WP 3 - Modelling of spatial interaction between target species and fisheries including connectivity among Marine Managed Areas

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WP 3 - Modelling of spatial interaction between target species and fisheries including connectivity among Marine Managed Areas

Lead: Conisma (Tommaso Russo)
Participants: Conisma, CNR, OGS, IOF
Duration: from month 6 to month 36

Objectives:

- To define a set of MMAs network scenarios based on different combinations of existing and new MMAs
- To identify and evaluate the occurrence and magnitude of spillover effects (e.g. spawning products, propagules, juveniles, adults) outside the network of marine protected areas in terms of stock abundance and fishery performance, considering prevailing hydrodynamics and the life cycles of the species;
- To understand the spatial structure of targeted fisheries with respect to the spatial distribution and connectivity of the network(s) of marine protected areas;
- To evaluate the possible effects on the redistribution of fishing efforts, including small scale and recreational fisheries;
- To evaluate, through a simulation approach, whether and how the establishment of no- trawling zones would enhance the effectiveness and efficiency of the spatial-based approach to fisheries management towards achieving MSY objectives, considering also the socio- economic effects;
- To evaluate whether, and the extent to which, human activities other than professional and recreational fisheries may conceal or undermine the positive effects a network of marine protected areas may have on exploited biological resources and on fishing yields with respect to the MSY

1. To define a set of MMAs network scenarios

2. o evaluate spillover effects outside the network of marine protected areas

3. To understand the spatial structure of targeted fisheries with respect to the spatial distribution and connectivity of marine protected areas

4. o evaluate the possible effects on the redistribution of fishing efforts

5. To evaluate, through a simulation approach, whether and how the establishment of no- trawling zones would enhance the effectiveness and efficiency of the spatial-based approach to fisheries management towards achieving MSY objectives, considering also the socio-economic effects

6. To evaluate the extent to which other human may conceal or undermine the positive effects of marine protected areas

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The path

- All these objectives should be based on the cross-analysis of existing information about spatial behaviour of fleets (i.e. fishing effort and related catches), environmental drivers (i.e. connectivity) and biological dynamics of living resources.
- The results of this cross- analysis will be integrated, to the extent possible, in stock assessment models to simulate the effect of area closure scenarios on the target stocks in ISIS-Fish (Pelletier et al., 2009) and SMART models (Russo et al., 2014).

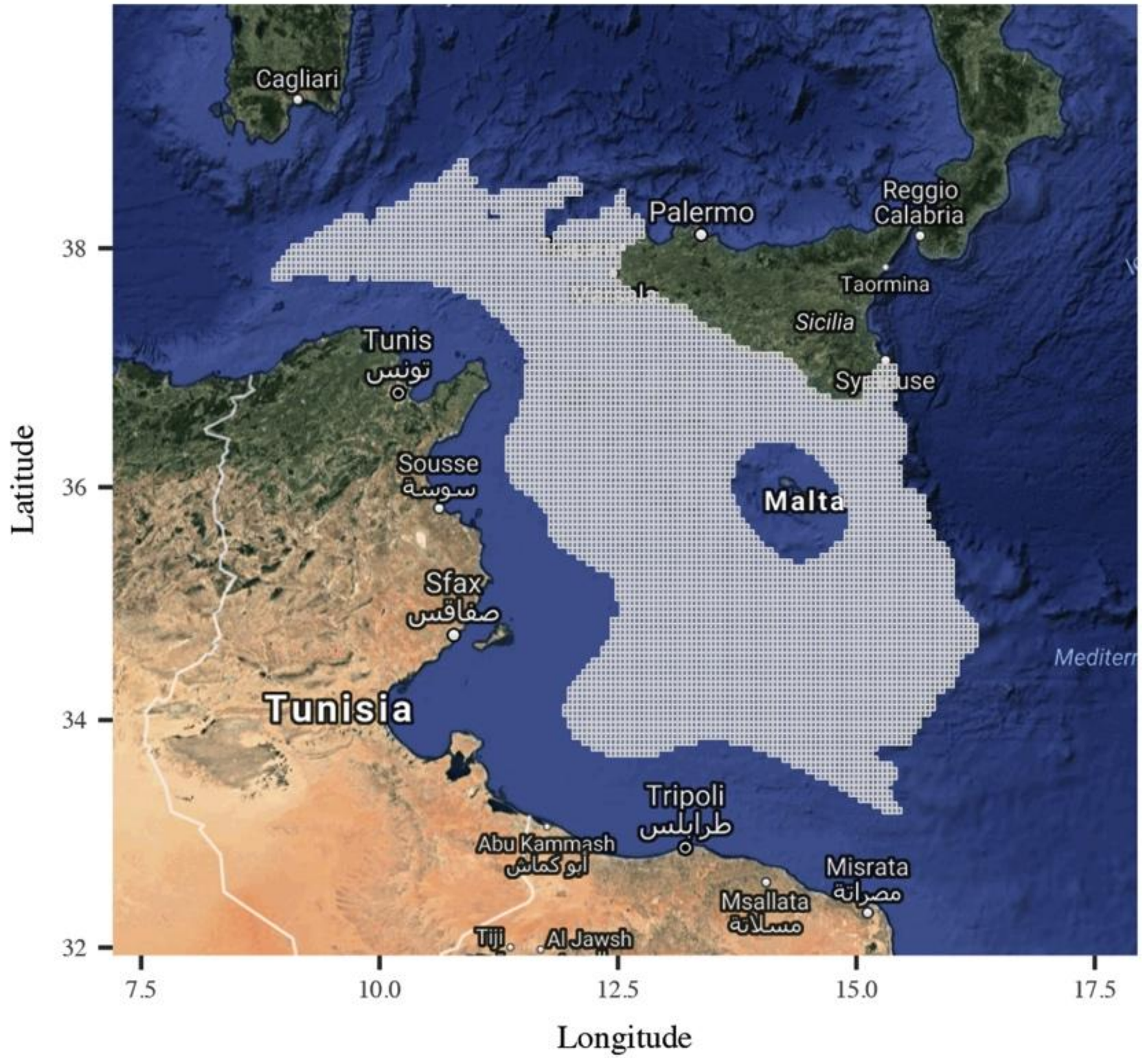
The path

- **Both ISIS-Fish and SMART are based on the partitioning the marine space (the "world" in which fleets operate and in which living resources live) into a set of areas with explicit reference to spatial and temporal structure of stocks and, accordingly, reflecting the main dynamics of exploitation (seasonal variability of fishing effort and of catches, even in terms of exploitation pattern and size spectra of catches).**
- **Thus, the first step is represented by the identification of sub-areas (namely "Fishing grounds") for each area of study. These fishing grounds will represent the basic units for the following analyses, including assessment of the connectivity and of the effect of different fishing effort patterns.**

Identification of fishing grounds: the case of the Strait of Sicily

- The regionalisation procedure is carried out on a grid for each area (Adriatic and Strait of Sicily).
- The provided grid comprises 6319 cells.
- The input data is composed of:
- bathymetry (downloaded by the National Oceanic and Atmospheric Administration - NOAA),
- substrates (downloaded by the EMODNET Project website) and
- the sum of the fishing time for each year for each cell of the grid.

A 3x3 Km square grid was defined for the GSA 12, 13, 14, 15, and 16 (with the exception of the territorial waters of the North Africa)



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A 3x3 Km square grid was defined for the GSA 17 and 18

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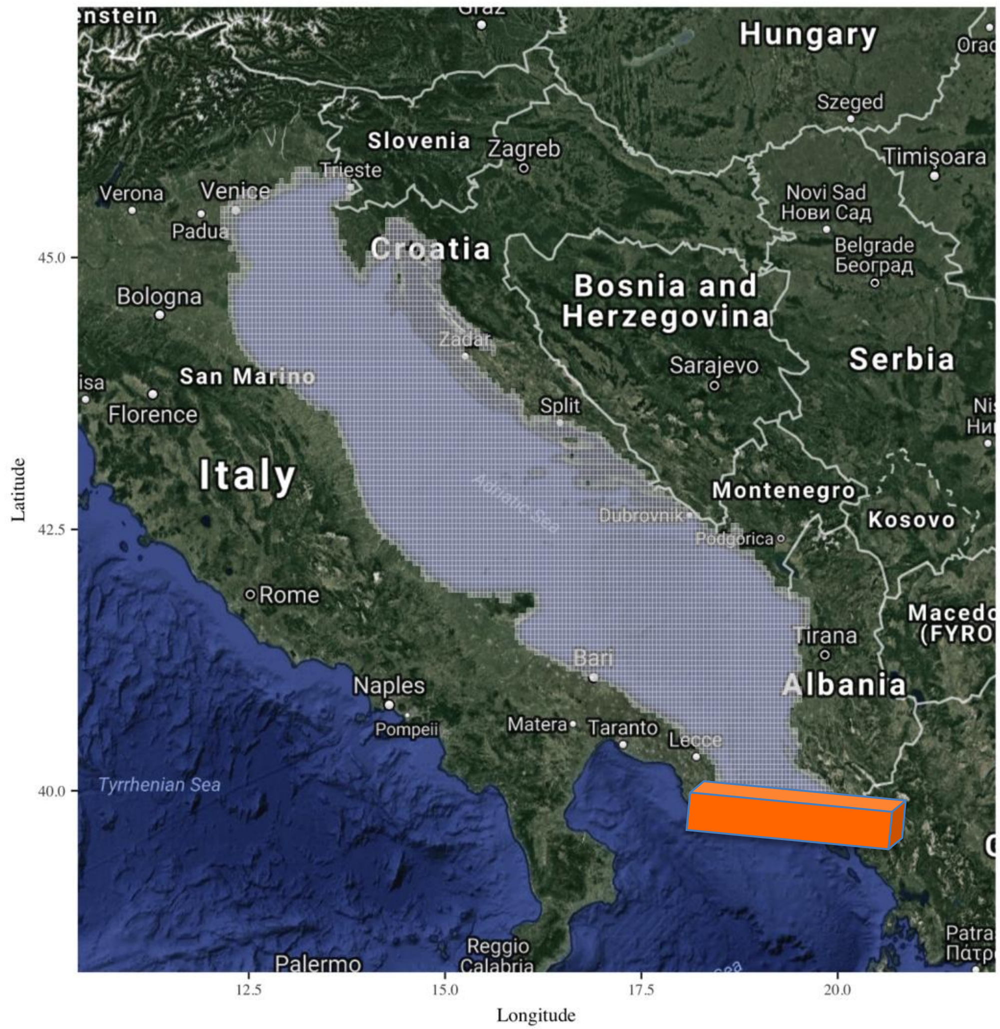
Both SMART and ISIS-FISH assume that each system is “closed”



