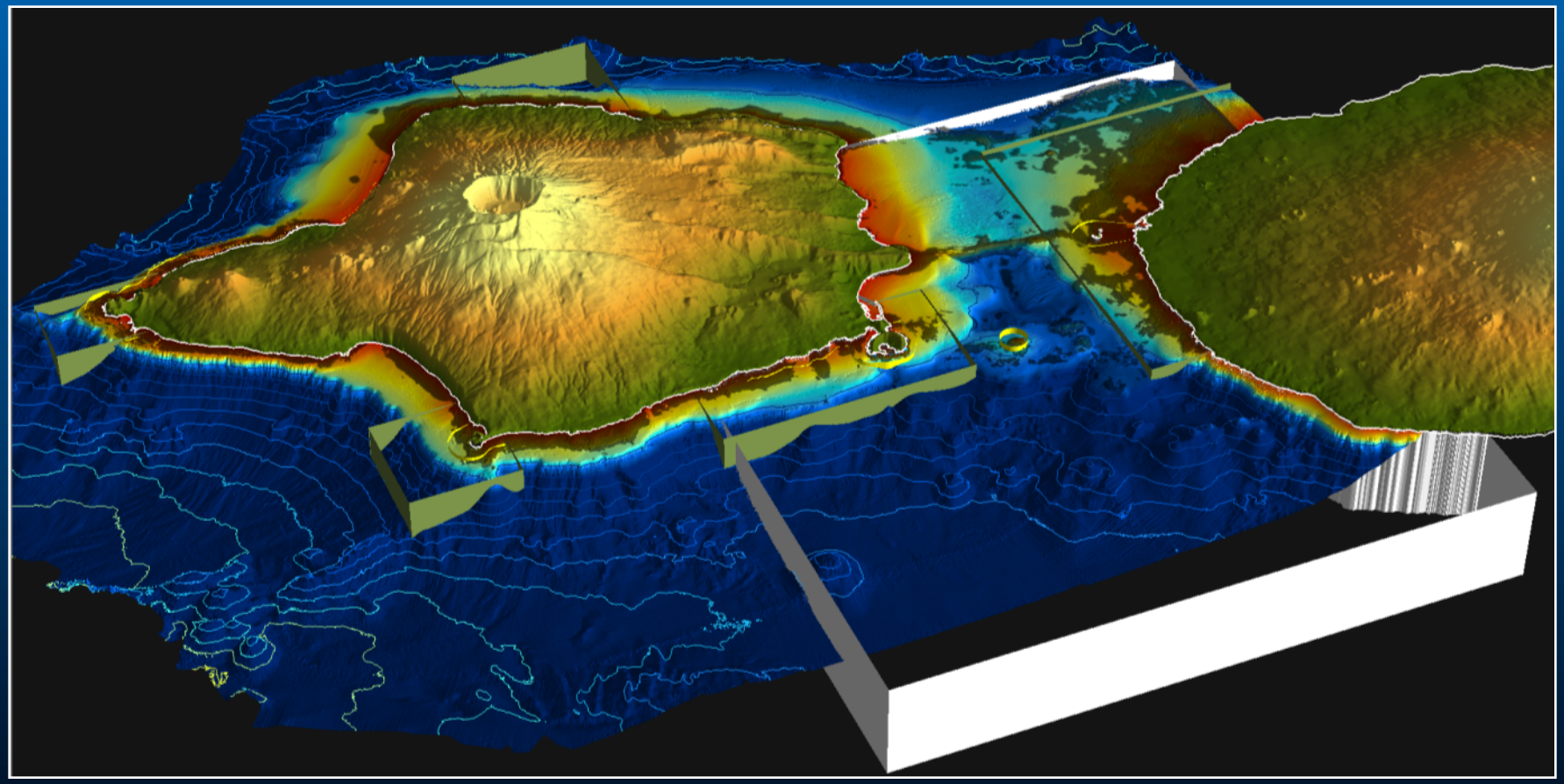
Getting a wider picture

MPA design using multiple conservation features

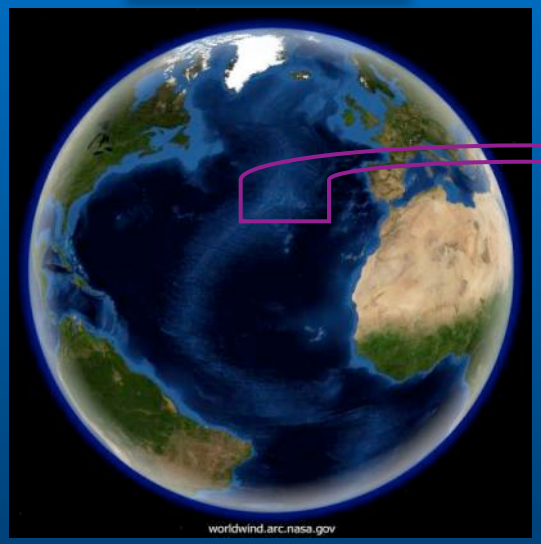


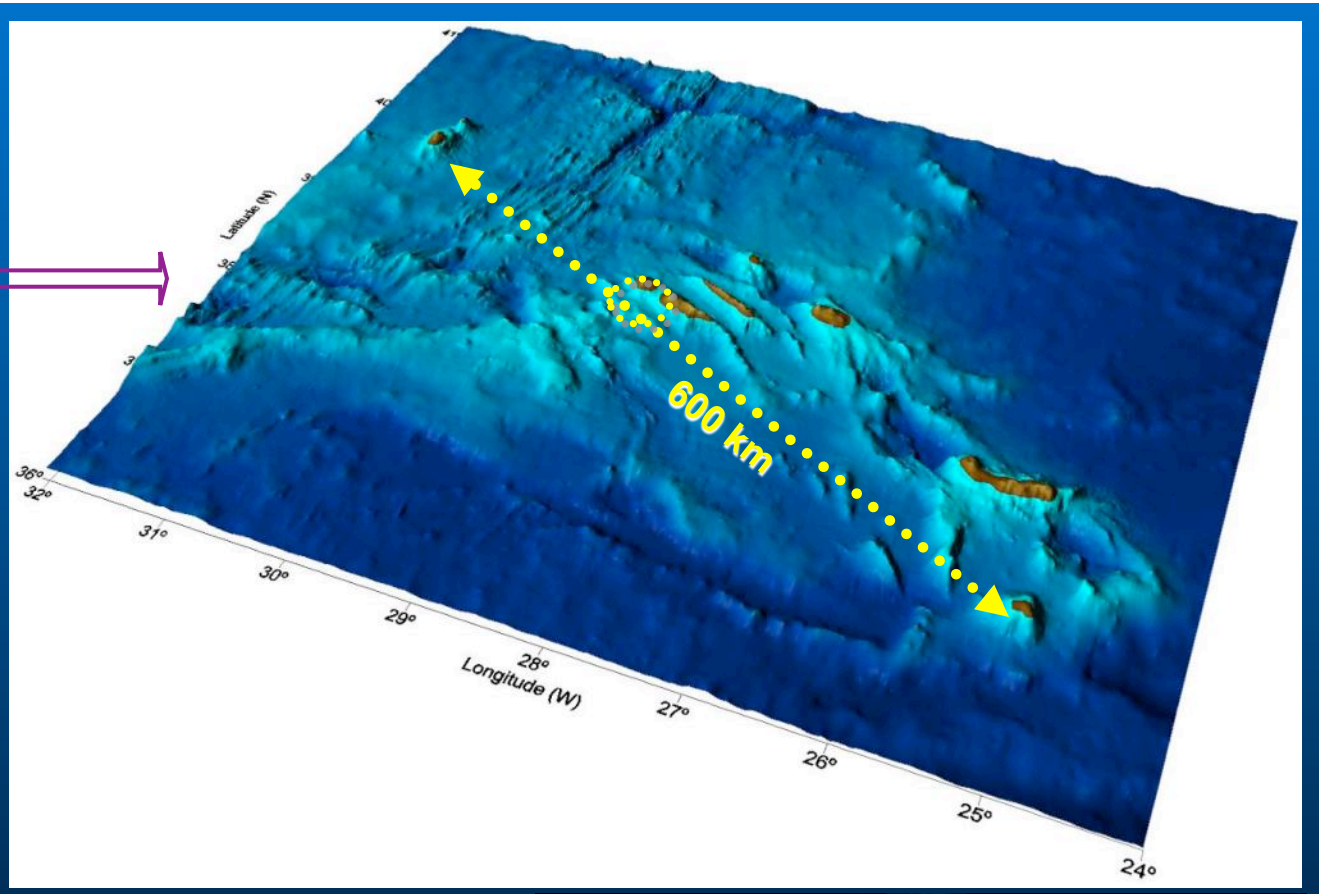
Pedro Afonso, Fernando Tempera, Mara Schmiing & Ricardo Santos

Dept. of Oceanography & Fisheries – University of the Azores

Pedro working on the … Seychelles

Azores

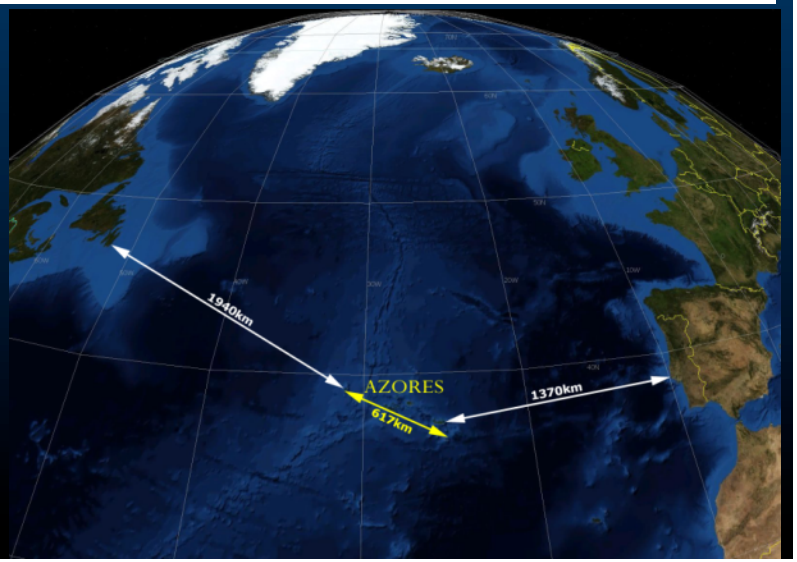




Geography
- archipelago of 9 islands
- spread over 600 km
- 1600 km W of mainland Portugal
- Population ~250.000
- EEZ sub-area: ~1 million km2

Geology
- located at the triple junction of the American, Eurasian and African plates
- oldest island only 8-10 My-old

Oceanography
- temperate regime with subtropical affinities
- oligotrophic oceanic waters
- localised enrichment by upwelling (seamounts, island coasts).

