ENSURING THE SURVIVAL OF ENDANGERED PLANTS IN THE MEDITERRANEAN

Zelkova sicula

Future challenges for plant conservation in the Mediterranean islands

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cnrs

IRD Institut de recherche pour le développement

Importance of Mediterranean islands for conservation issues

The unique nature of Mediterranean islands

- The Mediterranean encompass one of the largest number of islands in the world: ≈ 15.000 to 20.000 islands and islets (244 inhabited), ≈ 1200 in the western basin.

- Complex biogeographical histories (palaeogeography)

- Highly diversified insular conditions resulting from different geographical situations, and wide ranges of size (from the biggest island of Sicily with 25,700 km^2 to small islets of few dozen square meters), altitude (from 3342 m at the Mt. Etna to flat islets of only few meters), shape and geology.

Complex influence of biogeographical events

Syst. Biol. 57(2):269–285, 2008
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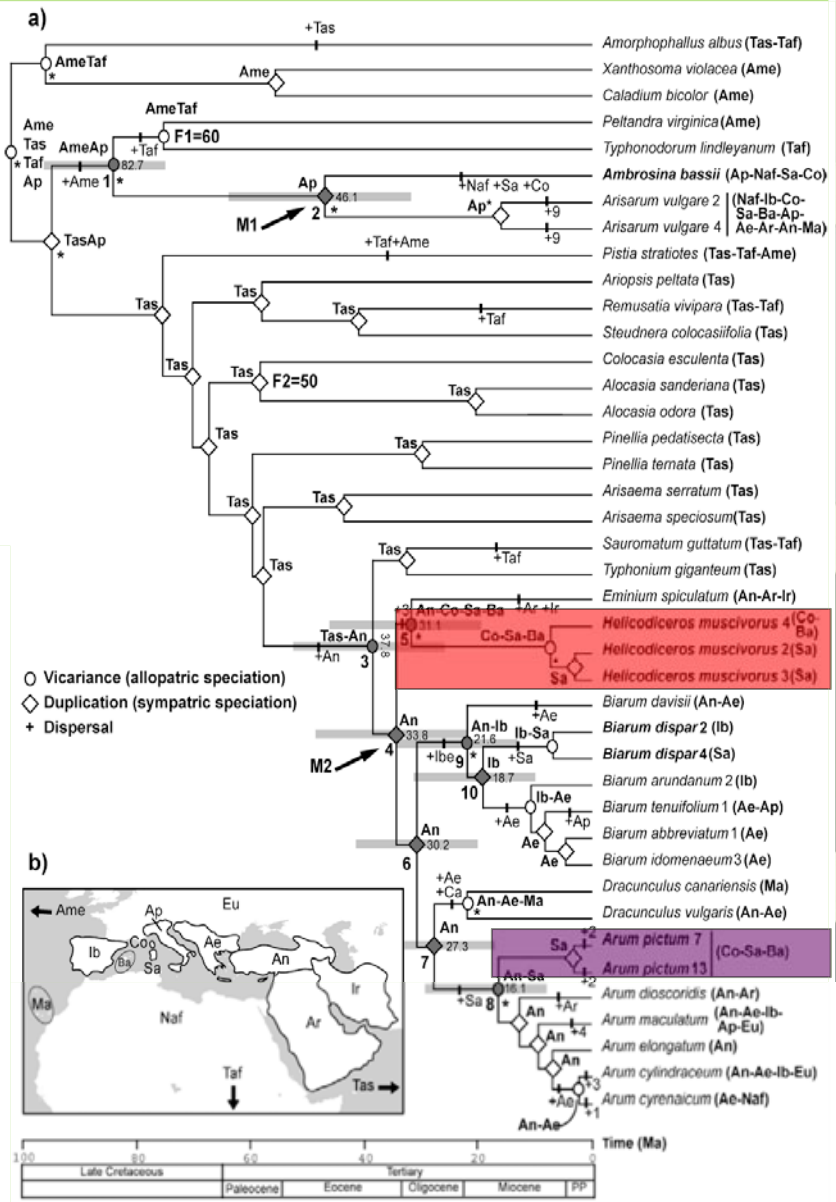
ISSN: 1063-5157 print / 1076-836X online
DOI: 10.1080/10635150802044029

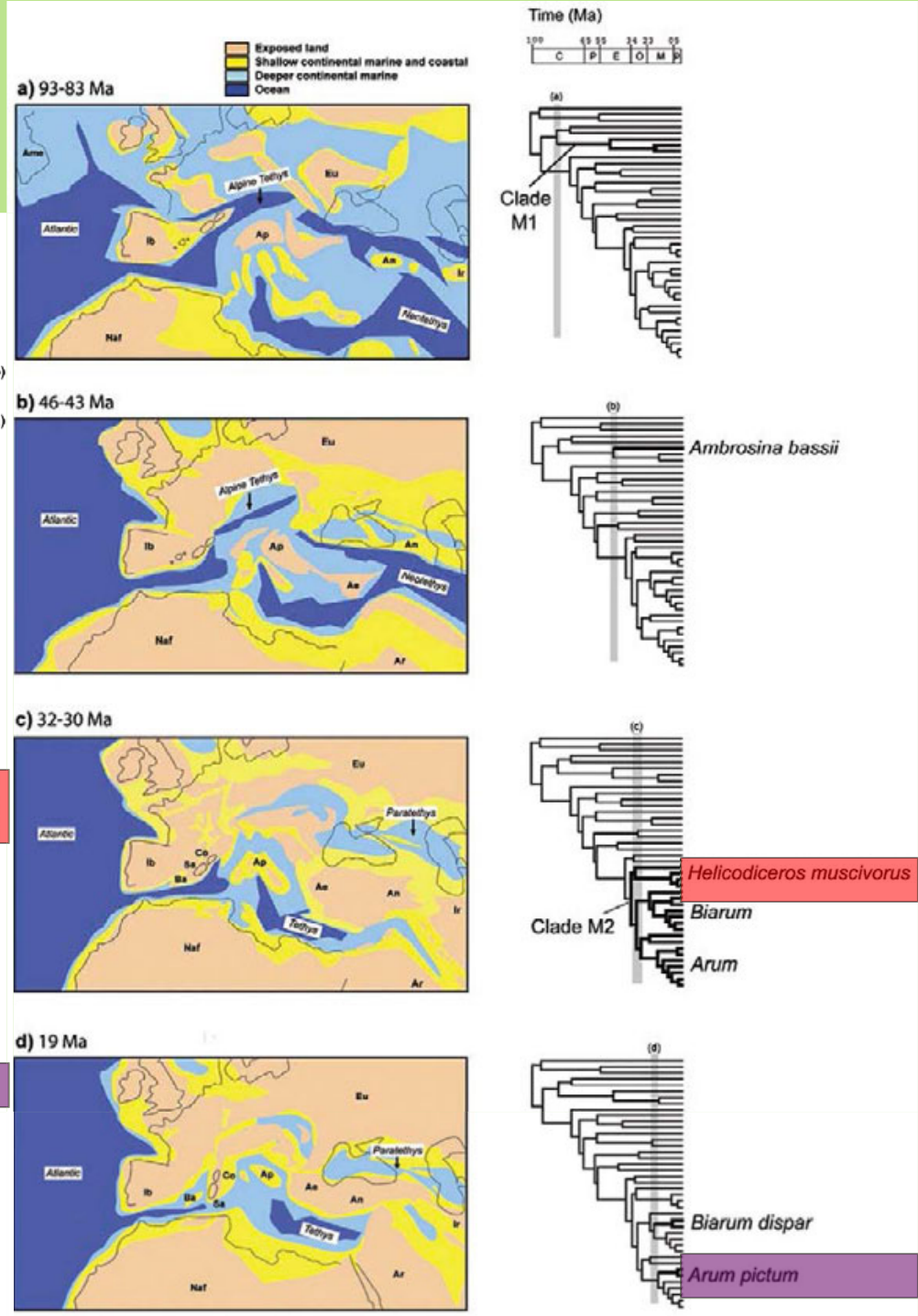
Phylogenetic Analysis Informed by Geological History Supports Multiple, Sequential Invasions of the Mediterranean Basin by the Angiosperm Family Araceae

GUILHEM MANSION,[1] GIDEON ROSENBAUM,[2] NICOLA SCHOENENBERGER,[3] GIANLUIGI BACCHETTA,[4] JOSEP A. ROSSELLÓ,[5] AND ELENA CONTI[1]

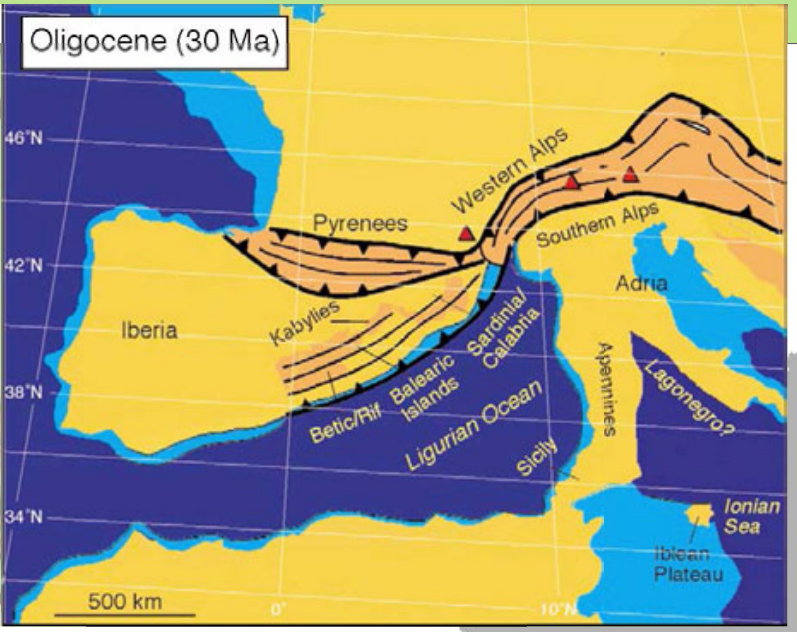
Helicodiceros muscivorus
(ca. 30 Myr)

Arum pictum
(ca. 15 Myr)





Mediterranean islands, current refugia of ancient lineages



Distribution of *Delphinium pictum* and *requienii* illustrating the areas of the former Protoligurian Massif

