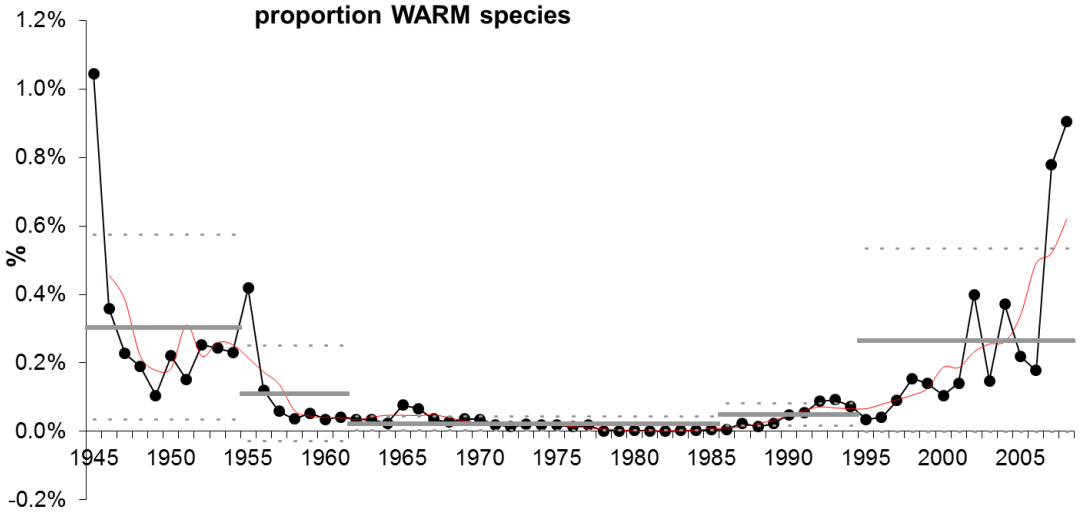
- decrease of the proportion of large species (*LFI*) of the community (L>40 cm)
- decrease of the relative biomass of Elasmobranchs (from ~10% to ~1%)

Large-sized species and elasmobranchs are highly vulnerable to fishing

Structural changes in the fish community probably linked to fishing exploitation *(top-down control)*

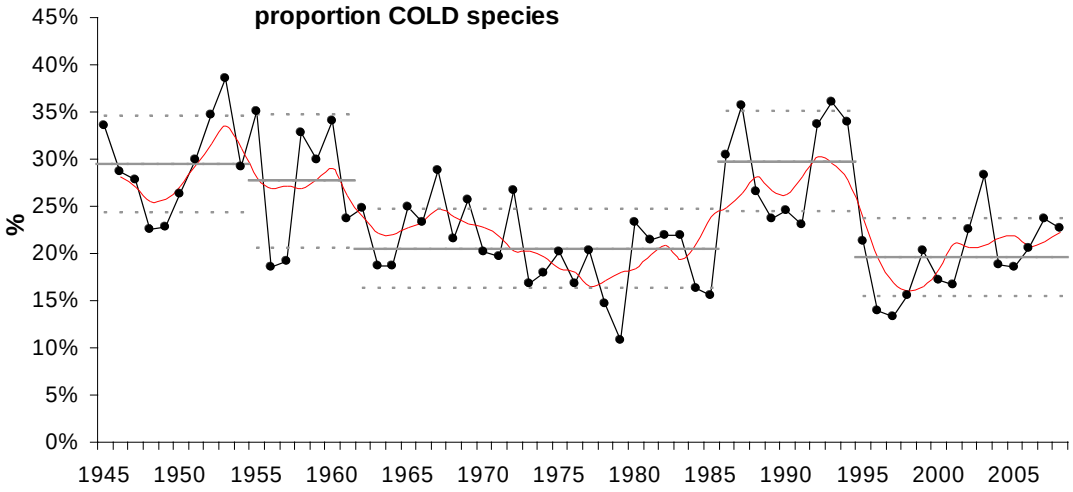
Thermal preference of species

•Species were assigned to a thermal preference category (warm, warm/temperate, temperate, temperate/cold, cold) by latitudinal ranges of presence



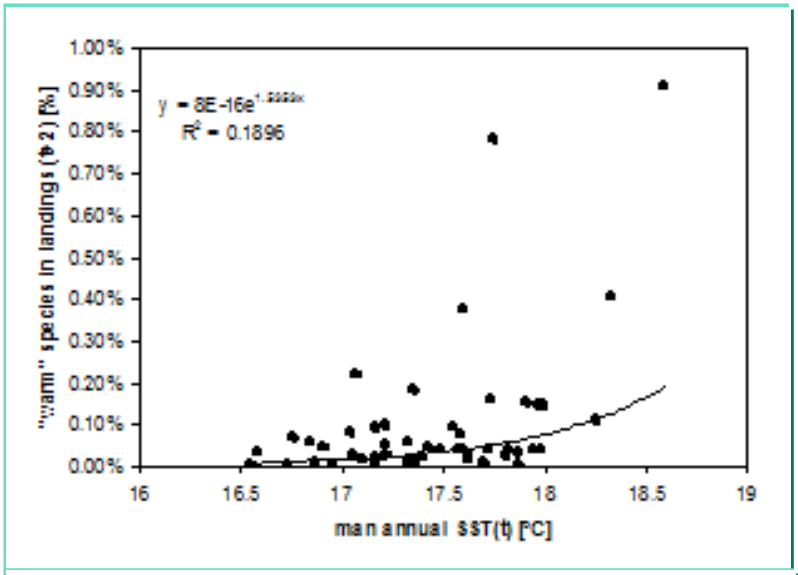
Sardinella aurita, Sciaena umbra, Umbrina cirrosa, Sarda sarda, Seriola dumerilii, Epinephelus marginatum

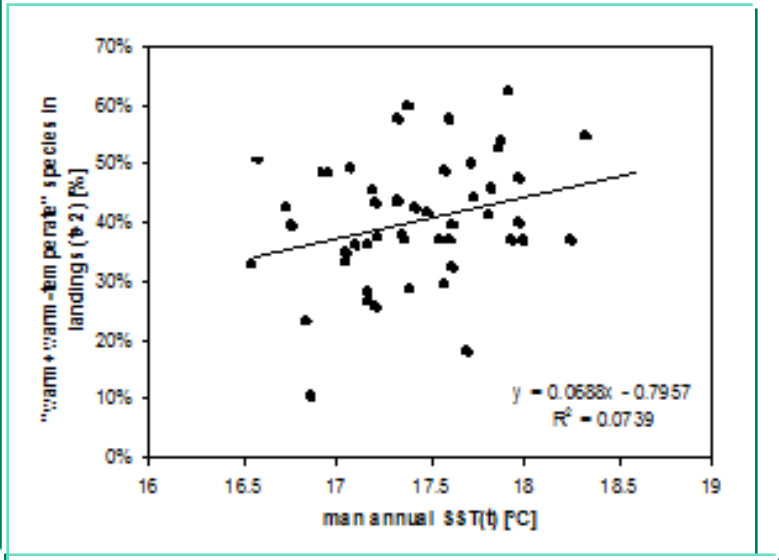
…..

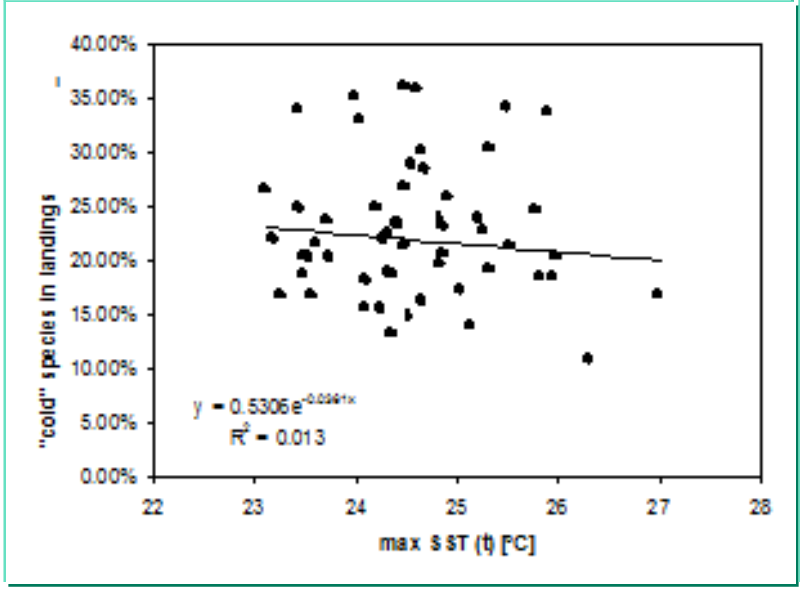


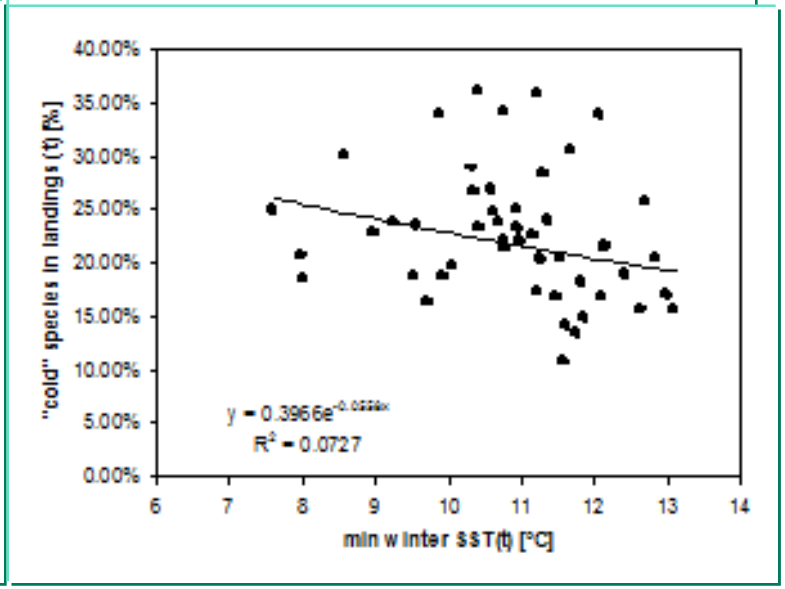
Sprattus sprattus, Platichthys flesus, Psetta maxima, Scophthalmus rhombus, Sepia officinalis, Solea solea…

Thermal preference of species





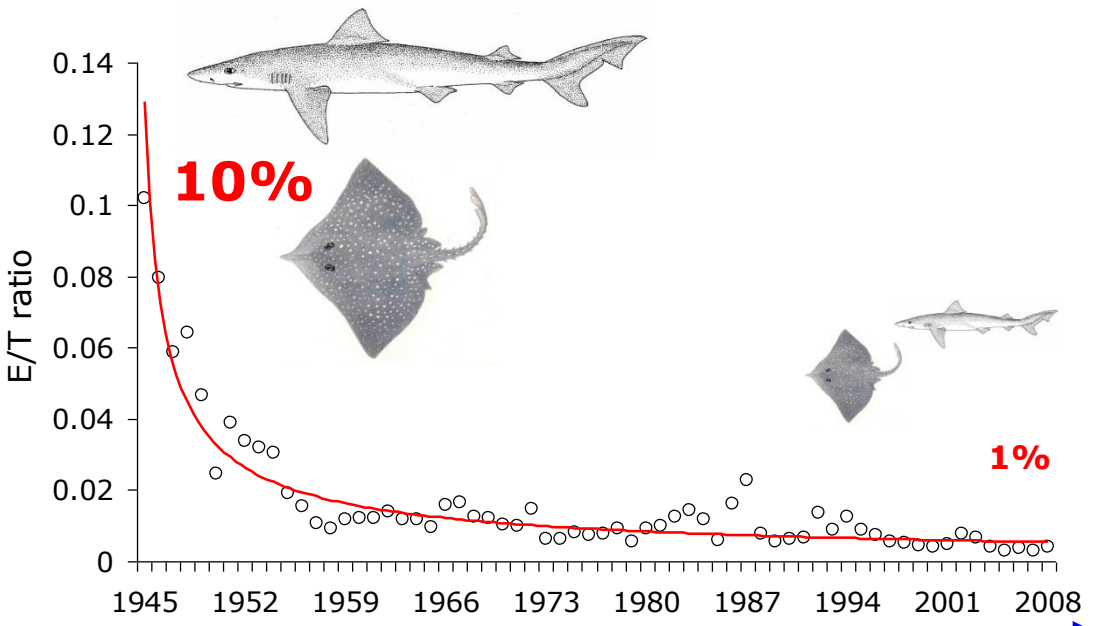




Some changes can be linked to climatic changes

How was the pre-industrial status of marine resources?

?



1800 **2000**

Naturalists descriptions: new information from old sources

Historical data rescue

naturalists' descriptions of fish assemblages

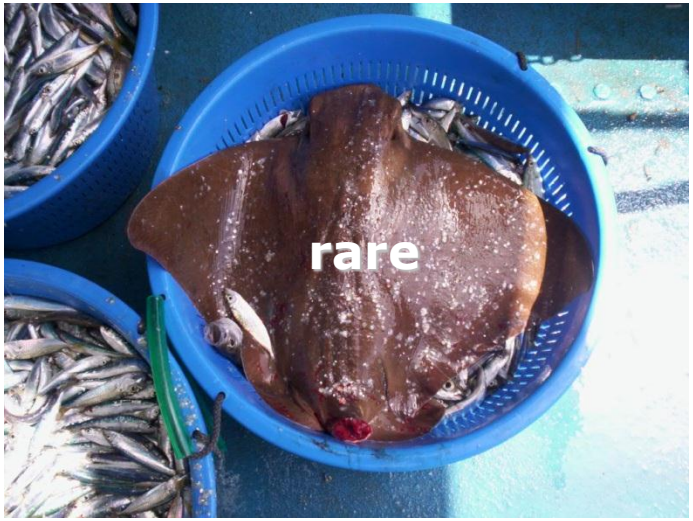
(*semi-quantitative data*)

- 36 naturalists' books (1818-1956)
- catalogues of species
- 394 fish species
- species "perceived abundance"
- geographical distribution
- size
- spawning season

Integration of naturalists' descriptions with landings

- total (for the whole area) annual landings
- mean landings for each 25-years chronological period
- species landings expressed as a percentage
- the periods with overlapping information was used for setting the base for the integration



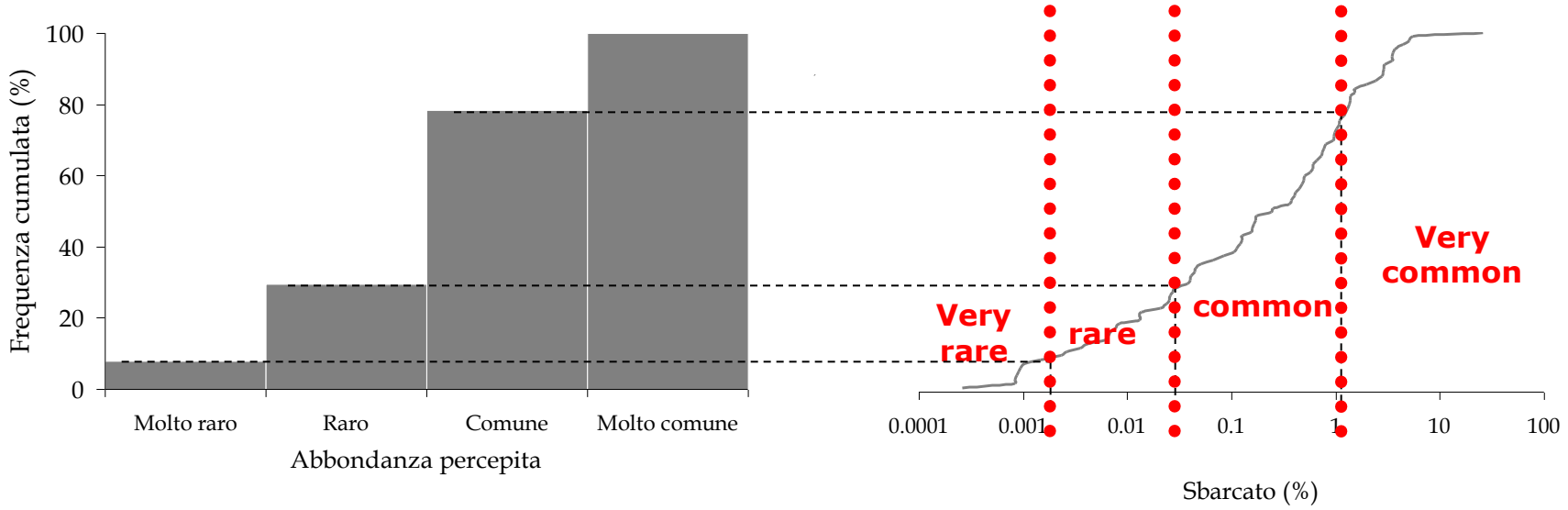



naturalists formed their evaluations on the abundance of species by observing catches at fish markets and ports