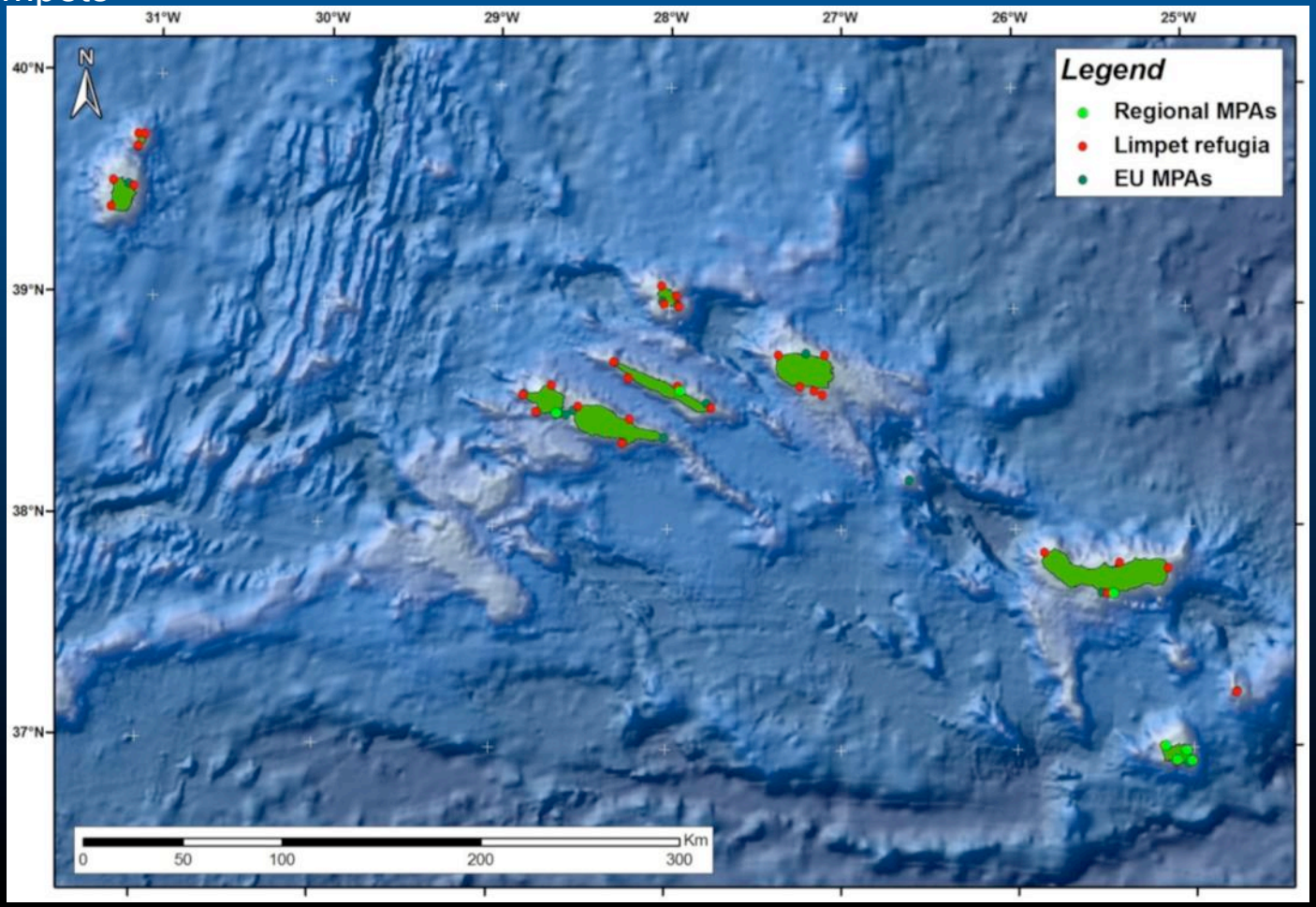


Azores MPAs

- 1st MPA declared in 1980
- Distribute over coastal areas, offshore banks & deep-sea hydrothermal vents

Total of 68 designated areas including

- 17 Marine Special Areas of Conservation (European Union Importance (SACs)
- 9 Regional MPAs
- 35 harvest refugia for limpets
- 7 OSPAR MPAs



Successful design of MPA network (island scale)

MULTIPLE CRITERIA

HABITAT REPRESENTATIVENESS

ESSENTIAL FISH HABITATS

CETACEANS

SEABIRDS

EXISTING MPAs

STAKEHOLDER CONFLICT MITIGATION

HABITAT USE
(scale of movements)

Seascape representativeness
Classes based on
•Depth
•Slope
•Bottom types
•Hydrodynamic exposure

When defining the landscape units

Benthic biotopes

Fish abundance (juvenile, adult)

Spawning grounds

Potential fecundity

Home ranges (biotelemetry)

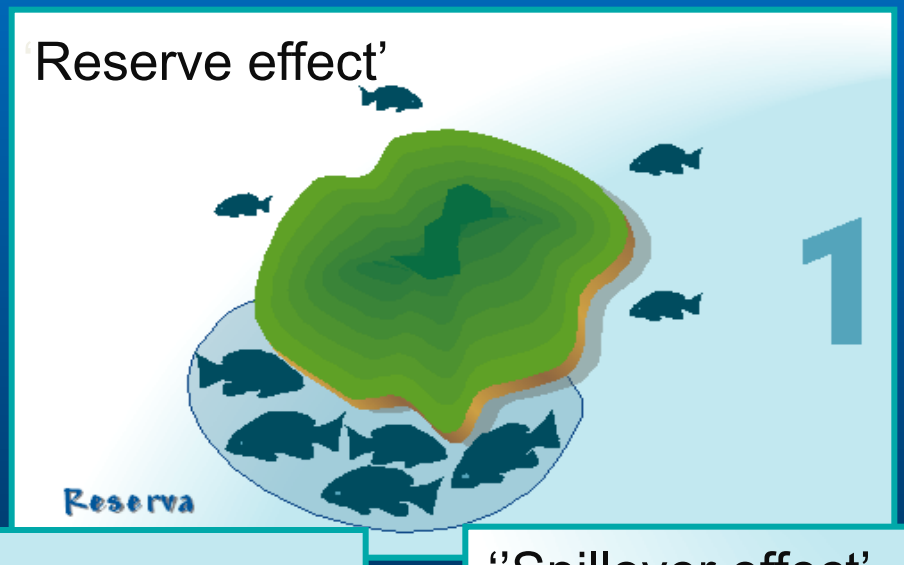
Explanatory variables for statistical models

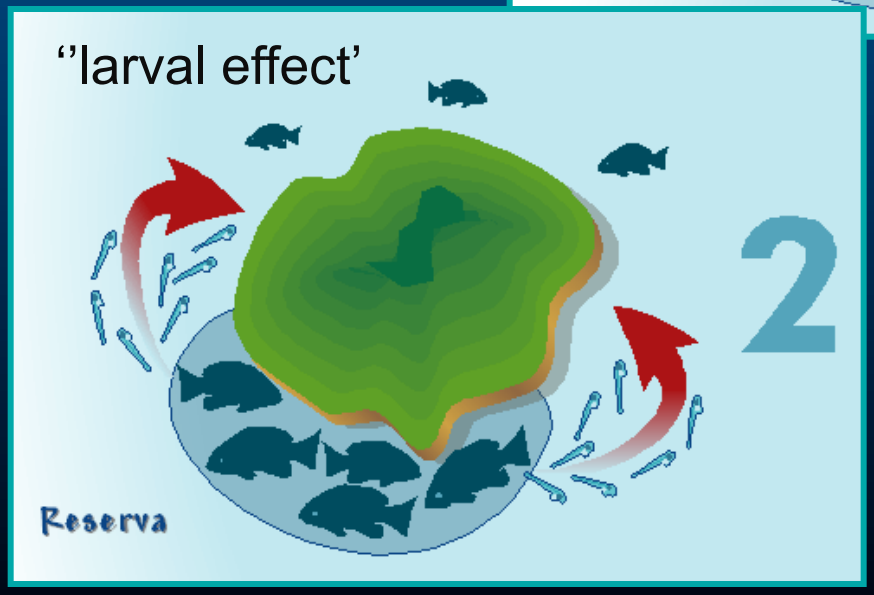
GEOMORPHOLOGICAL INFORMATION

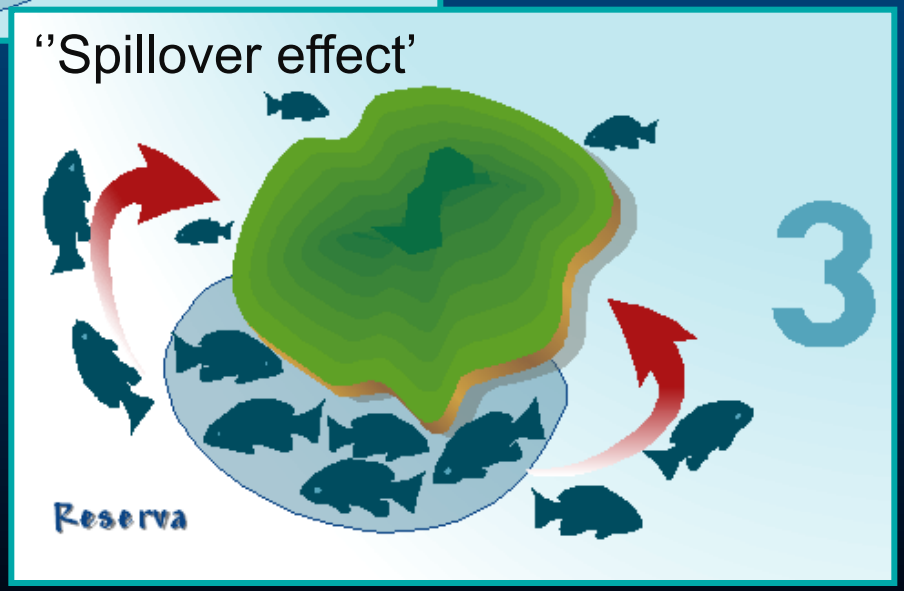
MULTISPECIES

Since most reef fisheries are multi-specific & different species have:
-different life histories
- different home range sizes & residency
- different habitat requirements