annual

Delphinium requienii

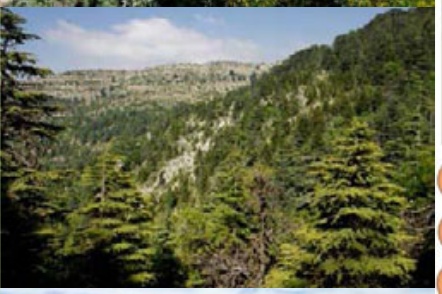
bisannual

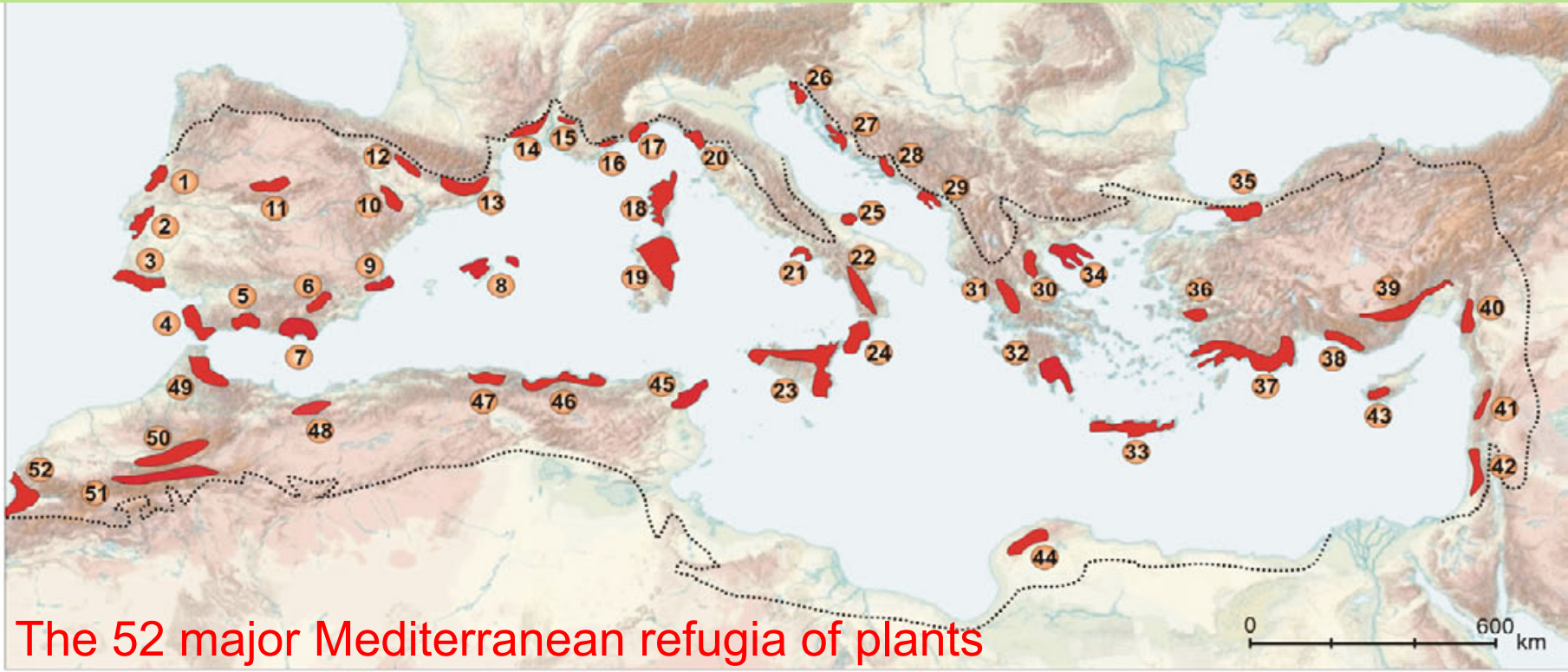
Delphinium pictum

perennial

bisannual

7 major insular refugia of plants according to phylogeography

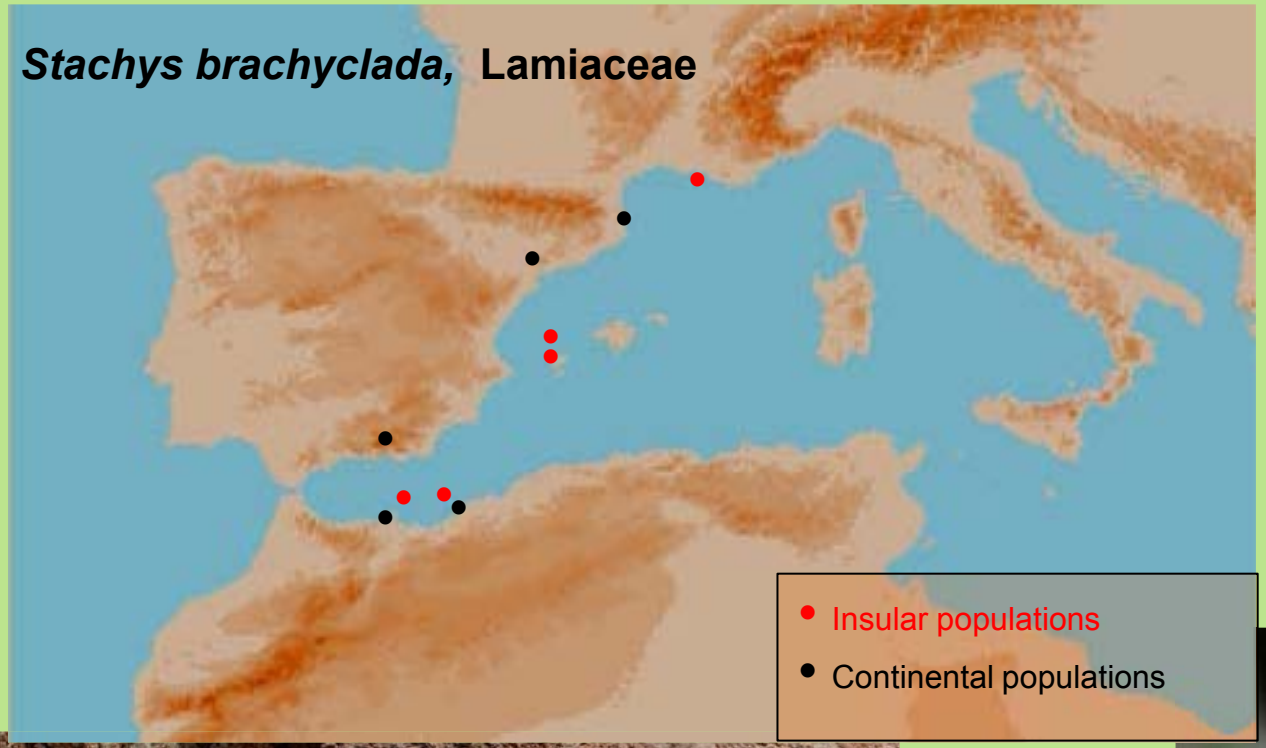


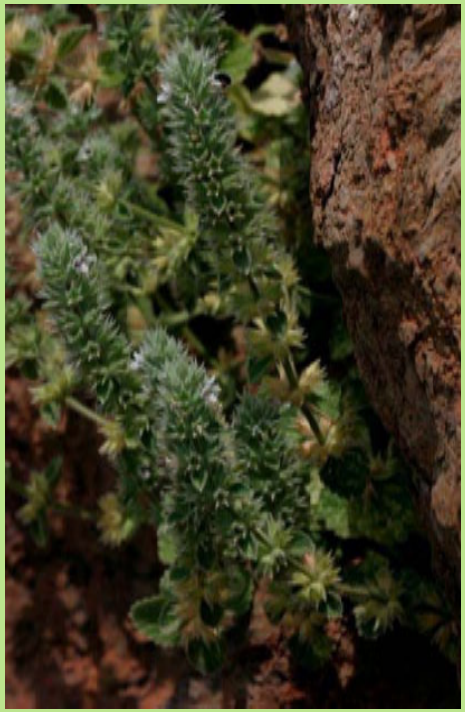


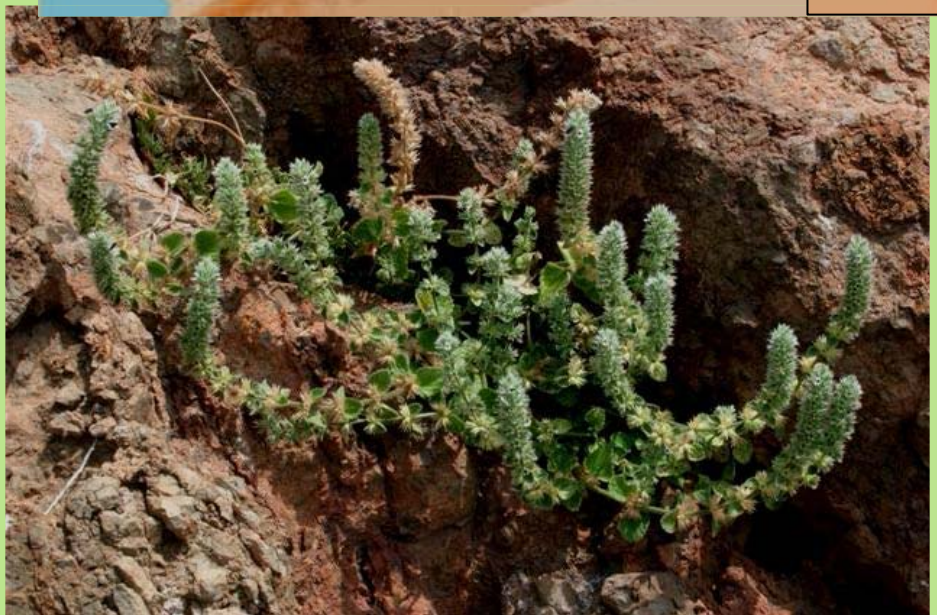
1 Beira litoral
2 Estramadura
3 Algarve
4 Cadiz/Algeciras region
5 Serrania de Ronda
6 Sierra Cazorla/Segura
7 Sierra Nevada/Gata
8 Balearic islands
9 Valencia region
10 Ebro valley
11 Sistema central
12 S. Pyrenees
13 S.E. Pyrenees
14 S. Cévennes
15 Mont Ventoux
16 E. Provence
17 Maritime Alps
18 Corsica
19 Sardinia
20 Alpi Apuani
21 Campania
22 Calabria
23 Sicilia
24 Aspromonte
25 Gargano
26 N. Istria
27 Velebit mountains
28 S. Bosnia/Biokovo
29 Montenegro
30 Olympe/Katalympos
31 C. Greece (Pindos)
32 Peloponnese
33 Crete
34 Chalkidiki peninsula
35 Izmit region
36 Boz/Aydin dag
37 S.W. Anatolia
38 C. Taurus
39 E. Taurus
40 Amanus
41 Lebanon range
42 Israel/Palestine
43 Cyprus
44 Cyrenaic (Lybia)
45 J. Zaghouan/Cap Bon
46 Petite Kabylie/de Collo
47 Grande Kabylie
48 Tlemcen mountains
49 Rif mountains
50 Middle Atlas
51 High Atlas
52 Souss/W. Anti-Atlas

Médail F. & Diadema K., 2009. *Journal of Biogeography*, 36.

Current refugia of very threatened plants on the continent





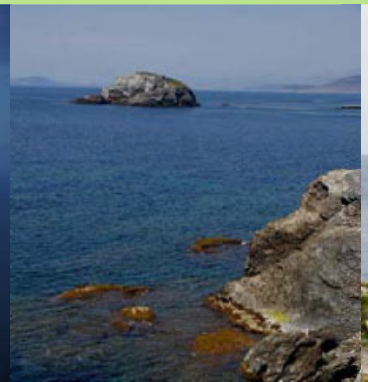


Photos E. Vela

Ecological and functional importance of islands

Structuration / continent	Functioning
Plant communities with original floristic composition	Specific functional processes (flux, biotic interactions)
Poor communities with few redundant species	Impacts exacerbated by exogenous disturbances
Higher abundance of rare, endemic and relictuals species, often in range limit	Inflation density: relaxation of competition processes / expansion of ecological niches
Isolated populations, founded by few individuals	Processus of genetic differentiation (genetic drift, founding effects) and local adaptation
Communities subject to drastic ecological stress, with an important stochasticity	Huge spatio-temporal fluctuations of plant richness and composition





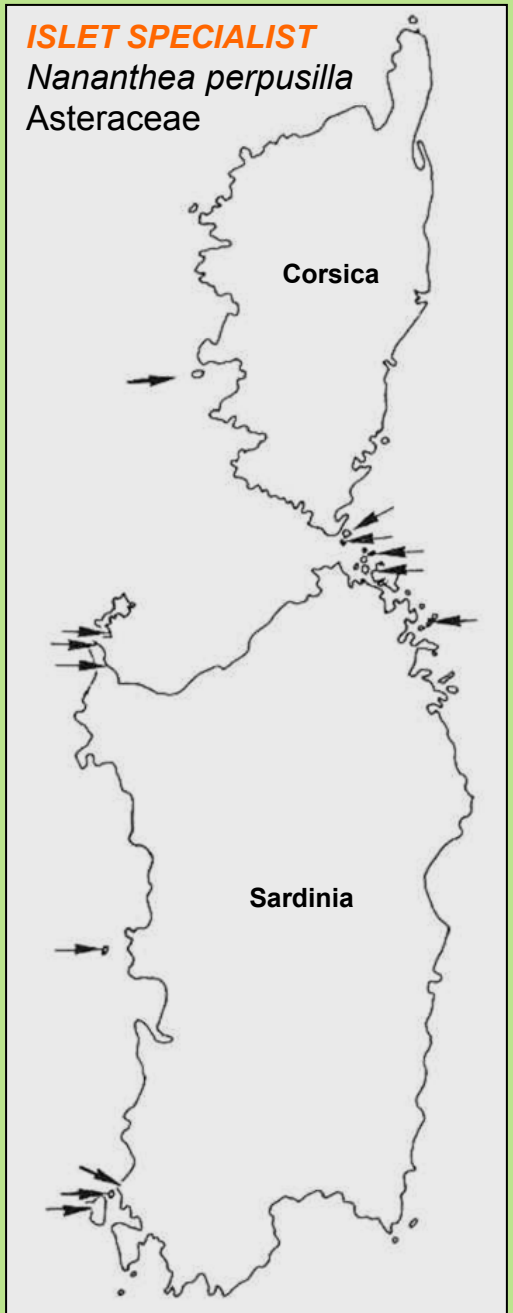

Conserving the unique flora of islands...
a disproportionate and highly complex task!

Each island or islet constitutes an unique biological entity...

Conservation and ecological monitoring of islands must be reinforced because of:

- Major refugia areas: presence of relictual or endemic plants, often threatened on the continent.

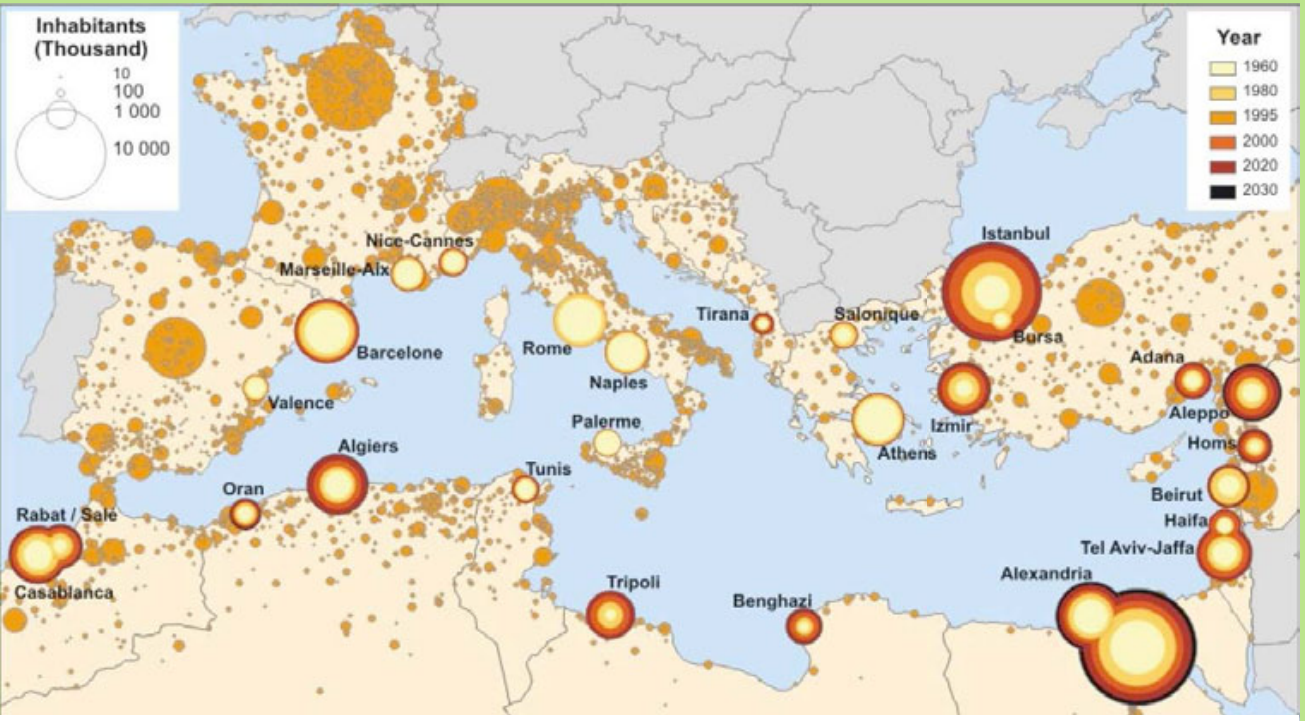
- Ecological uniqueness: even close islands show very different plant species composition and plant assemblages differ from those of coastal areas of the continent, even similar from a physiognomical point of view.