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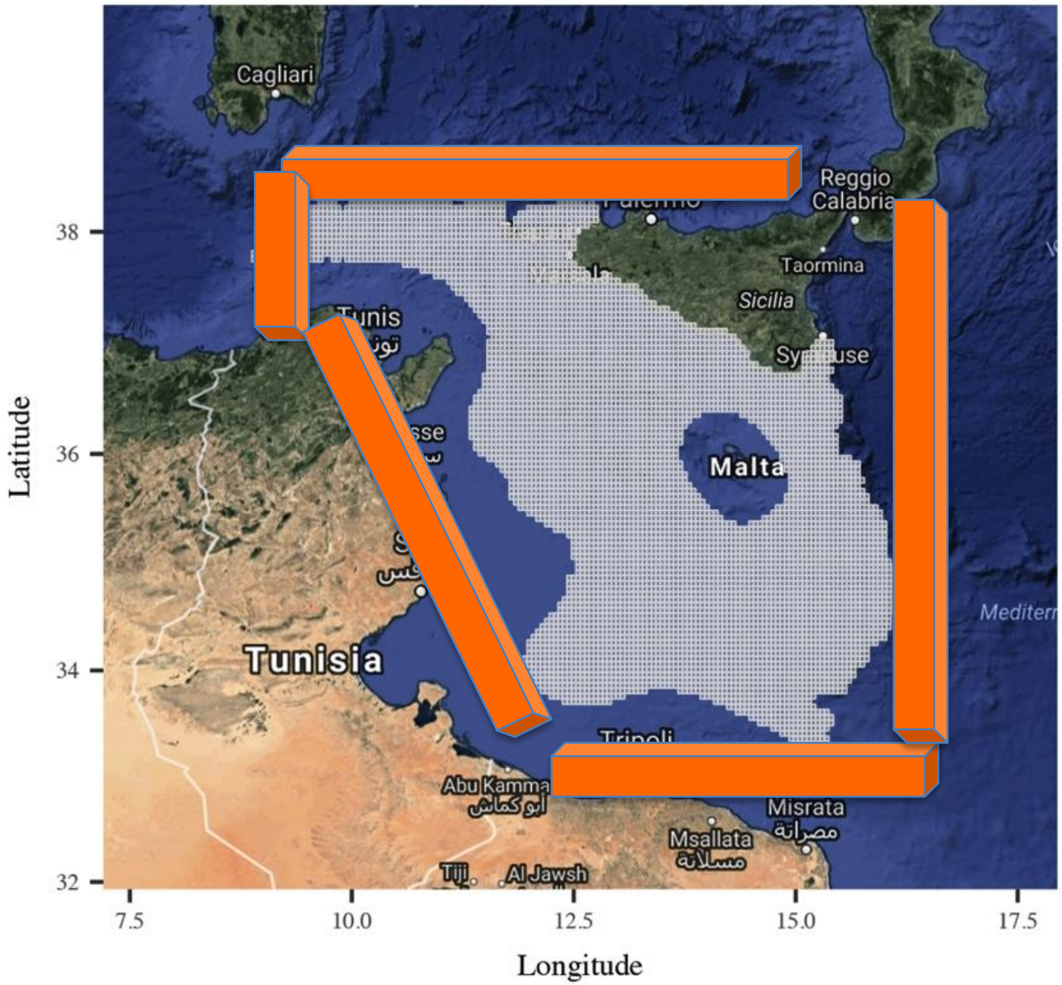
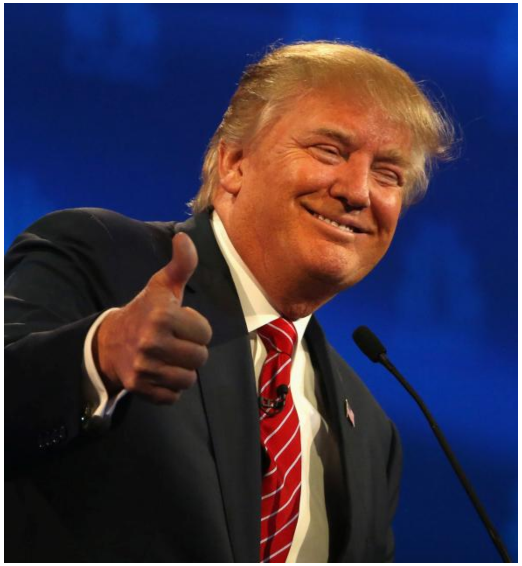
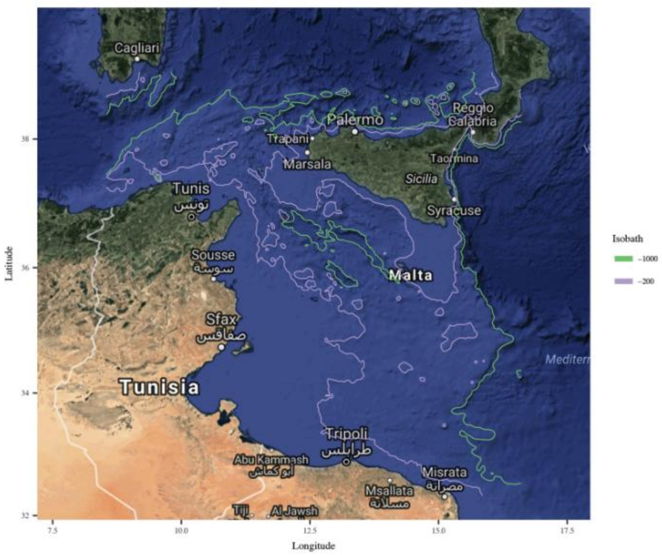


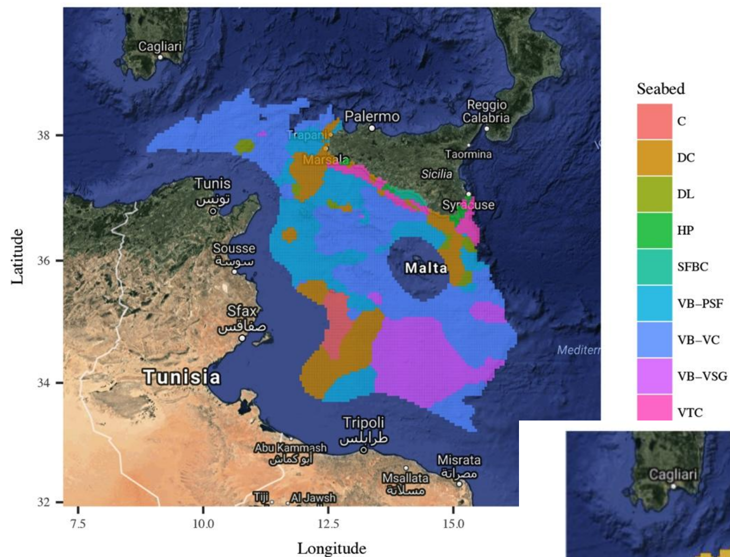


Identification of fishing grounds: the case of the Strait of Sicily

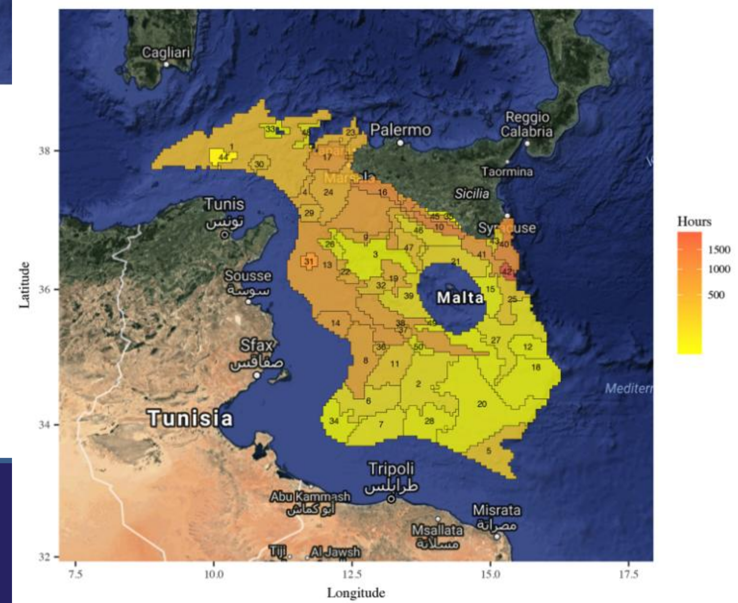
Bathymetry



Substrates

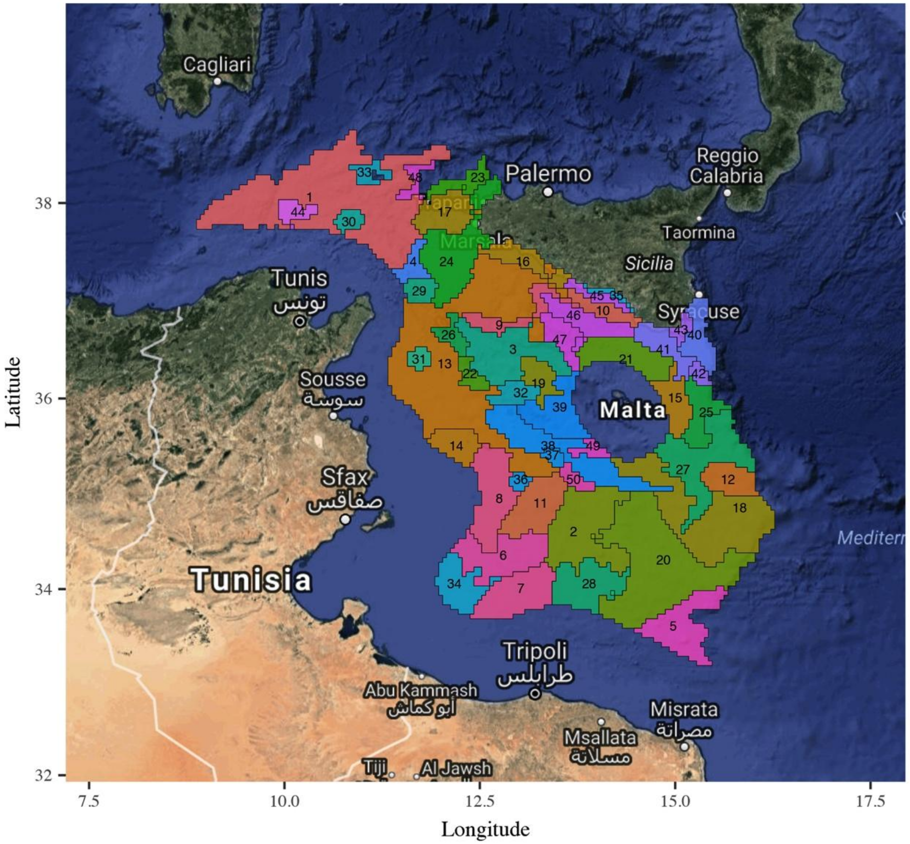


Effort



CONSTRAINED CLUSTERING

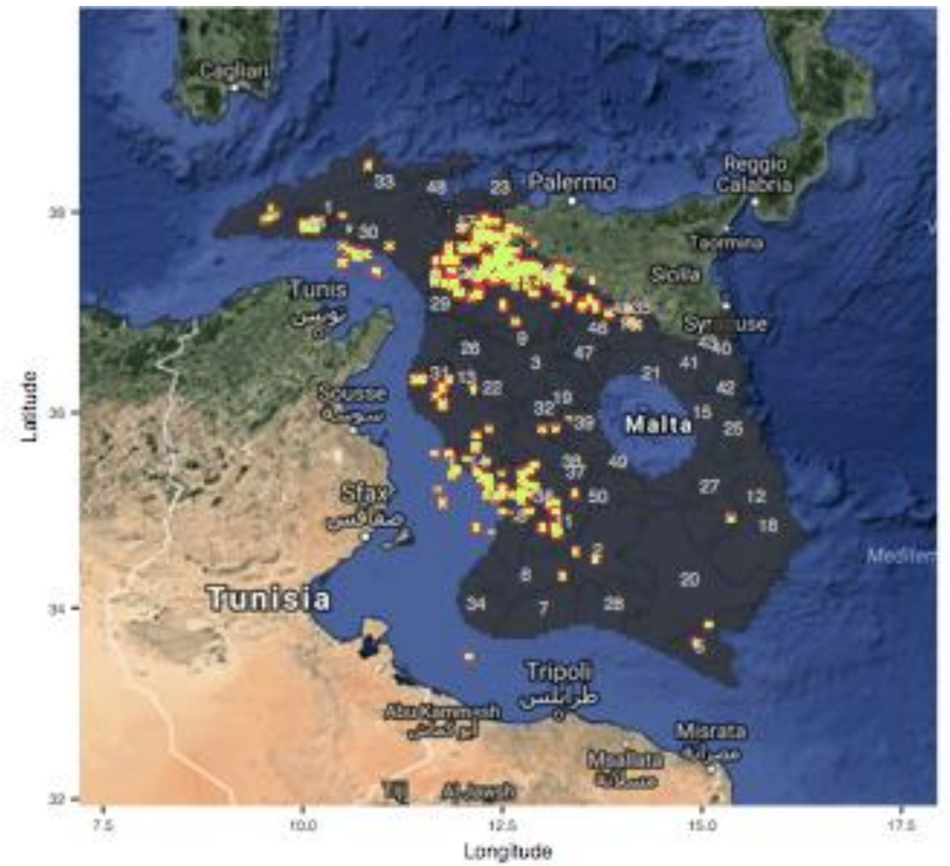
Identification of fishing grounds: the case of the Strait of Sicily



The final output (preliminary evaluated by the CNR colleagues) comprises 50 fishing grounds

Analysis of database of catches for the Red mullet in the Strait of Sicily

- After the identification of the sub areas (fishing grounds) for the Strait of Sicily, a large database comprising the catches self-collected by the fishermen of a selected list of fishing vessels was processed. This database was kindly provided by the CNR IAMC as partner within the MANTIS Project.
- The dataset of the red mullet fishery from the Strait of Sicily is stored as a data frame with the following fields: UTC, Length, Num of Fishing Ground, Year, Month. There are 22556 observations, one for each sampled fish.
- The length-frequency distribution of the population spans within a minimum of 6 cm to a maximum of 26 cm, the mean value is about 17 cm.
- The sampling time-span ranges from the 2009 to the 2015, for a total of 7 years of data.
  The sampling points positions are collected from 19 of the 50 fishing ground considered in this case study.