Definition of the numerical weights to be assigned to naturalists' classes of "perceived abundance"

Cumulative frequency of perceived abundance

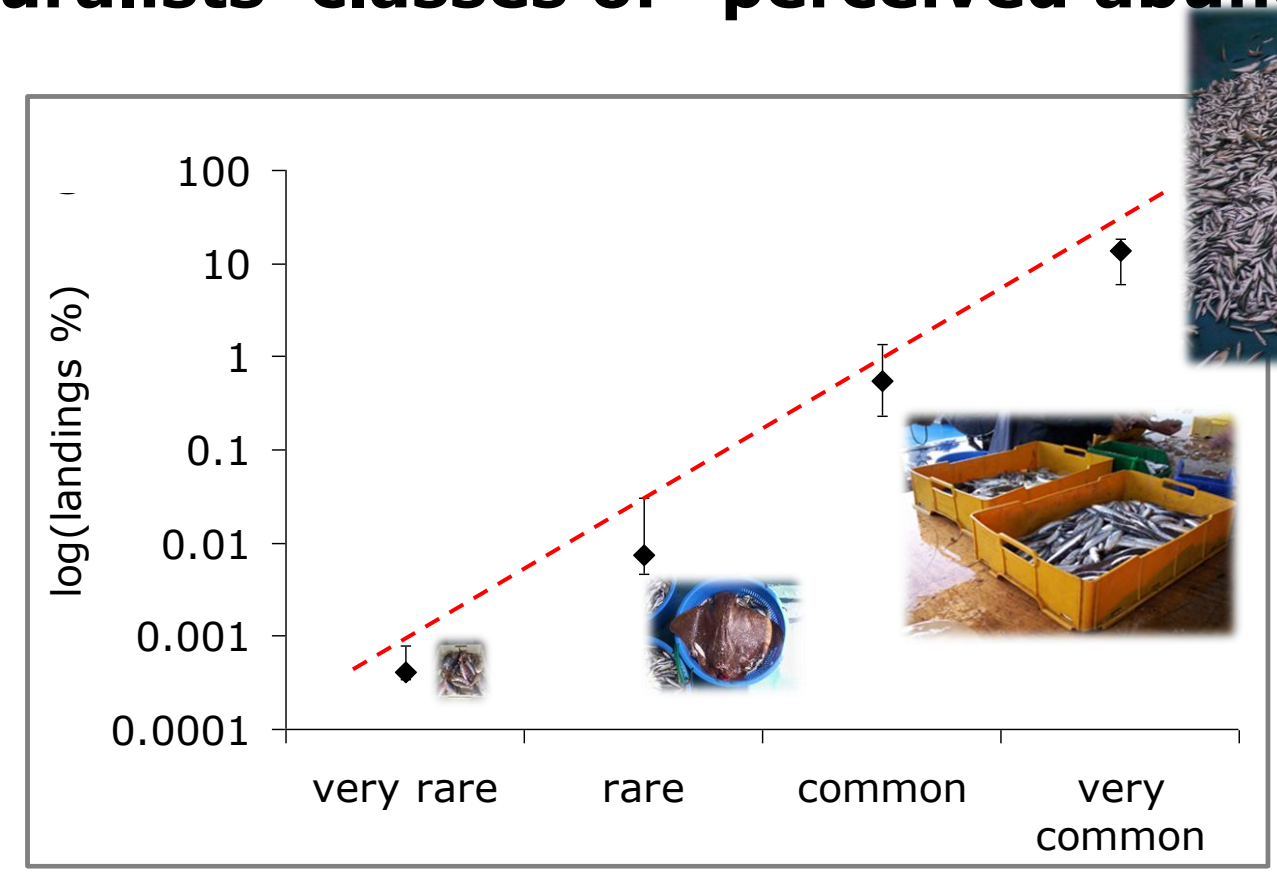
Cumulative frequency of landings



percentile in landings corresponding to the cumulative frequency of classes of "perceived abundance"

Fortibuoni, Libralato, Raicevich, Giovanardi, Solidoro (2010) PLOSone

Numerical weights to be assigned to naturalists' classes of "perceived abundance"

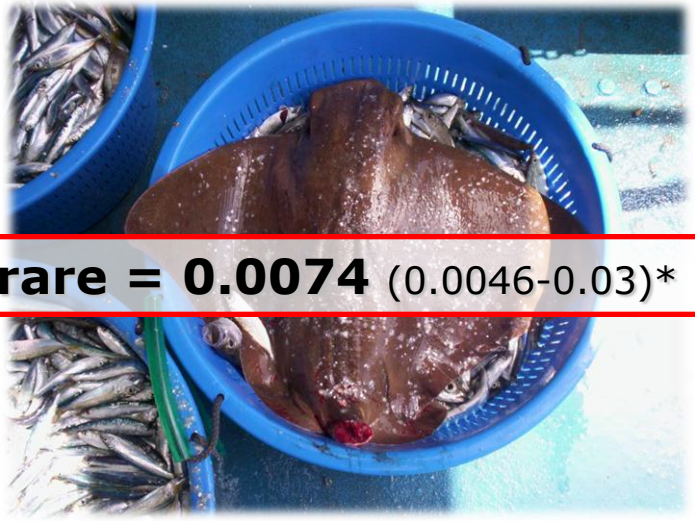


numerical weights follow an exponential scale

jackknife resampling technique (10 data randomly excluded from calculation, 1000 replicas) to test the robustness of the method and extimate sample statistics

Class weights

Very rare = 0.0004 (0.0003-0.0007)*



rare = 0.0074 (0.0046-0.03)*

common = 0.5394 (0.23-1.37)*

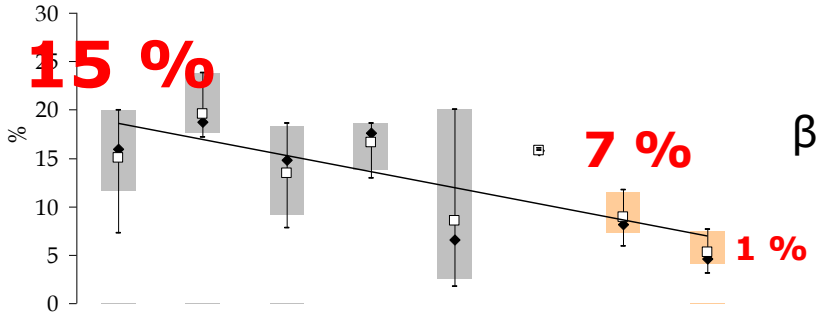
Very common = 13.70 (5.87-18.28)*

*jack-knife (1000 iterations)

1800 2000

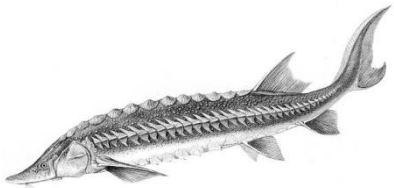
top predators decline

Chondrichthyes

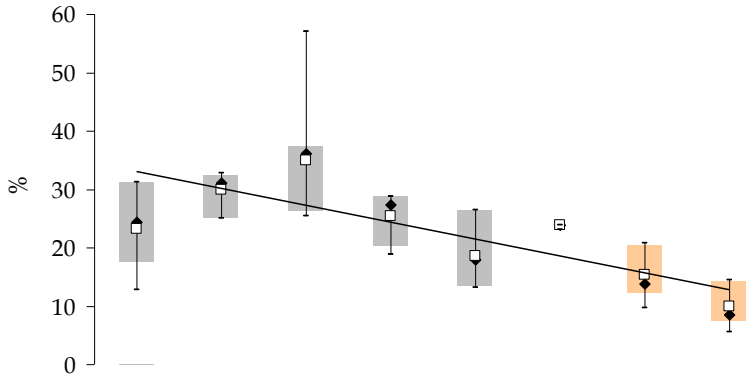


$\beta = -1.664$, $r^2 = 0.548$

$p < 0.05$

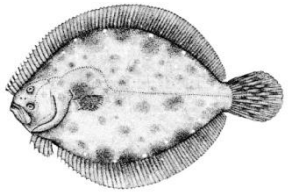


big demersal

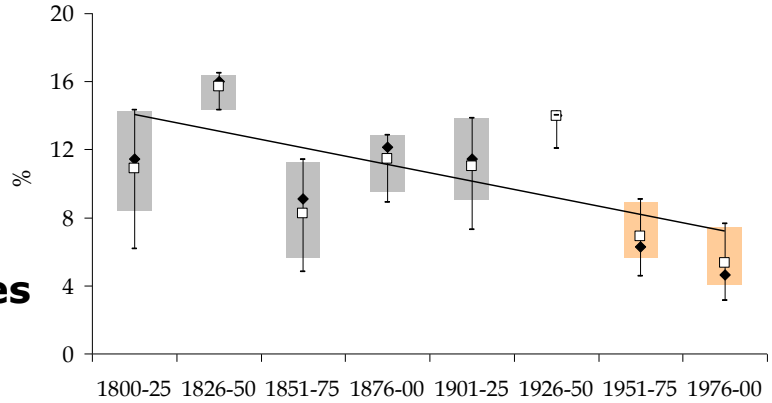


$\beta = -2.898$, $r^2 = 0.611$

$p < 0.05$



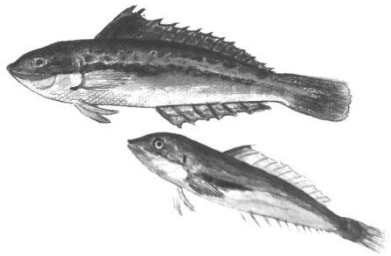
Late maturing species



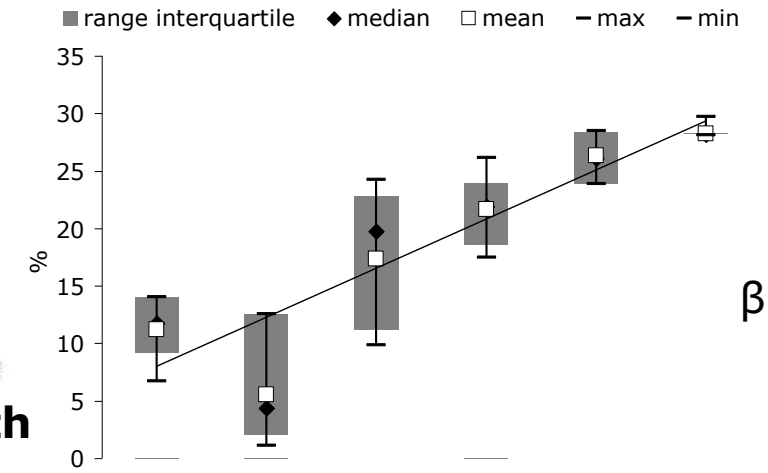
$\beta = -0.979$, $r^2 = 0.398$

$p < 0.1$

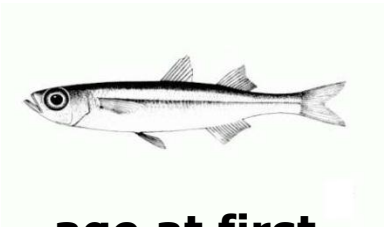
increase of small-sized/early-maturing species



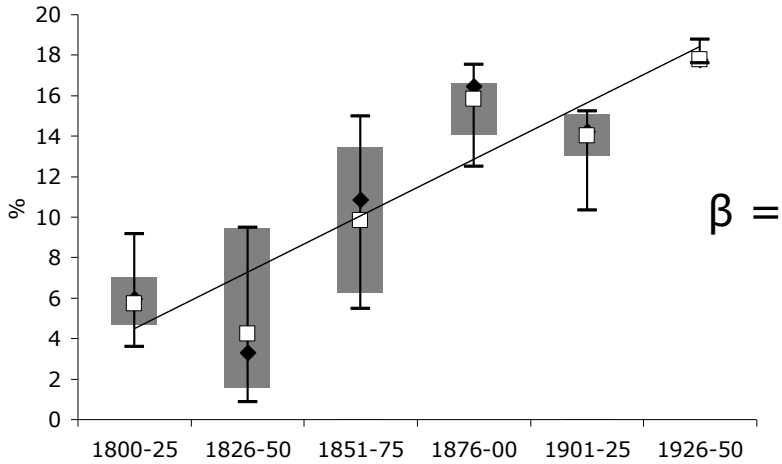
max. body length 25-55 cm



β = 4.276, r2 = 0.779, p < 0.05



age at first maturity < 1 year



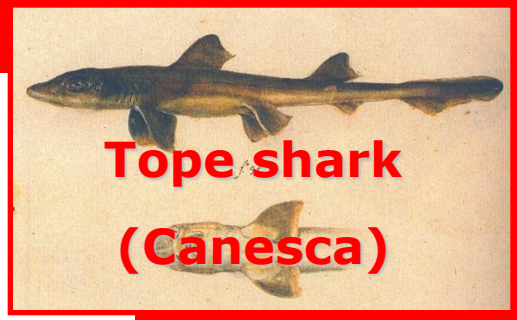
β = 2.788, r2 = 0.799, p < 0.05

Fortibuoni, Libralato, Raicevich, Giovanardi, Solidoro (2010) PLOSone

Species extirpation

naturalists' observations

Species	1800-1825	1826-1850	1851-1875	1876-1900	1901	Expedition VAR 1948)	MEDIterranean Trawl Survey (1998)	IUCN Red List (2008)
Angelshark (*Squatina squatina*)	common		common	common	com	YES	NO	Critically Endangered
Angular ro (*Oxynotus*			rare	rare	ra	YES	NO	Vulnerable
Sharpnose sha (*Heptranch*			rare	rare		YES	NO	Near Threatened
Bottlenos (*Rostrora*			common	common	com	YES	NO	Edangered
Blue s (*Dipturus batis*)					common			
Tope shark (*Galeorhinus galeus*)	common				common	common		
Sturgeon (*Acipenser sturio*)					common	common		
Dusky grouper (*Epinephelus marginatus*)		very rare				rare		



- species locally extinct in the Adriatic due to exploitation (Dulvy *et al.*, 2003)
- some of them were common till 1950

Dulvy N.K., Sadovy Y., and Reynolds J.D. (2003). Extinction vulnerability in marine populations. Fish and Fisheries, 4: 25-64

What are the causes of these changes?