Putative impacts of global change

Main threat induced by the increase of human impacts

A huge increase (≈ 50%) of human population on coastal areas



Population changes (1960-2000) and projections to 2030, for the main cities of the Mediterranean countries.

19000 km of insular coasts = 41%
(/ a total of 46000 km of coasts)

375 millions of tourists projected by 2020 in the Mediterranean area

Putative impacts of global change on Mediterranean ecoregions

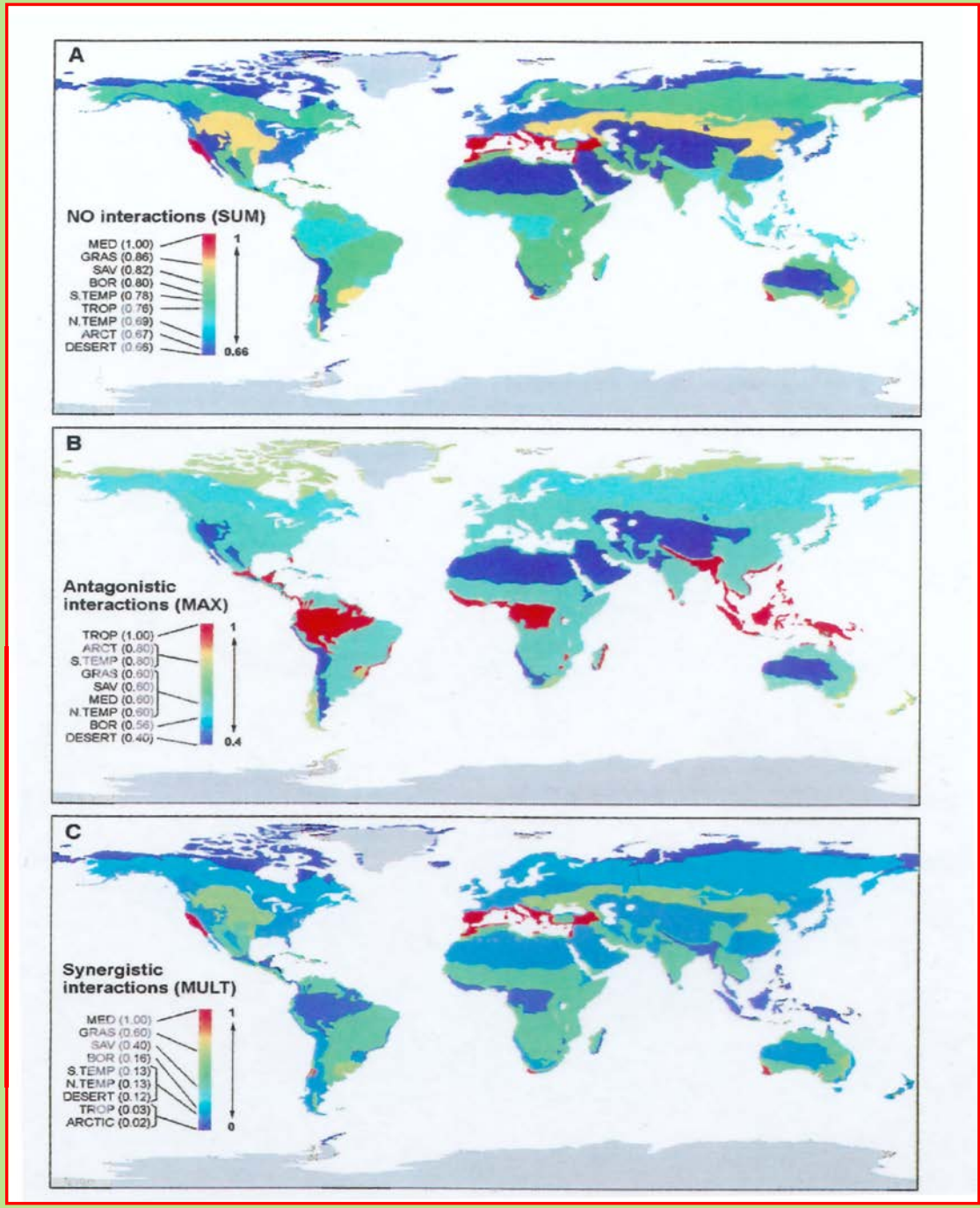
3 scenarios of expected change in biodiversity for the year 2100, in case of null (A), antagonistic (B) or synergistic (C) interactions.

According to different drivers:

- **Biotic exchanges**
- **Land-use changes**
- **Nitrogen deposition**
- **Atmospheric CO_2 deposition**
- **Climatic changes**

« The Mediterranean biome is projected to experience the largest proportional loss of biodiversity of all terrestrial biome due to its significant sensitivity to multiple biodiversity threats and interactions among these threats »

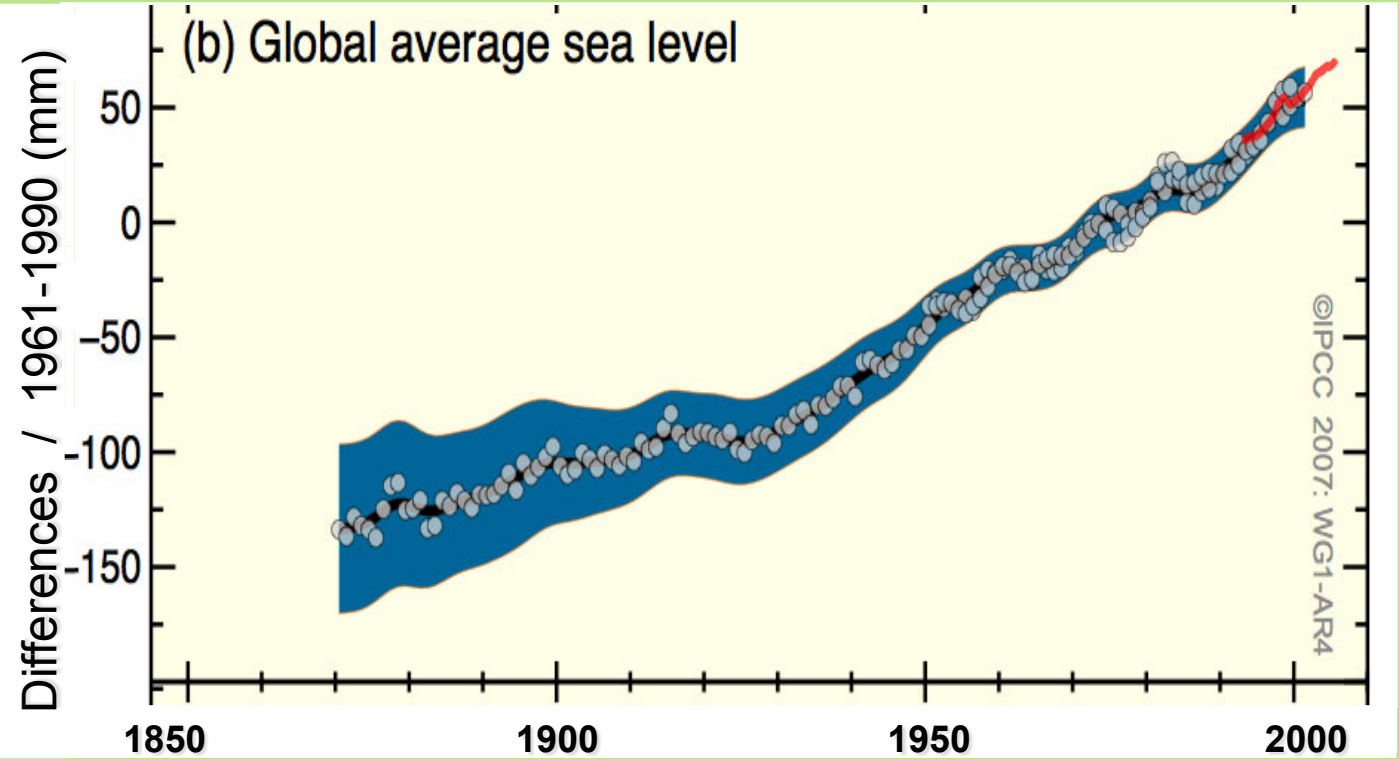
Klausmeyer & Shaw, 2009. PLoS ONE,4.



Sala O.E. *et al.*, 2000. *Science*, 287.

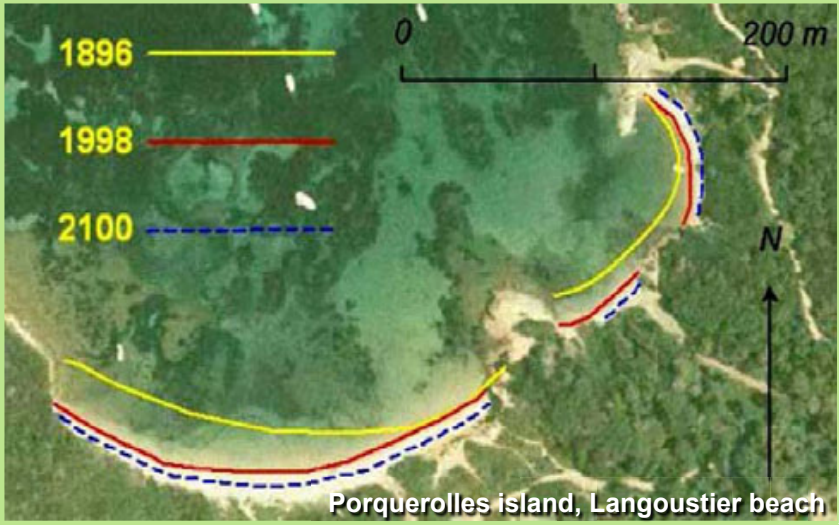
Difficulties to include uncertainties linked to global change

Increase of global average sea level: threat on flat islands and pocket beaches




Kerkennah islands (southern Tunisia)

Pocket beach vulnerability to sea-level rise in Provence



Porquerolles island, Langoustier beach

- Between 1896 and 1998
Average retreat of the shoreline of 12,1 ± 3,5 m with 5,8 ± 3,5 m induced by sea-leval rise (+ 11 cm between 1896 and 1998)

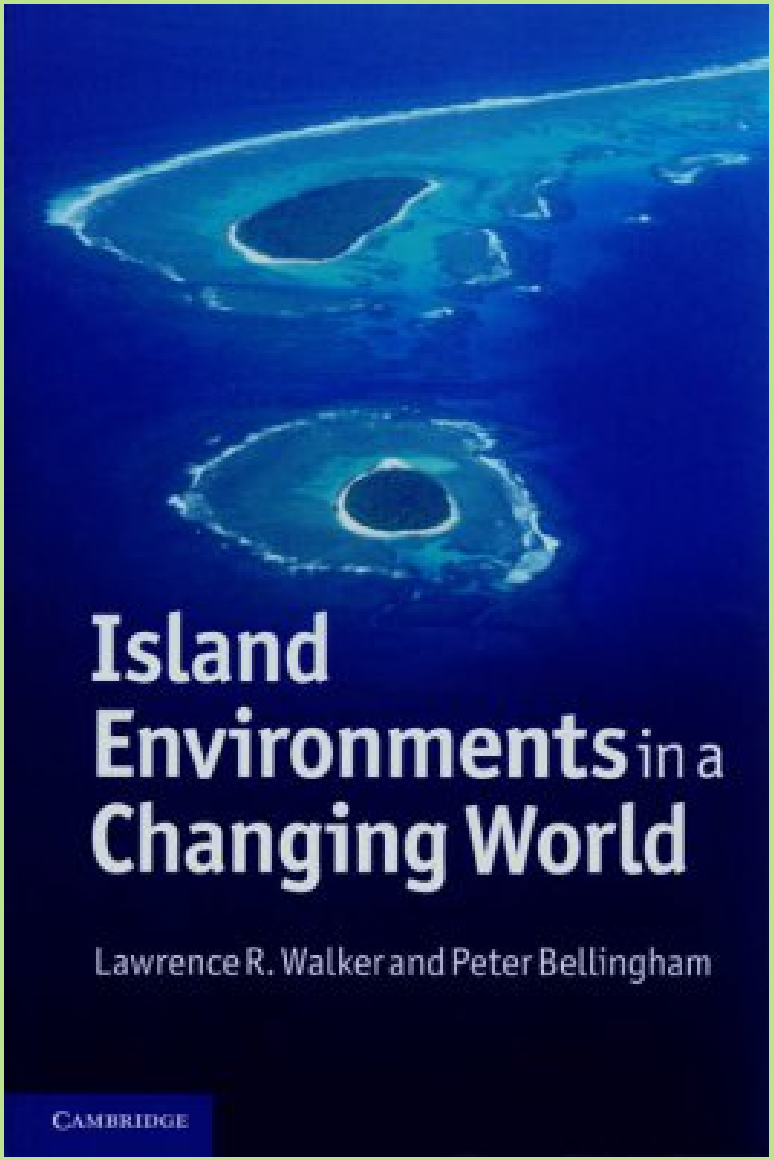
- En 2100
In the case of an increase in sea-level of about + 44 cm: quasi disappearance of pocket beaches (regression of 75-97% of their present surface area).