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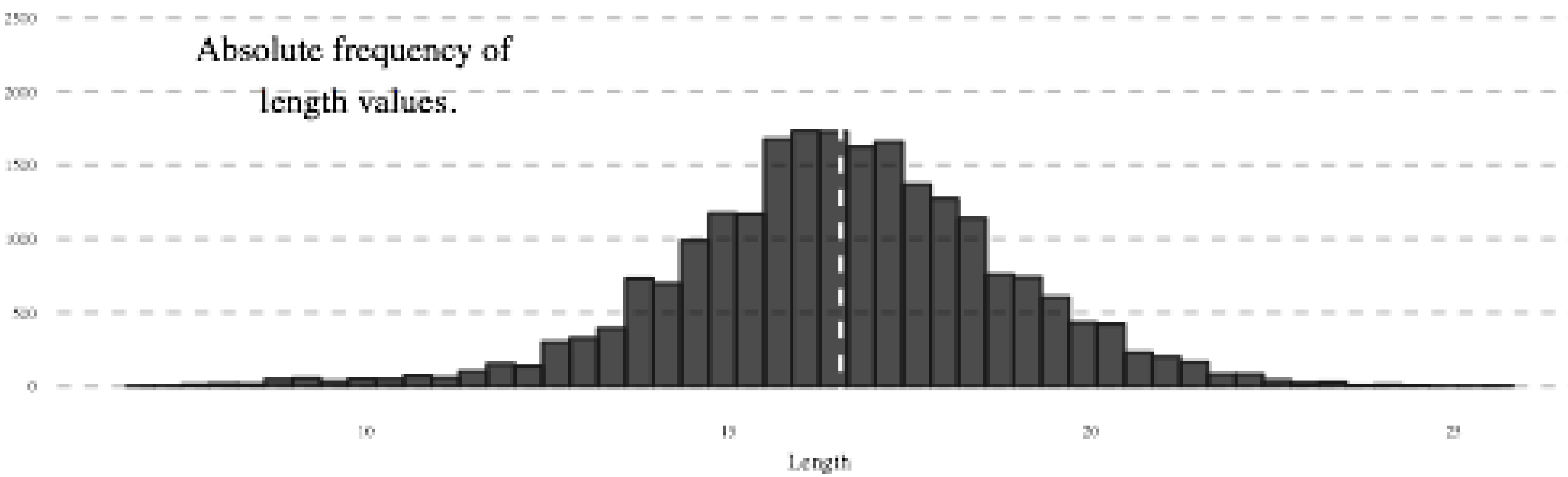


Analysis of database of catches for the Red mullet in the Strait of Sicily

- In order to allocate fish in the different cohorts, we assume a Normal mixture model in which the mean of the components (the cohorts) is the von Bertalanffy growth function. At age t, the expected length of a fish is given by:

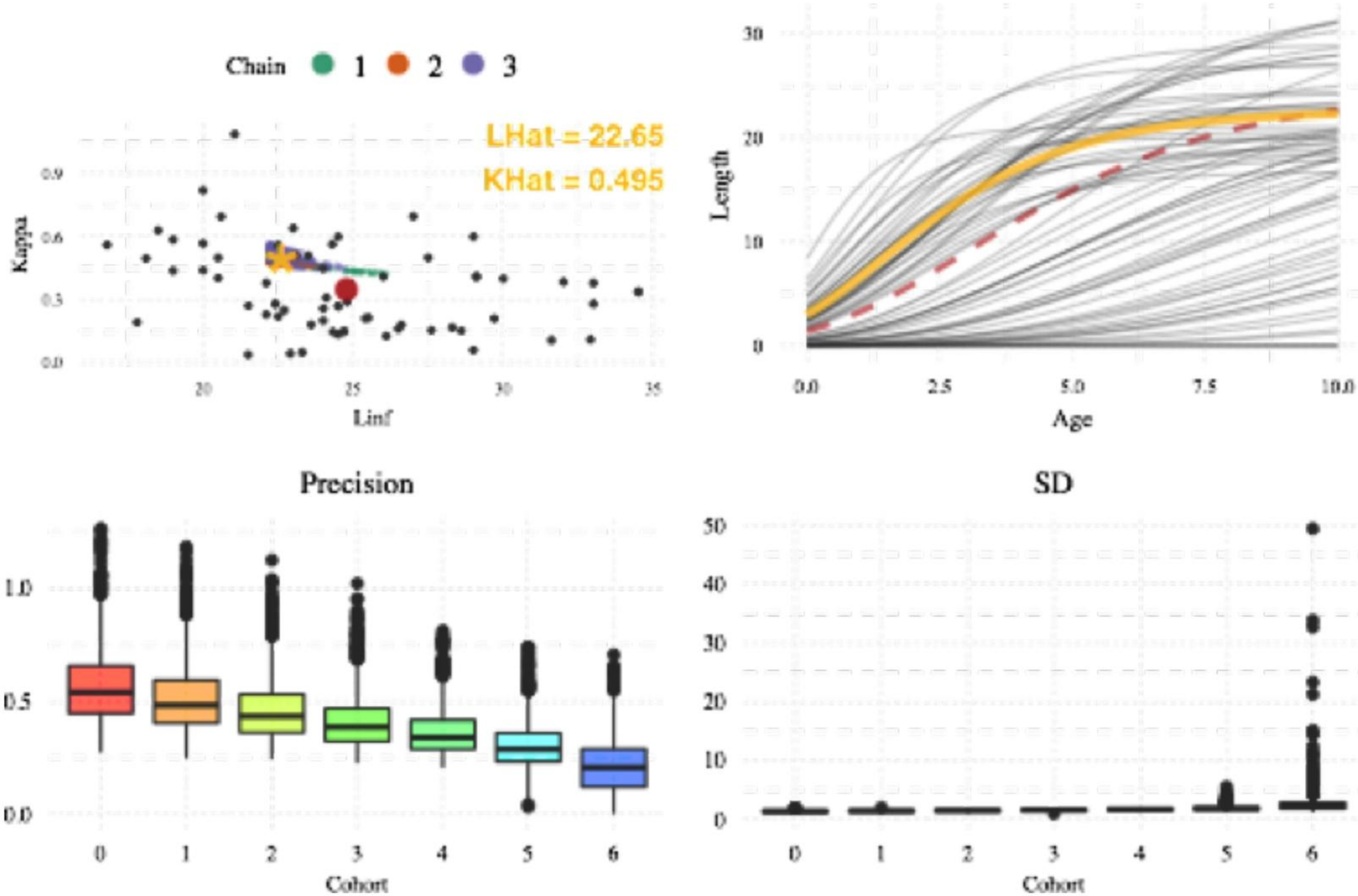
  $L_t = L_\infty e{-}k(t{-}t_0)$ (von Bertalanffy) or

  $L_t = ae^{-be*exp(-ct)}$ (Gompertz function)
- As we cannot observe the age of fish, we assume a mixture model for the lengths.
- The model has been estimated under a Bayesian perspective, using the software JAGS (Just Another Gibbs Sampler: It is a program for analysis of Bayesian hierarchical models using Markov Chain Monte Carlo (MCMC) simulation)

The growth model

- The software JAGS offers several advantages. In particular, it has a cross-platform engine and it is designed to work closely with the R language and environment. In fact, the routine has been integrated in R using the rjags package.
- The model requires only the specification of the model, up to the prior distributions, and the data. It crates a posterior sampler, runs a Markov chain, and returns several descriptive statistics.
- As output, the model returns the estimated age of each individual in the catches

The growth model



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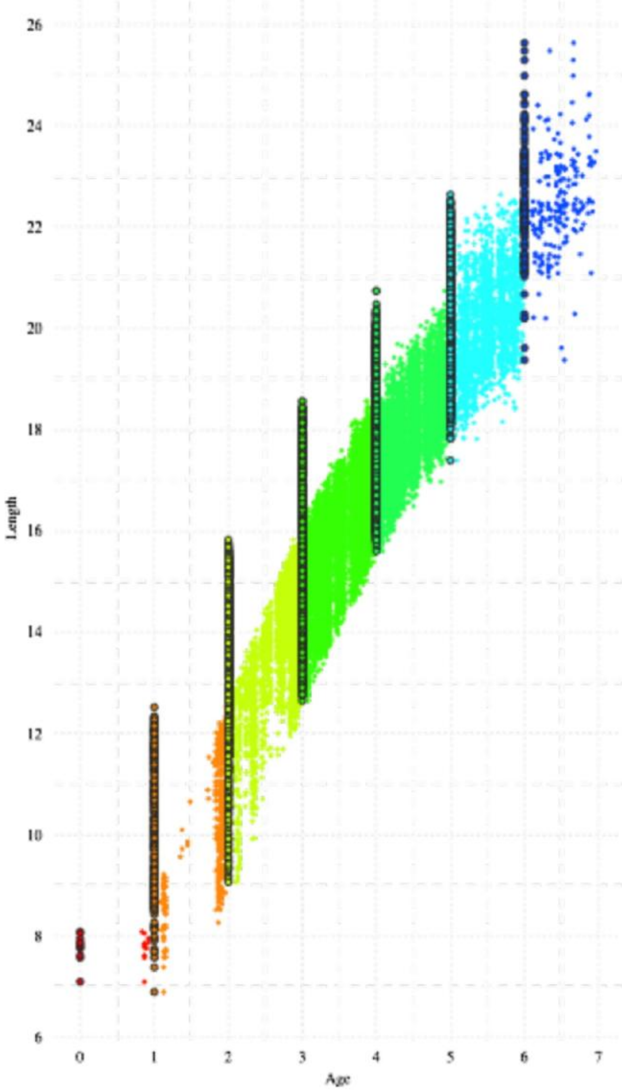
The growth model

- A key output provided by the growth model is represented by the Age-Length key
- Obviously it also provides the characteristics of each cohort/year in terms of mean length and variance

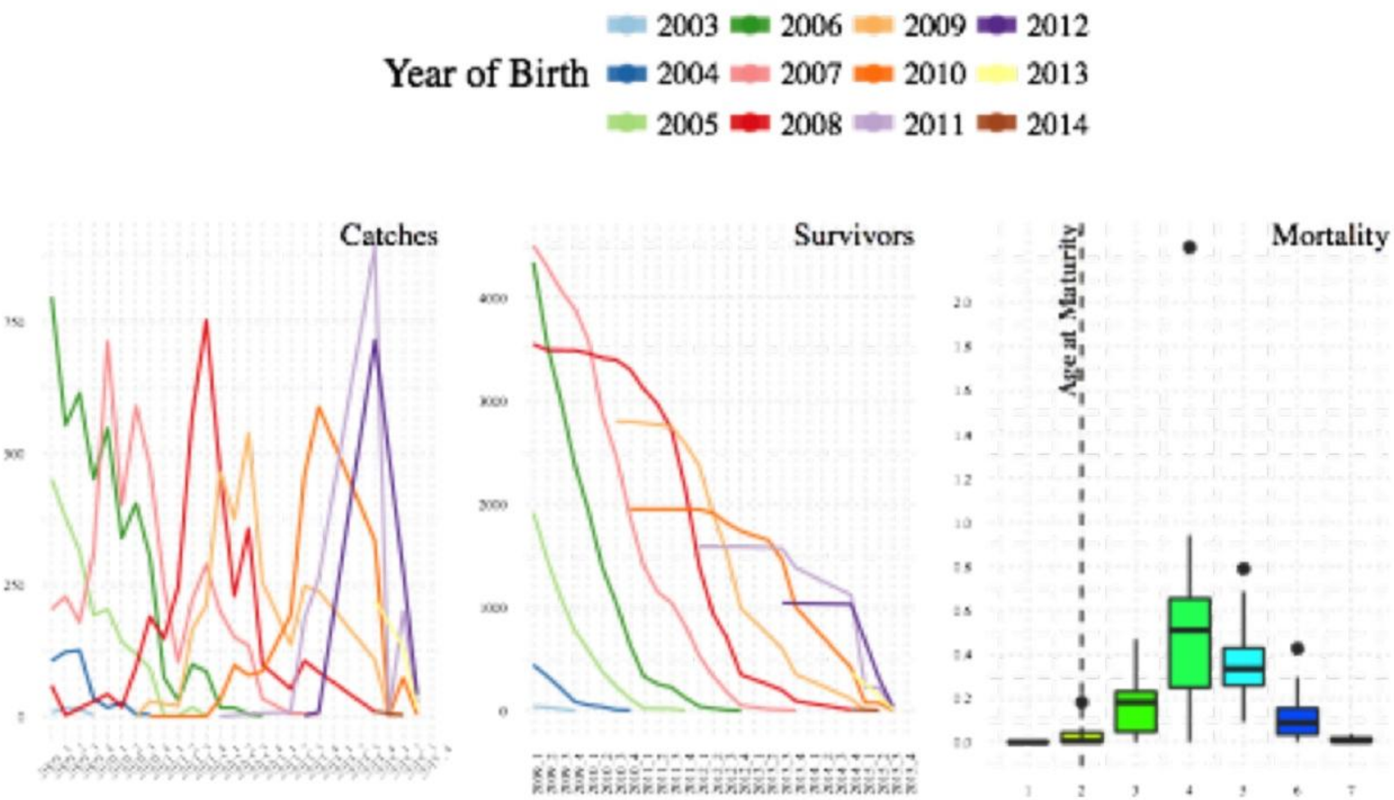


	0	1	2	3	4	5	6
7	1	2	0	0	0	0	0
8	10	20	0	0	0	0	0
9	0	101	15	0	0	0	0
10	0	74	34	0	0	0	0
11	0	85	88	0	0	0	0
12	0	82	290	0	0	0	0
13	0	1	747	87	0	0	0
14	0	0	1019	827	0	0	0
15	0	0	1055	2042	0	0	0
16	0	0	35	4111	319	0	0
17	0	0	0	2749	1801	1	0
18	0	0	0	576	2509	75	0
19	0	0	0	2	1385	581	1
20	0	0	0	0	206	917	4
21	0	0	0	0	2	487	26
22	0	0	0	0	0	125	82
23	0	0	0	0	0	2	58
24	0	0	0	0	0	0	16
25	0	0	0	0	0	0	5
26	0	0	0	0	0	0	1