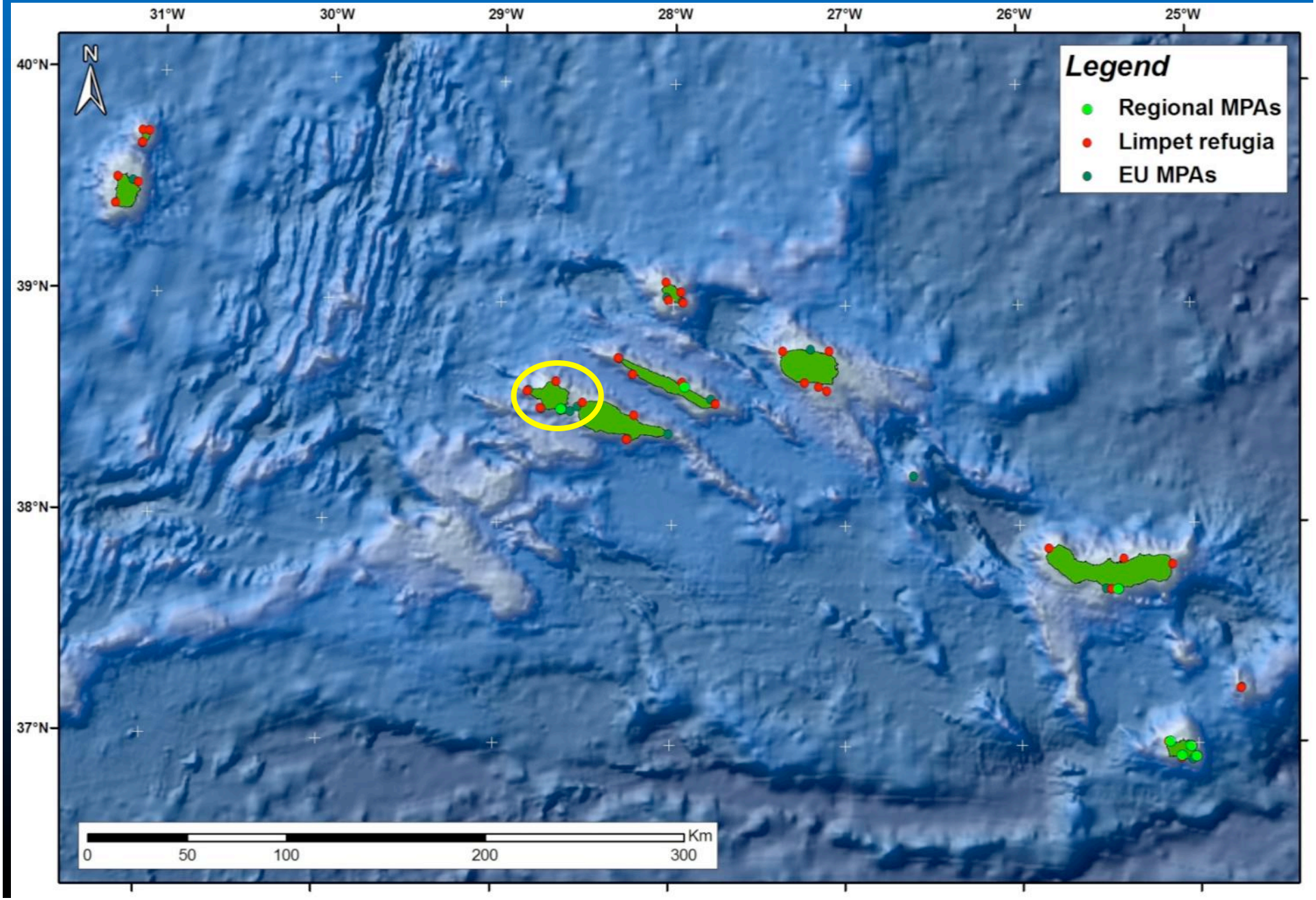
Which aims do we want to achieve?





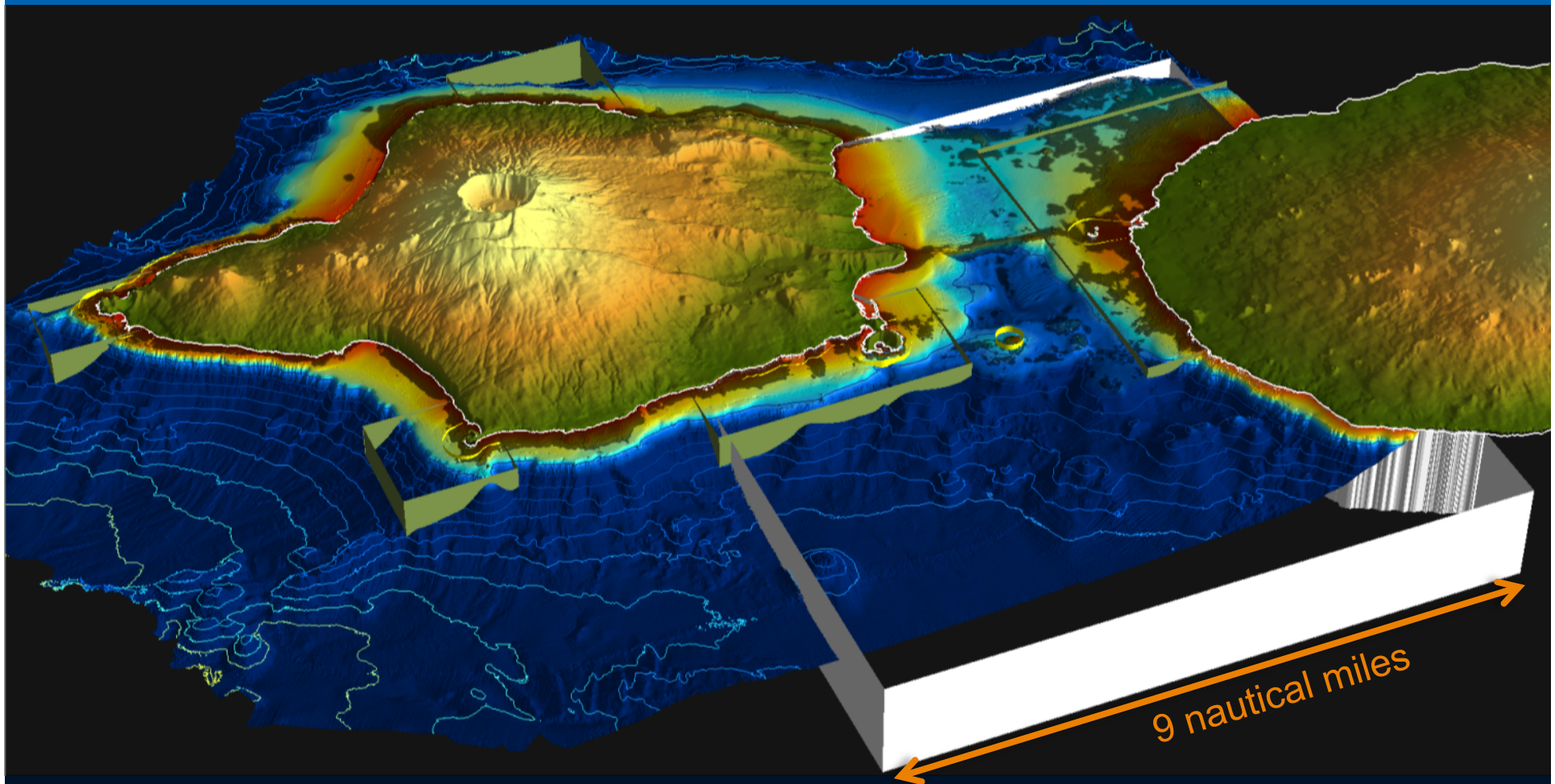


Our main experimental scenario



Our main experimental scenario

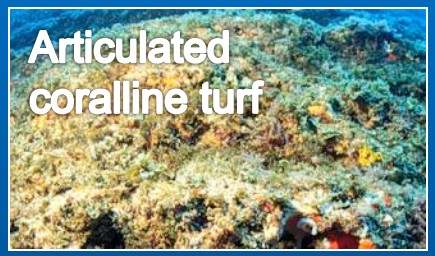
Faial island and neighbouring channel to Pico

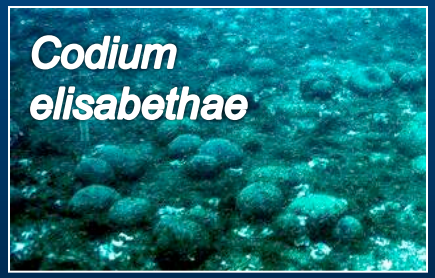


- 1 regional MPA (also classified under the OSPAR Convention MPA network)
- 5 Marine SACs (EU) (3 of them contained in the regional MPA)
- 5 harvest refugia for limpets (2 of them partially contained in the regional MPA)

Where have we started?

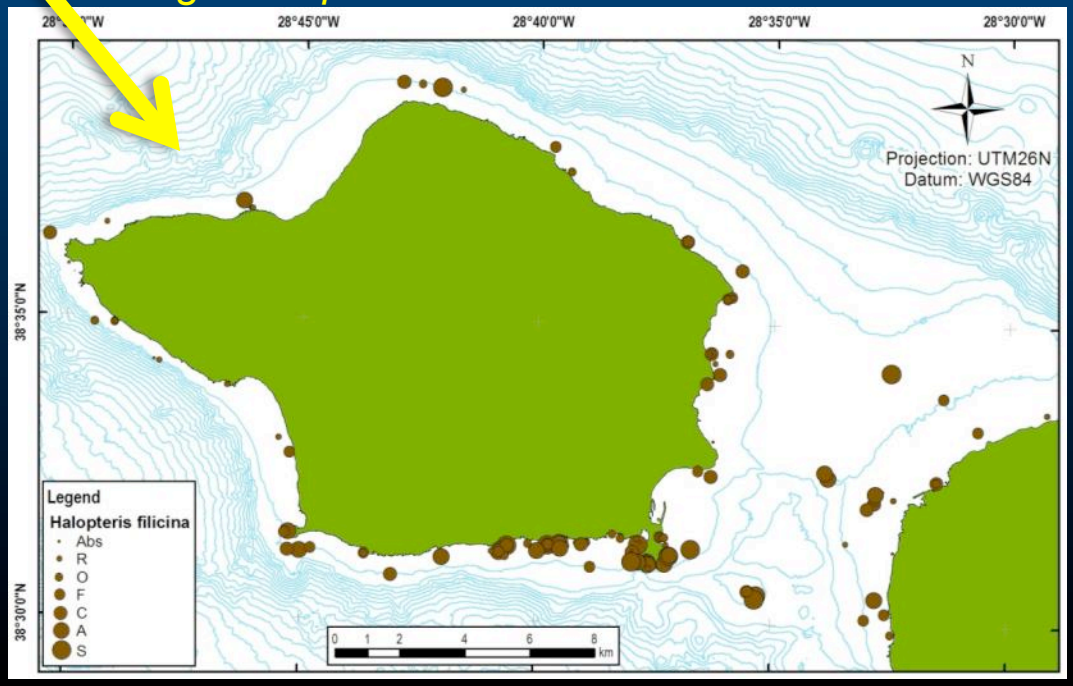
Infralittoral biotope distribution: 6 dominant macroalgae





- Abundance estimates obtained by scuba diving transects (<40m) as well as ROV and drop-down camera deployments (>40m)
- Total: 117 stations surveyed between 1999 and 2005
- Data were in semi-quantitative ordered categories (SACFOR scale + Absence)

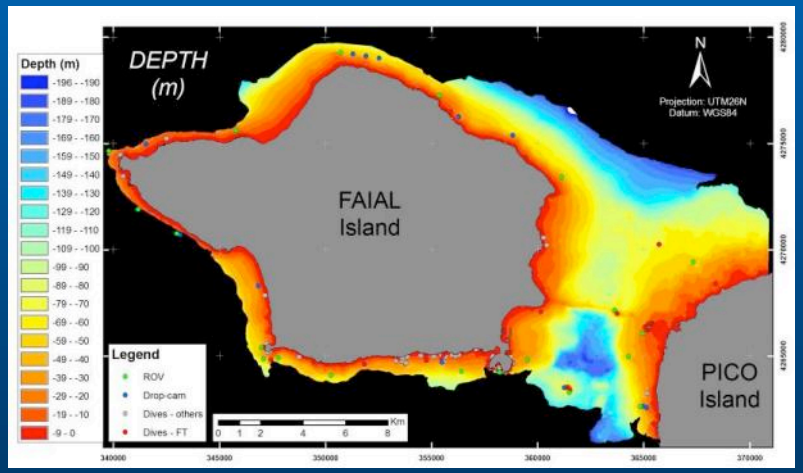
E.g.: *Halopteris filicina* abundance raw data