Likely fishing played an important role, but climatic changes could also have contributed (and others habitat loss, pollution, eutrophycation)

Coding early naturalists's accounts

OPEN ACCESS Freely available online

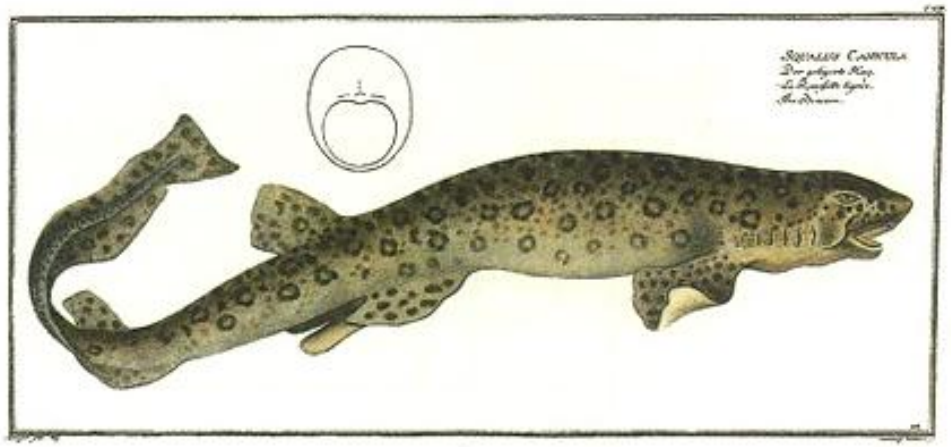
PLoS one

Coding Early Naturalists' Accounts into Long-Term Fish Community Changes in the Adriatic Sea (1800–2000)

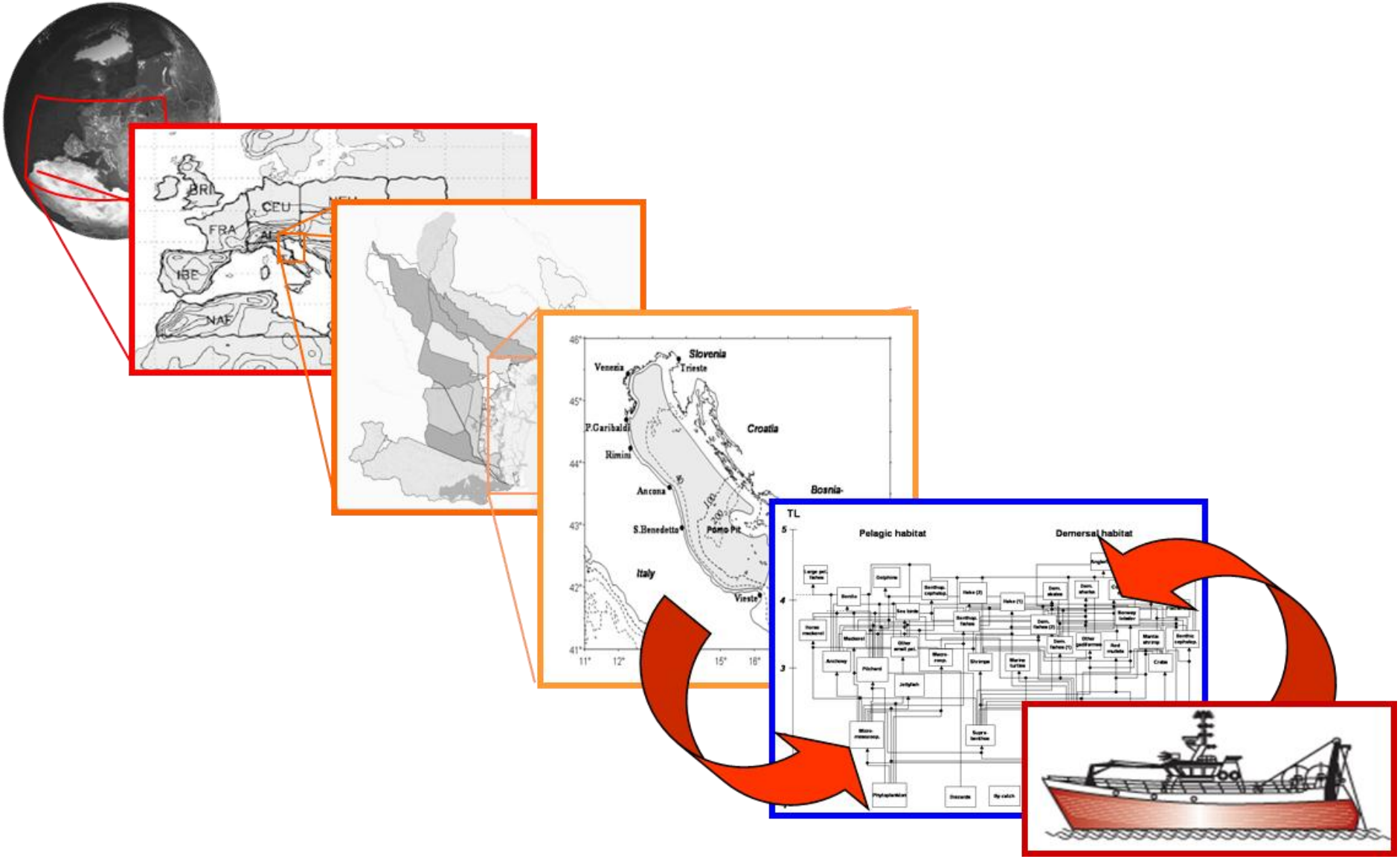
Tomaso Fortibuoni[1,2]*, Simone Libralato[1], Saša Raicevich[2], Otello Giovanardi[2], Cosimo Solidoro[1]

1 Department of Oceanography, Istituto Nazionale di Oceanografia e Geofisica Sperimentale, Sgonico, Italy, **2** Istituto Superiore per la Protezione e la Ricerca Ambientale, Chioggia, Italy

ISPRA
Istituto Superiore per la Protezione
e la Ricerca Ambientale



Climate changes & fisheries effects on food webs

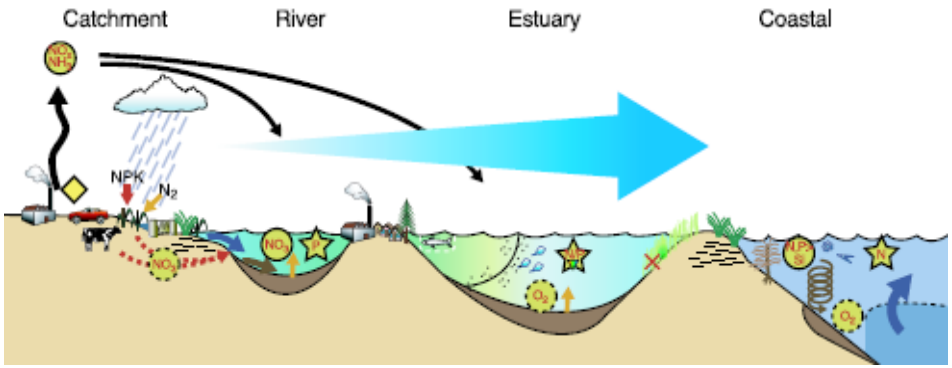


One potential impact of CC on food webs

Climate changes projections for 21st century are expected to cause a number of potential impacts (IPCC 2007).

While changes in sea level appears the most obvious threat to costal areas, **changes in precipitation patterns and therefore in timing and volume of freshwater and nutrient delivery** to coastal wetlands will also be critical.

Scavia et al., 2003

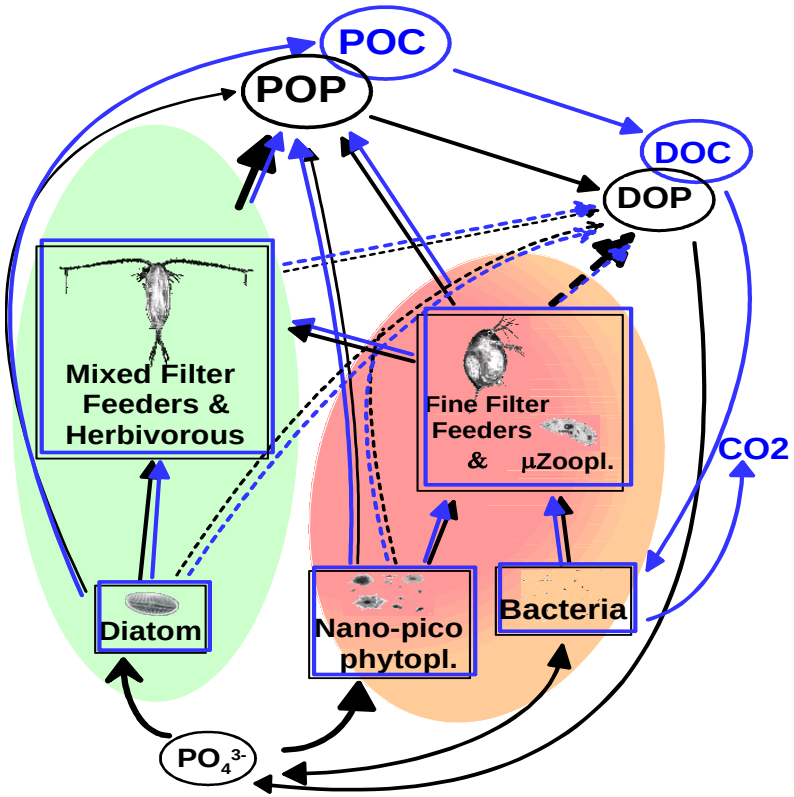


How coastal <u>ecosystems</u> respond to TIMING & VOLUME of freshwater and NUTRIENT delivery?

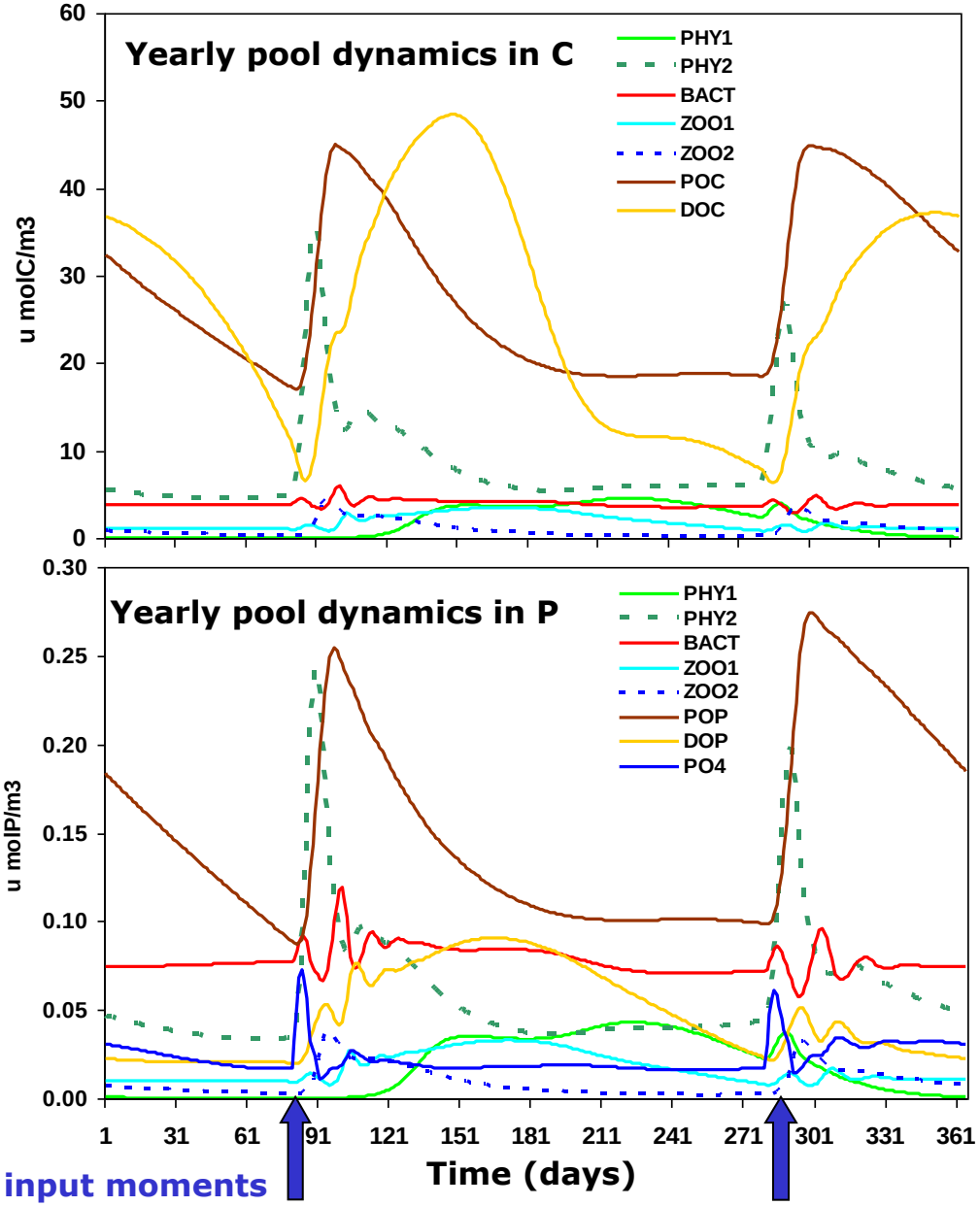
<u>Aim</u>: assessing the potential impact of changes on **seasonal/interannual precipitation patterns** on the biogeochemistry <u>and</u> on food webs of the North-Central Adriatic Sea

1) The BGC model

Cossarini & Solidoro, Ecol Mod, 2008

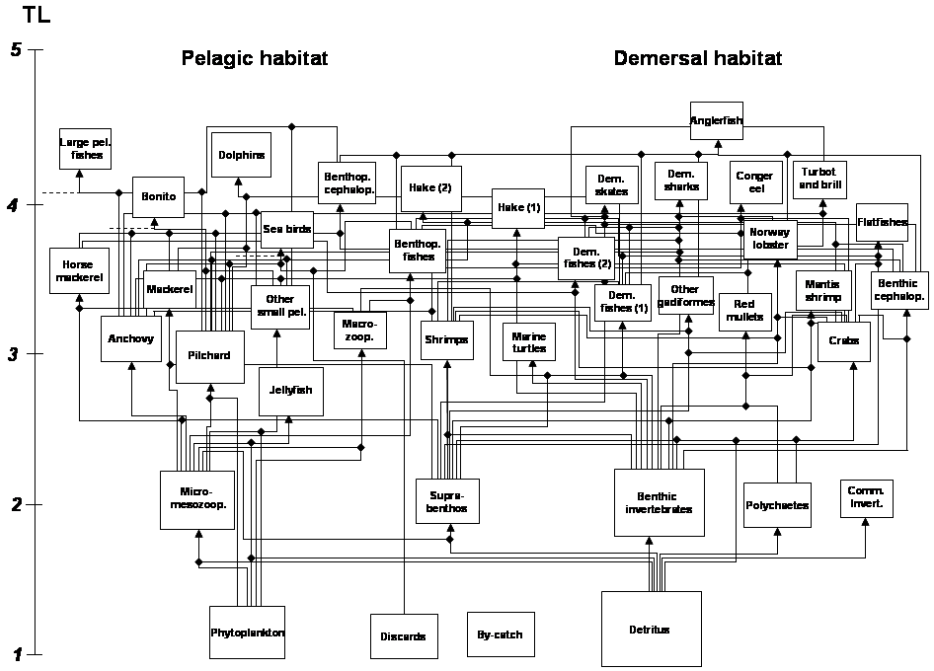


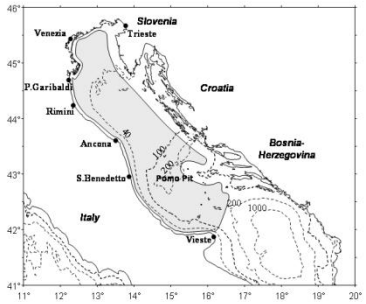
1D NPZD model, with complicated biology: 2 phytoplankton pools, 2 zooplankton pools, bacterioplankton, C & P dynamics (dissolved, particulated, inorganic P, detritus).

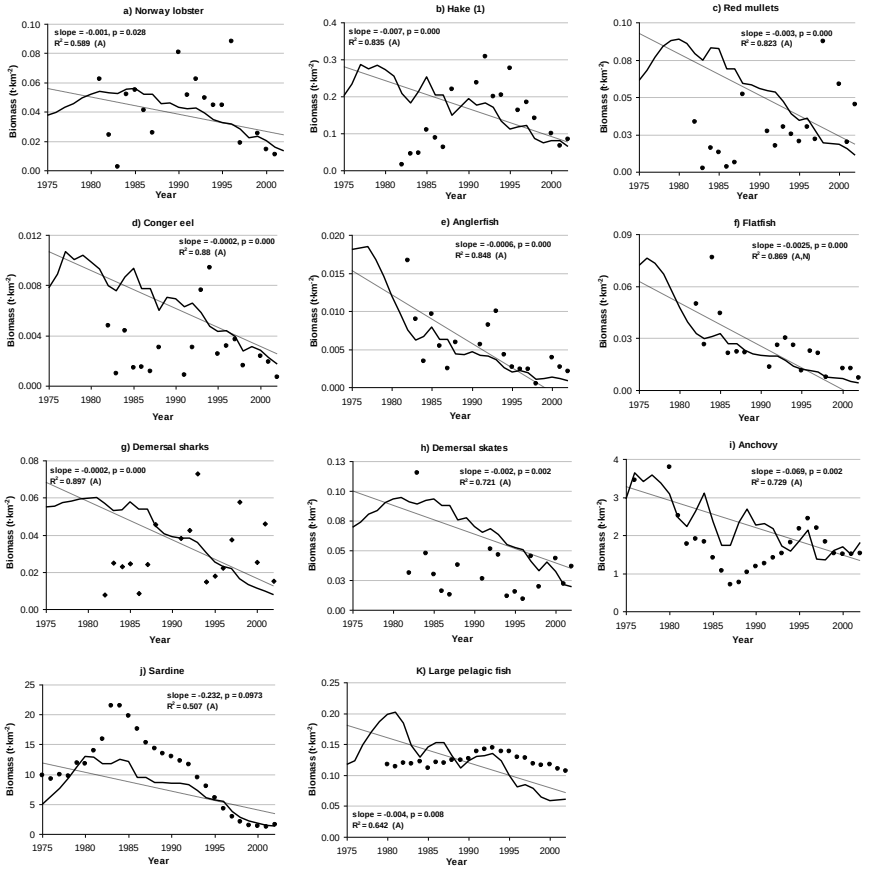


2) The food web model

The food web model is built using the **Ecopath with Ecosim** software package (v 5): **40 functional groups, 5 fishing fleets**