Brunel & Sabatier, 2007. *Journal of Coastal Research*, SI 50.

Difficulties to include uncertainties linked to global change

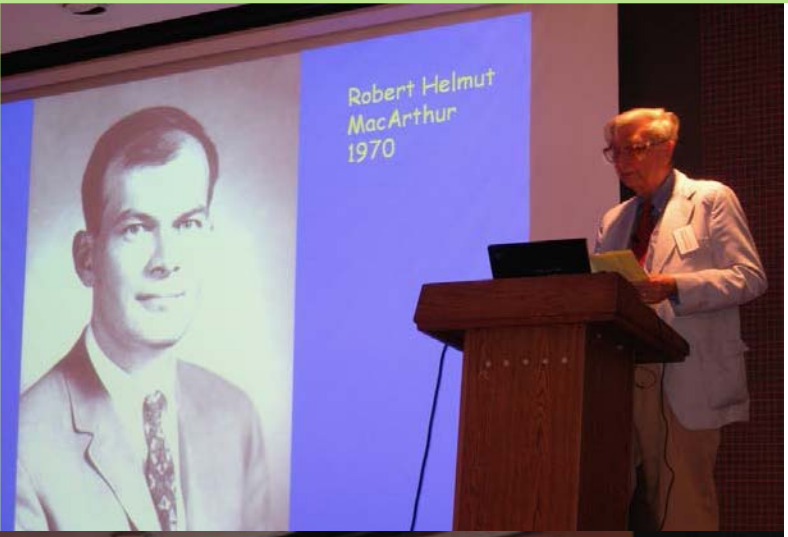
- Uncertainties of vegetation and species' range shifts under climate change and climate adaptation potential of species
- Uncertainties in the rate of habitat conversion
- Uncertainties about the future role of current protected areas

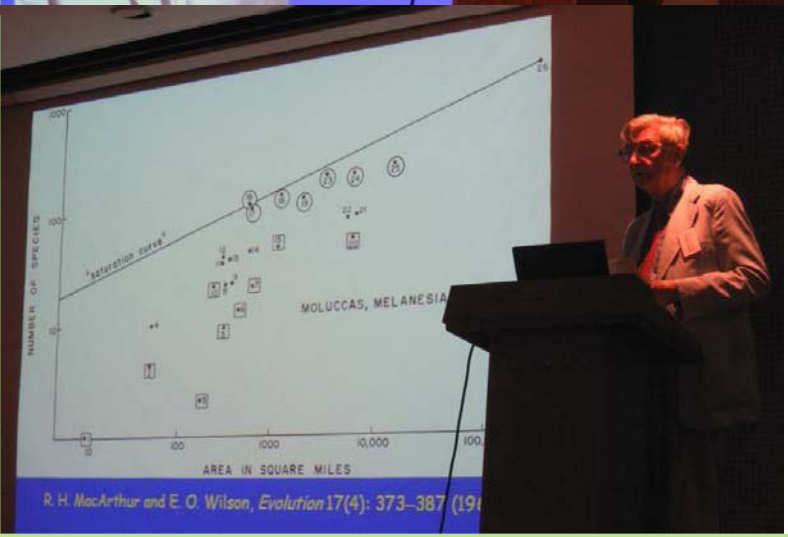
➔ These impacts will be probably exacerbated on islands because of no (or highly limited) adjacent areas of expansion



Some key issues for future researches

A robust scientific theory for insular biogeography





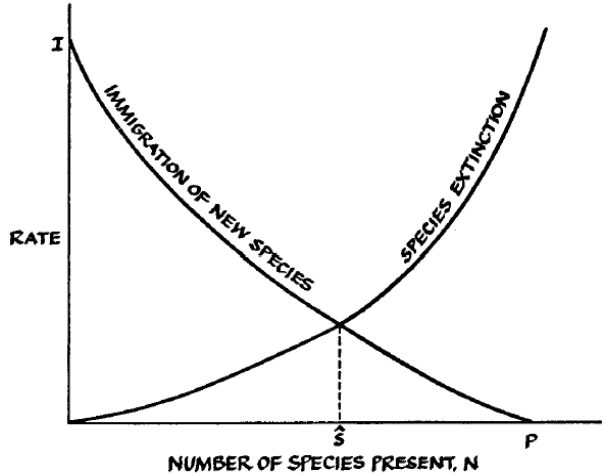


Figure 1. Equilibrium model of a biota of a single island (From MacArthur and Wilson 1967).

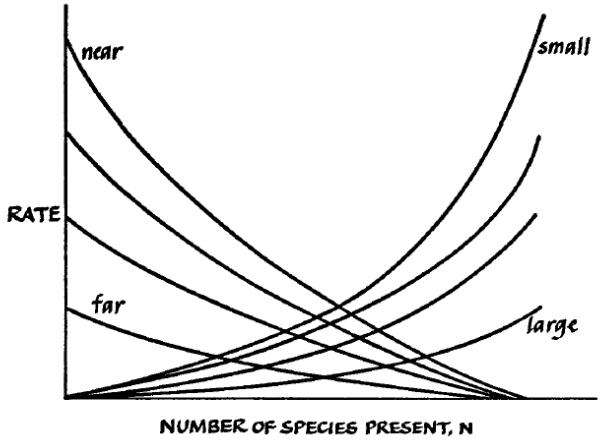
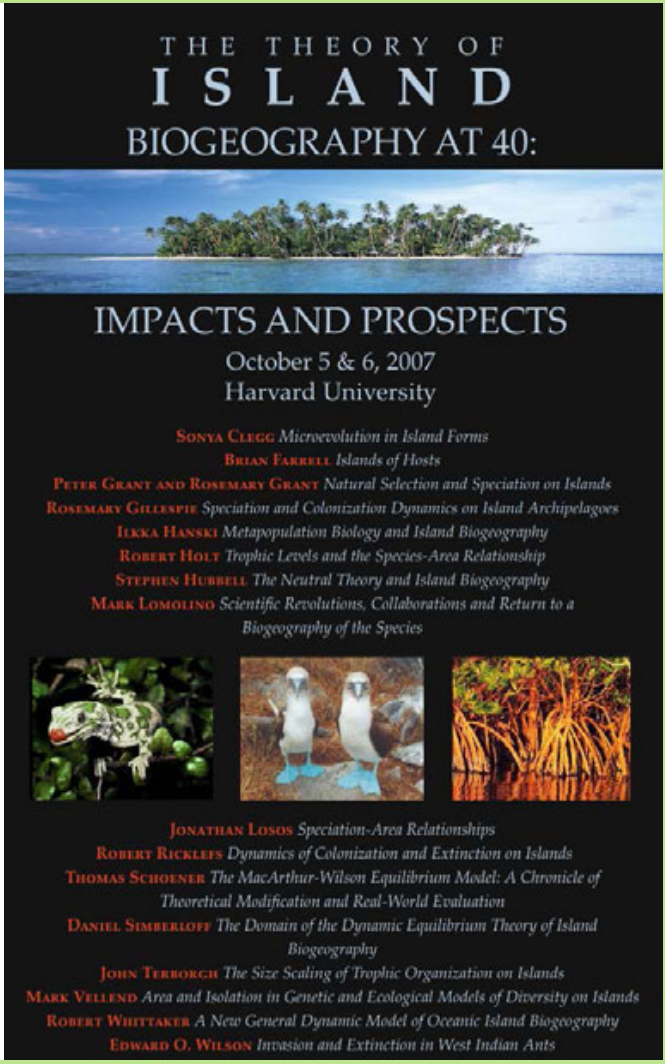


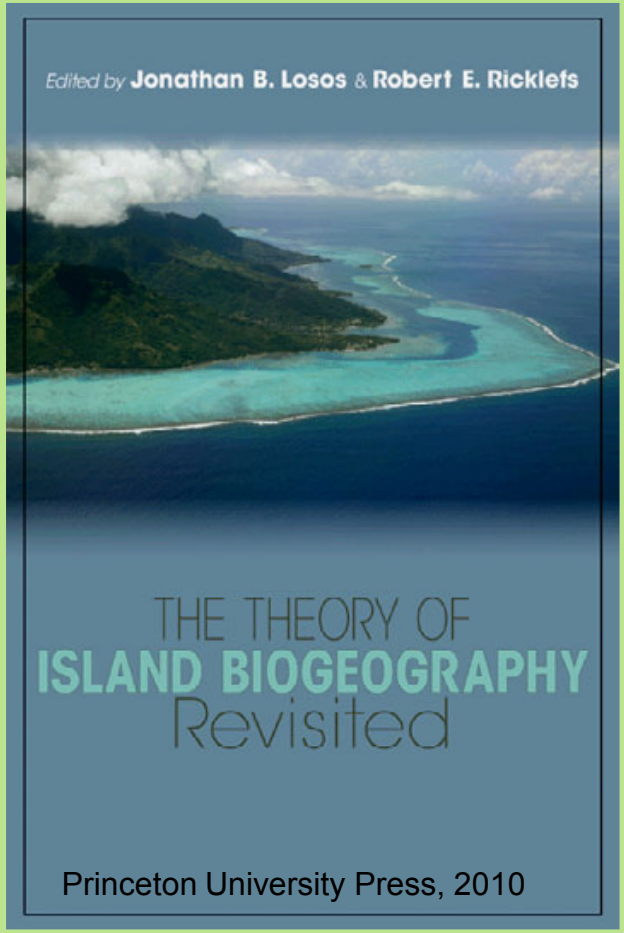
Figure 2. Equilibrium models of biotas of several islands of varying distances from the principal source area and of varying size (From MacArthur and Wilson 1967).



Evidences to include evolution in the island theory

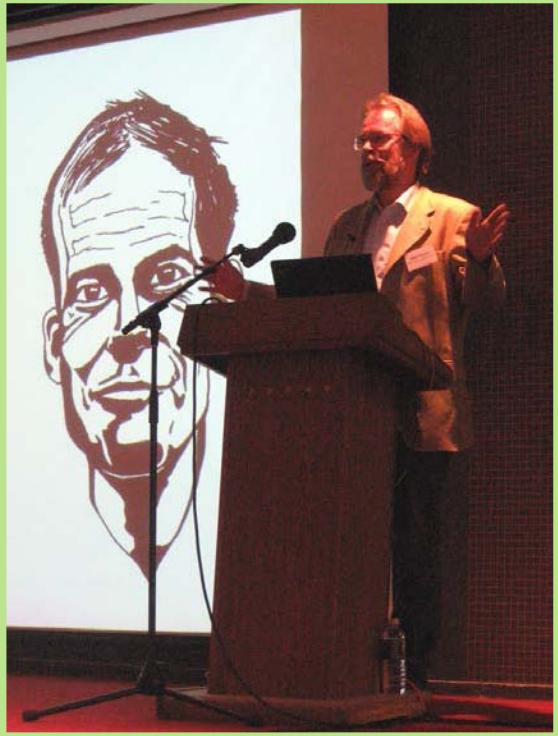
« MacArthur & Wilson island theory is a special case of Metapopulation General Model »