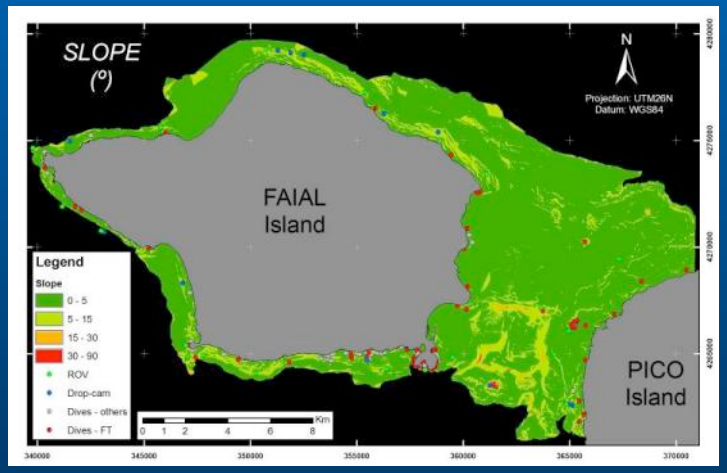
Infralittoral biotope distribution

Mapping of primary explanatory variables: seafloor

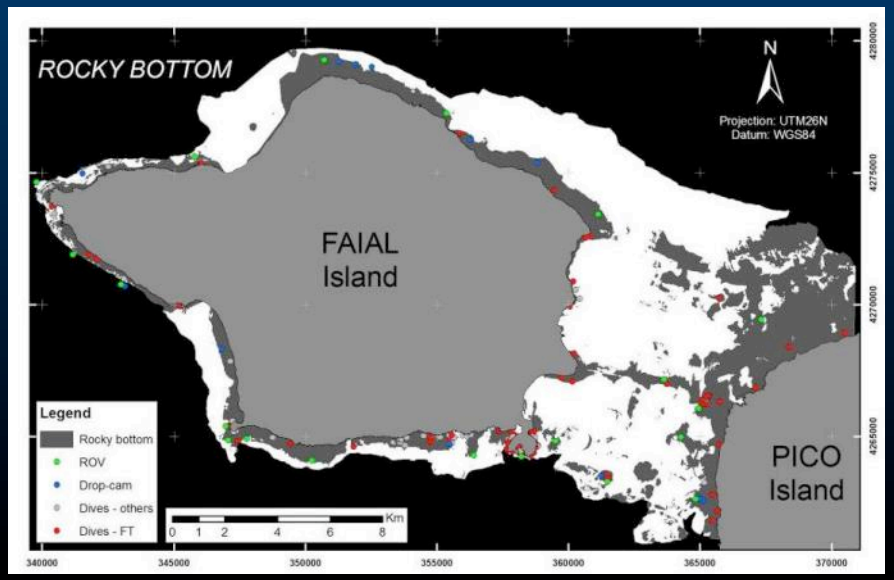
Depth



Slope



Hard substrate location



Used as mask or as binomial variable

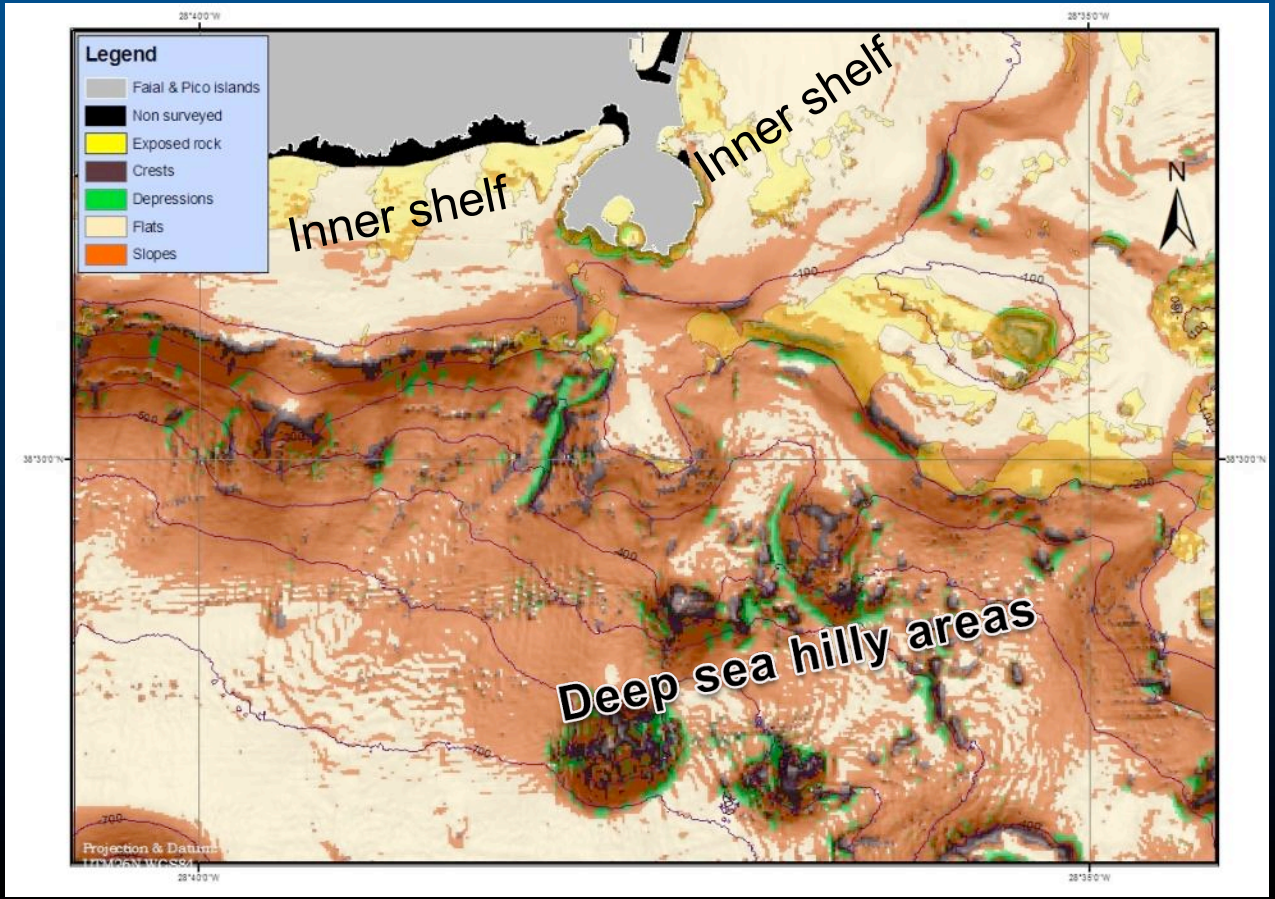
Infralittoral biotope distribution

Mapping of primary explanatory variables: other geomorphological variables

E.g.: **Benthic Terrain Modeller (**OSU/NOAA)

For the inner shelf areas we are working in, seafloor was segmented in just 2 categories: shelf and slope.

We considered that a better explanatory variable would be achieved using **slope** as a continuous variable directly in the statistical models instead of using what would be a binomial variable.

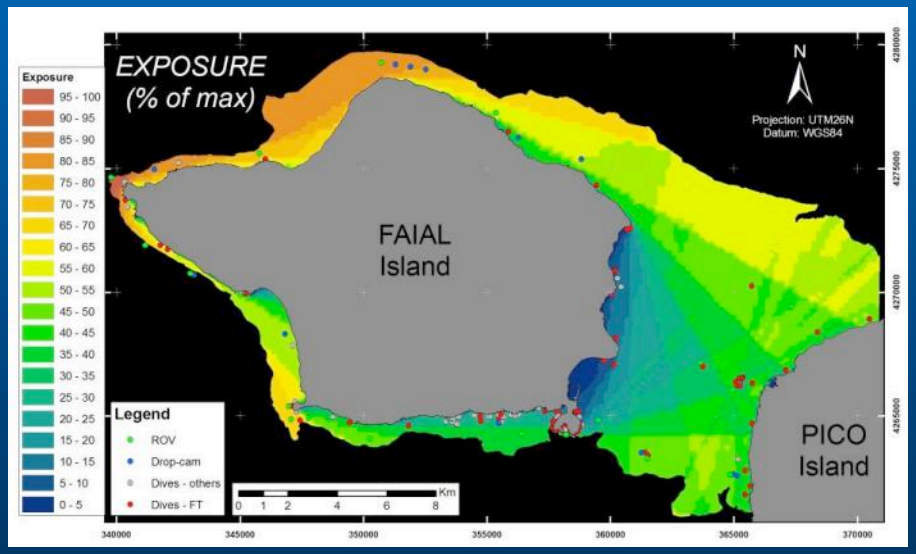


The defined dictionary will work better in rougher terrains (seamounts, hilly areas) at broader scales

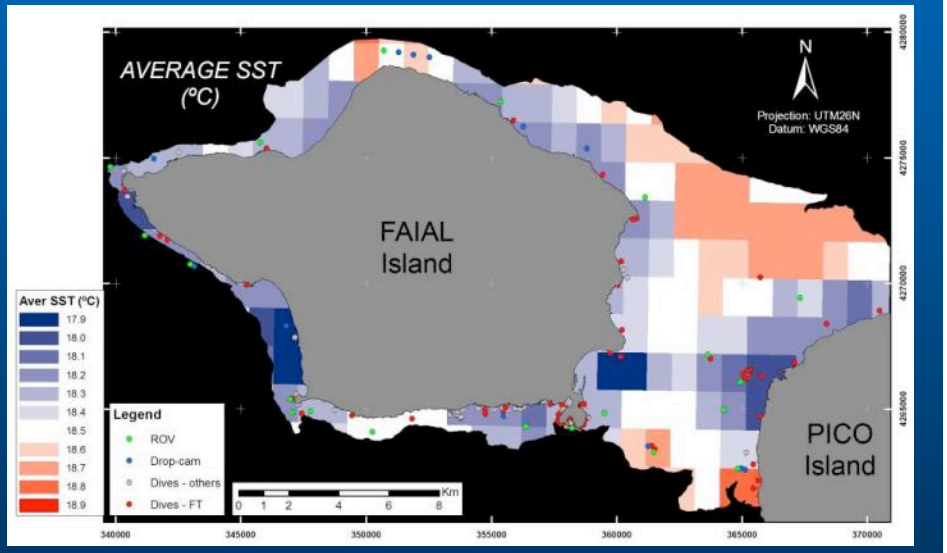
Infralittoral biotope distribution

Mapping of primary explanatory variables: oceanography

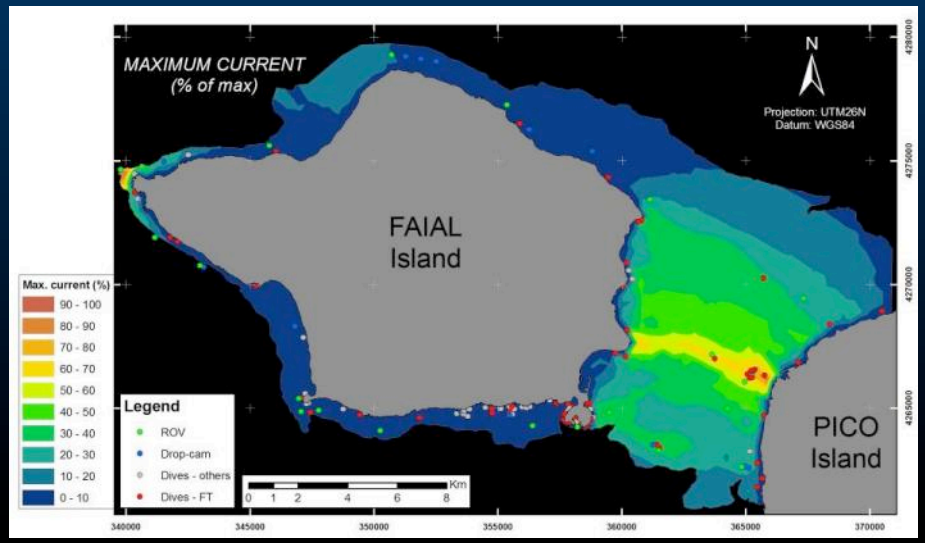
Exposure to swell (GIS)