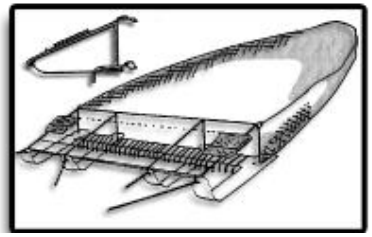
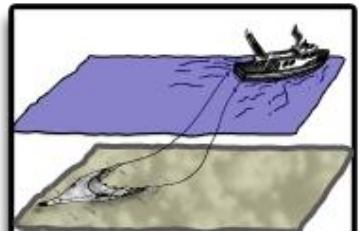
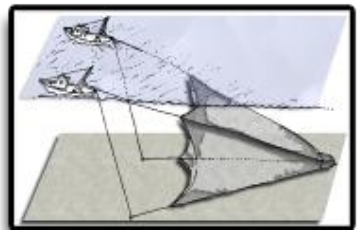
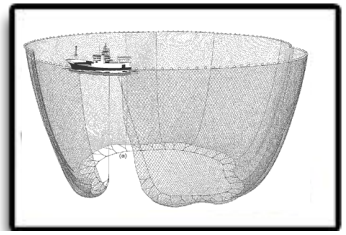
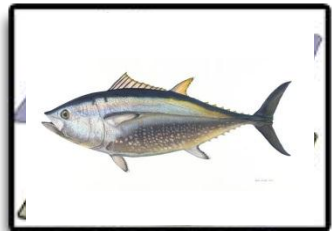


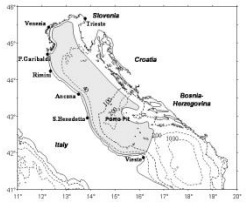


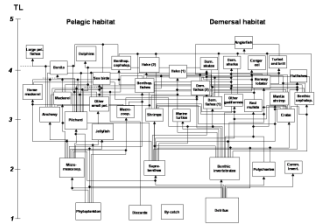


Time series of biomass and catches from **1975 to 2002**, were used for hindcast the model

Coll et al. 2006. Ecological Modelling, 198: 53-70; Coll, et al.,. Marine Ecology Progress Series, 381: 17-37

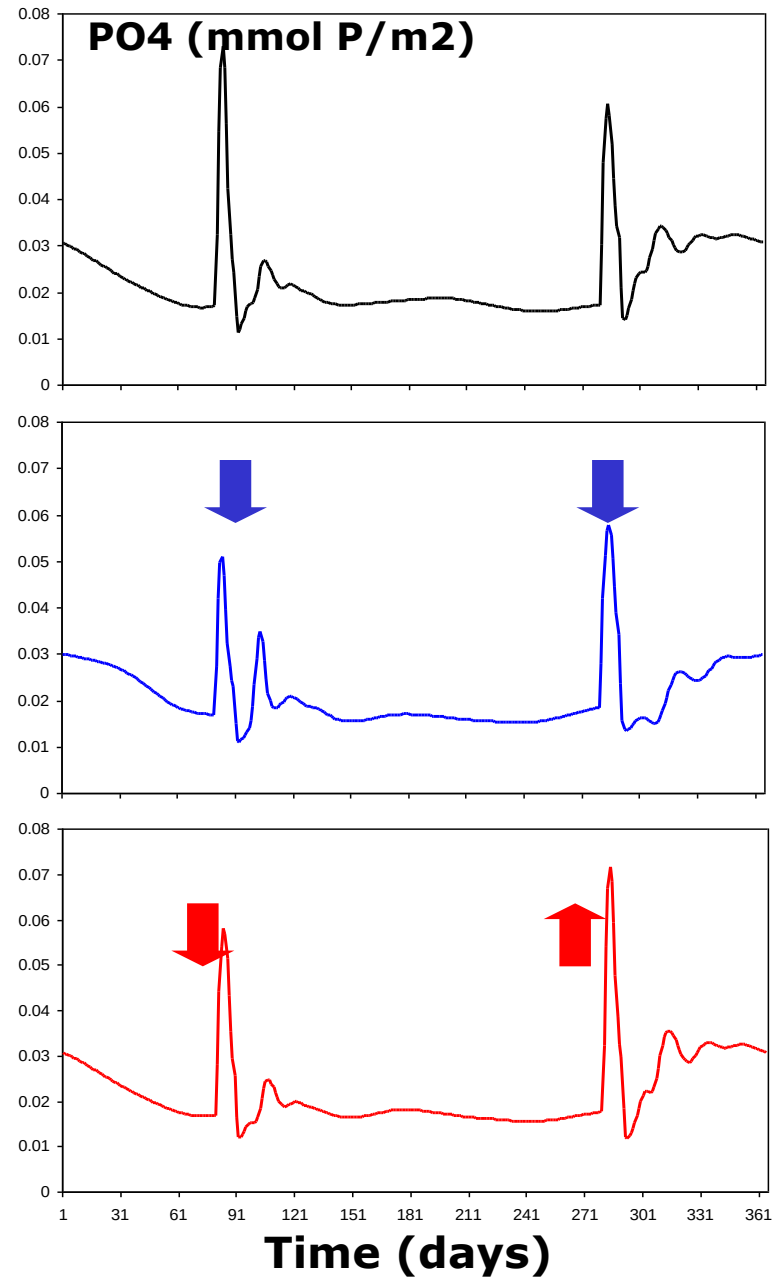
Rapido/beam trawl	Strascico/ Bottom trawl	Volante/Mid-water trawl	Lampara/purse seine	Tuna fleets
				
targets				
Flatfishes/Bivalves	**Benthic species Cephalopoda**	**Nekton species**	**Bivalves**	**Tuna**
Solea vulgaris *Platychthis flesus* *Squilla mantis* *Aequipecten opercularis* *Pecten jacobaeus*	*Merluccius merluccius* *Mullus barbatus* *Eledone cirrhosa* *Octopus vulgaris* *Sepia officinalis* *Squilla mantis*	Sardines Anchovies *Scomber scomber* *Sprattus sprattus*	Sardines Anchovy	*Thunnus thynnus* Large pelagics Atlantic bonito
discards				
Macrobenthos Flatfish Benthic fishes	Macrobenthos Flatfish planktivorous fish	Dolphins Small individuals of small pelagics	No discards	No discards



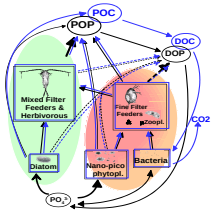


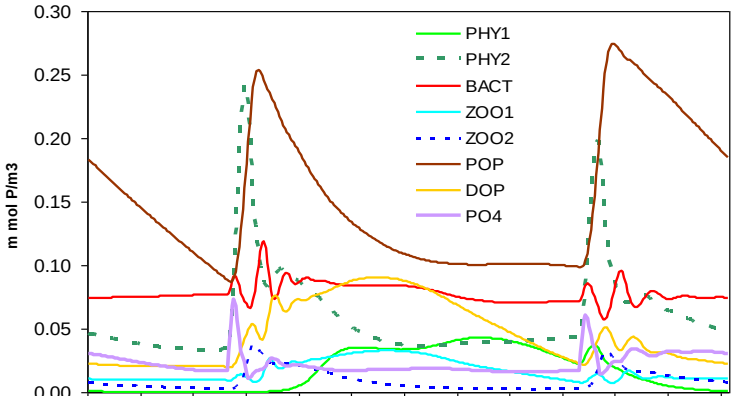
Coll, et al.,. MEPS, 2007; Libralato et al. Cons. Biol., 2010

Climatic scenarios for nutrient inputs: effects on BGC

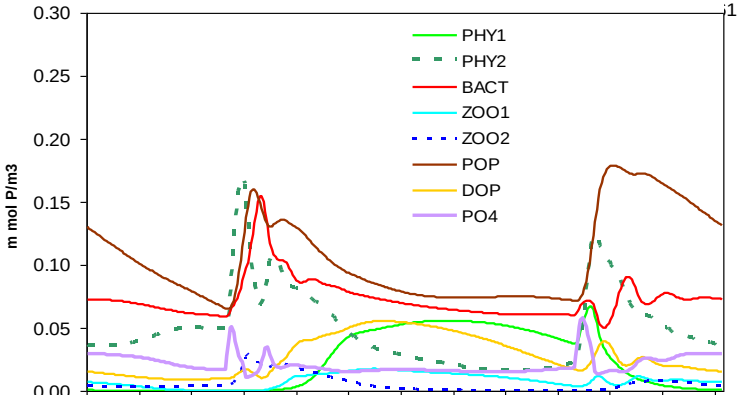


REFERENCE scenario

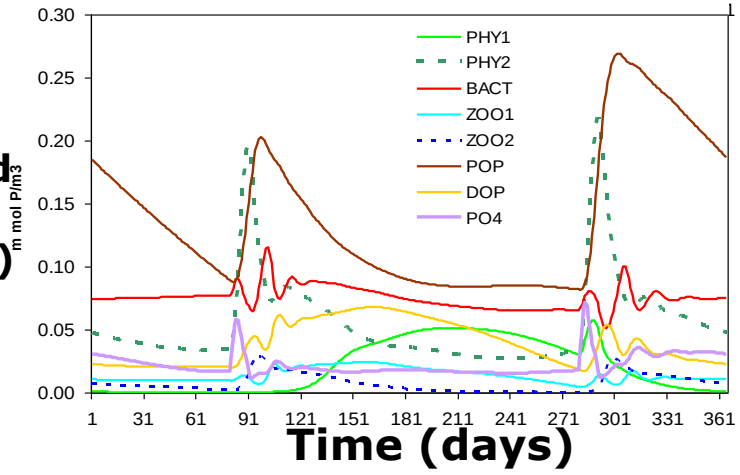




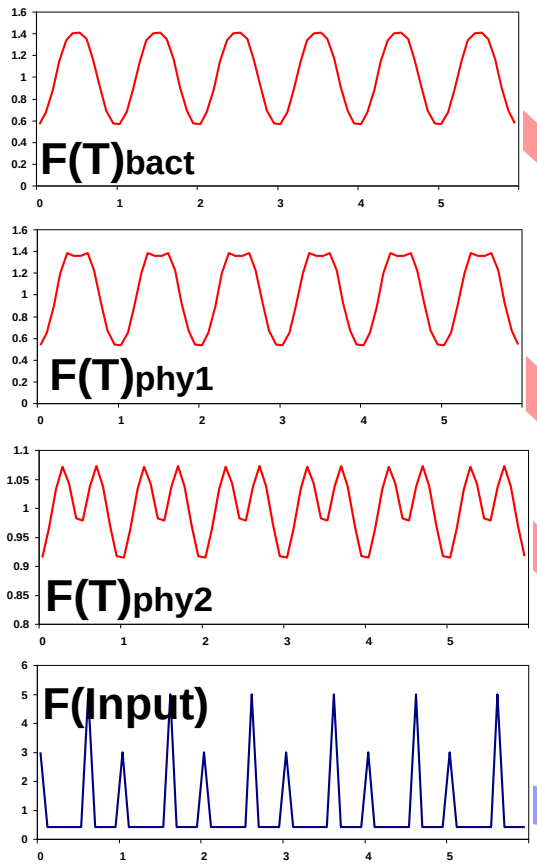
Local sustainability scenario (reduction of 25% inputs; ~IPCC B2)

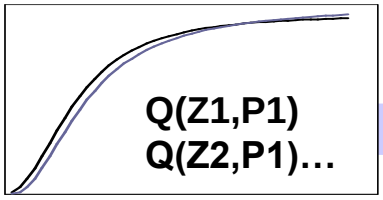


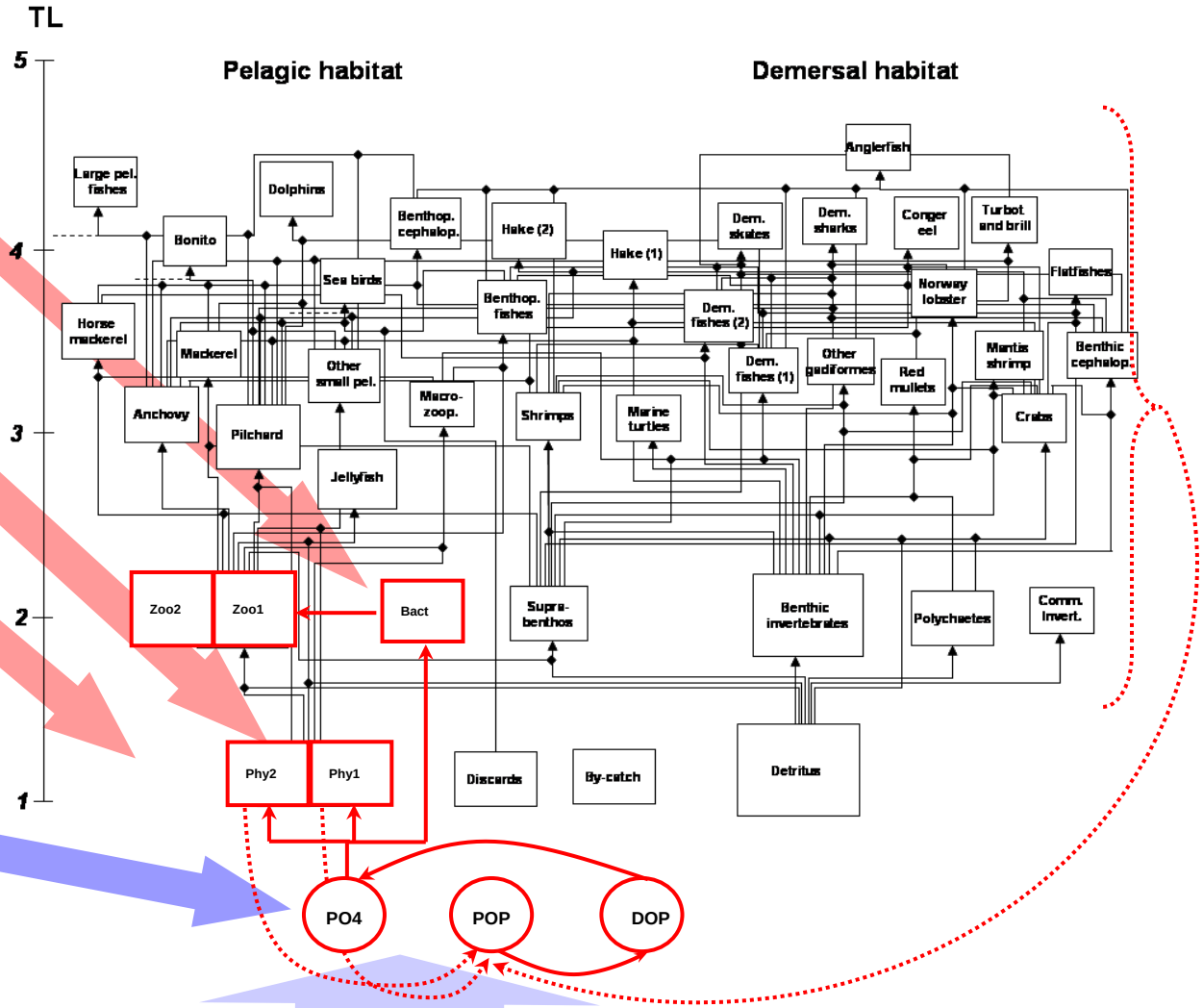
Market oriented scenario (changed precipitation pattern;~IPCC A2)



The End-to-End model: 1st step - extension







Libralato & Solidoro (2009) Ecological Modelling 220: 2960–2971

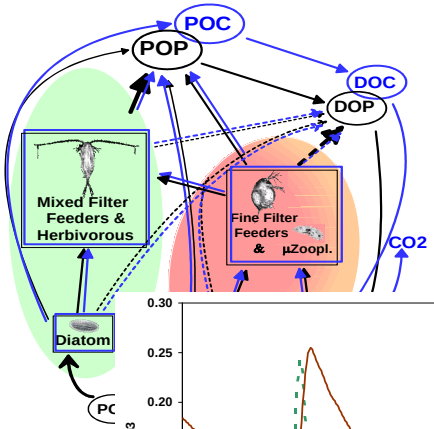
Climate and fishing scenarios

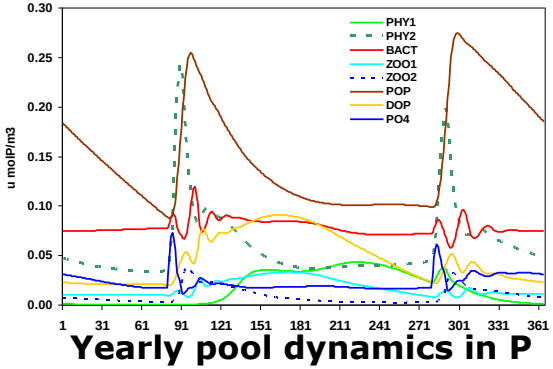
3 Climate scenarios x 27 fishing scenarios