Age	coh.mean	coh.var	coh.num
0	7.77	0.07	11
1	10.25	1.57	365
2	13.75	1.4	3283
3	15.97	1.05	10094
4	17.96	0.76	6122
5	20.08	0.81	2188
6	22.51	1	193

The growth model

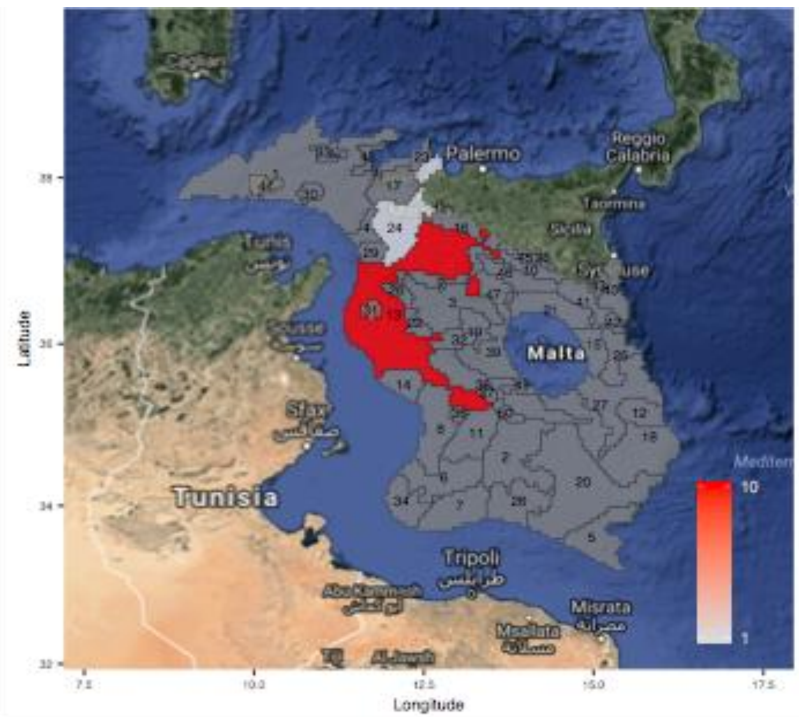
- Moreover, it allows estimating the trends of catches, survivors and mortality for each cohort/year

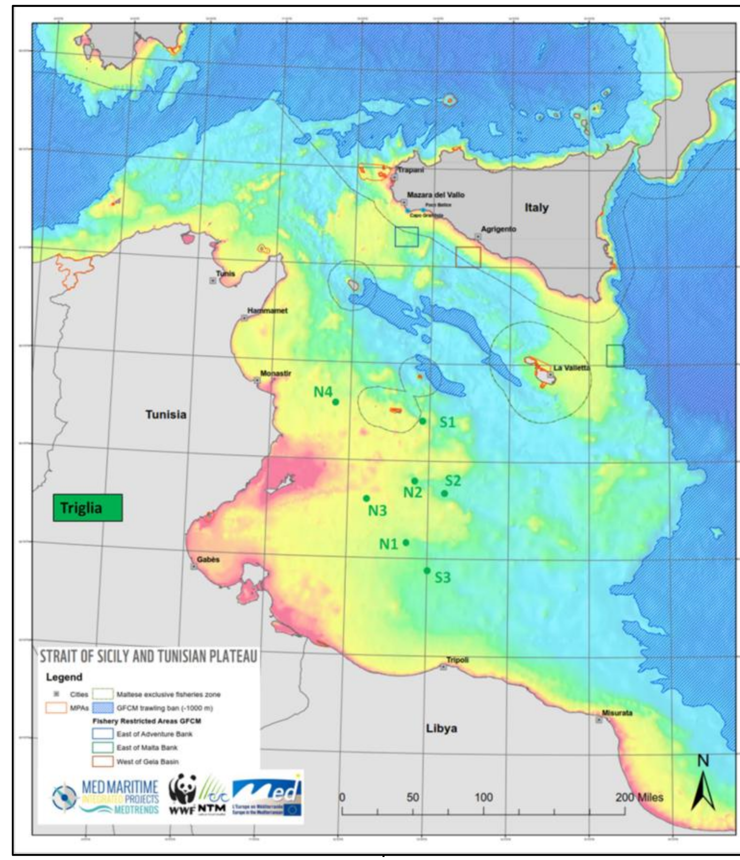


The growth model

- Last but not least, the spatial distribution of each cohort/year could be explored

Age 0





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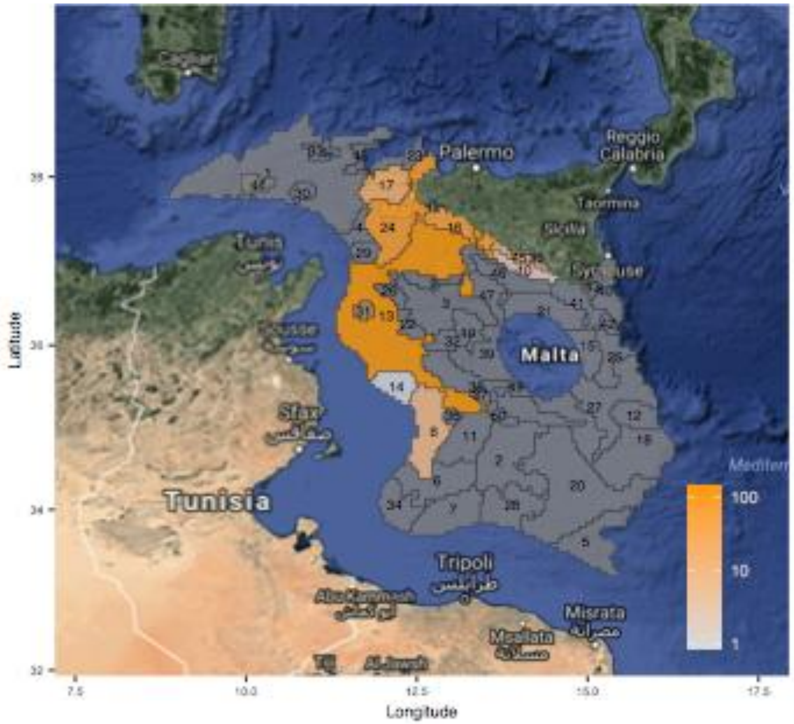
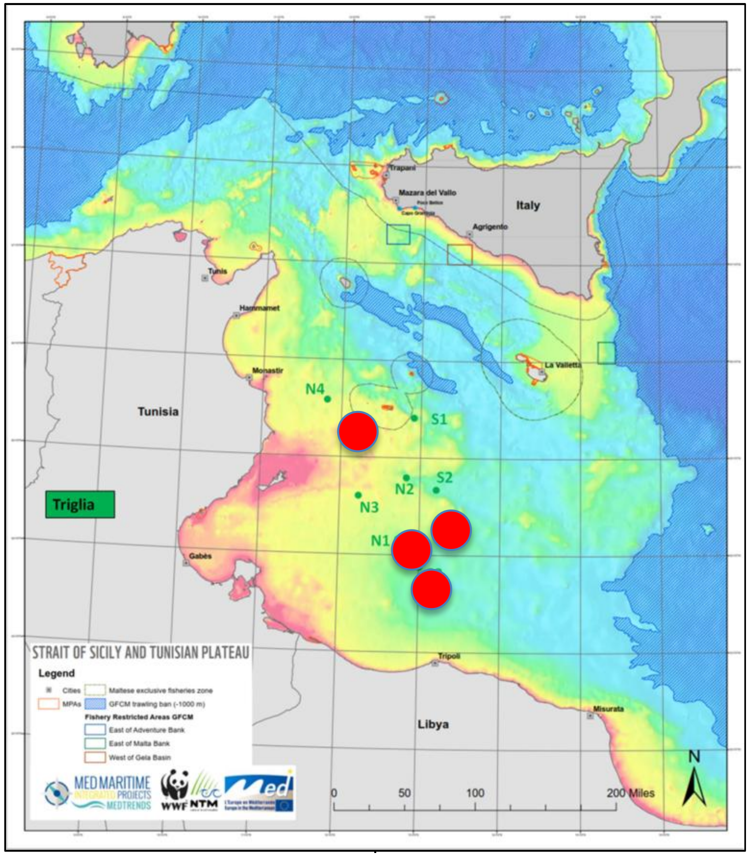
Age 1

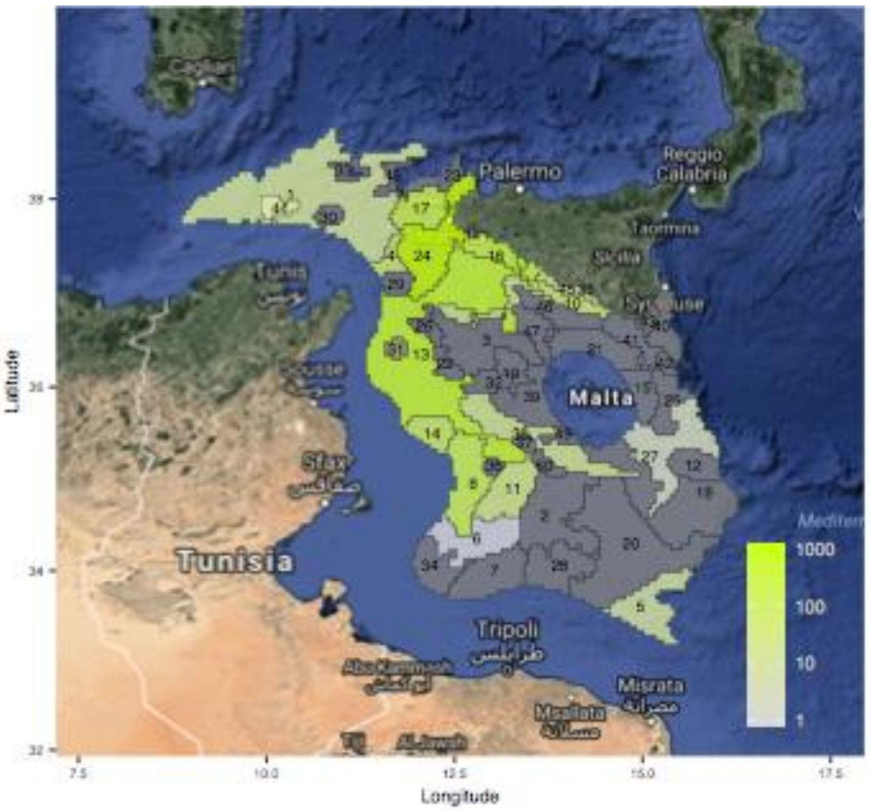




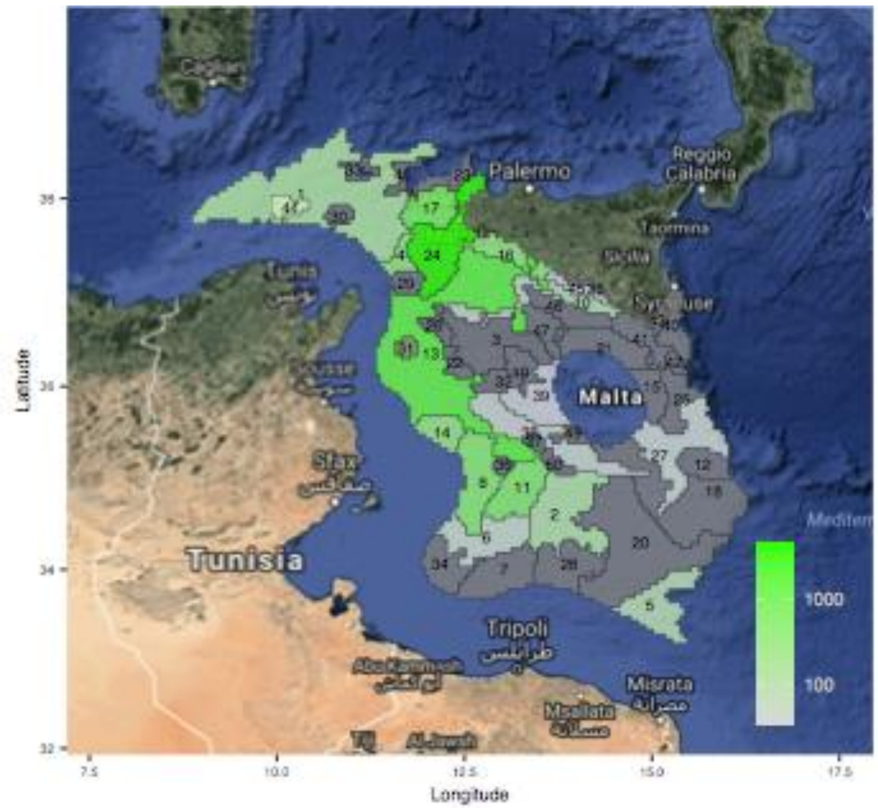
The growth model

- Last but not least, the spatial distribution of each cohort/year could be explored