MacArthur & Wilson's Theory of Insular Biogeography

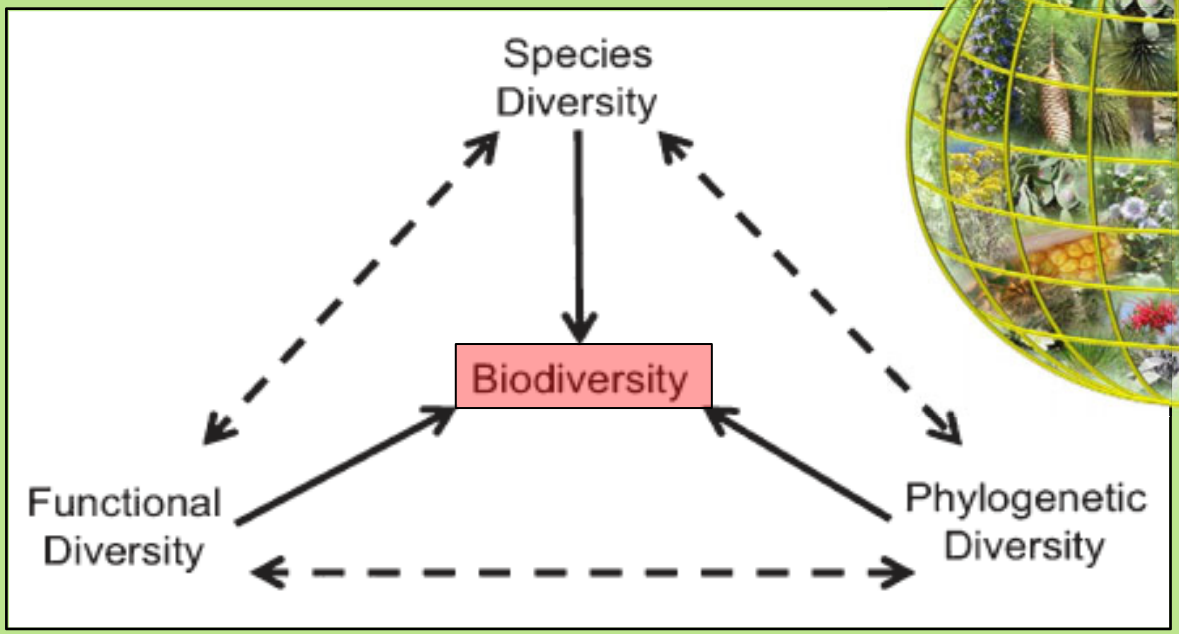


Metapopulation Ecology & Biology

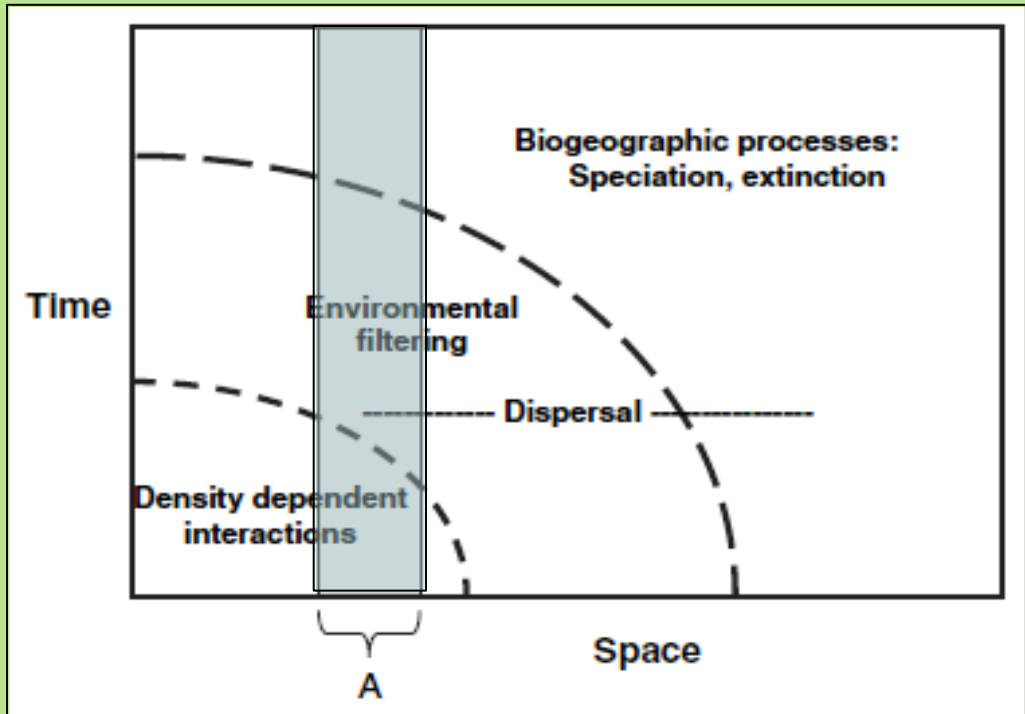
Spatial Ecology & Evolutionary Biology



Need to consider the different biodiversity levels



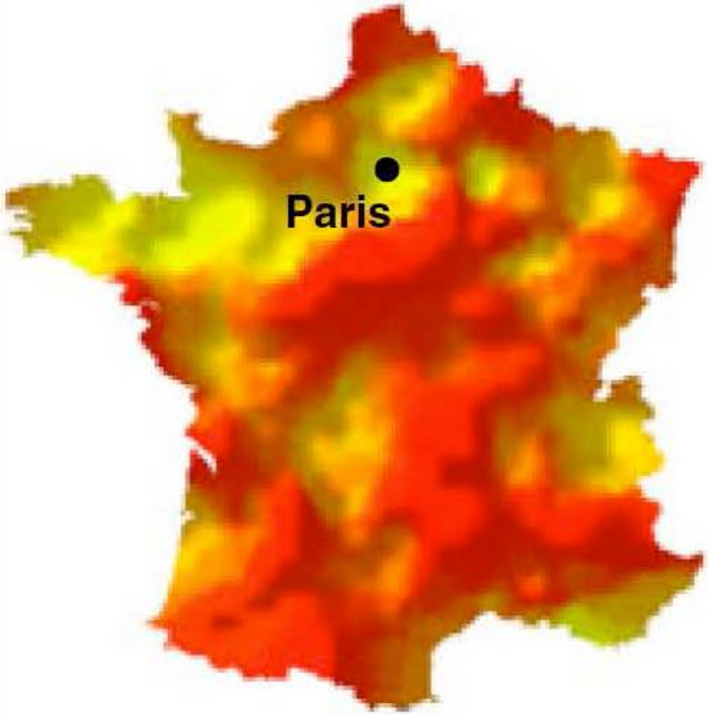
Taxonomic diversity:
- not sufficient to develop a more proactive approach of biodiversity conservation
- uninformative about functional and phylogenetic differences among species or populations



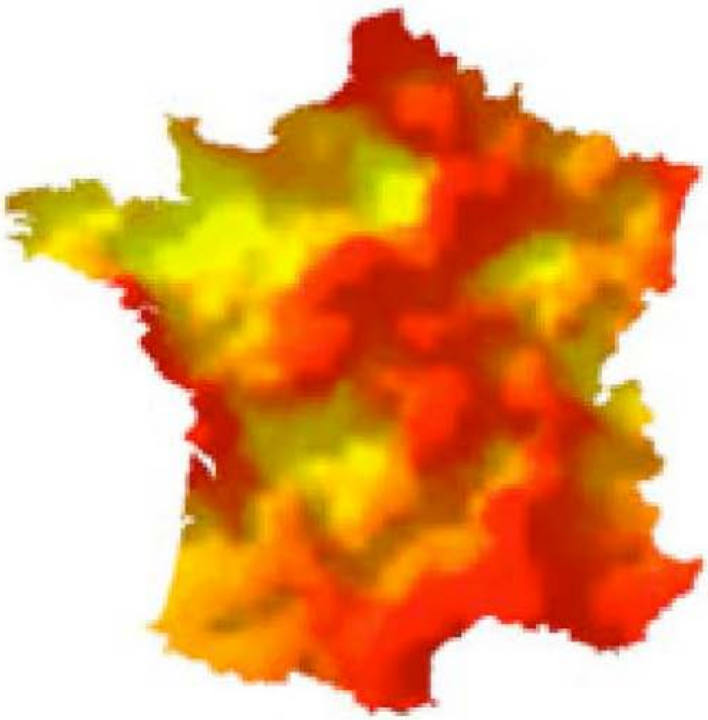
Need to test the spatial congruence of ≠ biodiversity levels

Spatial distribution of 3 diversity levels for terrestrial breeding birds in France

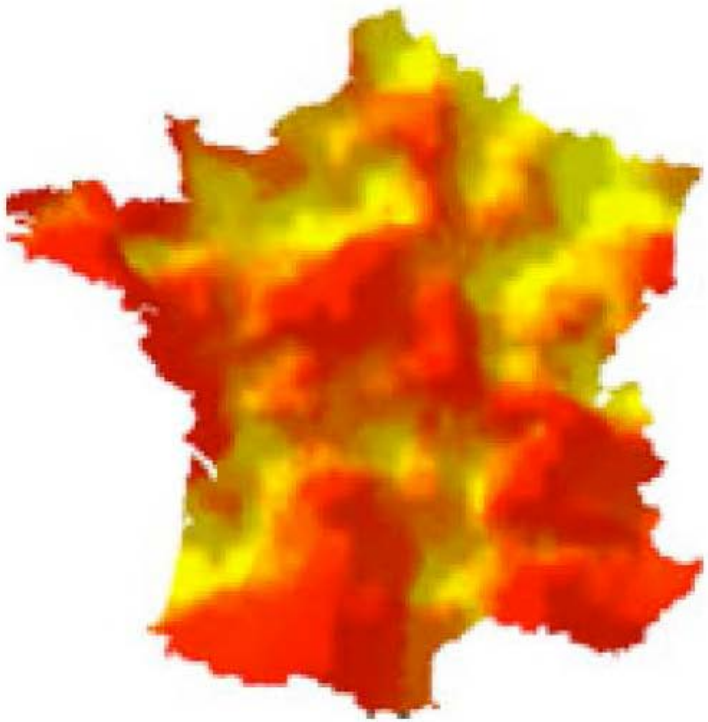
Taxonomic diversity

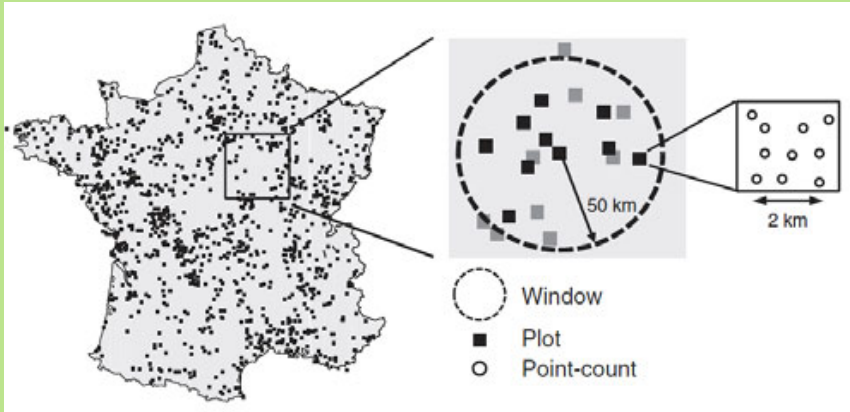


Phylogenetic diversity



Functional diversity





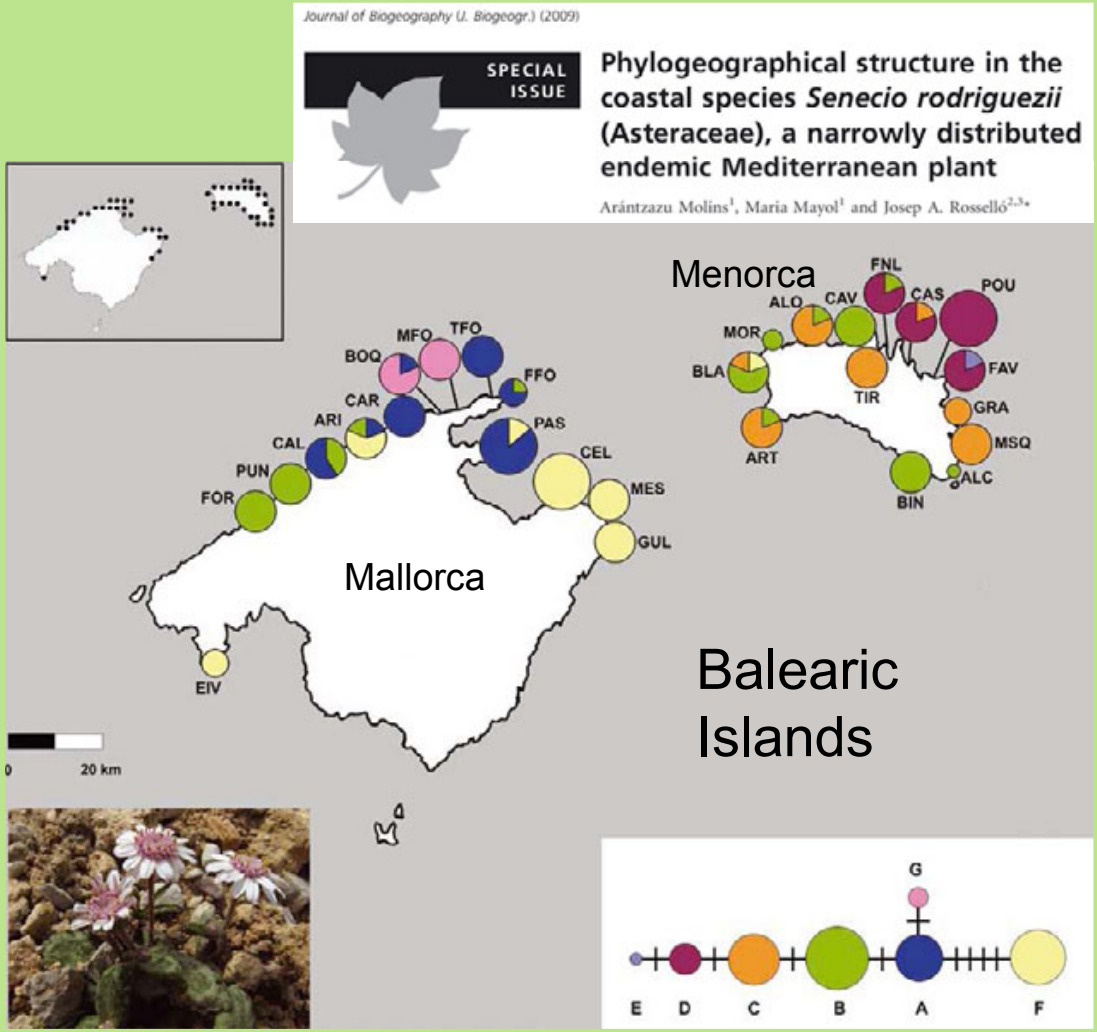
Devictor V. *et al.*, 2010. *Ecology Letters*, 11.