RF - Reference

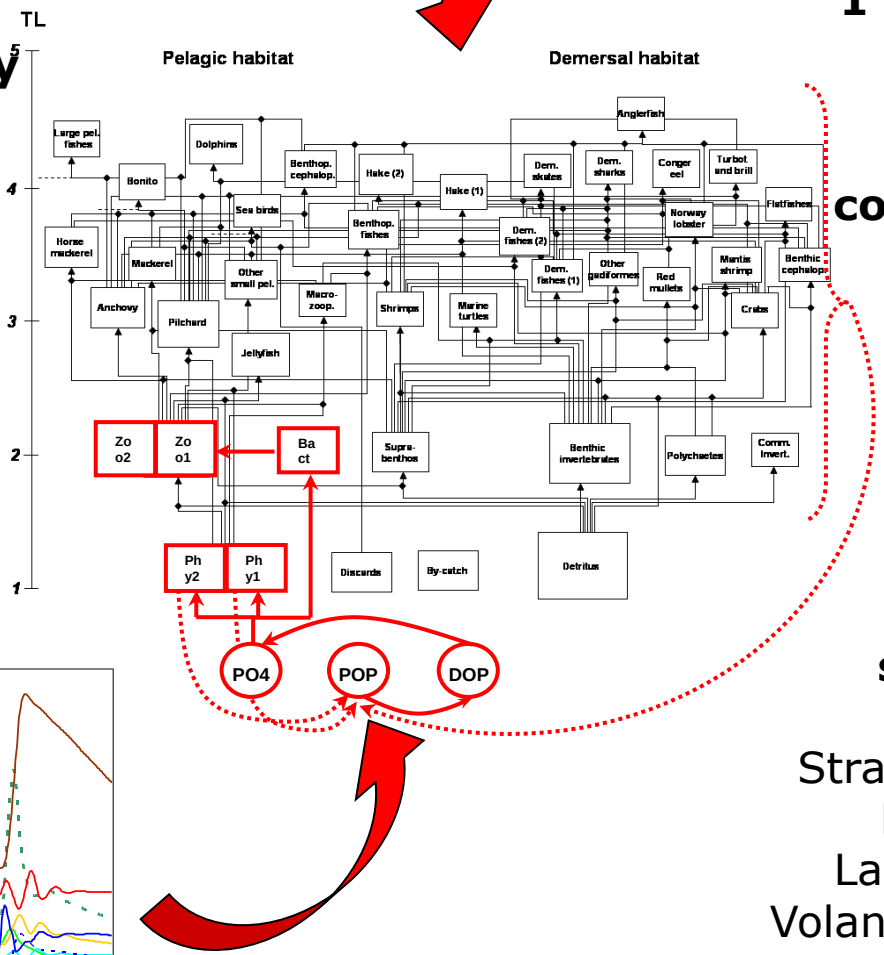
B2 – Local sustainability
(reduction of 25% inputs; ~IPCC B2)

A2 – Market oriented
(changed precipitation pattern;~IPCC A2)





Yearly pool dynamics in P



1 baseline scenario

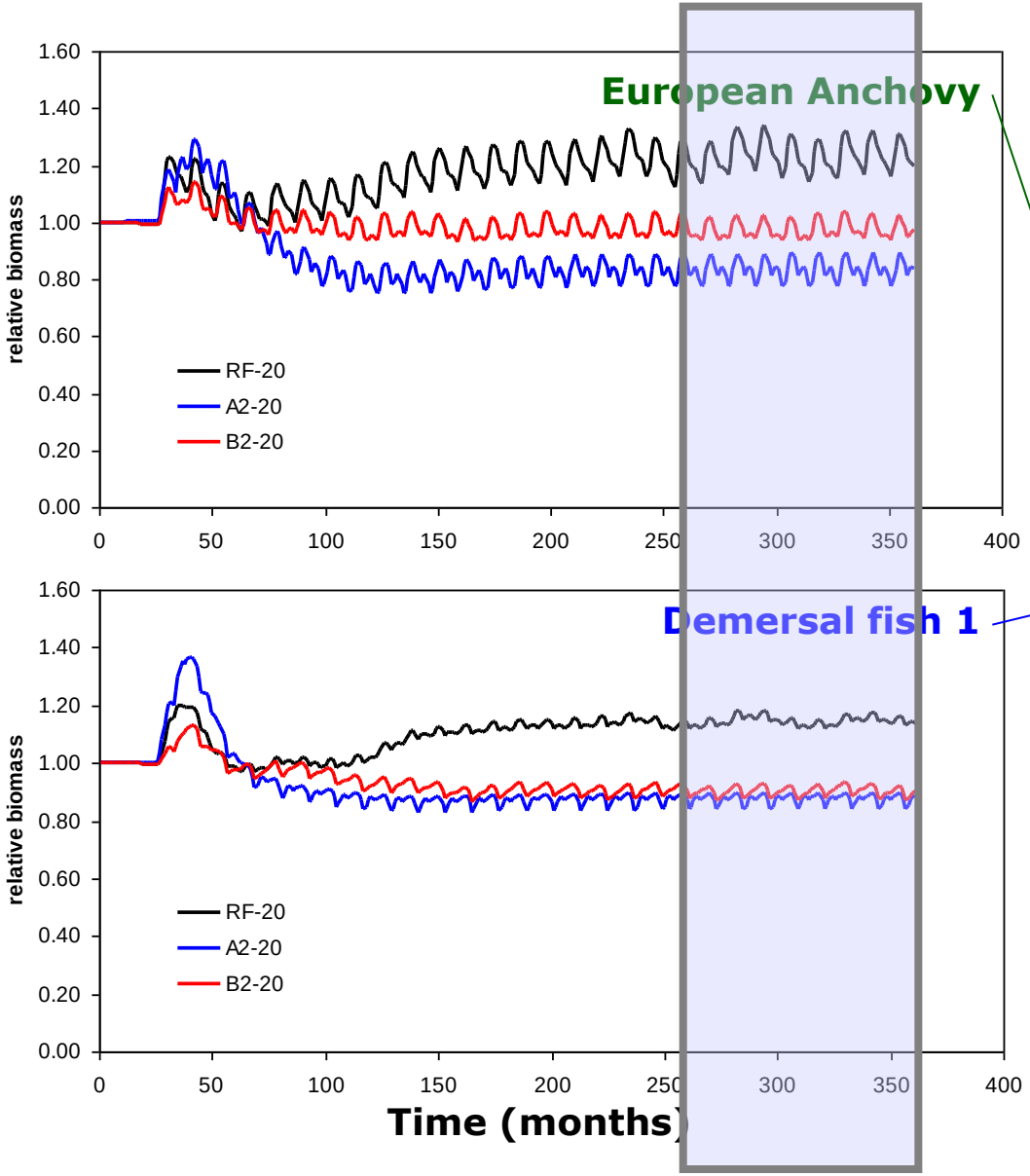
16 management scenarios of commercial species

(+/- 25% 50% for
Anchovy F
Sardine F
Hake F
Red Mullet F)

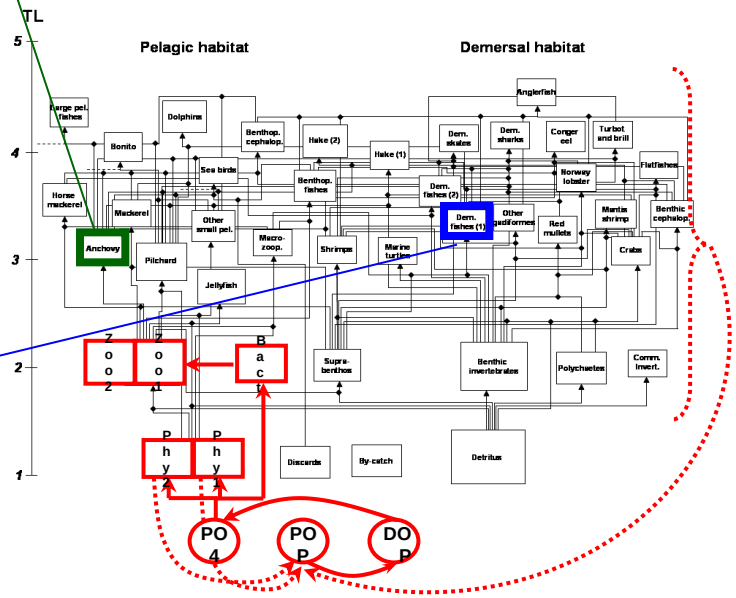
10 management scenarios by fleet
(+/- 25% effort for
Strascico/bottom trawl,
Rapido/beam trawl,
Lampara/purse seine,
Volante/mid water trawl,
Tuna fleets)

Libralato et al (in prep)

Outputs for the resulting 81 scenarios



Scenarios for 25 reduction of "rapido" fleet (beam trawling) fishing effort



Scenarios of 30 years dynamics for 47 state variables for 81 scenarios

Synthetic results for averages in the last 10 years of simulation

Outputs for the resulting 81 scenarios

Biomass of 46 FG

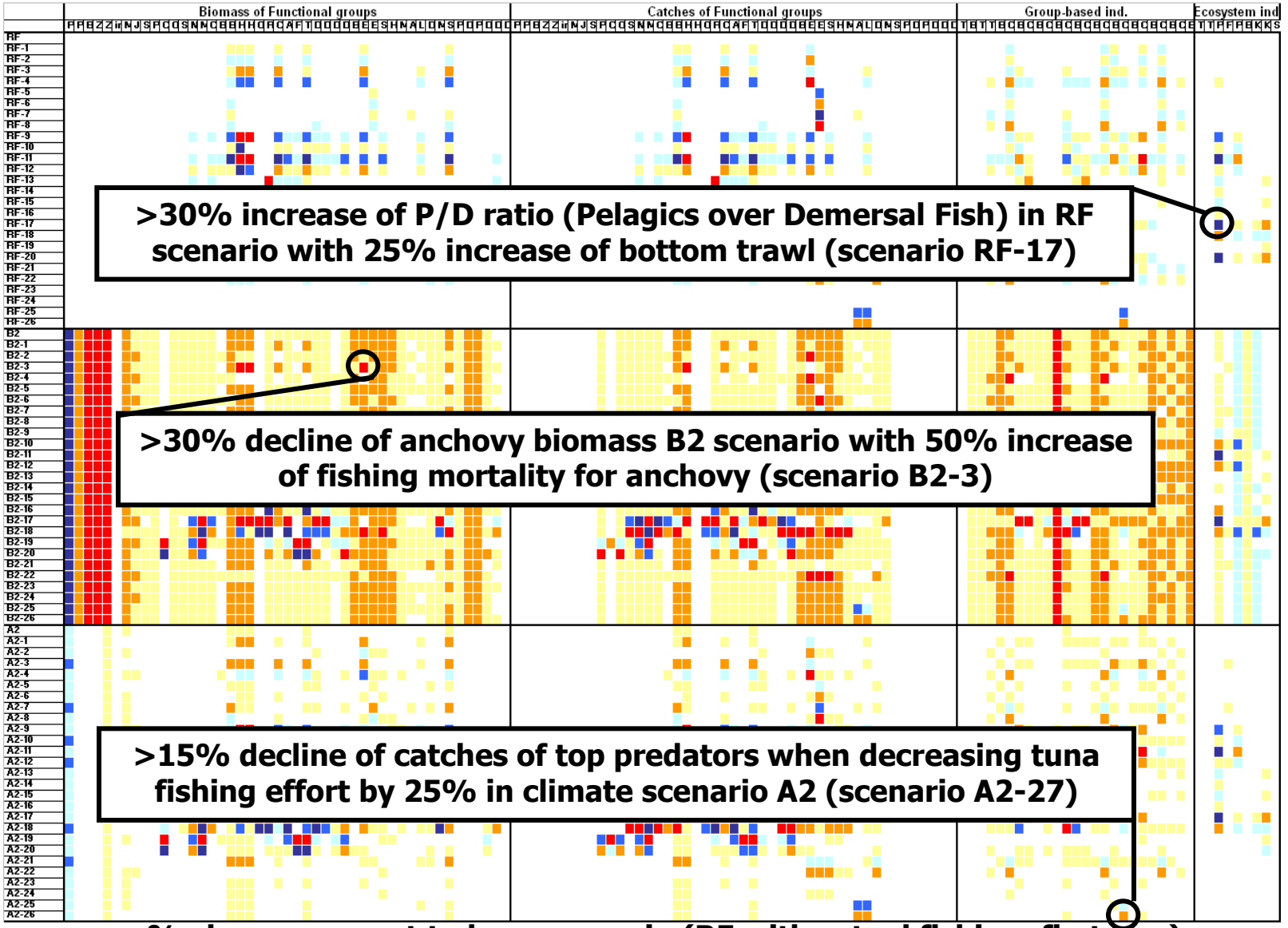
catches of 46 FG

Indicators
25 Group-based 9 Ecosystem

RF + 26 fishing scenarios under RF

B2 + 26 fishing scenarios under B2

A2 + 26 fishing scenarios under A2



>30% increase of P/D ratio (Pelagics over Demersal Fish) in RF scenario with 25% increase of bottom trawl (scenario RF-17)

>30% decline of anchovy biomass B2 scenario with 50% increase of fishing mortality for anchovy (scenario B2-3)

>15% decline of catches of top predators when decreasing tuna fishing effort by 25% in climate scenario A2 (scenario A2-27)

Color Legend

>0.3
0.15< <0.3
0.05< <0.15
-0.05< <0.05
-0.15< <-0.05
-0.3< <-0.15
<-0.3

% change respect to base scenario (RF with actual fishing: first raw)

Outputs for the resulting 81 scenarios

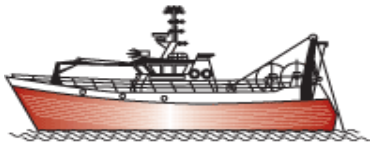
25 Group-based indicators

TB	Total biomass in the ecosystem
Bco	Biomass of the consumers
TexpB	Total exploitable biomass
Tcatches	Total catches
Bpelagic	Biomass of pelagic fish
Cpelagic	Catches of pelagic fishes
Bdemersal	Biomass of demersal fish
Cdemersal	Catches of demersal fish
Bbenthicinv	Biomass of benthic invertebrates
Cbenthicinv	Catches of benthic invertebrates
Bpelinv	Biomass of pelagic invertebrates
Cpelinv	Catches of pelagic invertebrates
Bbenthicfish	Biomass of benthic fish
Cbenthicfish	catches of benthic fish
Bpelfish	Biomass of Pelagic fish
Cpelfish	Catches of Pelagic fish
BtopP	Biomass of Top pradators
CTopP	Catches of Top pradators
Bother predators	Biomass other predators (TL>3.5)
Cother predators	Catches other predators
Bprey	Biomass of prey (TL<3.5)
Cprey	Catches of prey
Bcomm	Biomass of commercial species
Ccomm	Catches of commercial species
Bbiod	Biomass of consumers with TL>3.5

9 Ecosystem indicators

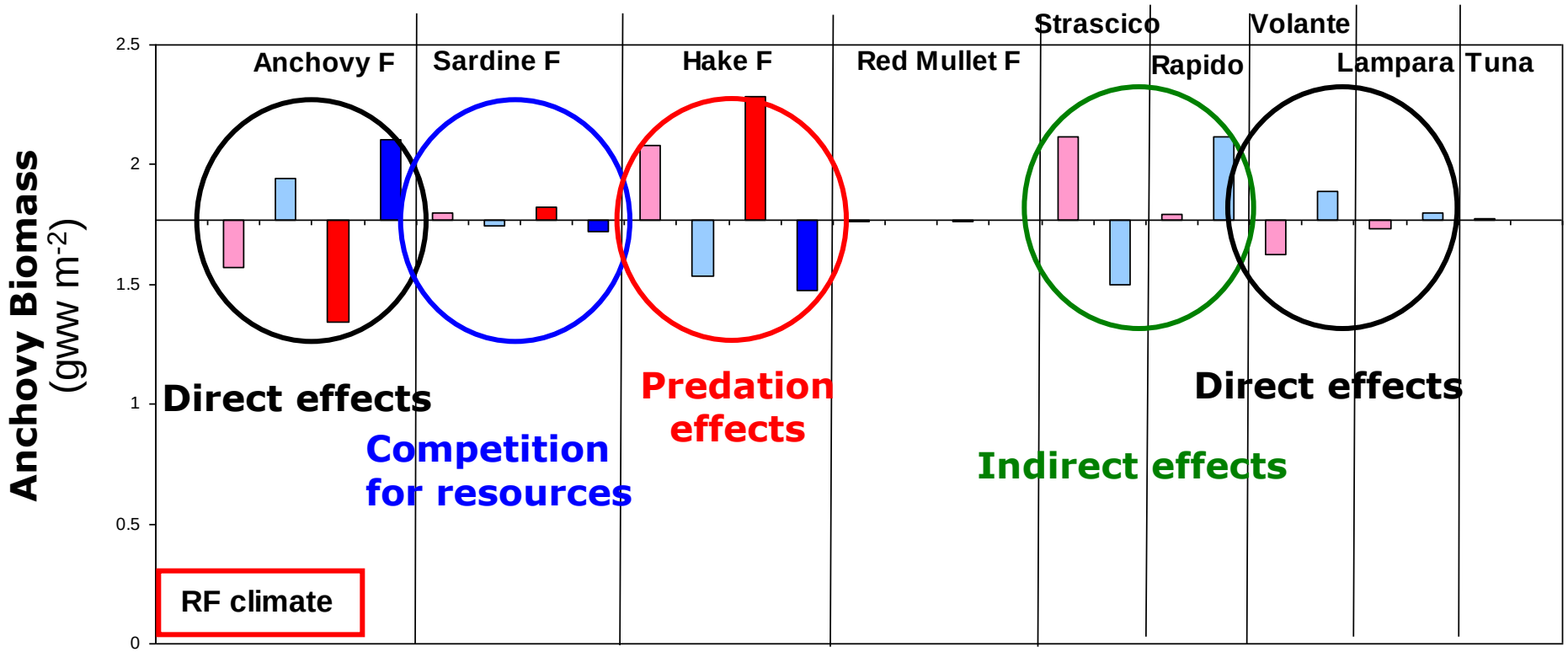
TLco	Trophic Leval of the community
TLc	Trophic level of the catches
P/D ratio	Pelagic/Demersal ratio
Fish/Inv	Fish/Invertebrate biomass ratio
Pred/Prey	Predator/Prey biomass ratio
BiodivIndex	Informational diversity index H
Kempton Q'	Kempton modified diversity (Q90)
Kempton Original	Kempton diversity (Q)
SOI	System Omnivory Index