Age 2



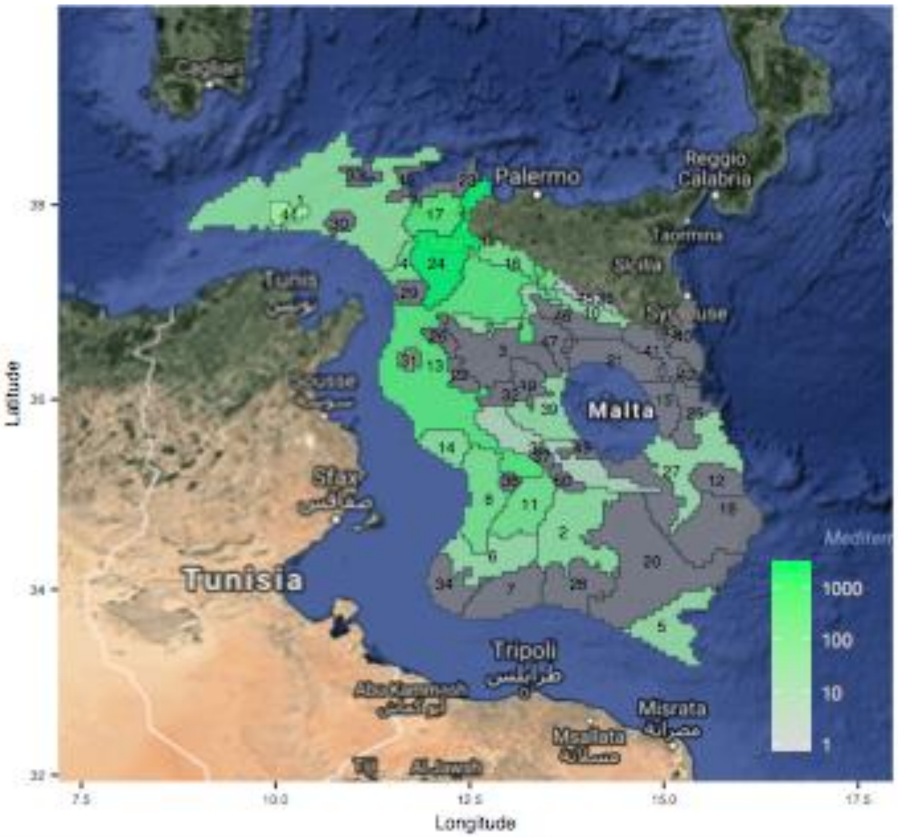
Age 3



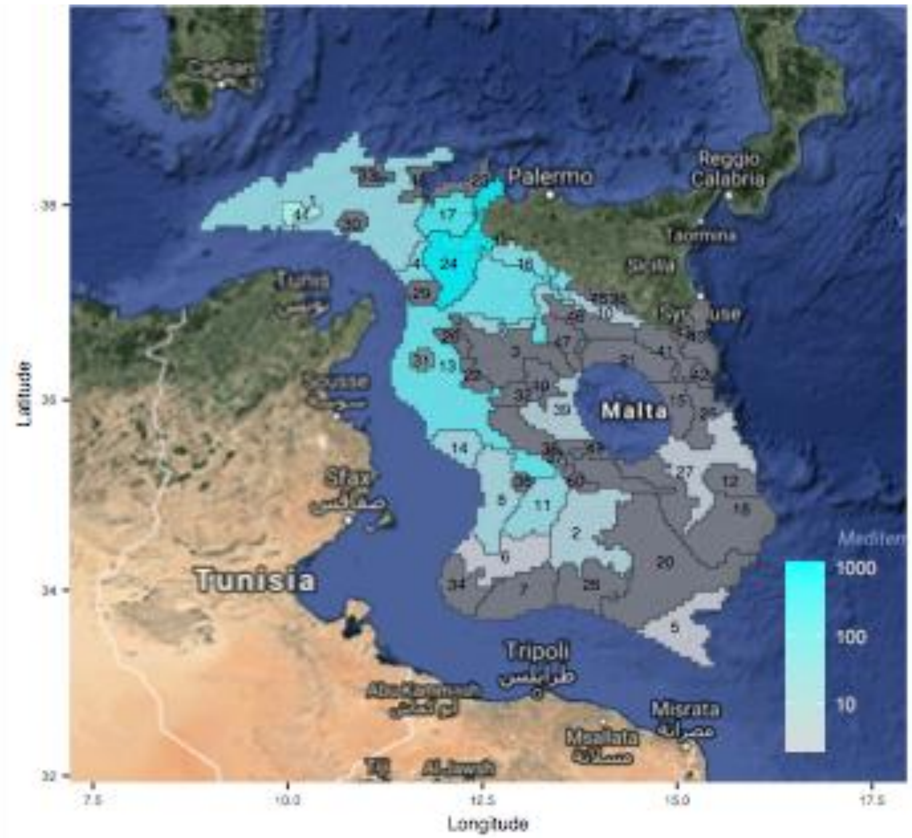
The growth model

- Last but not least, the spatial distribution of each cohort/year could be explored

Age 4



Age 5

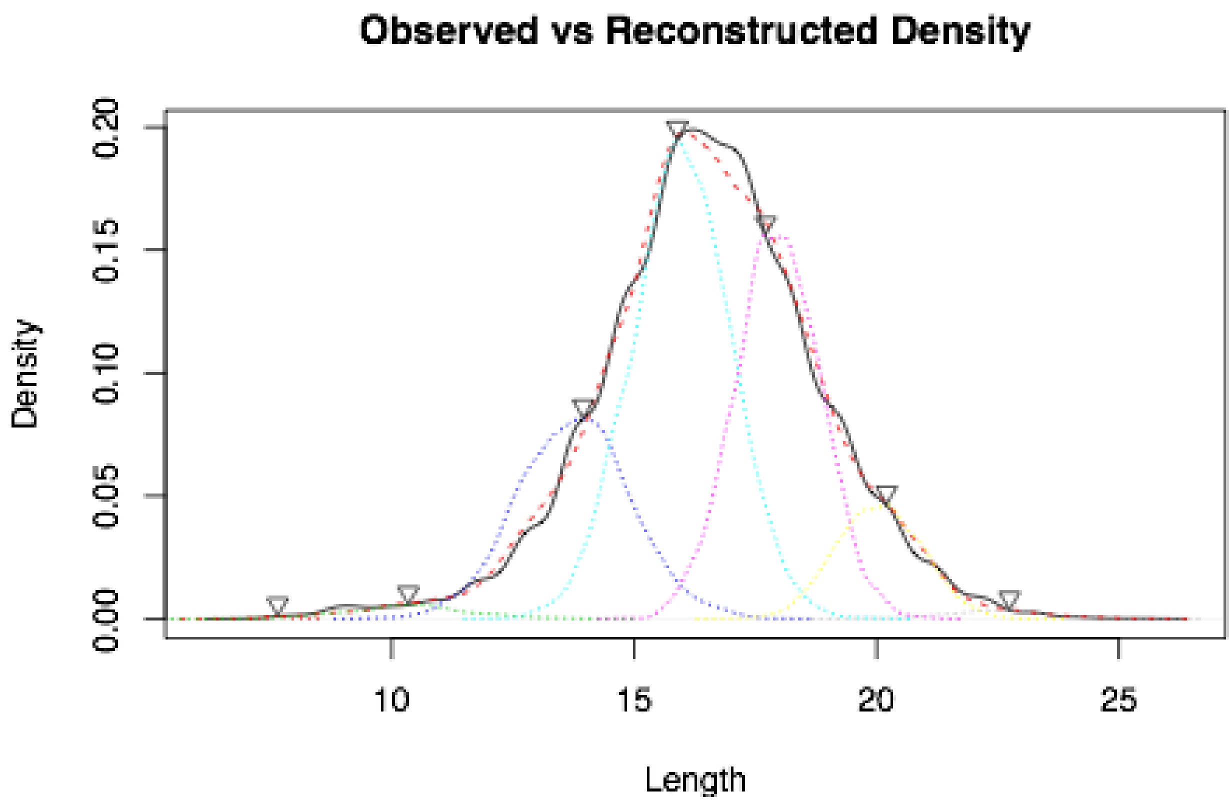


The growth model

Given that we estimate the distribution of each cohort:

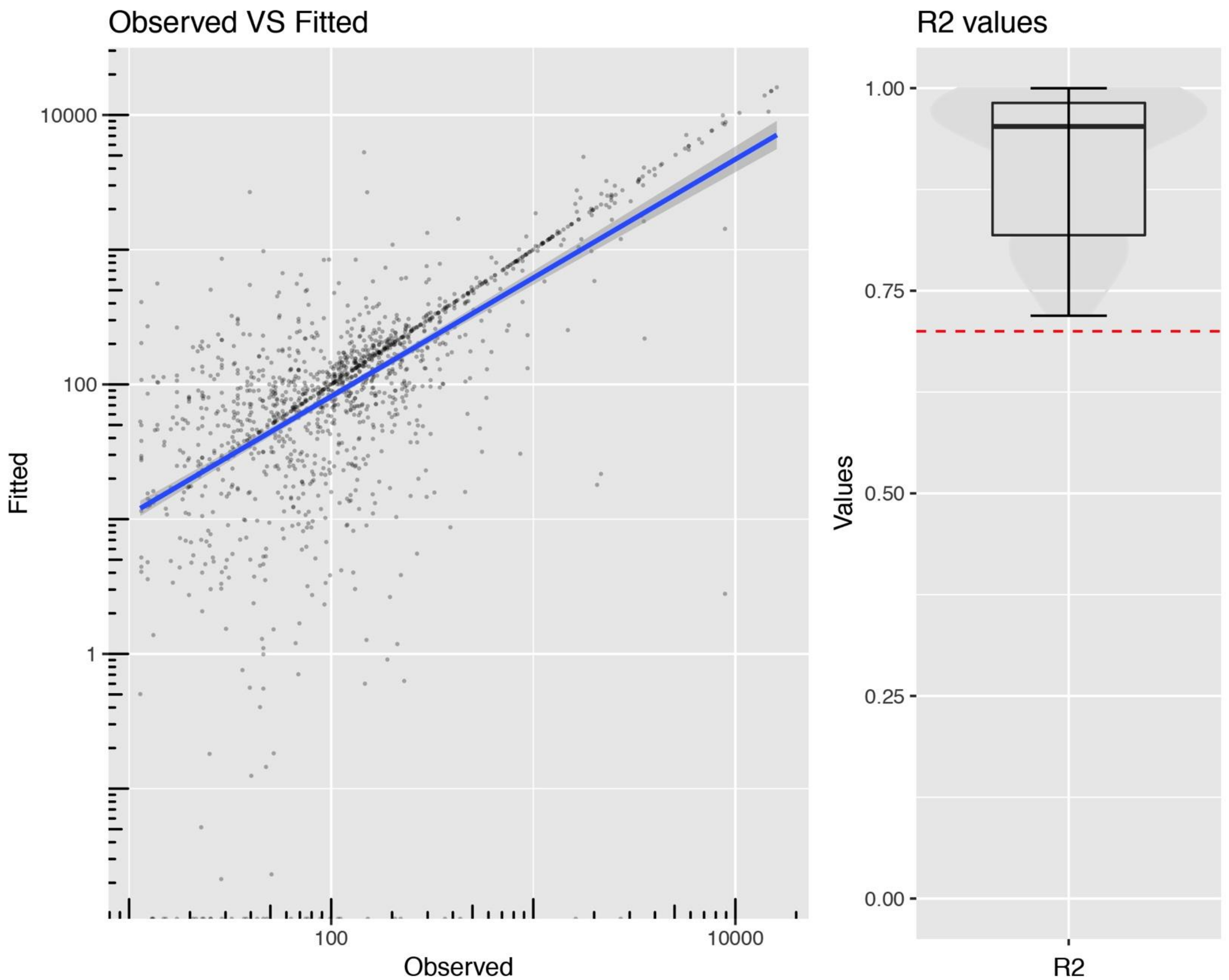
- By fishing ground
- By time (month)