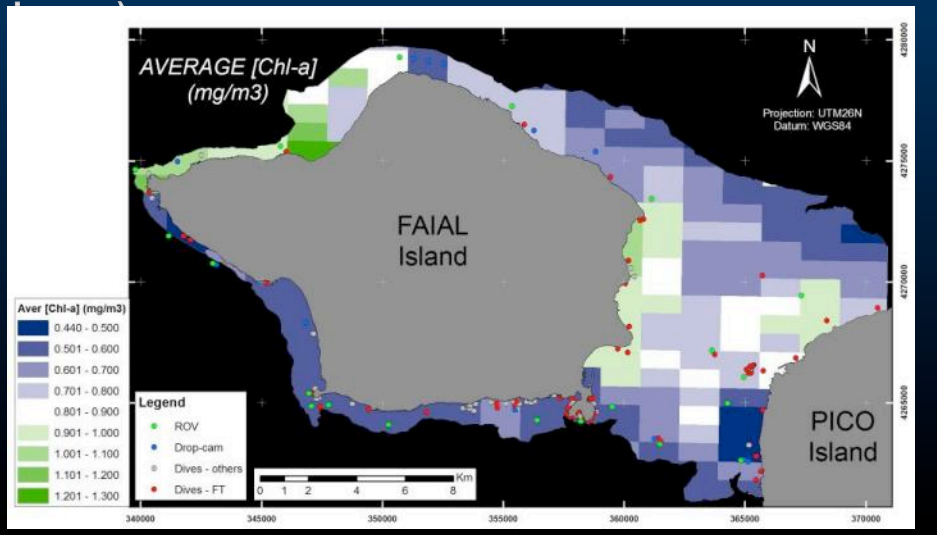
Sea surface temperature (sattelite imagery)



Exposure to tidal currents (Oceanog. model)



Surface chlorophyll-*a* concentration (sat.



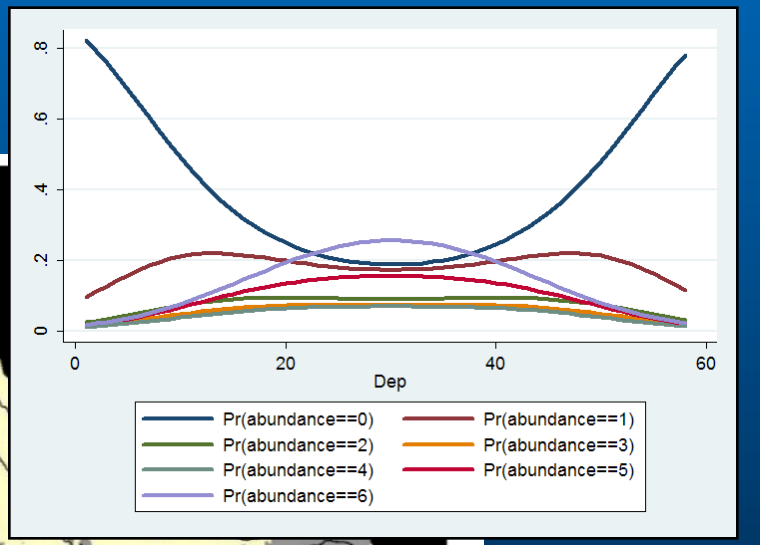
Infralittoral biotope distribution

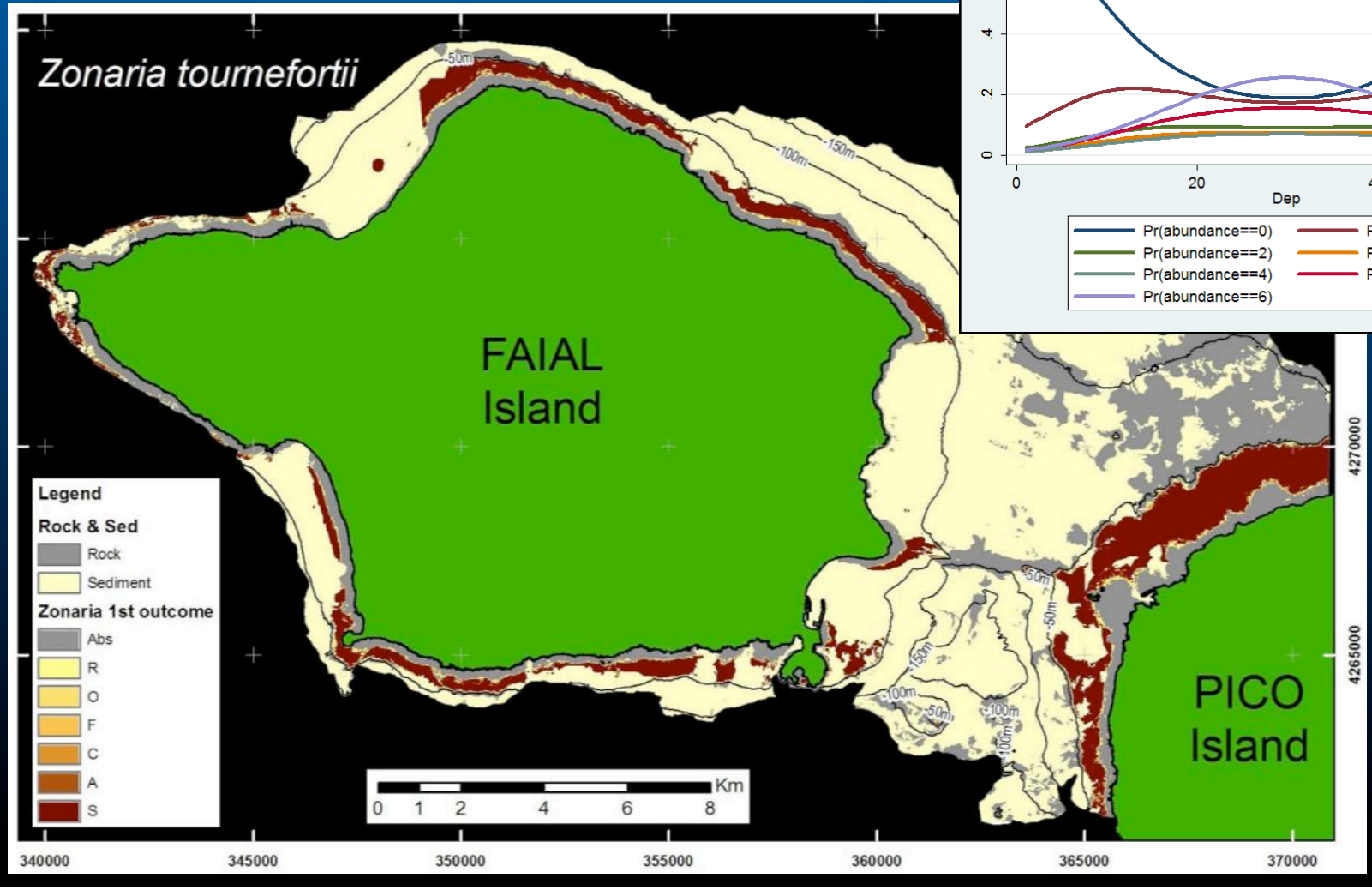
Statistical Modelling

Spatial intersection between georreferenced biological information and maps of explanatory variables

Model fitting in STATA using ordered logit models

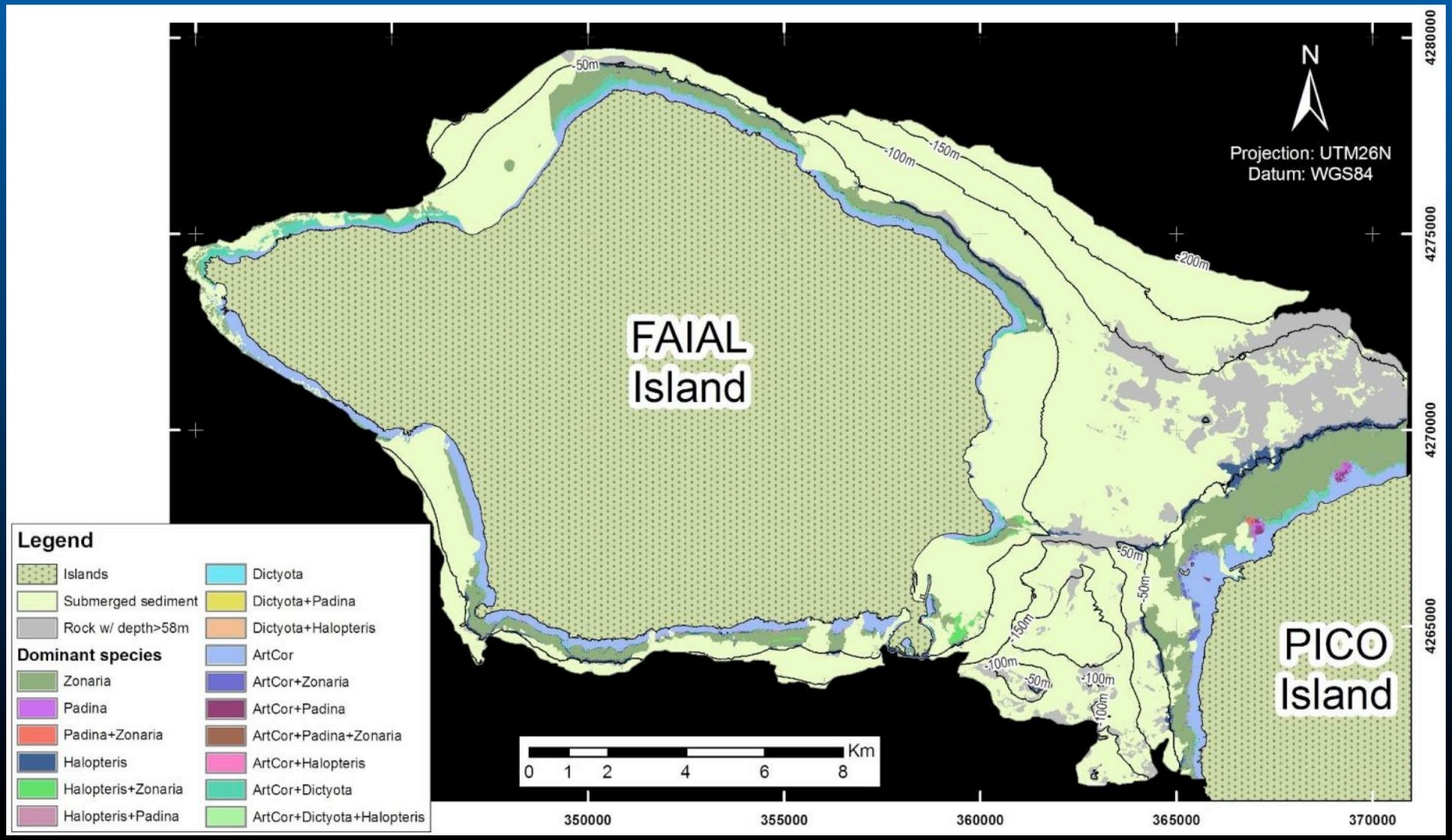
Re-spatialization in GIS





Infralittoral biotope distribution

Composite of the dominant macroalgae distributions as proxy for the distribution of infralittoral biotopes