Results ANCHOVY



Fishing scenarios

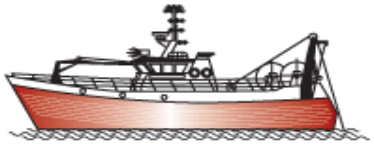
+ 25% + 50%
- 25% - 50%



These should be considered indicative of changes in the suitability of the system to support such biomass

Libralato et al (in prep)

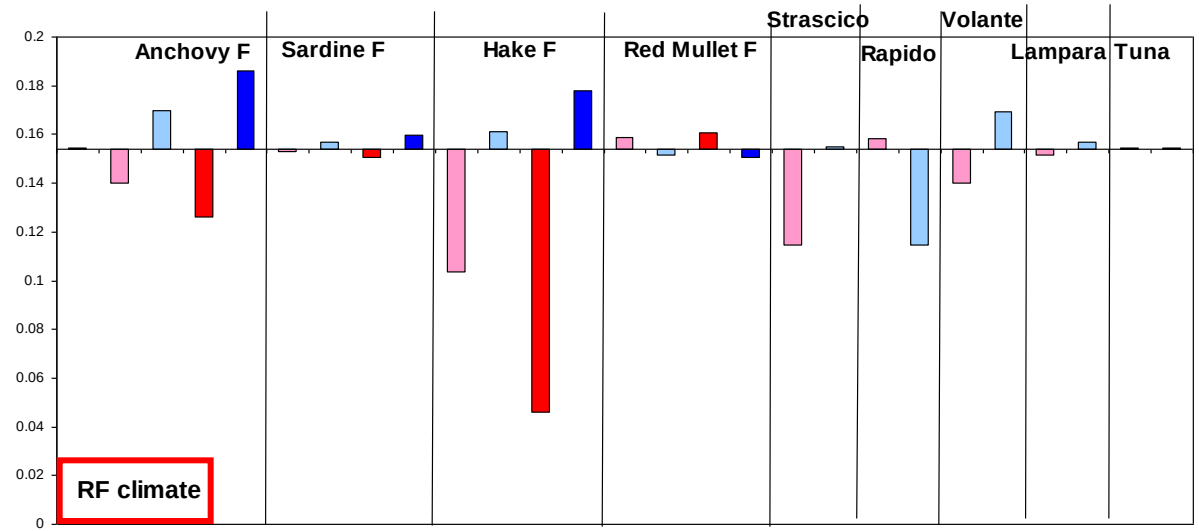
Results HAKE

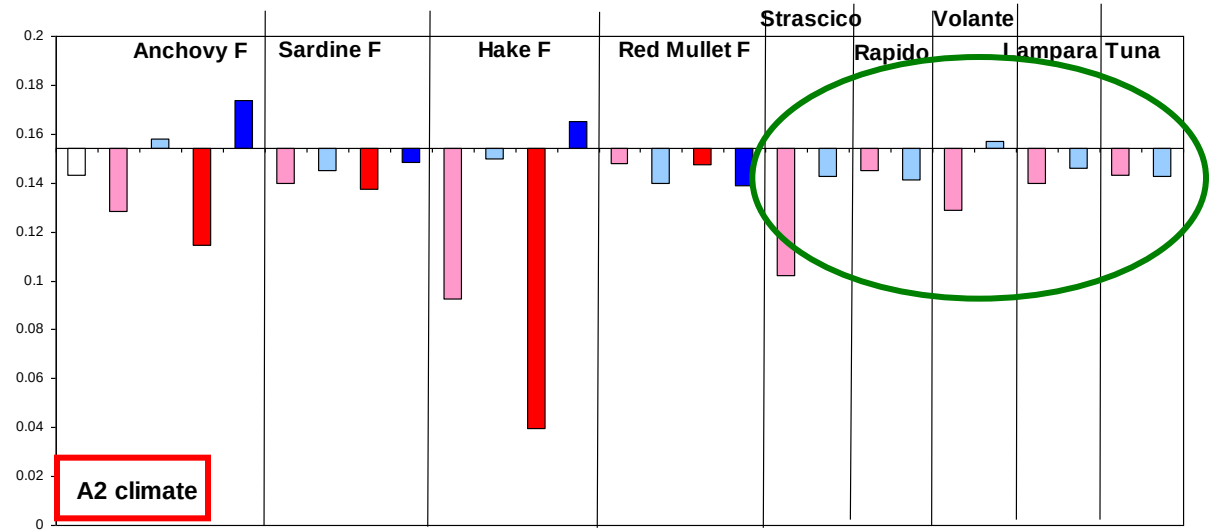


Fishing scenarios

+ 25% + 50%
- 25% - 50%

Hake Biomass (gww m^{-2})



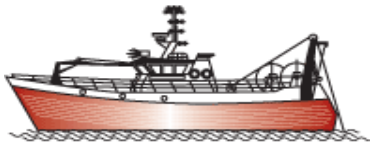


Indirect effects all negative

Changes in run-off seasonality decrease trophic possibilities that are not compensated by fisheries management

Libralato et al (in prep)

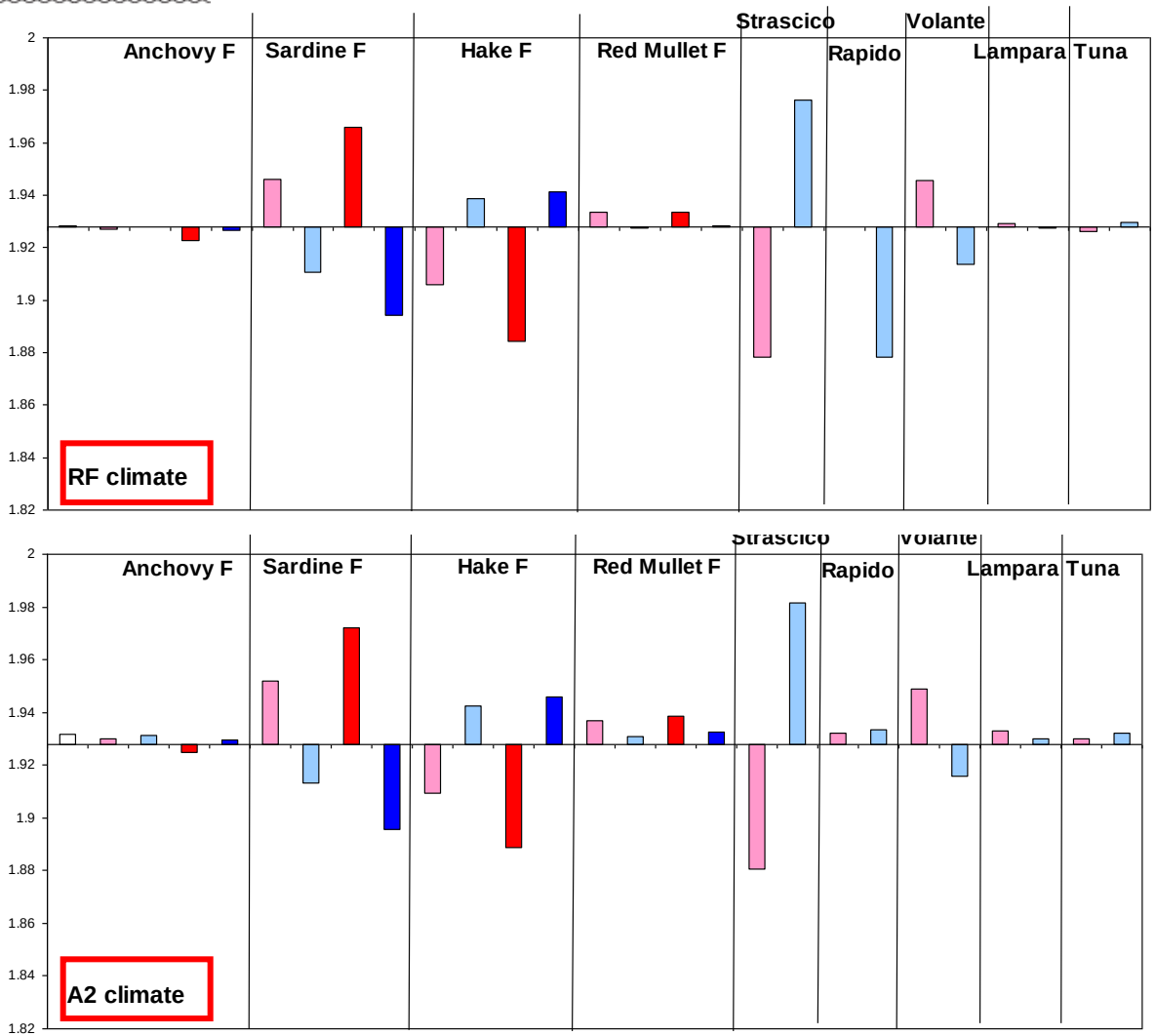
Results BIODIVERSITY INDEX (H)



Fishing scenarios

+ 25% + 50%
- 25% - 50%

Biodiversity Indicator
( )



Strong effects of fishing on biodiversity, whereas trophic adjustments after climatic change partially counterbalance negative effects

Libralato et al (in prep)

Climate and fisheries effects: synergies and antagonisms

The value of model output obtained in different fishing (ONLY) scenarios

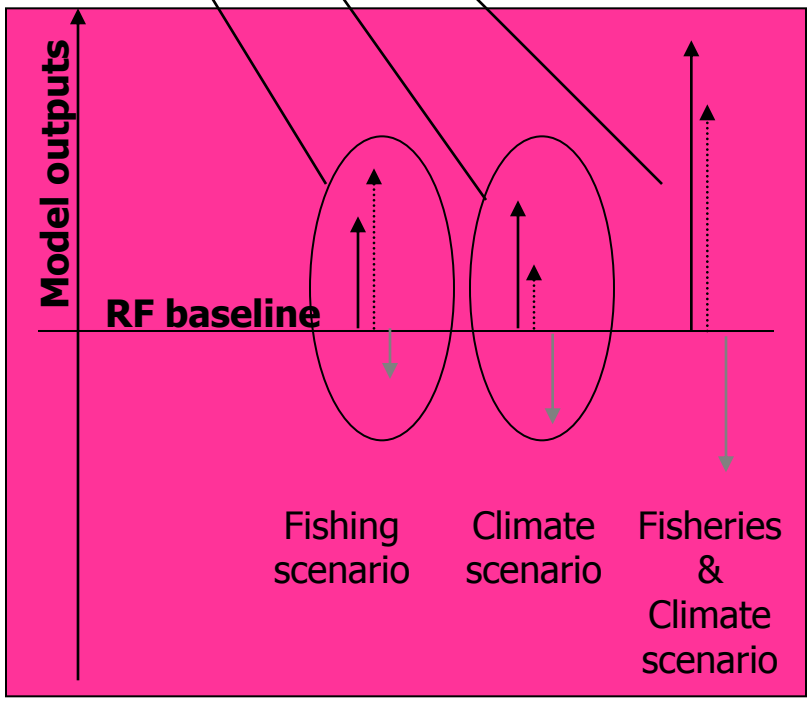
The value of the same model output obtained in different climate (ONLY) scenarios

The value of the same model output obtained in different fishing+climate scenarios

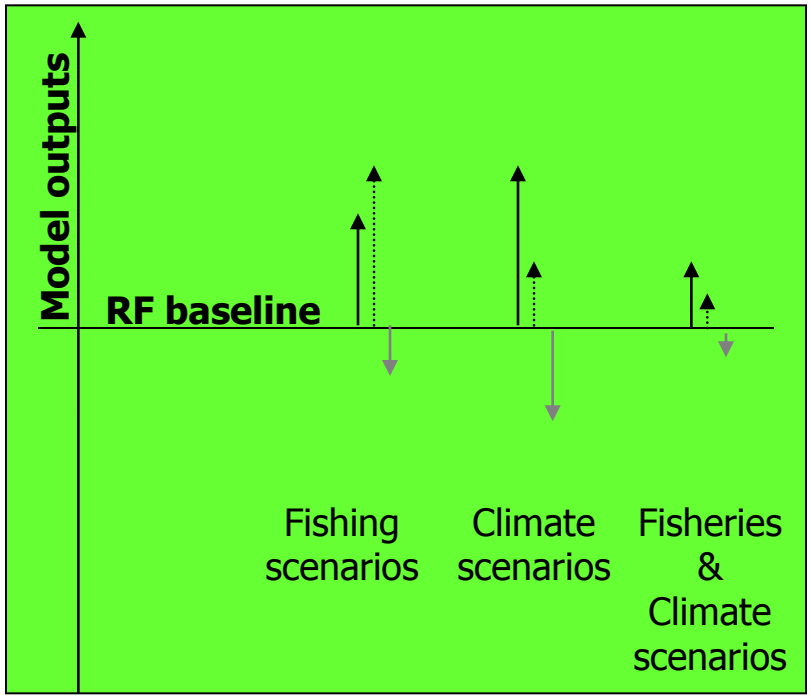
Highlighted for all outputs:
Biomass of 46 FG

catches of 46 FG

Indicators
25 Group-based 9 Ecosystem

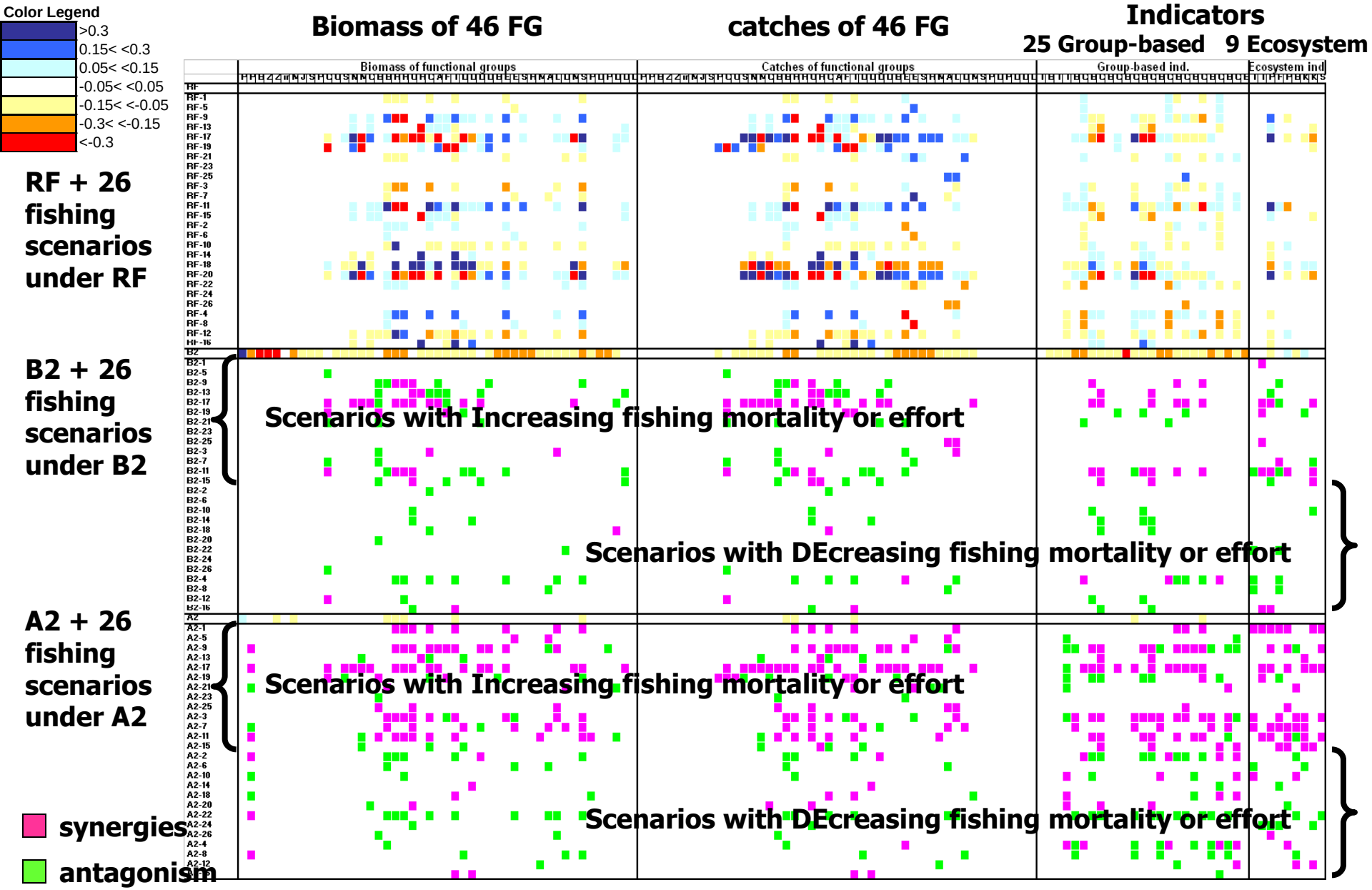


SYNERGISTIC EFFECT BETWEEN climate + fishing



ANTAGONISTIC EFFECT BETWEEN climate + fishing

Climate and fisheries effects: synergies and antagonisms



Conclusions

In order to evaluate effects of climate changes on ecosystems, other forcings need to be accounted (fisheries)