Needs to develop fine and local phylogeographies

Mediterranean islands constitute a significant reservoir of genetic diversity, not only for widespread Mediterranean plants, but also for endemic ones

Importance of phylogeography for conservation planning on the island's scale:

- To predict hotspots of endemism
- To distinguish cryptic diversity
- To discover independently evolving lineages



Geographical distribution and parsimony network relationships of seven chloroplast haplotypes found in *Senecio rodriguezii*

Needs to develop fine and local phylogeographies

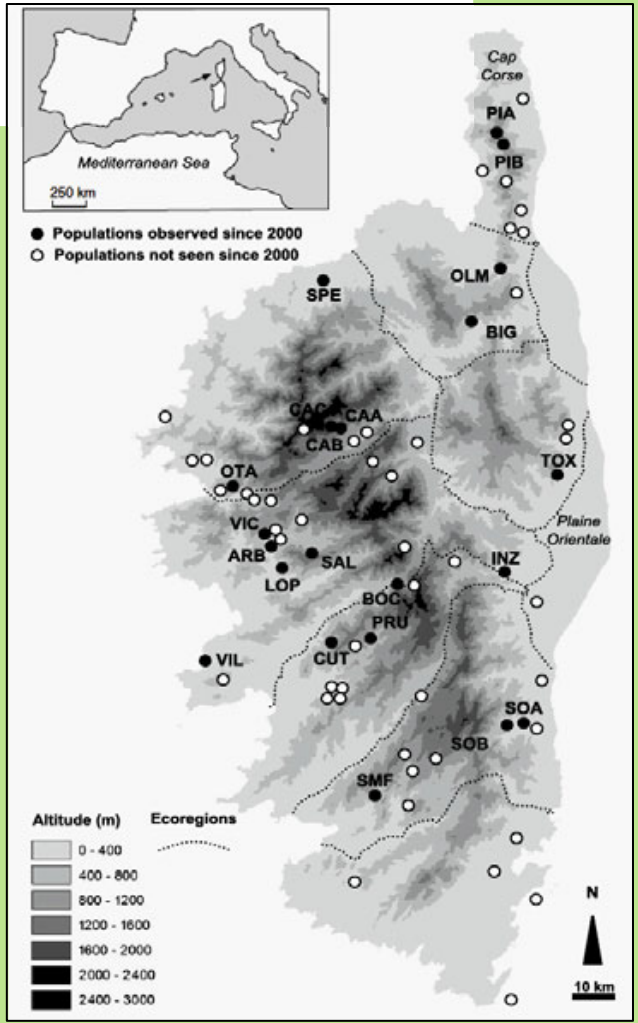
Phylogeography / population genetics and the distinction of ESUs

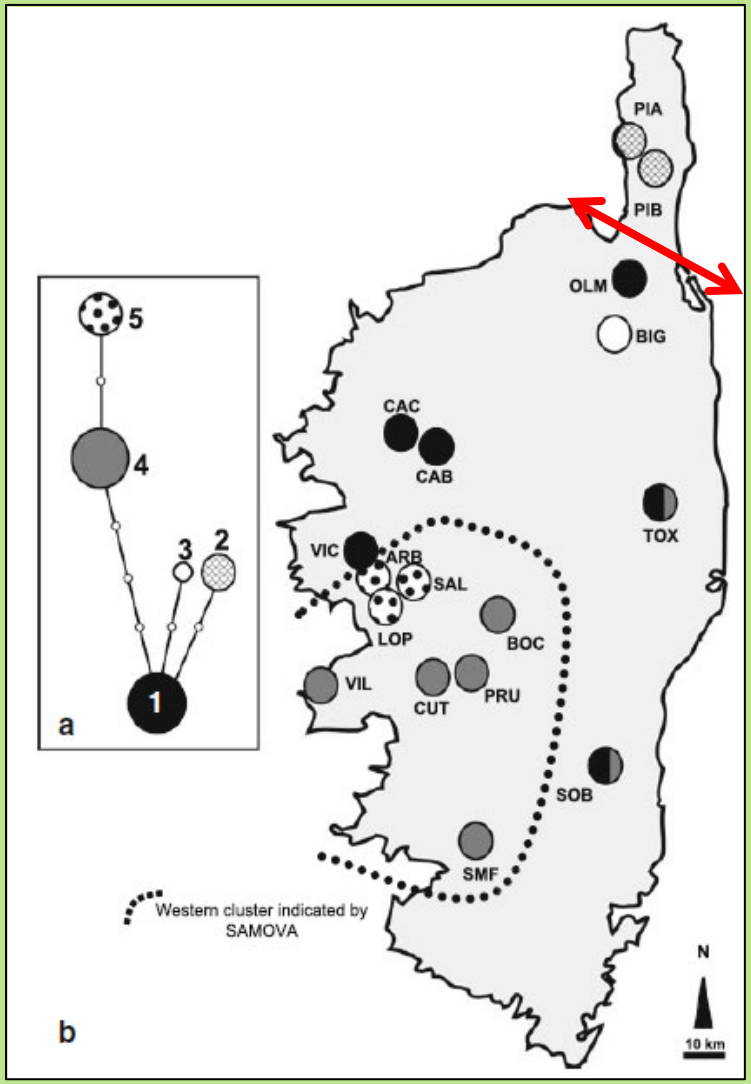
Popul Ecol
DOI 10.1007/s10144-011-0266-5

ORIGINAL ARTICLE

Genetic diversity and structure of a Mediterranean endemic plant in Corsica (*Mercurialis corsica*, Euphorbiaceae)

Jérémy Migliore · Alex Baumel · Marianick Juin · Katia Diadema · Laetitia Hugot · Régine Verlaque · Frédéric Médail





Collectivité Territoriale de Corse
Office de l'Environnement de la Corse

The need to reconstruct palaeoenvironment and ancient human impact

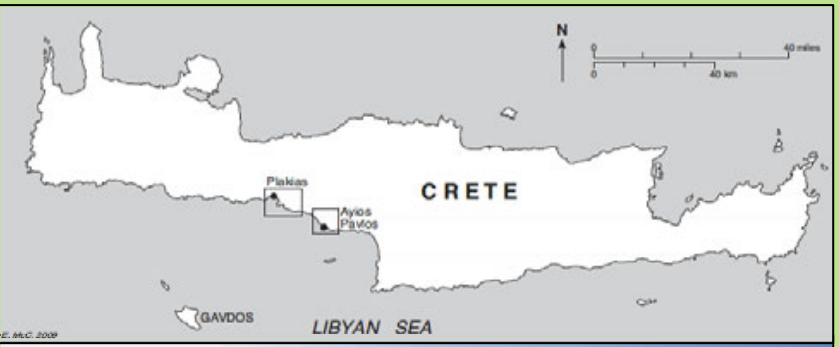
An astonishing early colonisation of Crete by seafaring during the Palaeolithic

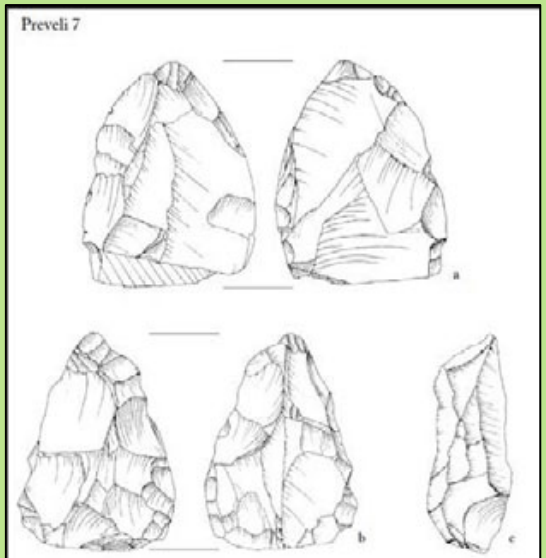
HESPERIA 79 (2010)
Pages 145–190
Thomas F. Strasser *et al.*

STONE AGE SEAFARING IN THE MEDITERRANEAN

EVIDENCE FROM THE PLAKIAS REGION FOR LOWER PALAEOLITHIC AND MESOLITHIC HABITATION OF CRETE

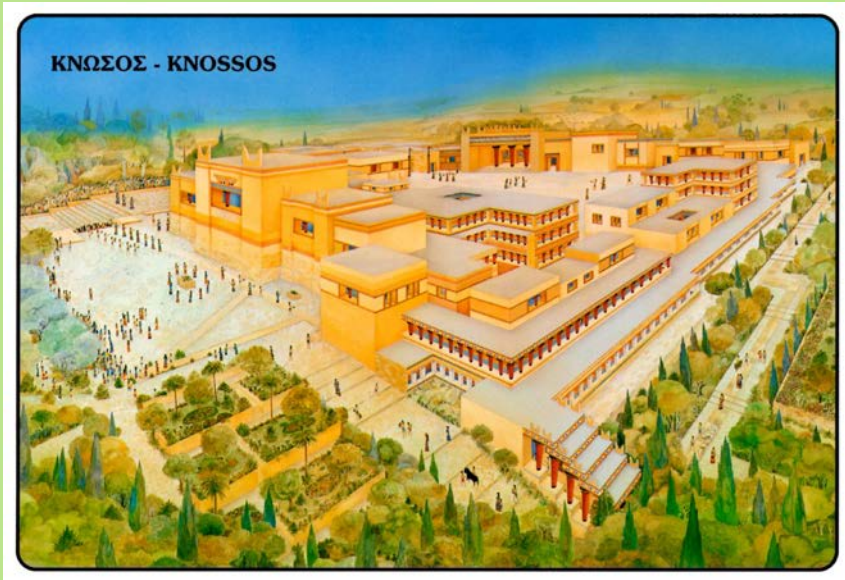
Lower Palaeolithic occupation dated to at least 130,000 years ago.
The early inhabitants of Crete reached the island using seacraft capable of open-sea navigation and multiple journeys.
A finding that pushes the history of seafaring in the Mediterranean back by more than 100,000 years!





Palaeolithic quartz artifacts

A good while after…
the Minoan phase (1900≈1450 BC)



Assessing functional diversity on island system

Linking biodiversity of a community to ecological function and the delivery of ecosystem services

➔ Needs to quantify the loss of functional diversity

➔ Needs to take into account biological interactions

➔ Biogeography of functional diversity loss?
FD is often correlated with island area, isolation index, elevation and island age

Probably, a putative dramatic loss of community function incurred by species extinction, especially on trophic-oversimplifyed small islands which exhibit particularly low resilience.

Fig. 2. *M. balearicus* skull (MNIB 81723) from Cova des Tancats (Menorca) in lateral view. The presence of a single evergrowing incisor, reduction of number of premolars and frontalization of eye orbits are some of the most important derived features in the skull of the species. Scale bar 2 cm.

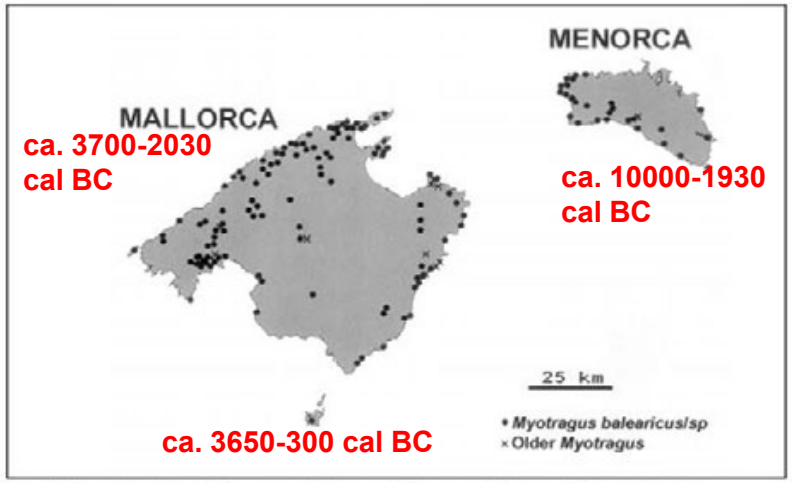


Fig. 2. Map of localities of *Myotragus* findings on Mallorca and Menorca (Balearic Islands).

Bover P. *et al.*, 2003. *Journal of Biogeography*, 30.