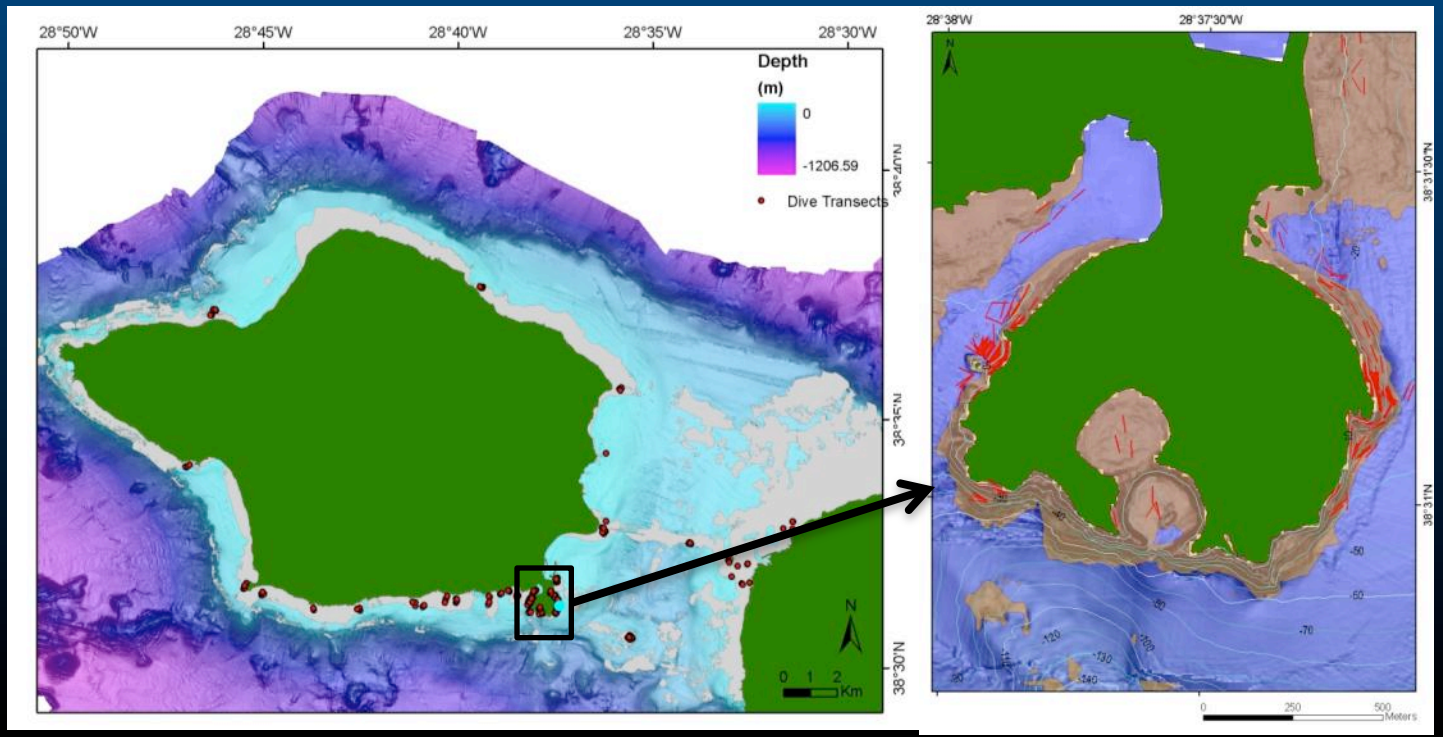


Fish Abundance Modelling

- Data from an Underwater Visual Census Programme (1997-2004)
- 462 transects (50m long x 5m wide)
- down to 40m depth
- around Faial & Western Pico islands

Information recorded

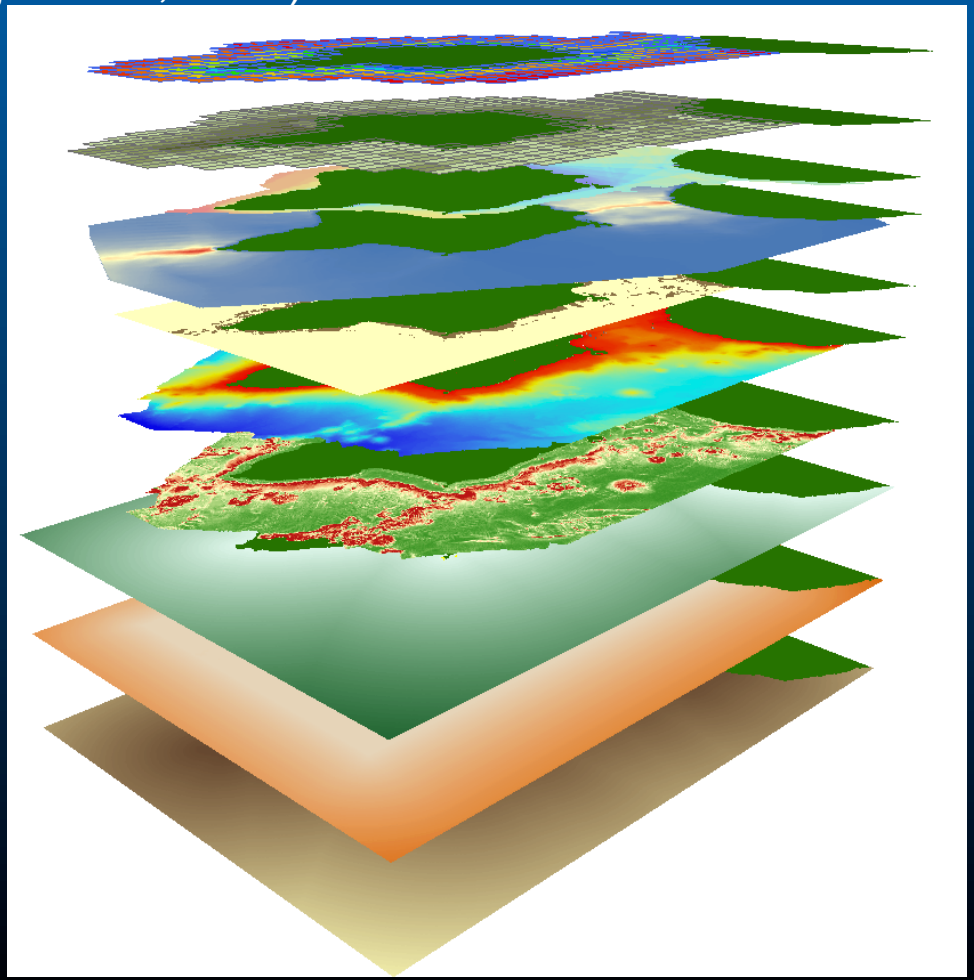
- Fish: numbers by species, size class, sex (where species are externally dimorphic)
- Also metadata on the stations and transient environmental variables (e.g., visibility, waves, current, weather, water temperature)



Fish Abundance Modelling

Response variable
fish abundance
(juvenile, adult)

GLM/GAM



Explanatory variables

- Depth
- Slope
- Rugosity
- Distance to shoreline
- Distance to rock
- Distance to sand

Geomorph.?

- Exposure to swell
- Exposure to tidal currents
- Benthic biotope (dominant macroalgae facies)
- Sea surface temperature
- Surface chlorophyll-a concentration

Fish Abundance Modelling

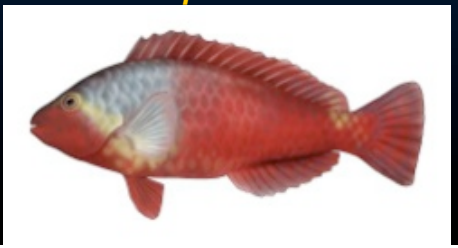
Marine Geospatial Ecology Tools (MGET)
http://mgel.env.duke.edu/tools (Roberts et al, in review)

Free ArcGIS extension that links to R for statistical analyses
Fits statistical model allowing control over model parameters
and produces the predictive raster