Long terms analyses showed marked community changes in the Adriatic Sea, primarily linked to long terms fisheries impacts

Climatic changes seems to have already affected our communities, and fisheries can take advantage of "new resources" (warm species)

A preliminary methodology for an End-to-End modelling highlighted synergistic and antagonistic effects of fishing and climate
by species and by ecosystem measures (indicators)

Scenario analysis at the moment does not include the effects of temperature: it would be possible with biological information on temperature effects on trophism and especially with information on species adaptation and migration to T changes

Acknowledgments

Cosimo Solidoro, Gianpiero Cossarini, OGS (Trieste, ITALY)

Tomaso Fortibuoni, Sasa Raicevich, Otello Giovanardi, ISPRA (Chioggia, ITALY)

Enrico Arneri, Alberto Santojanni, CNR-ISMAR (Ancona, ITALY)

Marta Coll, Isabel Palomera, ICM-CSIC (Barcelona, SPAIN)

Filippo Giorgi, ICTP (Trieste, ITALY)

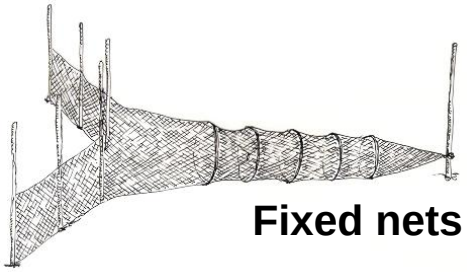
Thank you!

Other slides

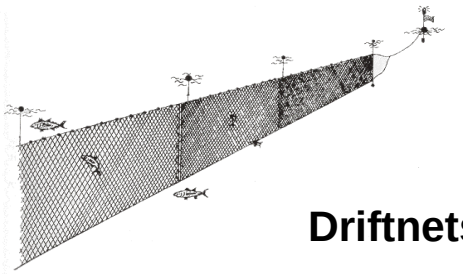
Beyond impacts on target species

Fishing activities include a very wide set of practices targeting fish, shellfish and other marine species

Fisheries produce direct impacts on target species



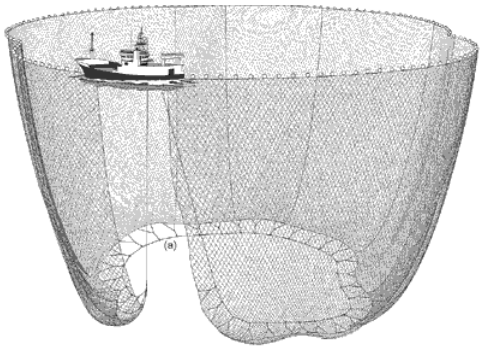
Fixed nets



Driftnets

But also a set of other IMPORTANT impacts/effects:

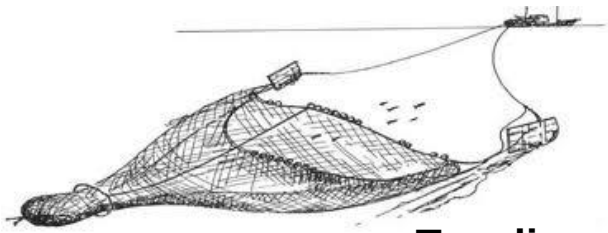
Direct impacts on non target species



Purse seine

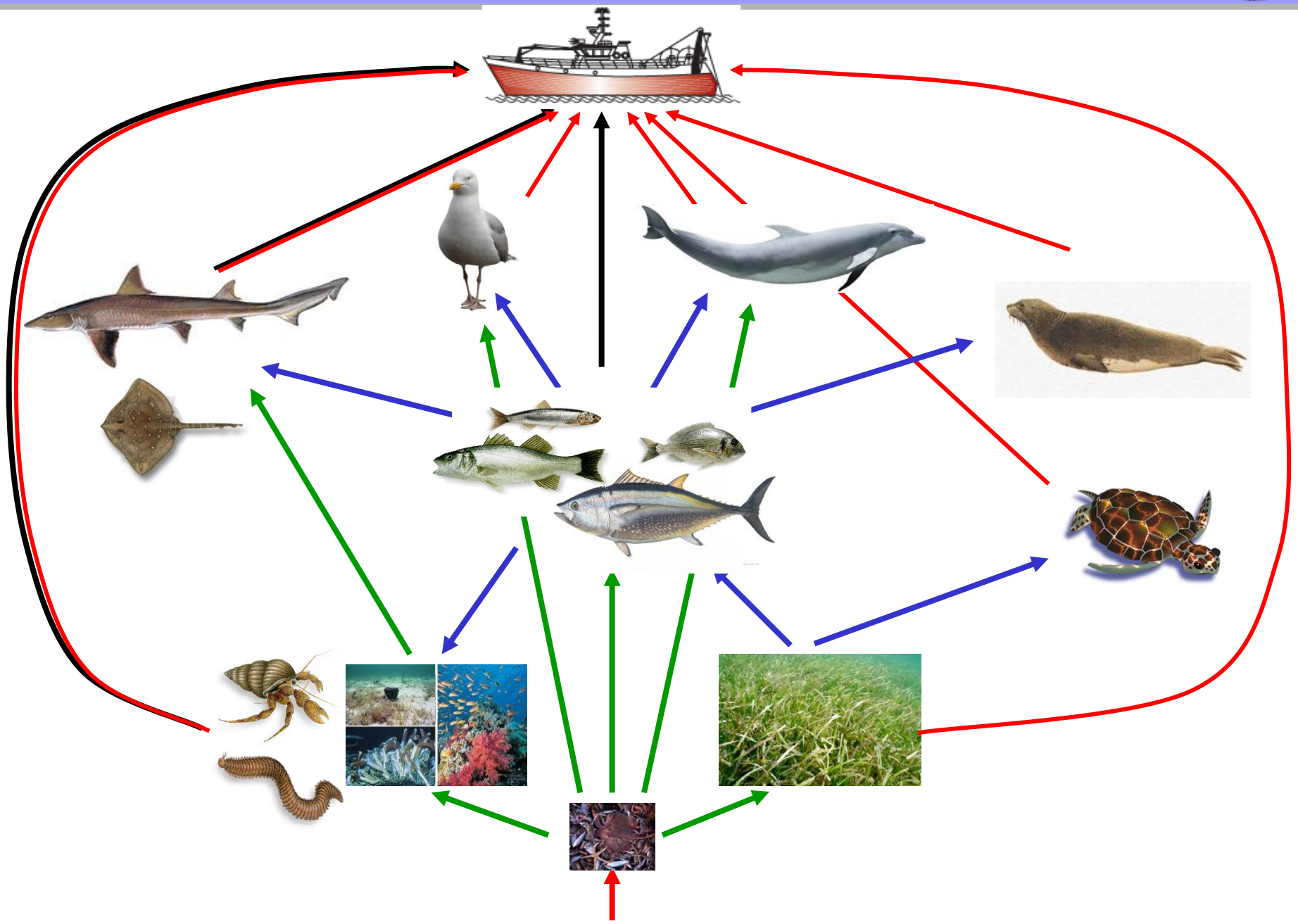
Impacts on target populations have indirect impacts other species

Impacts on non-target populations have indirect impacts other species (including targets!)



Trawling

Can we account for all these effects?



Beyond targets: benthic habitat

Benthic habitats (not only seagrass meadows) are deeply damaged by trawl fisheries.

Several species caught as by-catch: increasing mortality of benthic invertebrates

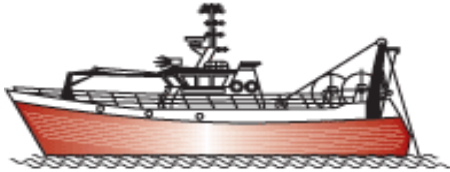
Removal of bioturbation species (clams), useful for bottom sediments oxygenation

Increase of mortality of benthic species might change trophic structure (increase of scavengers; e.g. *Liocarcinus depurator*)

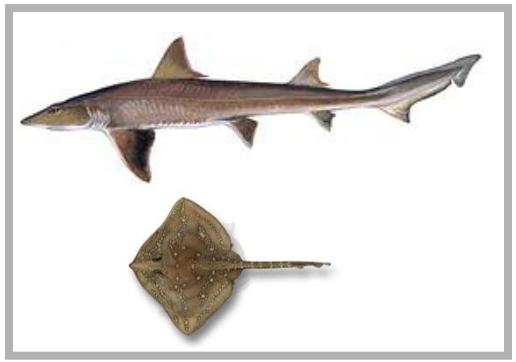
Destruction of habitats and biomass reduction might reduce preys for other fish species, including targets of the fishery!

Beyond targets: Chondrichthyans

SHARKS and RAYS are sensitive species
- slow growing/long living species;
- late age of maturity;
- low reproductive rate;

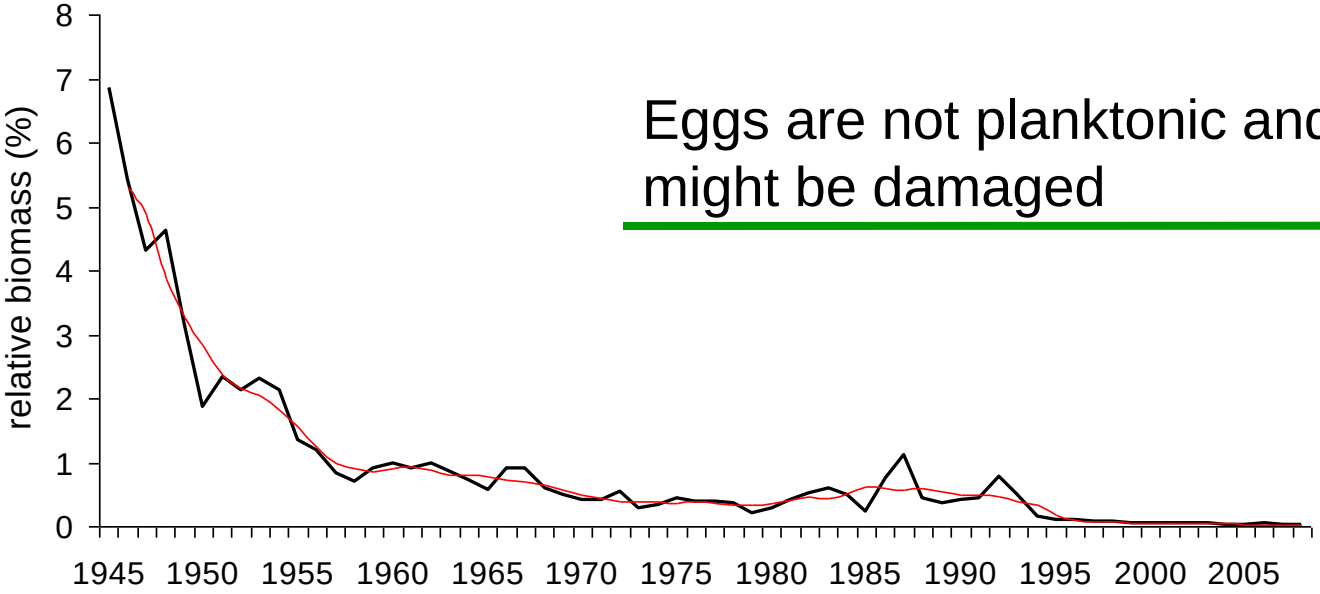


Direct target in some fisheries



caught as by-catch (drifters, longlines and trawlers)

Eggs are not planktonic and might be damaged



Proportion of sharks and rays in N Adriatic landings

(Libralato et al., 2012)

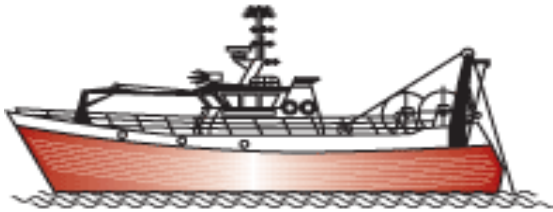
Beyond targets: Seabirds

Albatross, Sea-gulls (e.g. *Laurus audinii*), Cormorants/Shag

caught as by-catch
(especially of longlines but also trawlers)

Discards from fisheries (especially trawling) might be beneficial for scavenging sea-birds (positive indirect effect)

Depletion of stocks target by fishery can indirectly affect seabirds



Beyond targets: marine turtles

Three main species: Loggerhead (*Caretta caretta*), green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*)

- low turnover
- adult survival seems the main problem
- fecundity seems a less significant

Deliberate killing is rare, fishing them for food is also rare

Main issue is mortality due to incidental capture

More than 60000 turtles are captured each year by fisheries in the Mediterranean sea. Examples: Spanish longline: more than 20000 turtles per year. Italian driftnets: 16000 per year in the Ionian **(Tudela, 2004; FAO Studies and Reviews)**

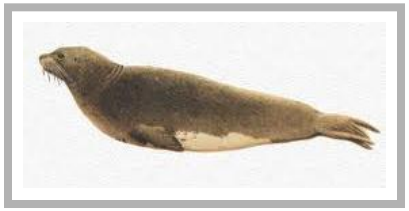
Beyond targets: monk seal

Monk seal (*Monachus monachus*) is in danger in the Mediterranean:

- slow growing/long living
- low reproductive capacity
- disturbance to reproductive sites

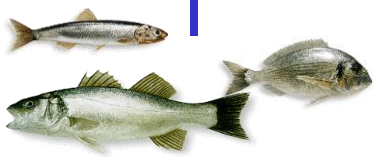
Deliberate killing by fishermen

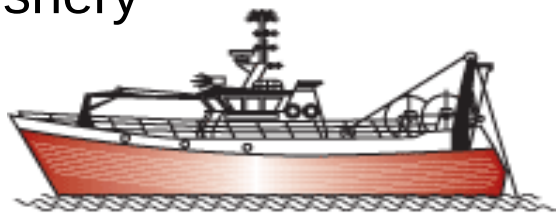
Incidental entanglements in nets



Depletion of stocks target by fishery can indirectly affect the Monk Seal population that might suffer for the high competitiveness of fishery

Target fish stock decline





Beyond targets: cetaceans

Several species from abundant such as striped dolphin (*Stenella coeruleoalba*) to very rare as porpoise (*Phocoena phocoena*)

Deliberately killed by fishermen (example: 30 bottlenose/year in the Balearic), considered a pest

Captured incidentally: purse seines release most animals alive but driftnets cause high mortality: e.g. 1682 cetaceans are estimated to be caught in 1991 (Di Natale, 1995)

Depletion of target fish stocks can cause starvation for dolphin

Beyond targets: seagrasses

Seagrass meadows represent an important habitat for species refuge, reproduction and foraging. Covers 2% of littoral areas in the Mediterranean

Can be directly impacted by some kind of fisheries (bottom trawling, rapido)

Resuspension of sediments by intensive trawling can decrease light penetration affecting seagrass