Assessing key biological interactions: the case of mutualistic disruptions on islands

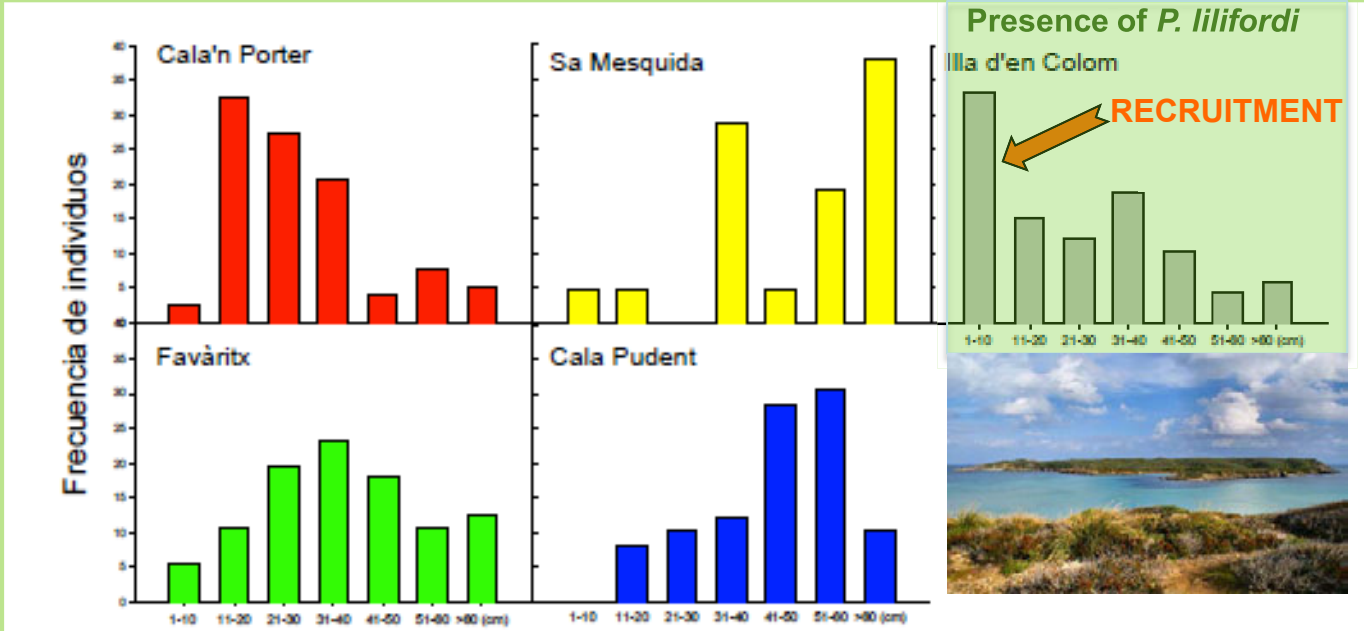
Plant Ecol (2010) 207:269–280
DOI 10.1007/s11258-009-9671-7

Seed dispersal effectiveness in a plant–lizard interaction and its consequences for plant regeneration after disperser loss

Javier Rodríguez-Pérez · Anna Traveset

What are the functional effects of extinction?

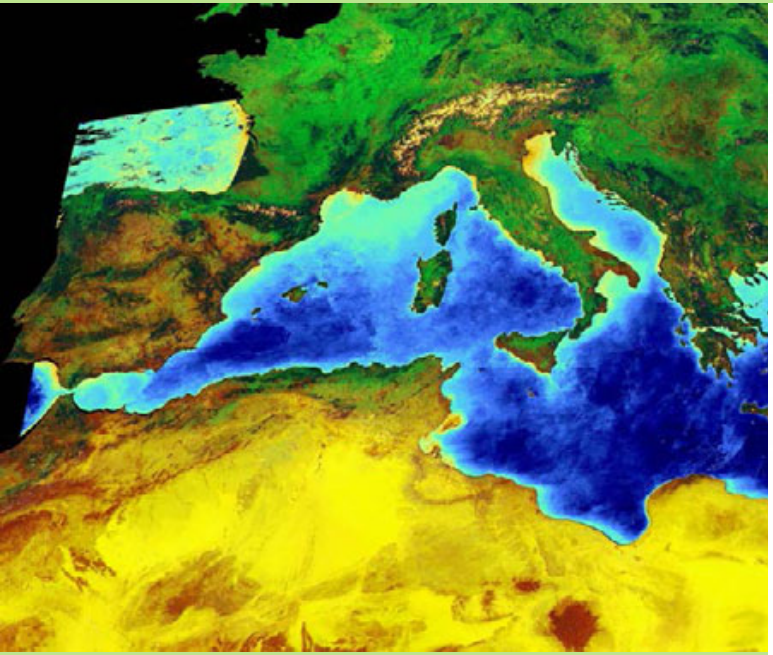
Introduction of carnivorous mammals in the Balearic Islands cause a dramatic mutualism disruption, between 2 Menorcan endemics: a plant *Daphne rodriguezii*, and a lizard *Podarcis lilfordi*.



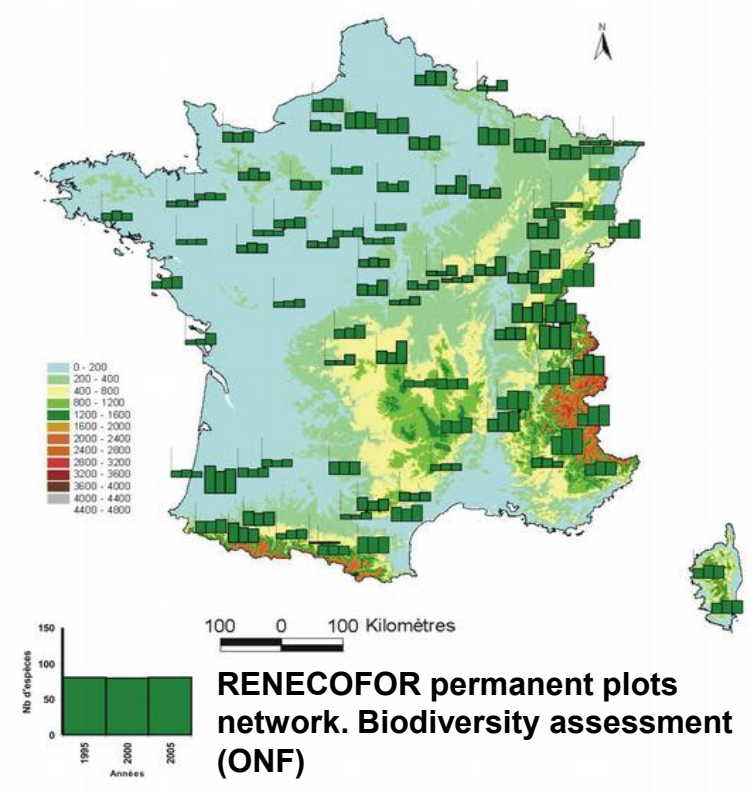
Plant size distribution for 5 populations of *Daphne rodriguezii*

Seed dispersal by lizards is the criticial stage that limits population expansion and seedling recruitment, drastically reducing its populations except in the Colom islet where lizards still persist.

The need for long-term observation and monitoring at various spatial scales



AVHRR vegetation index cover land and CZCS Ocean Colour phytoplankton concentration



RENECOFOR permanent plots network. Biodiversity assessment (ONF)

Eddy flux measurements over holm oak coppice (Puechabon, France)

- Inventoring, monitoring, observing vegetation and biodiversity status (observatories = a posteriori experiments)
- Assessing fluxes (CO_2,H_2O, VOC…)
- Networking long term research sites and observation plots (≈ LTER)
- Observation and monitoring should become integral part of management

Importance to develop biodiversity prediction

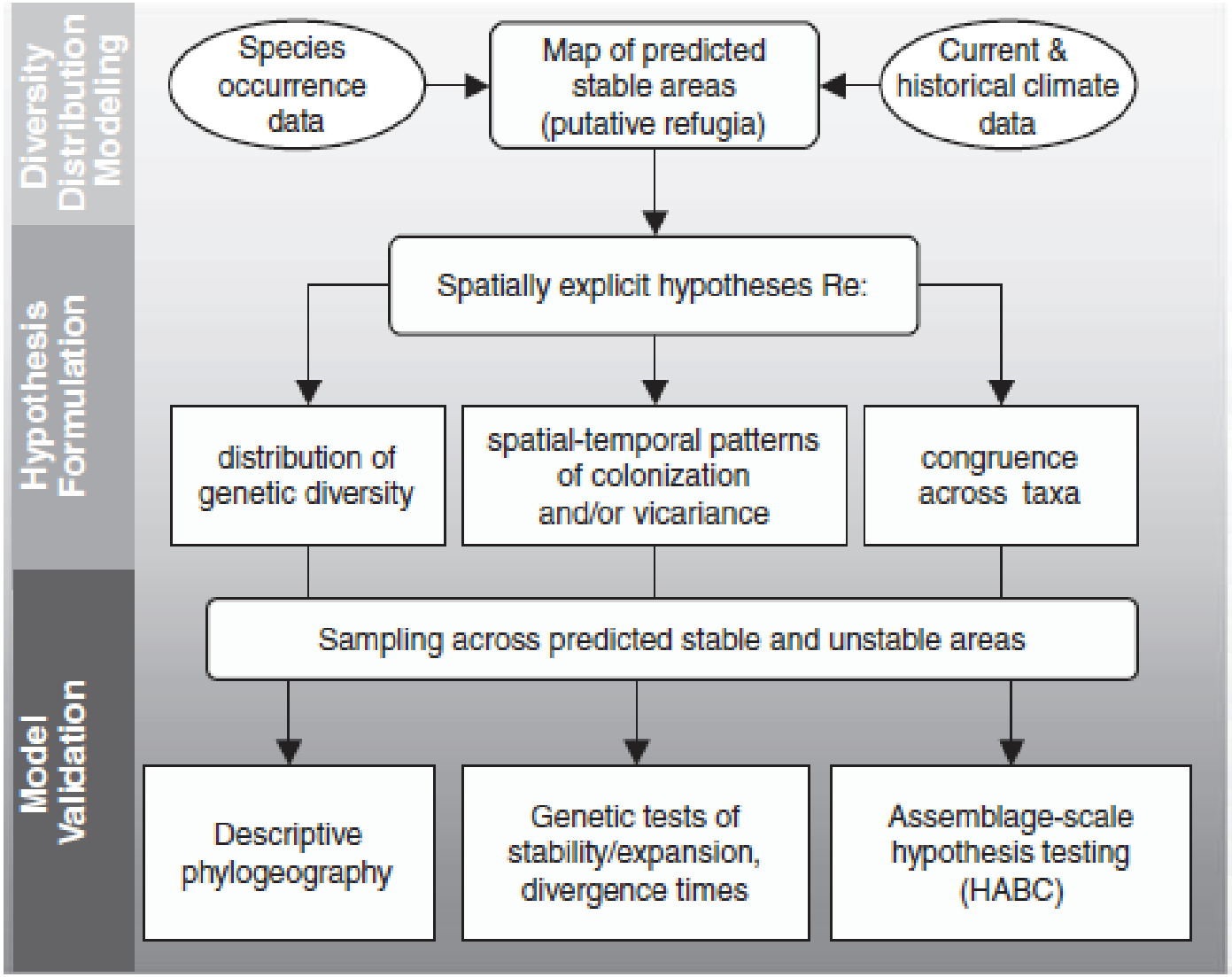
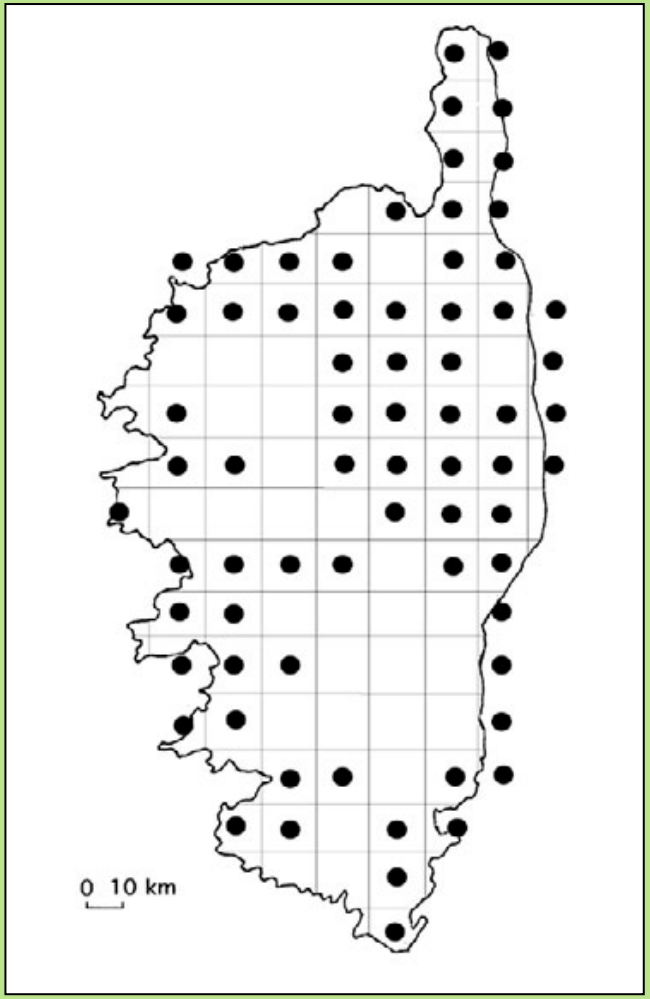


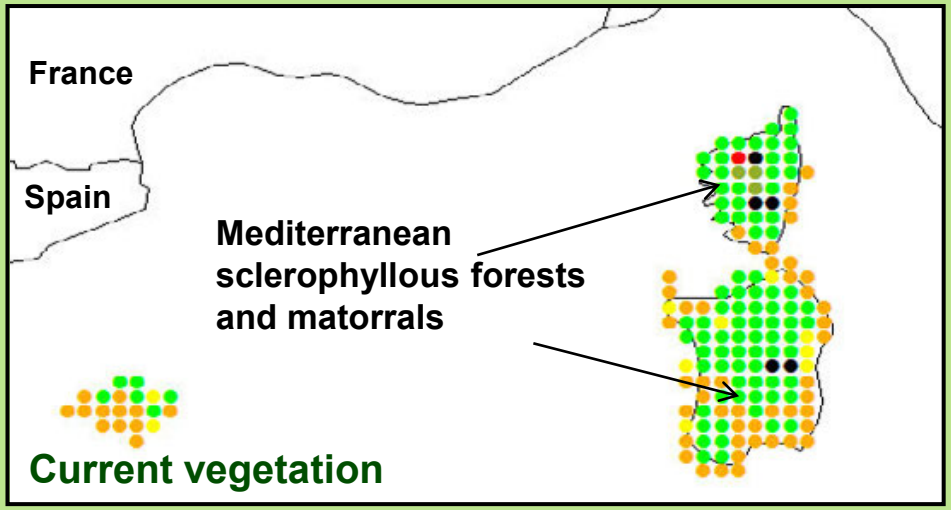
Fig. 1. Proposed method of biodiversity prediction. Three stages are involved: biodiversity distribution modeling (top), model-based hypothesis formulation (middle), hypothesis testing and model validation (bottom).