GLM examples for

blacktail comber *Serranus atricauda*

and parrotfish *Sparisoma cretense*



Fish Abundance Modelling

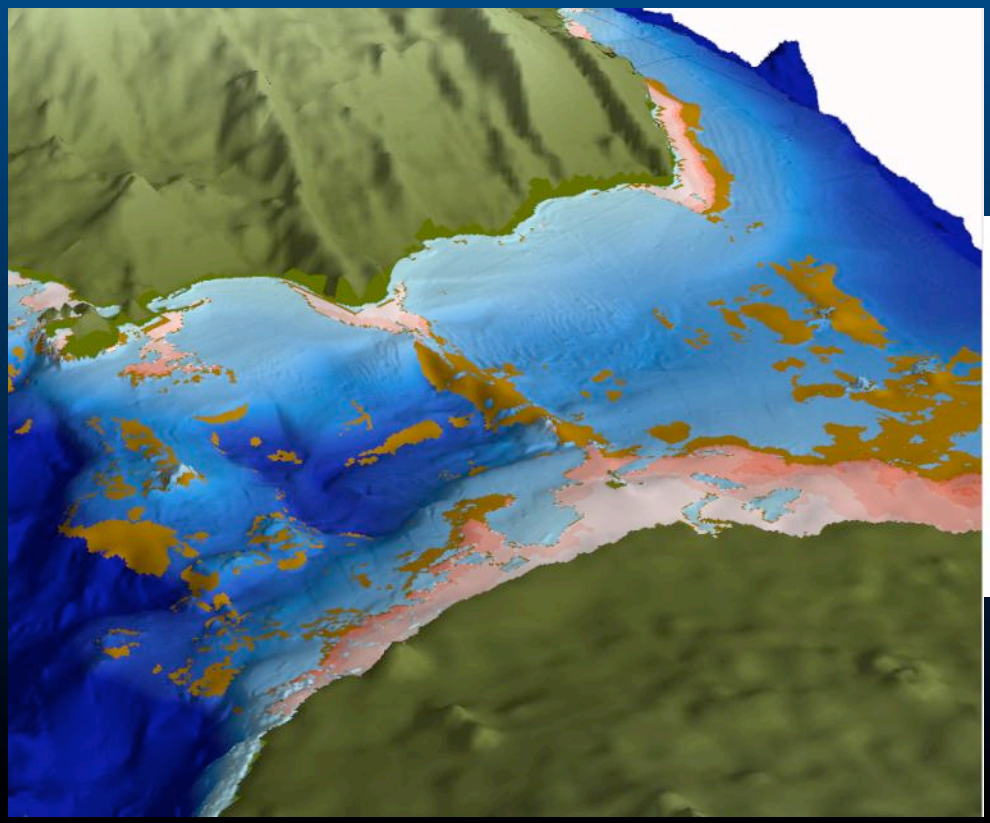
Blacktail comber (*Serranus atricauda)*

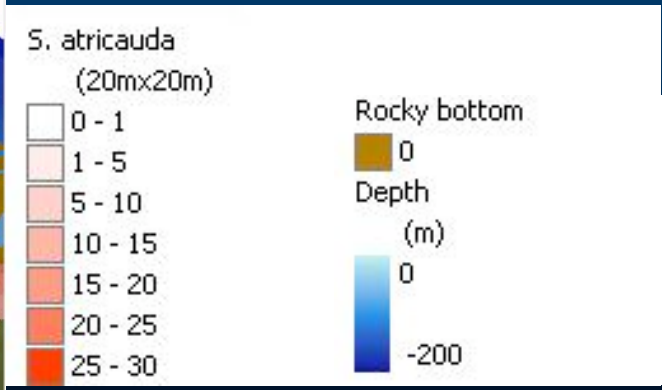
Model fitting & production of predictive map

Predicted abundance = 0.3851574[a] - 0.0524896×Depth[a] - 0.3848869×Distance rock[a] + 0.0006957×Distance sediment[b] -0.0052818×Exposure to currents[a]

Signif. codes: [a] = 0.001 [b] = 0.05

AIC: 1874.2





Fish Abundance Modelling

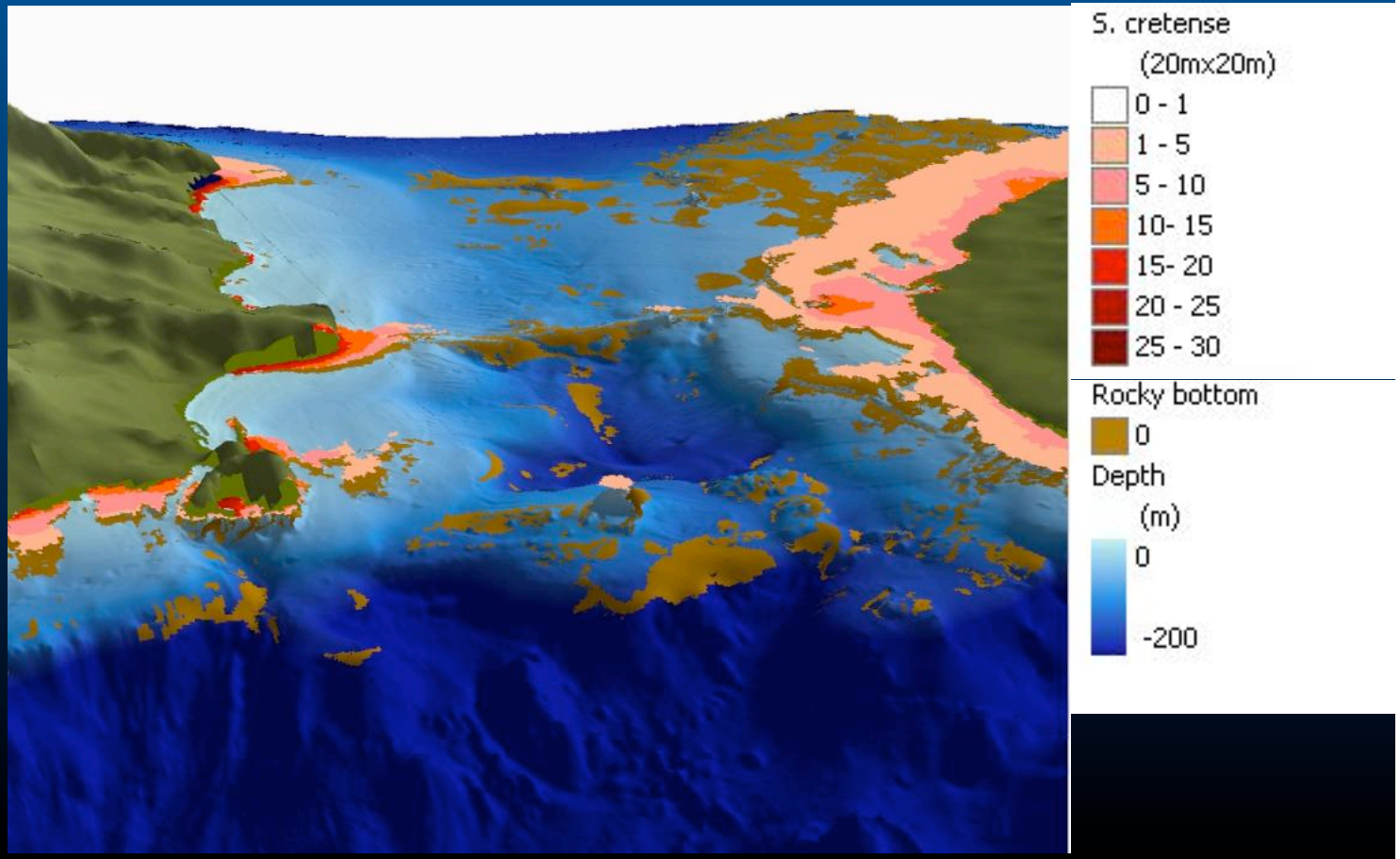
Parrotfish (*Sparisoma cretense)*

Model fitting & production of predictive map

Predicted abundance = $2.7622230^{a} + 0.0405099 \times \text{Depth}^{a} - 0.9910829 \times \text{Dist. rock}^{a} + 0.0004228 \times \text{Dist. sediment} + 0.0058250 \times \text{Exp Currents}^{a} - 0.0336560 \times \text{Exp. Swell}^{a}$

Significance: $^{a} = 0.001$)

AIC: 4224.7



Fish telemetry studies

Analysis of the scale of the movements of coastal fish
Analysis of its relationship with benthic habitats (define preferential/essential habitats)

- Parrotfish- *Sparisoma cretense* (Scaridae)
- Red porgy- *Pagrus pagrus* (Sparidae)
- White trevally- *Pseudocaranx dentex* (Carangidae)
- Dusky grouper - *Epinephelus marginatus* (Serranidae)
- Blacktail comber - *Serranus atricauda* (Serranidae)
- Yellowmouth barracuda - *Sphyraena viridensis* (Sphyraenidae)
- Almaco jack - *Seriola rivoliana* (Carangidae)