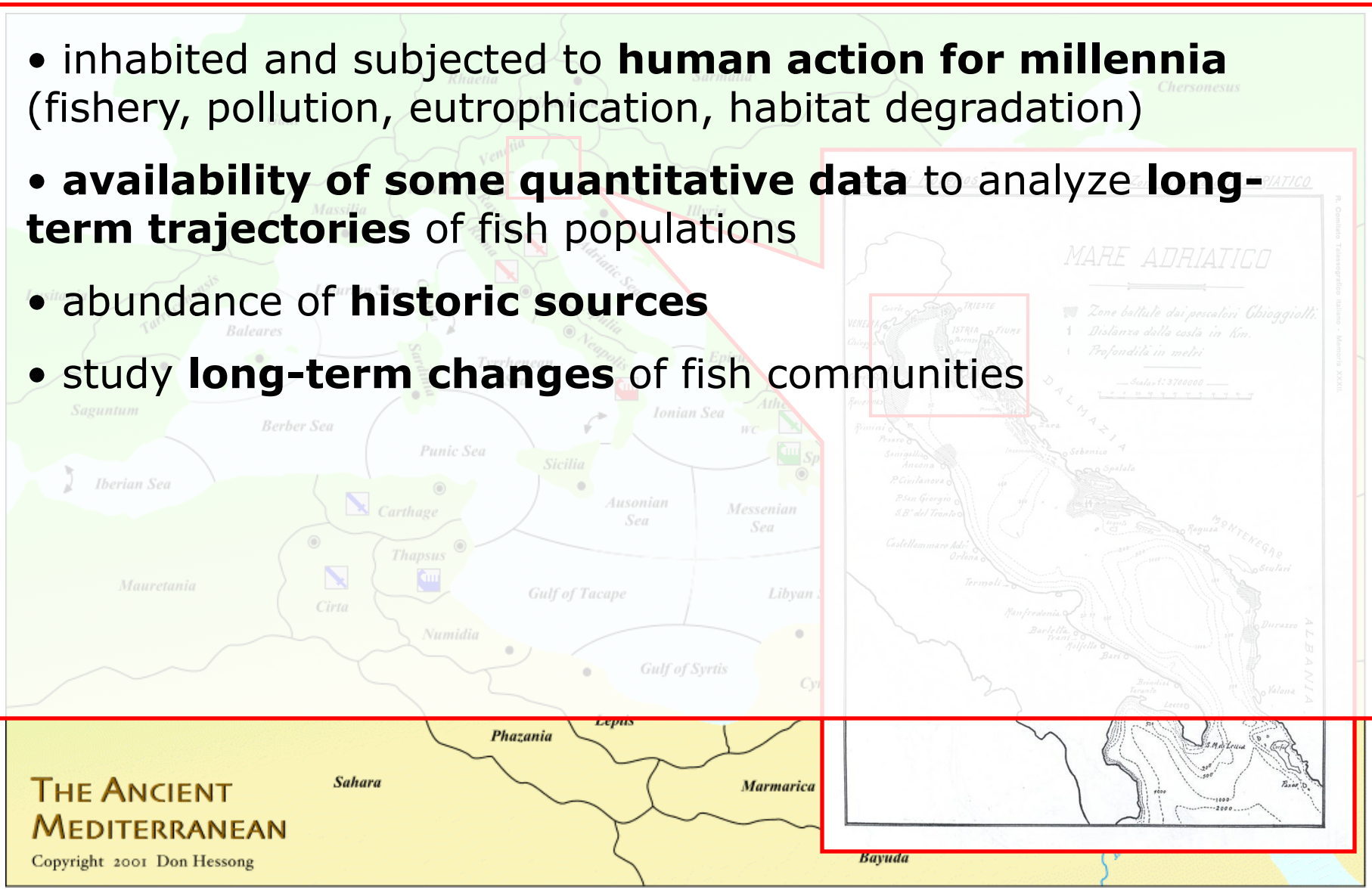
Reduction of seagrass coverage produce important changes in trophic structure of the fish and macrobenthic populations

Enforce regulations for banning trawling in *Posidonia* beds

(Tudela, 2004; FAO Studies and Reviews)

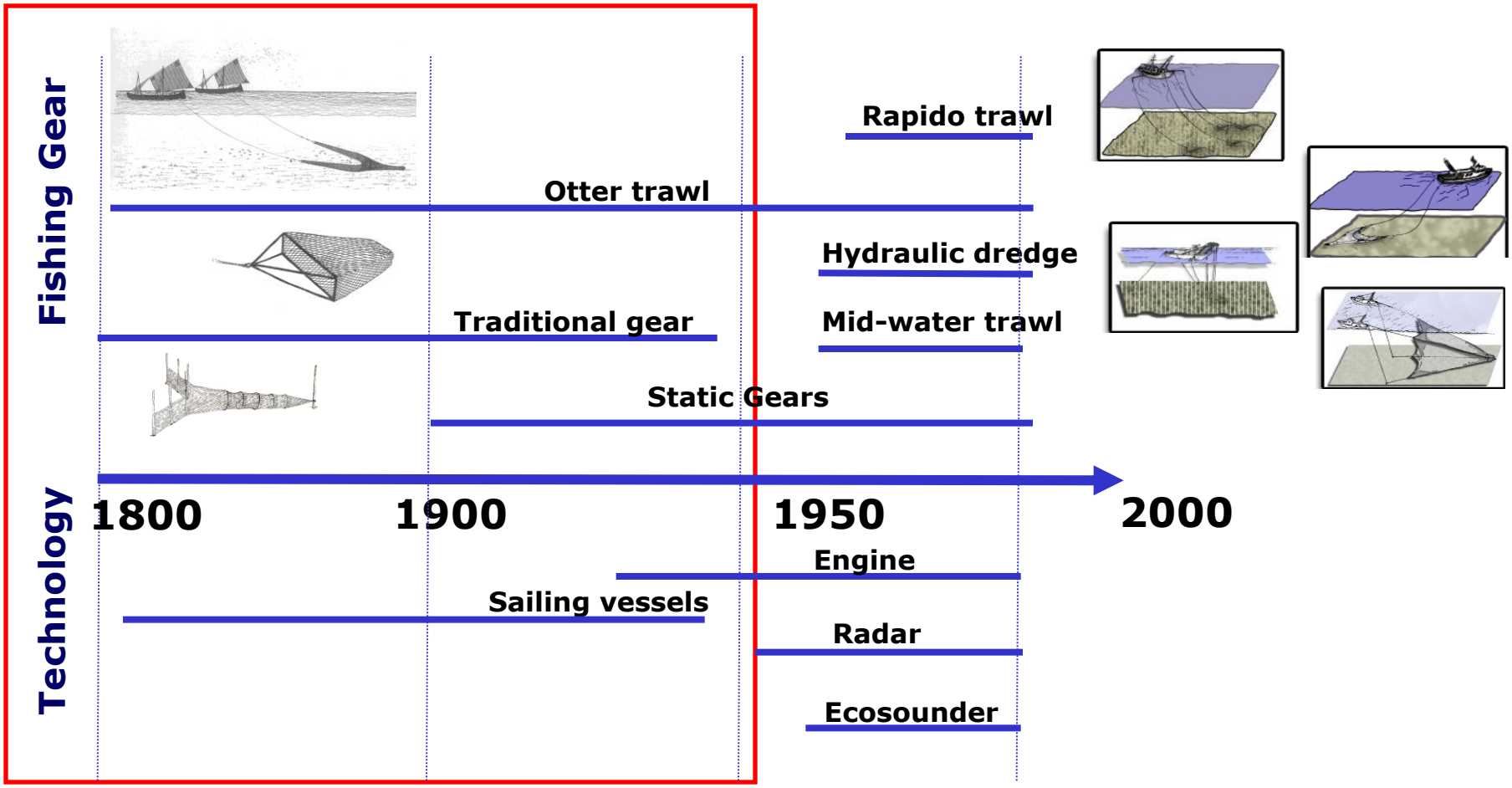
The Northern Adriatic Sea

- inhabited and subjected to **human action for millennia** (fishery, pollution, eutrophication, habitat degradation)
- **availability of some quantitative data** to analyze **long-term trajectories** of fish populations
- abundance of **historic sources**
- study **long-term changes** of fish communities



Fishery in the Northern Adriatic Sea

- one of the most productive basins of the Mediterranean Sea
- heavly exploited since ancient time
- before the industrialization of fishery (1950s)



Archival research

Venice

- Museo di Storia Naturale
- Biblioteca Nazionale Marciana
- Biblioteca del ISMAR-CNR
- Archivio di Stato
- Archivio Storico Comunale
- Biblioteca Querini Stampalia
- Camera di Commercio
- Istituto Nazionale di Statistica (ISTAT)
- **Mercato Ittico**

Split

- Biblioteca dell'Istituto di Oceanografia e Pesca

Padua

- Biblioteca della Facoltà di Scienze Statistiche

Triest

- Museo di Storia Naturale
- Museo del Mare
- Biblioteca Civica
- Archivio di Stato
- Archivio Generale
- ex Laboratorio di Biologia Marina
- **Mercato Ittico**
- Camera di Commercio

Chioggia

- Biblioteca Civica
- **Mercato Ittico**

Rome

- Istituto Nazionale di Statistica

Naturalists' descriptions of fish assemblages

36 observations (columns)

394 species (rows)

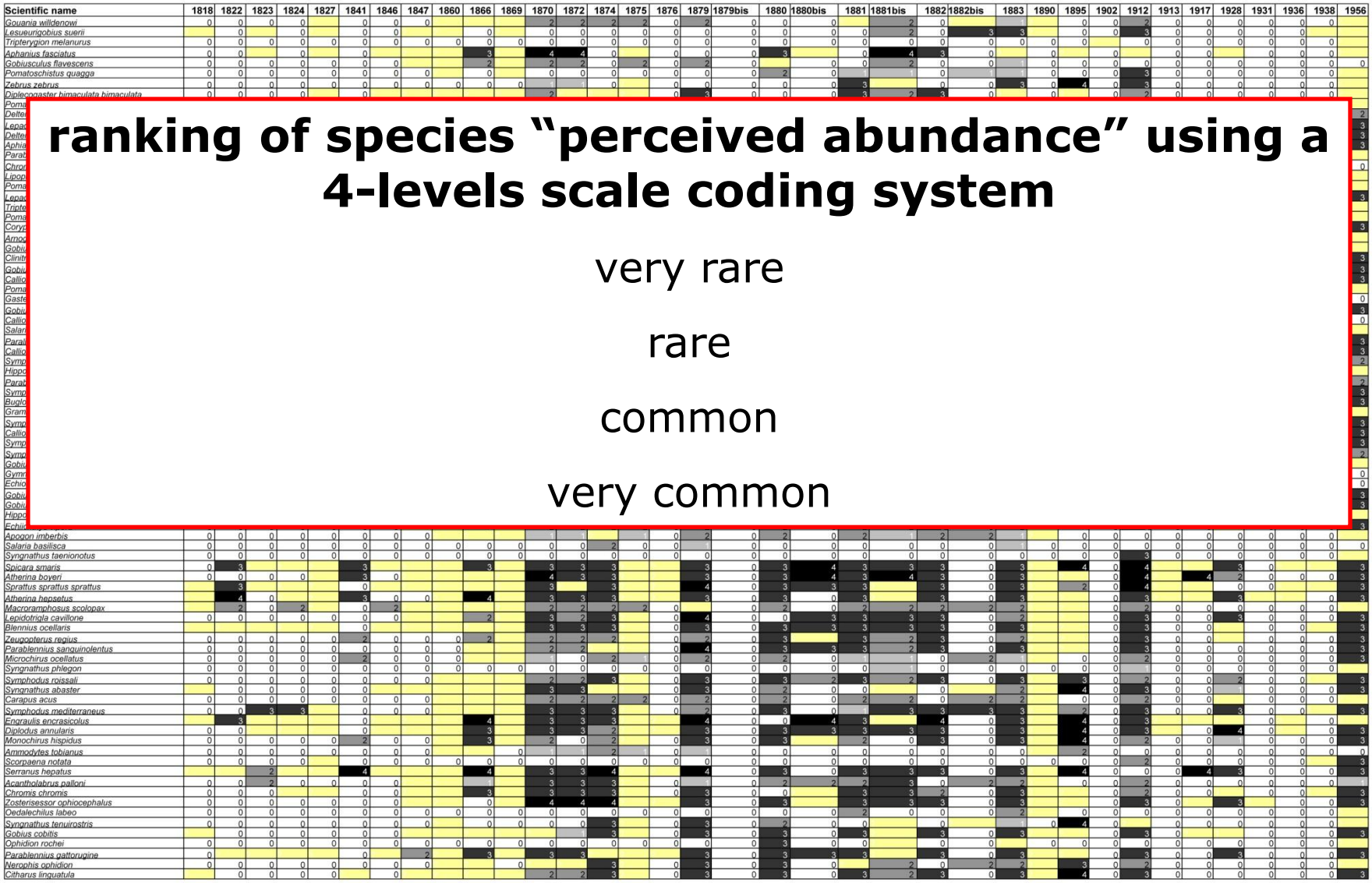
ranking of species "perceived abundance" using a 4-levels scale coding system

very rare

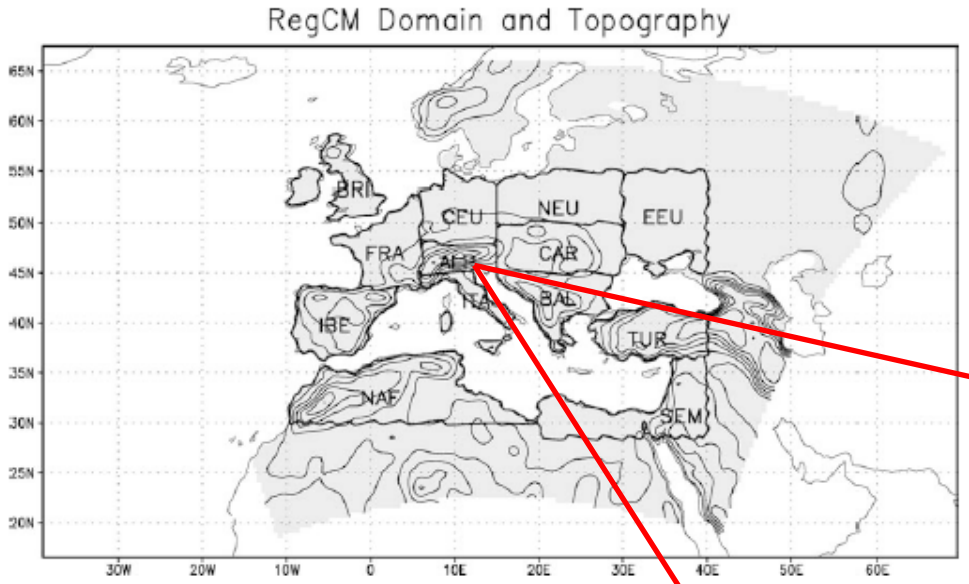
rare

common

very common

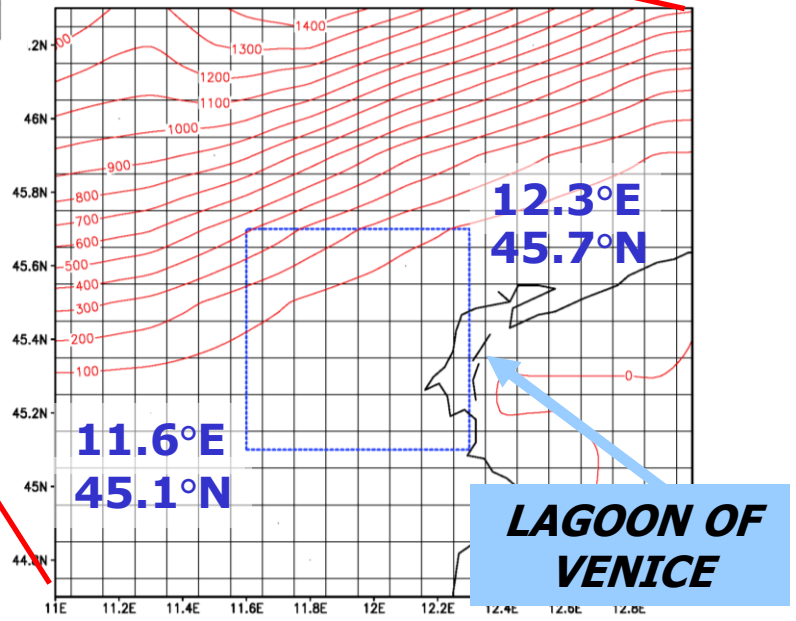


Previous downscaling study for the North Adriatic



Used the Regional Climate Model (RegCM) State of the art regional climate model, one way nested in Global Climate Model HadAM3H, resolution 20km

Giorgi et al. 2004a,b
Gao et al. 2006
ICTP (Trieste, ITALY)



We use results of rain, T, wind, humidity and pressure fields for the drainage basin

3 runs:

RF – reference condition 1961-1990

A2 - simulation of future condition 2071-2100 based on IPCC A2 scenario [CO_2 *~800ppm*]

B2 - simulation of future condition 2071-2100 based on IPCC B2 scenario [CO_2 *~600ppm*]

(Salon et al., *Clim. Res.*, 2008; Cossarini et al., *Clim. Res.*, 2008)