It is possible to reconstruct the exploitation pattern or predict it as a function of the fishing effort pattern

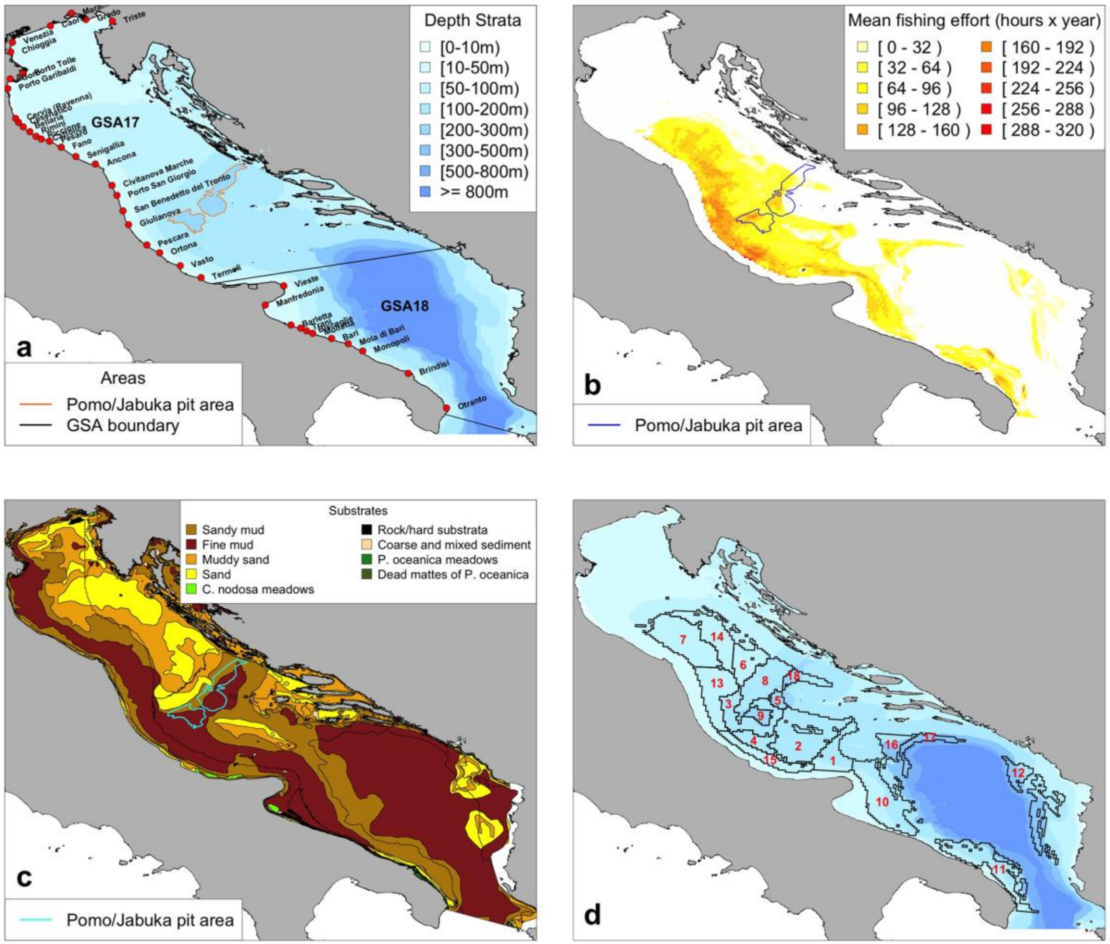


The production

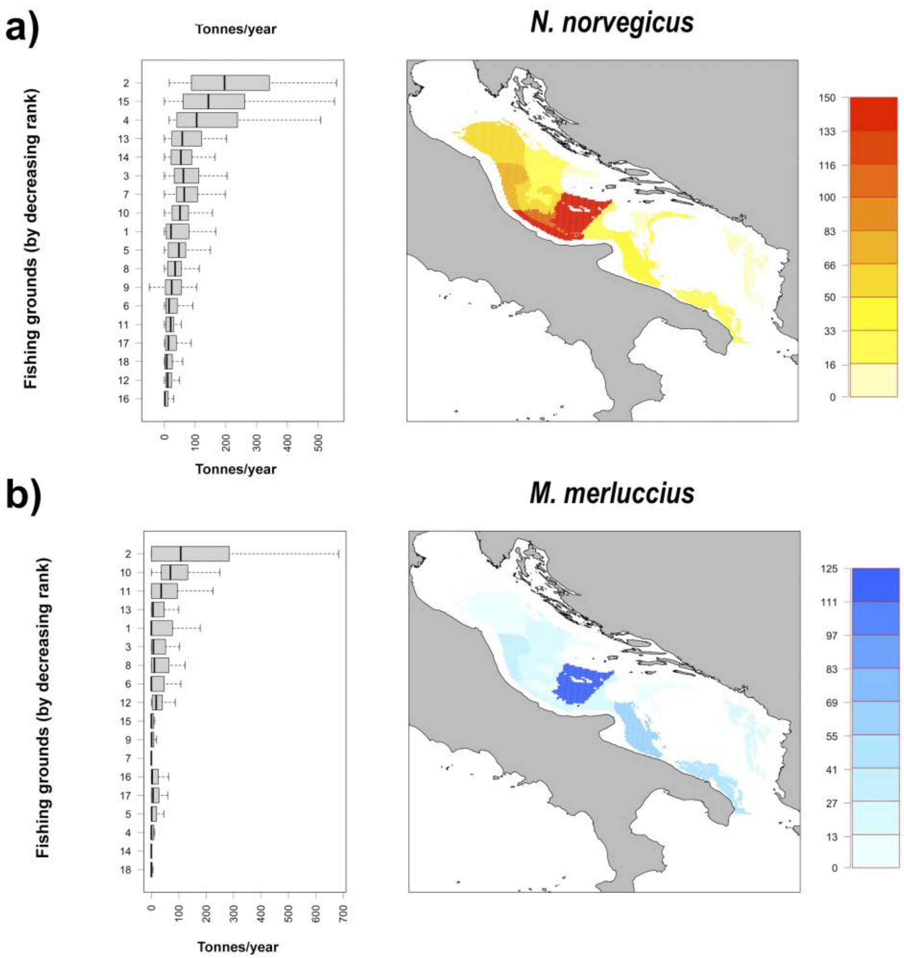
- The total amount of catches could be ALSO estimated from landings survey (ITAFISHSTAT): the total monthly landings for each species/fishing vessel are regressed on the fishing effort pattern (by fishing grounds).
- A paper describing this method is under review (Russo & Morello et al., Fisheries Research)