Fish telemetry studies

capture

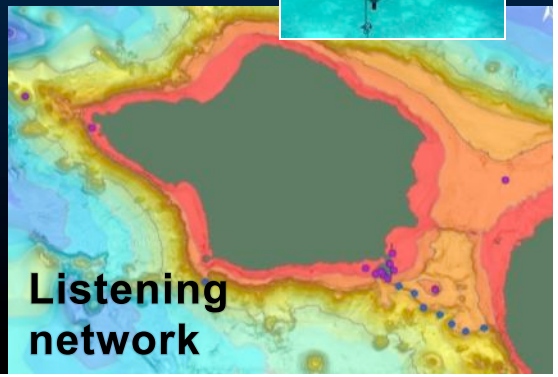
surgery

release

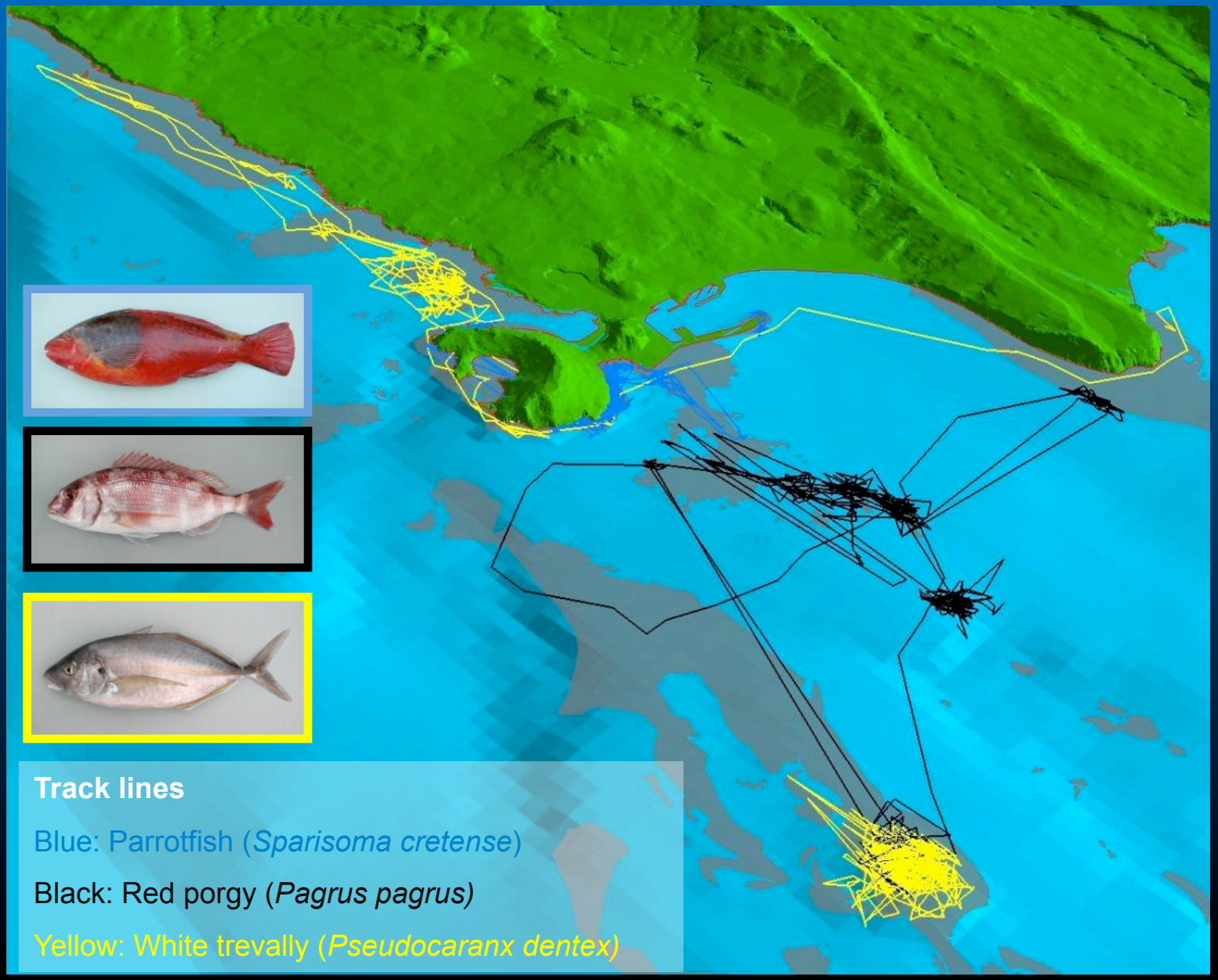
Fish minding their own business…

Active telemetry

Passive telemetry



Fish telemetry studies



Track lines

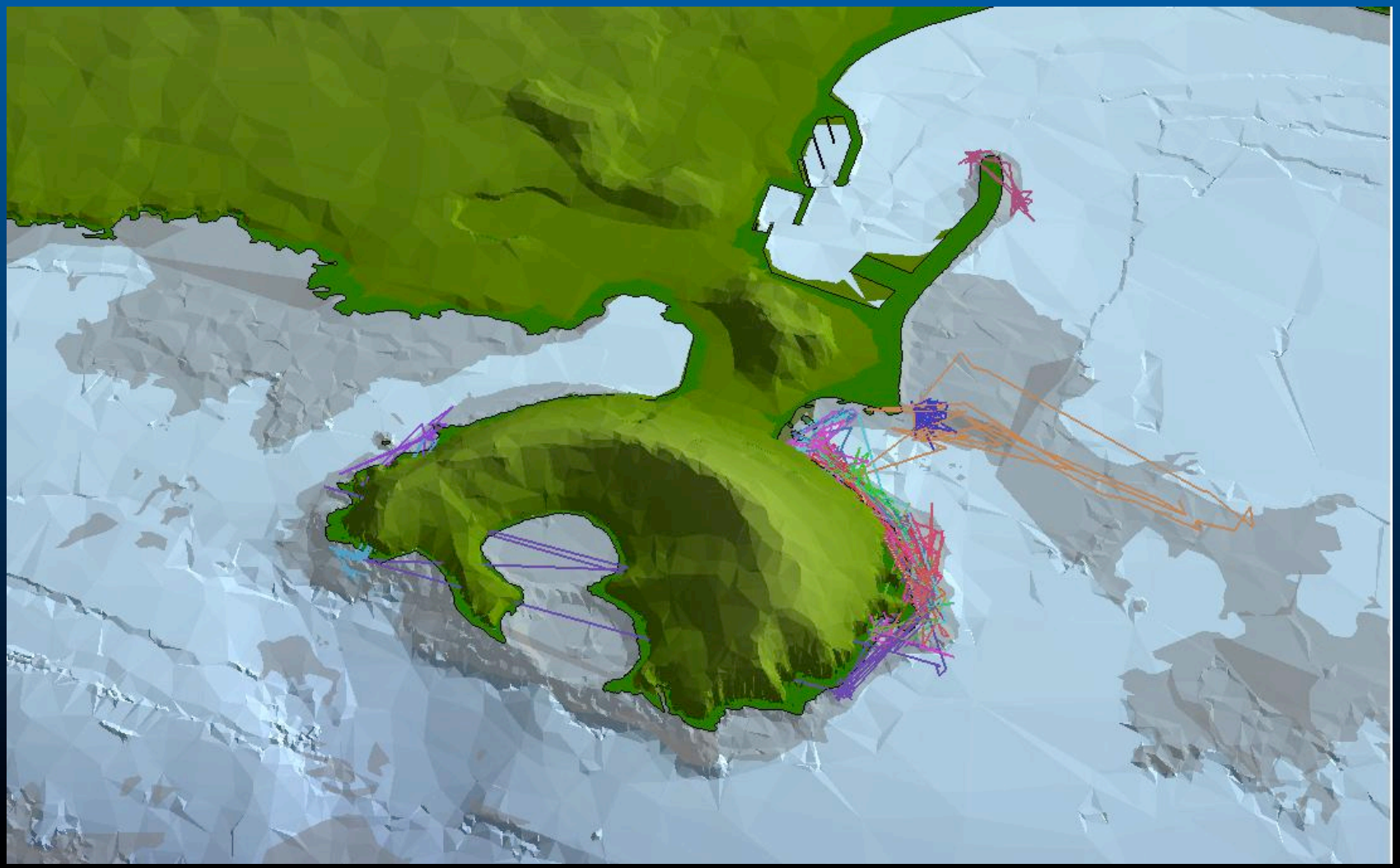
Blue: Parrotfish (*Sparisoma cretense*)

Black: Red porgy (*Pagrus pagrus)*

Yellow: White trevally (*Pseudocaranx dentex)*

Fish telemetry studies

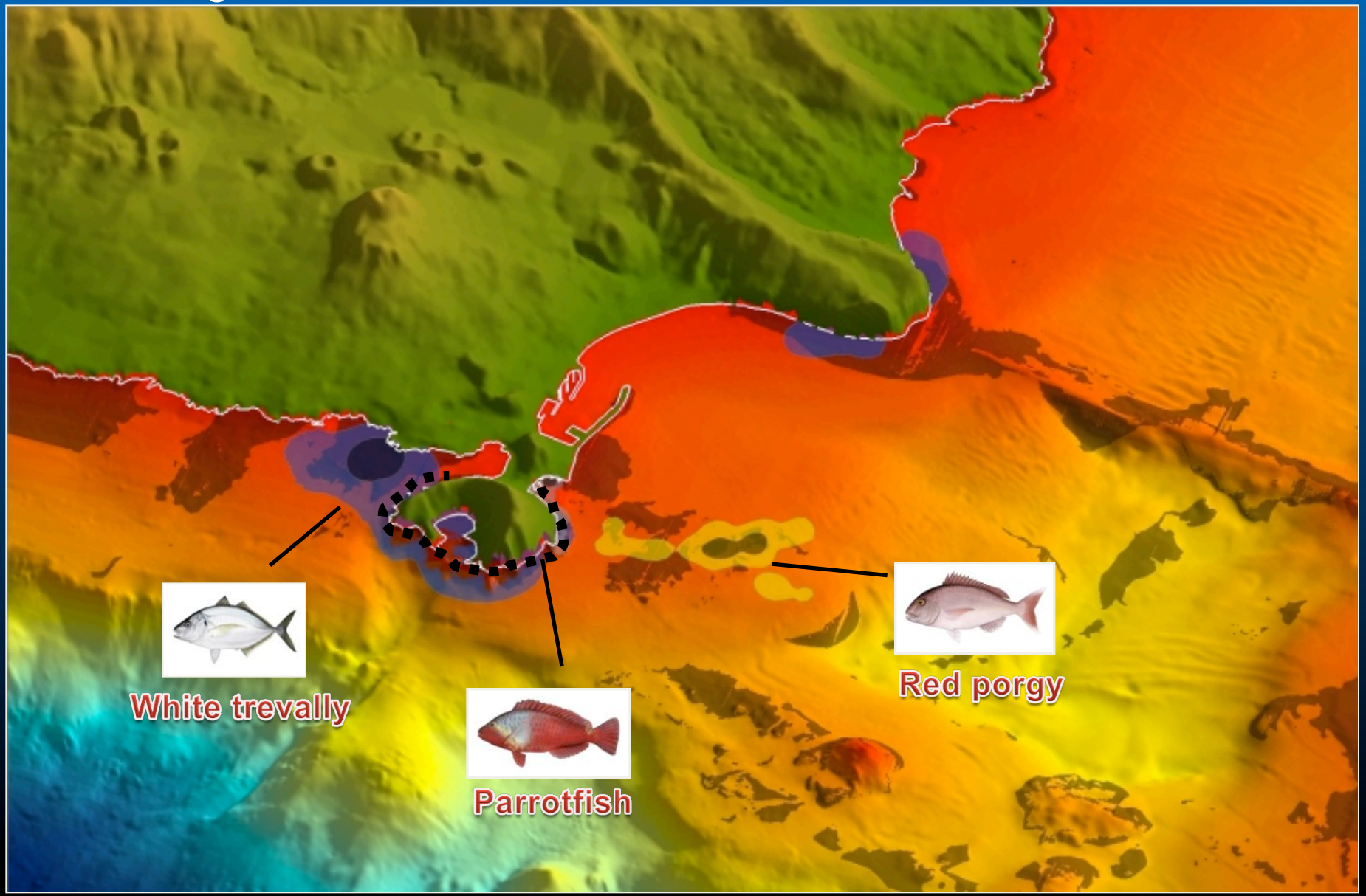
Example: tracks of 5 parrotfish individuals



Coastal fish home ranges

How much space does a fish need?

And how big should the reserves be, then?



Future work

- Advance into GAMs or other statistical frameworks to improve model fitting for fish abundances
- Modelling directly with R to have greater statistical control
- How to deal with clustering of fish counts
- “Refine” input rasters for environmental variables
- MGET had trouble processing large rasters in the predictive step, which forced us to diminish our resolution to 20mx20m. Alternatively use model equations directly in ArcGIS Raster calculator
- Use MARXAN or ZONATION to weigh all the different variables and obtain MPA design scenarios
- Test whether the present set of designated areas could provide a robust network
- Develop a procedure to use the information on individual home ranges to produce a layer for “population home ranges“ that can reflect the potential for spill over as well as the exposure of the protected stocks to the fishing in the adjacent non-protected areas

Pedro thanks you all from the Seychelles!!!

Work supported by projects at the Dept. of Oceanography and Fisheries - Univ. of the Azores (DOP/UAç)

- **CLIPE** - Climatic effects on the ecology of littoral fishes: A geographic and phenological approach (PRAXIS-XXI/3/3.2/EMG/1957/95).
- **MAREFISH** - Benefits of marine protected areas: testing the theory with field experiments (POCTI/BSE/41207/2001).
- **EMPAFISH** – European marine protected areas as tools for fisheries management and conservation (FP6 2003 SSP3 – P006539).
- **MARÉ** - Integrated Management of Coastal and Marine Areas in the Azores (Life-Nature B4-3200/98/509).
- **MAROV** - Coastal Marine Habitats, Thematic Mapping of the Seabed Using GIS, AUV & ASV. (PDCTM/P/MAR/15249/1999).
- **MAYA** - Development of a Miniaturized Autonomous Underwater Vehicle for Habitat Mapping (AdI/POSI/2003).
- **OGAMP** - Management of Marine Protected Areas in Macaronesia (Azores, Canaries and Madeira) (INTERREG IIIb - MAC/4.2/A2 2001).
- **MARMAC** - Knowledge, Promotion and Valorisation for a Sustainable Use of Marine Protected Areas in Macaronesia (INTERREG IIIb - 03/MAC/4.2/A2 2004).
- **MARINOVA** - Marine Aquaculture and Artificial Reefs: New models of integrated production (INTERREG IIIb/MAC/4.2/M11)

This study is funded by the European Union 6th Framework Programme through a Marie Curie Research Training Network (Project Freesubnet, MRTN-CT-2006-036186)