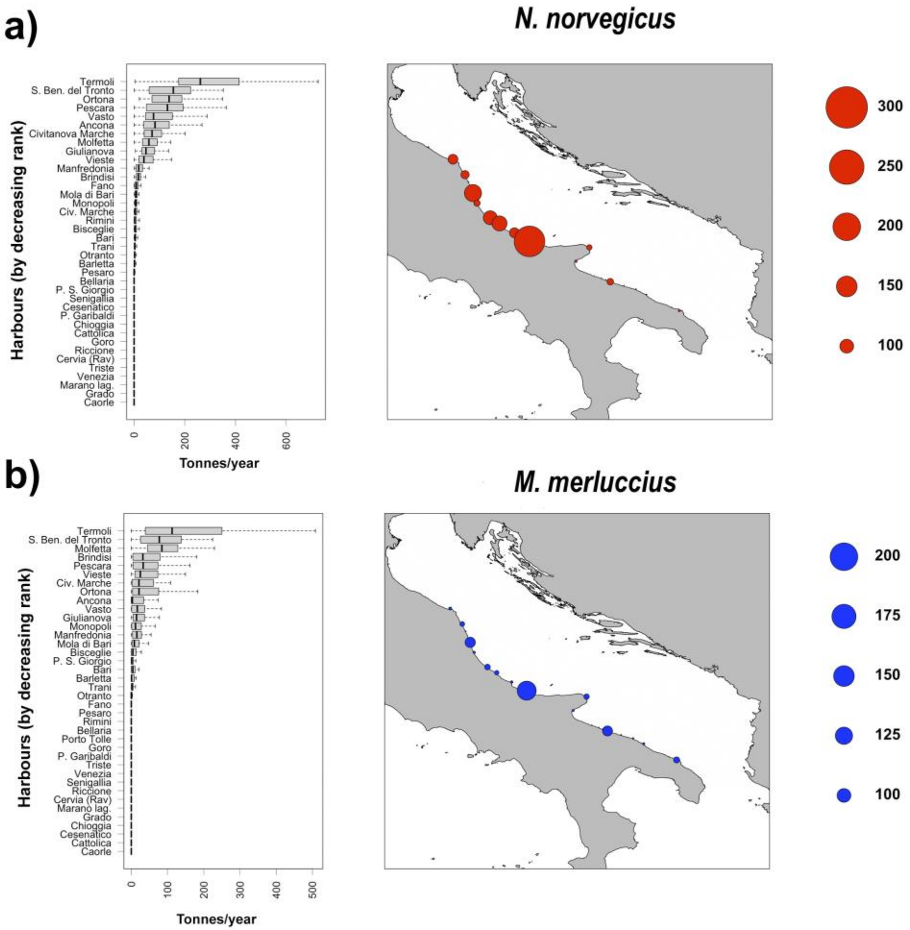
The production



The production by fishing ground

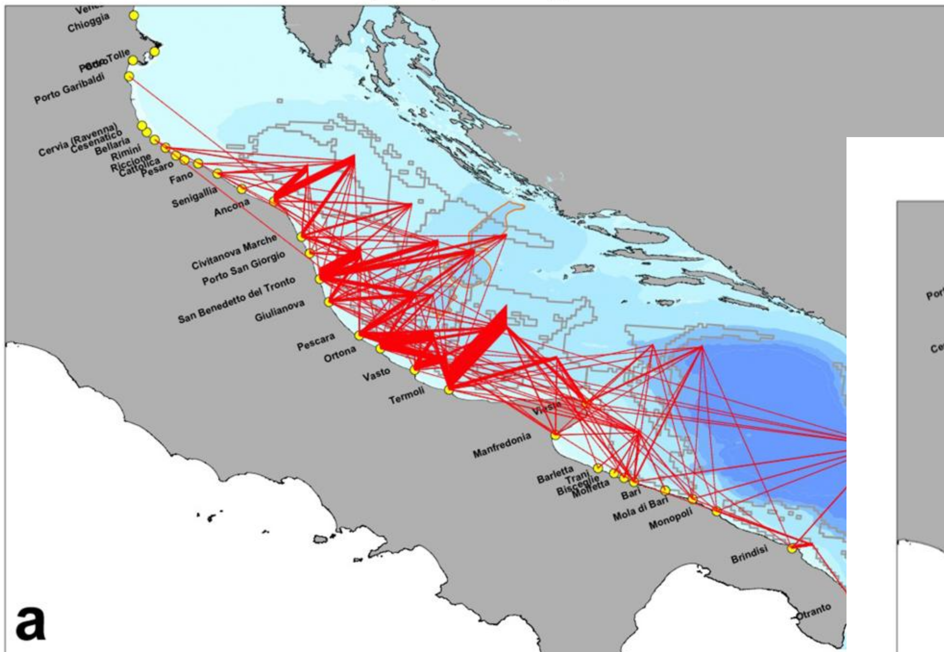


The production by harbour

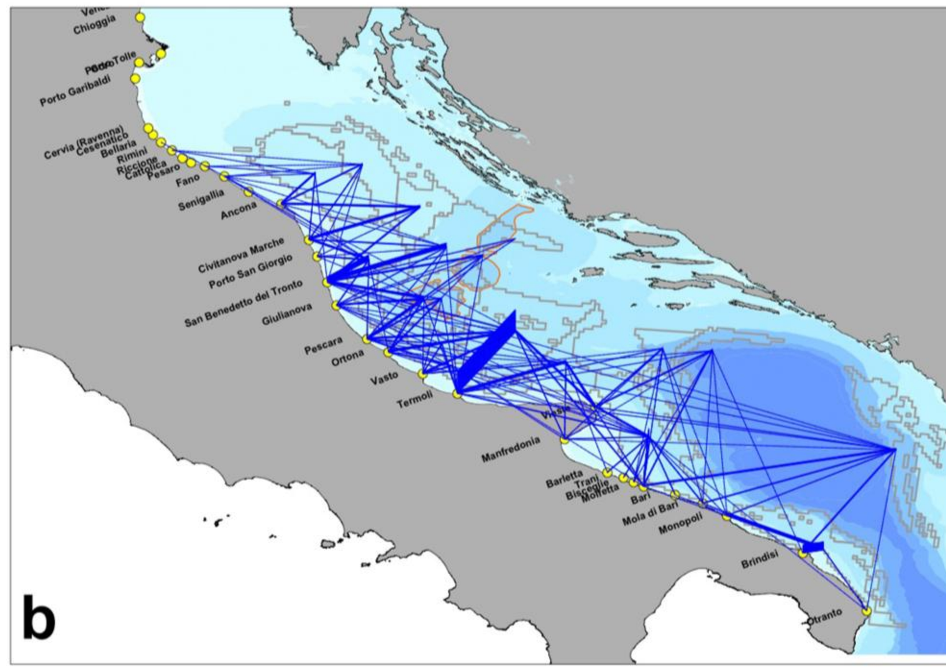


The production

Nephrops norvegicus

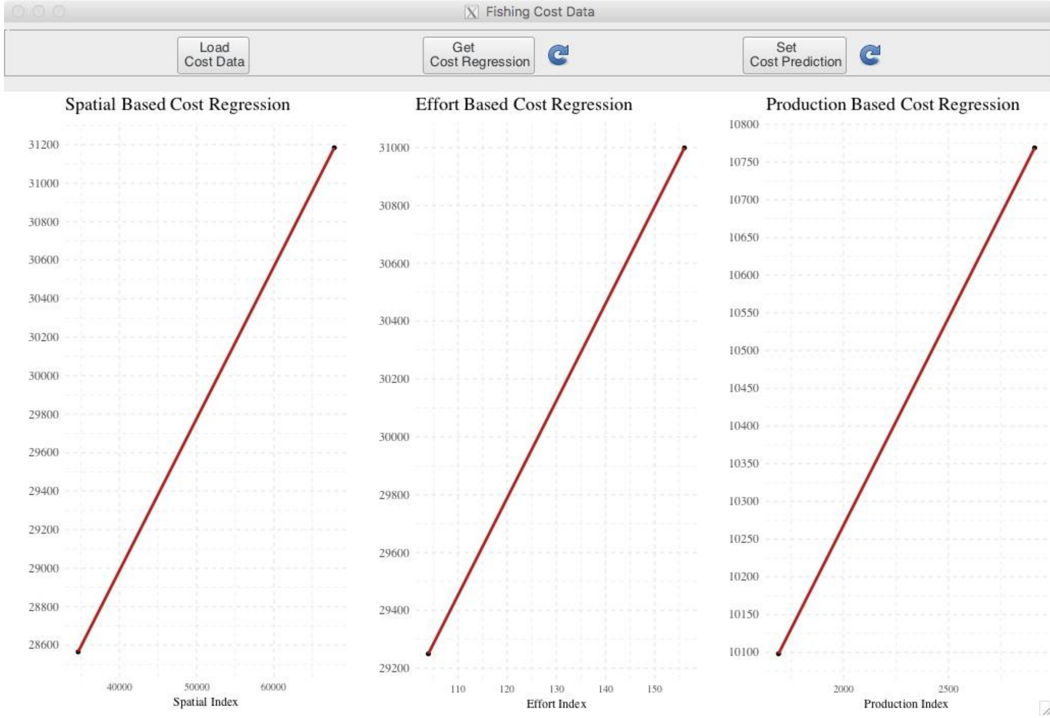


Merluccius merluccius



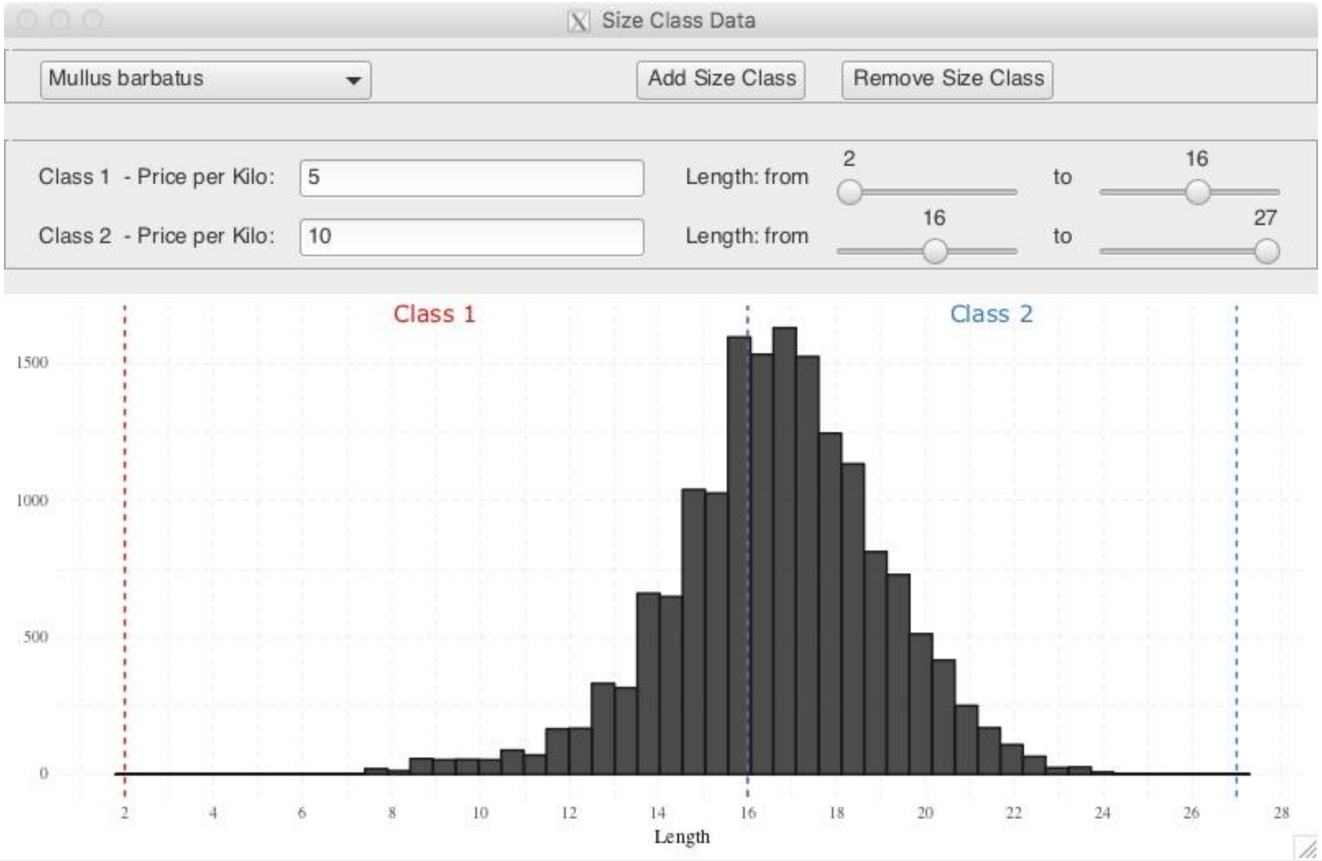
The costs

- The fishing effort is associated to a series of costs, namely:
    - Spatial-related costs (WHERE YOU FISH)
    - Effort-related costs (HOW MUCH YOU FISH IN TERMS OF DAYS AT SEA and HOW LARGE IS THE VESSEL as a proxy of crew size etc.)
    - Production-related costs (commercialization etc.)
- NISEA kindly provided a small dataset to set up the method for estimating all these costs for each vessel/temporal frame



The revenues

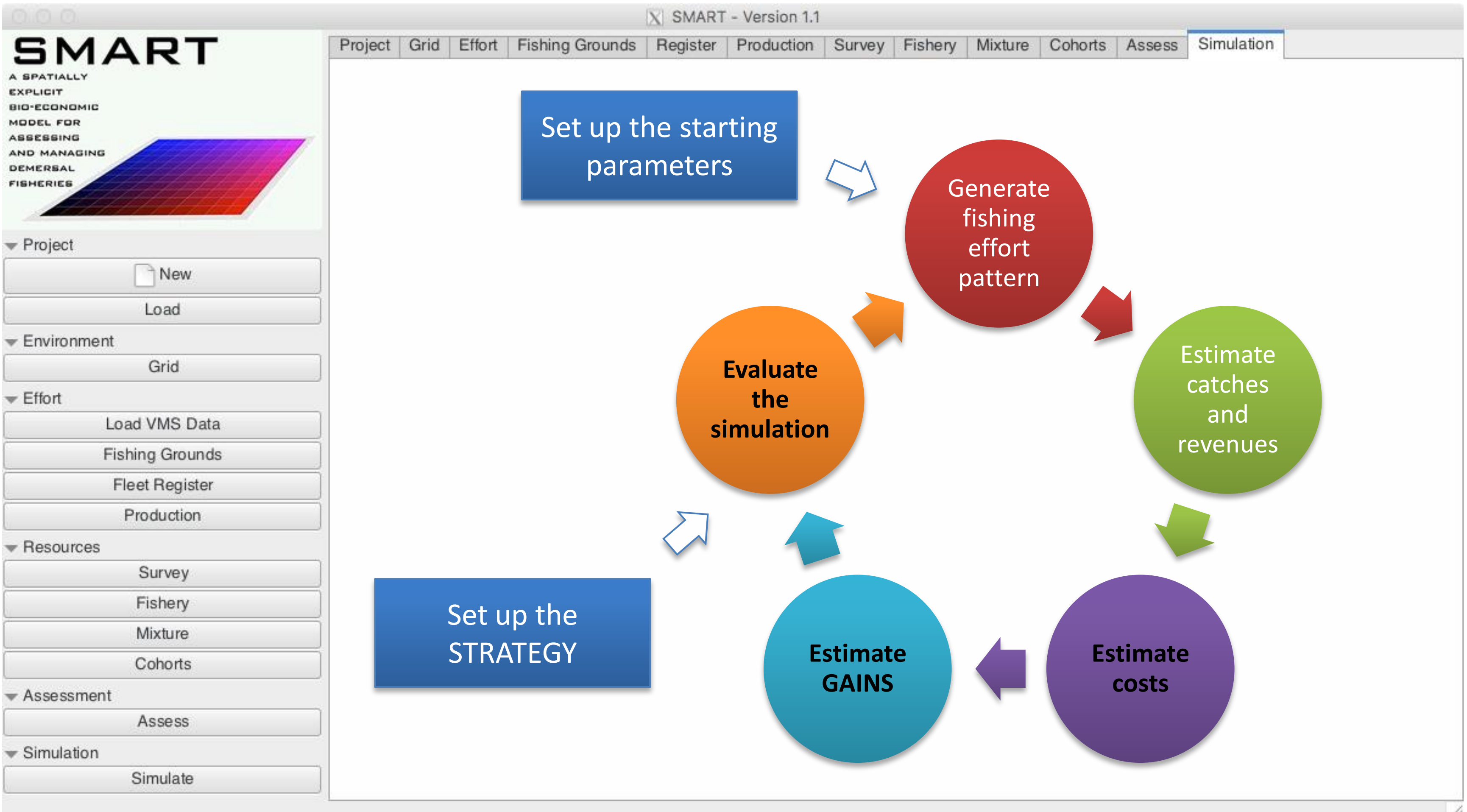
- The fishing effort is associated to revenues, for each species, as vector of prices for different size classes



In summary

- At this stage, for a given fishing effort pattern, we can:
  - Estimate total catches
  - Estimate the composition of catches (LFD)
  - Associated Costs
- This means that we can simulate the effects of new fishing effort patterns in terms of:
  - CATCHES FOR AGE/LENGTH CLASS
  - TOTAL PRODUCTION
  - COSTS
- Given that CATCHES & PRODUCTION could be easily converted in REVENUES, we can estimate GAINS
- CATCHES FOR AGE/LENGTH CLASS (together with ALK ect.) could be used as input for a stock assessment procedure

The new SMART: the Simulation module



The new SMART: the Simulation module

- Starting parameters:
  - Spatial and/or temporal closures
  - Changes of fishing effort (i.e. fishing capacity or activity)
  - Changes of fish price or fuel price
- STRATEGY:
  - Maximize GAINS
  - Minimize COSTS / RISKS
- Uncertainty:
  - SMART allows taking into account for different levels of compliance with (e.g.) closures

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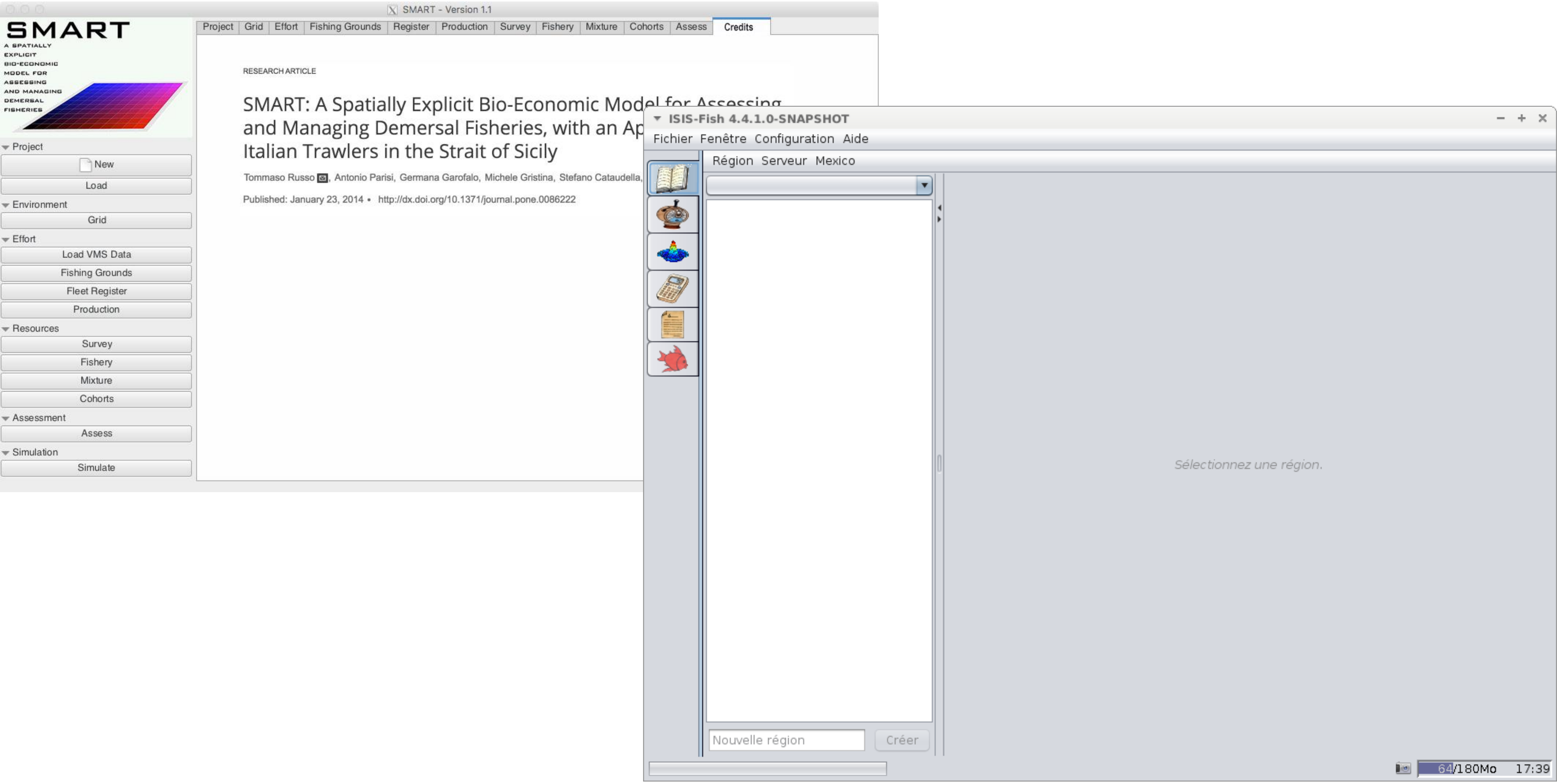
The tools: SMART & ISIS-Fish

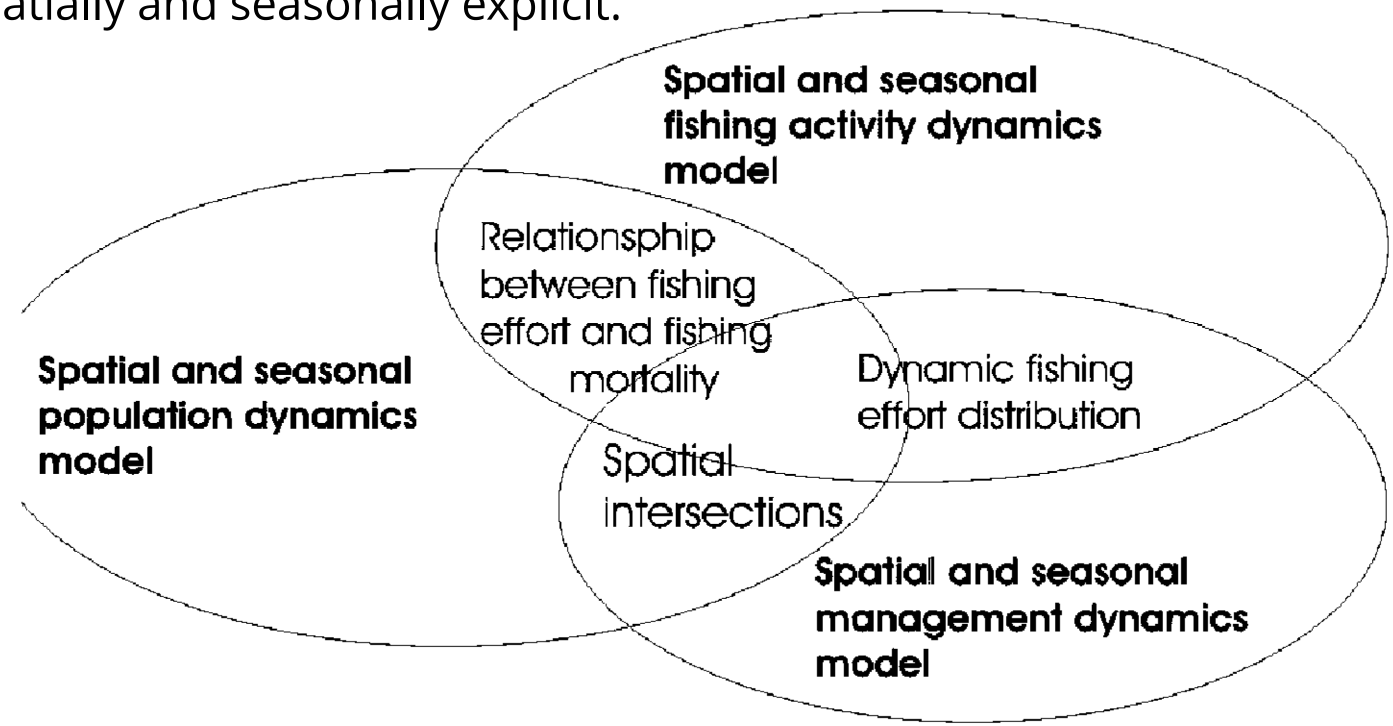


ISIS-Fish

The fishery model is based on three submodels:

- a population dynamics model,
- a model for fishing activity
- a model for management measures.

Each submodel is spatially and seasonally explicit.



ISIS-Fish

Many of the inputs needed could be obtained by SMART!!!

Table 1
Principal parameters for describing a population in the population dynamics model

Non-spatial biological parameters	Number of stages and stage width
	Natural mortality per stage
	Fecundity function
	Weight at stage
	Distribution of reproduction over months
	Distribution of recruitment over months
	Growth function
Spatial biological parameters	Population zones including reproducyion and recruitment zones
	Coefficients of migration and emigration
	Number of immigrants
	Catchability coefficients

ISIS-Fish

Many of the inputs needed could be obtained by SMART!!!

Table 2
Principal parameters of the fishing activity dynamics model including several fleets

Structural entities of the model	Parameters of the entity
Fleet	Number of fishing units Number of fishing trips per month Duration of fishing trip
Gear	Value of the controllable parameter (numerical or categorical) Selectivity function for each species Standardisation factor
Métier	Gear used (unique) Seasons Zones Target species and corresponding target factors
Strategy	Set of métiers used Proportion of fishing units per fleet Monthly distribution of fishing units among the métiers used

ISIS-Fish

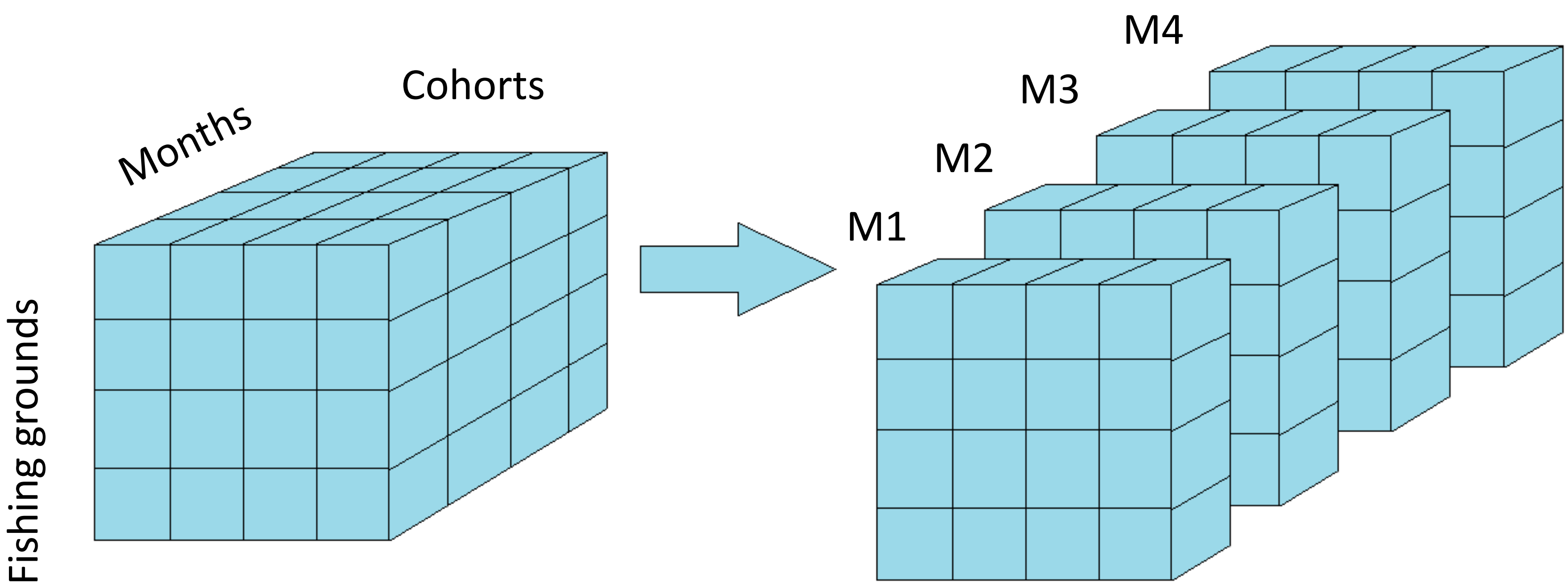
Many of the inputs needed could be obtained by SMART!!!

Table 3
Principal parameters for describing a management measure in the management dynamics model

Structural entities of the model	Parameters for the specification of the entity
Measure	Management zone Management season (months) Period of application (years) Control condition required for application
Fishers' reaction	Decision rules

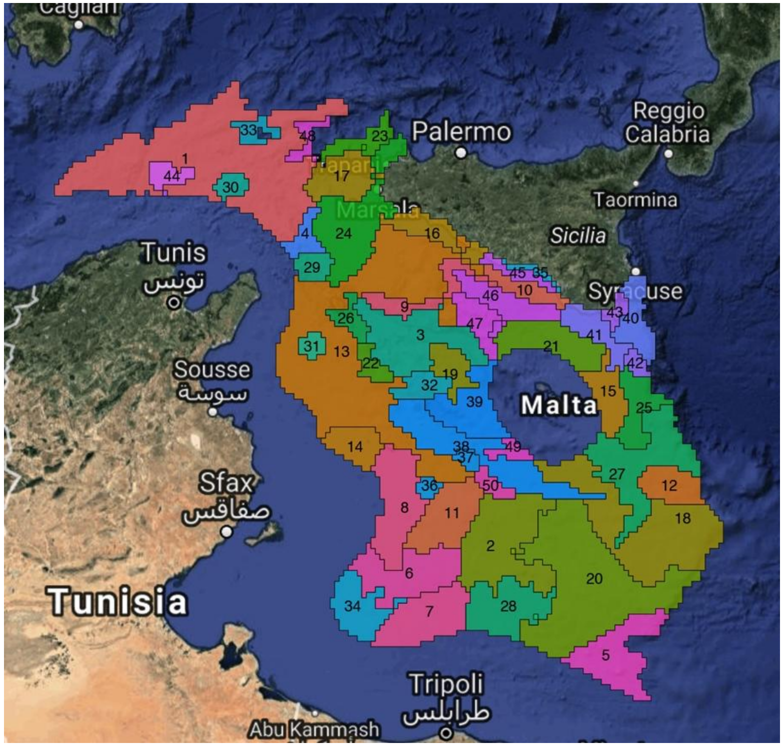
ISIS-Fish

Within SMART, the spatial distribution of each species is represented as a three-dimensional array



ISIS-Fish

A possible way to integrate the effects of connectivity (at the fishing ground level) could be represented by a series of (seasonal/monthly) CONNECTIVITY MATRICES (one for each cohort)



Fishing grounds

Fishing grounds