Carnaval *et al.*, 2009. *Science*, 323.

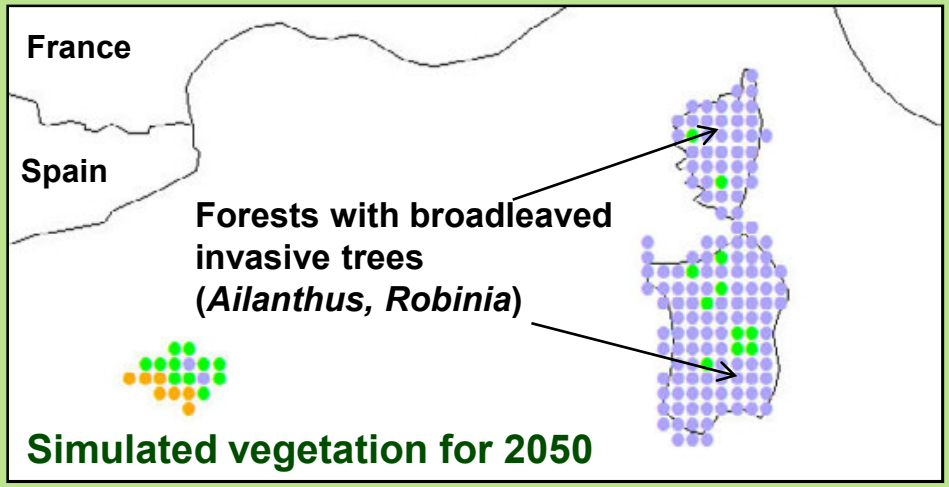
Modeling invasion in relation to land-use / climatic changes



Current distribution of *Ailanthus altissima* in Corsica
(UE project EPIDEMIE, IMEP)

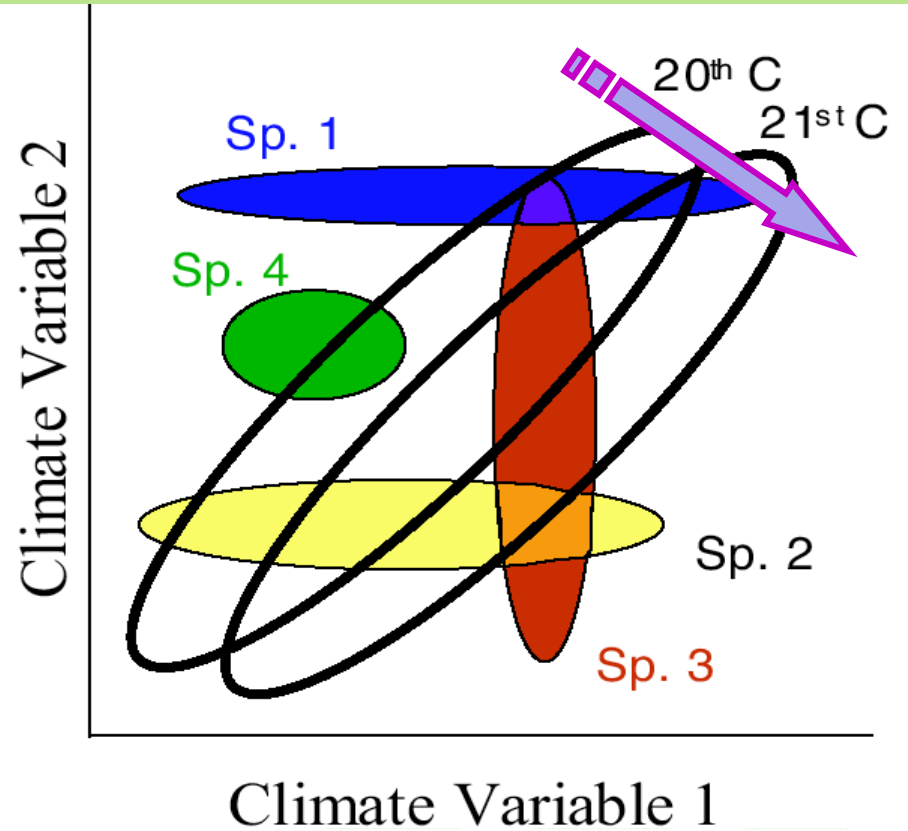


Vegetation map of the Tyrrhenian islands according to the LJP-Guess model



Gritti, Smith & Sykes, 2006. *Journal of Biogeography*, 33.

Necessity to improve model uncertainty and performance

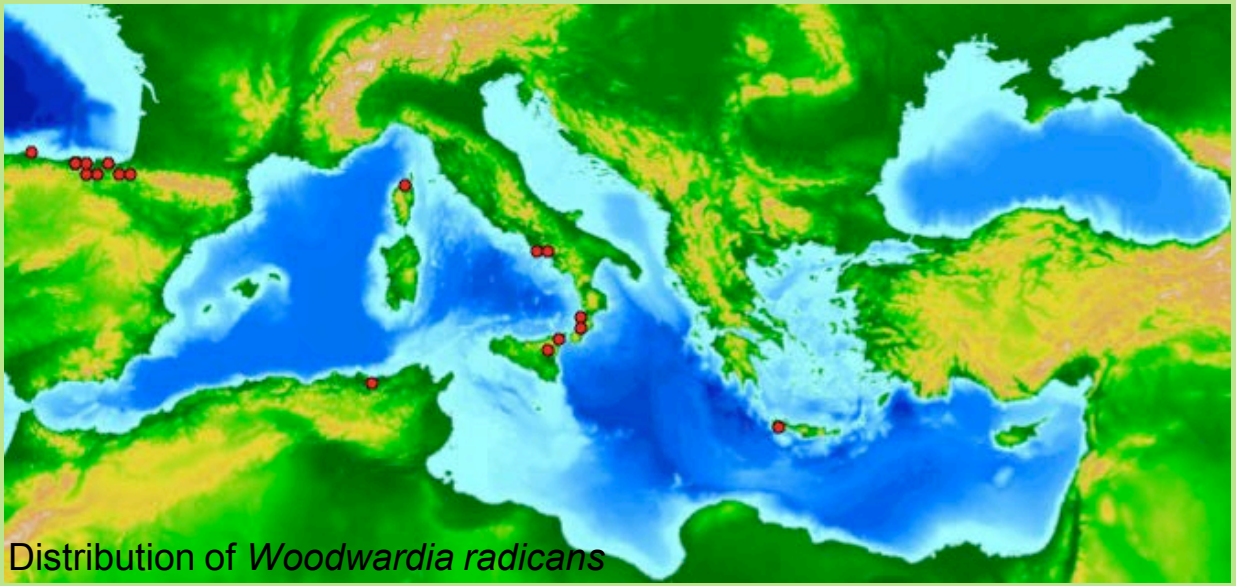


Conceptual diagram showing the intersection among the fundamental niches for 4 species and climatic envelopes

Future climate change may cause:

- **Shifts in species distribution and community disaggregation (sp. 1 et 3)**
- **New communities forming (sp. 2 et 3)**
- **Extinction (sp. 4)**

Williams *et al.*, 2007. *PNAS*, 104.



Distribution of *Woodwardia radicans*

To develop scientific-sounded operations of ecological restoration

Ecological restauration of Bagaud Island, 58 ha (Port-Cros National Park, France)

An integrated approach between science & conservation

Port-Cros Parc National

imbe

AIM

To acquire robust qualitative and quantitative data concerning biodiversity and ecosystem functioning before eradication

OBJECTIVE

To assess the eradication programme for biodiversity preservation
To control the ecological process and resilience

TOOLS

Implementation of standardized protocols related to diverse biological components of the invaded ecosystem

Conservatoire du littoral

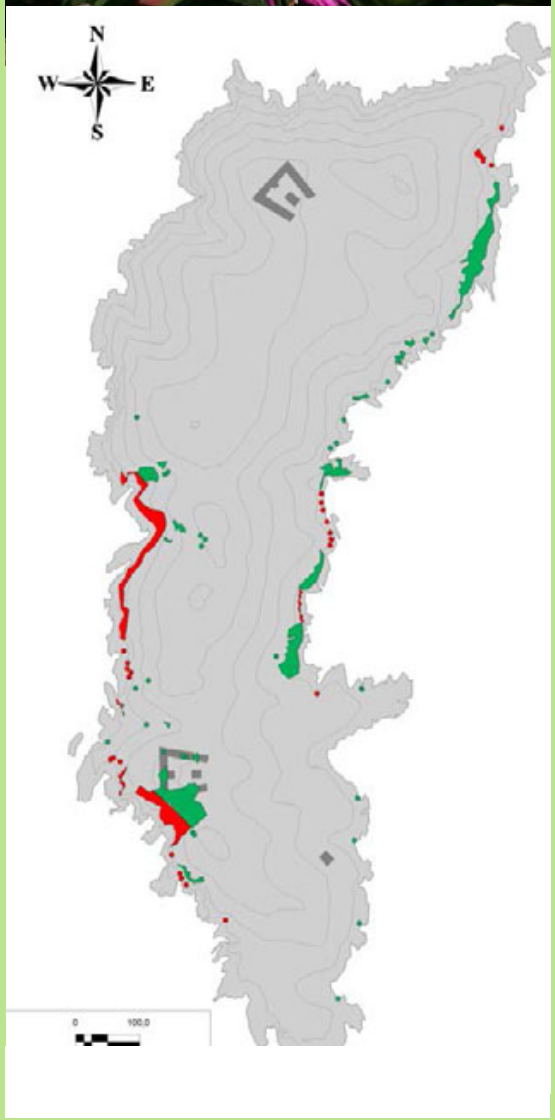
pim

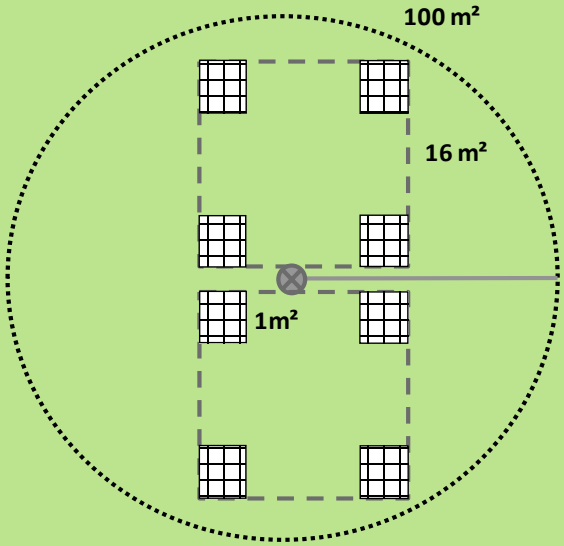
FONDATION TOTAL

REPTIL'VAR

UNION EUROPÉENNE

To develop scientific-sounded operations of ecological restoration





Permanent plot for vegetation surveys

First eradication actions of *Carpobrotus*

Some key issues for conservation planning on islands, including smallest ones

The need for a systemic and interdisciplinary approach of biodiversity and landscape conservation

The most important changes in flora/vegetation will be (still) induced by human practices

- Important modifications of socio-economic trajectories within ≈ 50 years

➔ Considerable land-use changes

➔ Severe threats on traditional activities

- Economic vulnerability of islands

➔ Structural handicap, low diversification of production, high exposure to international and local fluctuations.


Crete, Nida plateau (Psiloritis Mts)


Gozo, terracing of Zebbug


Malta

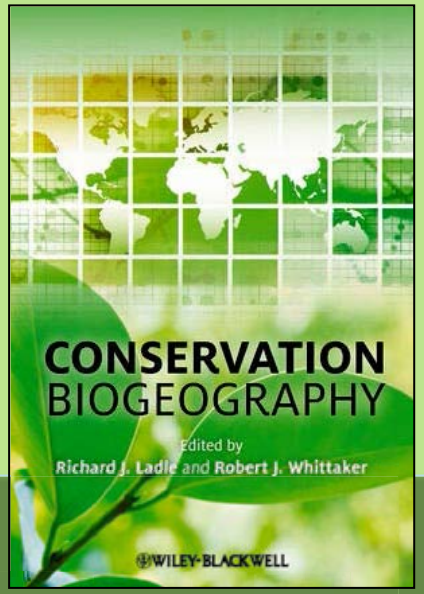
Assigning conservation priorities by Conservation biogeography

Diversity and Distributions, (Diversity Distrib.) (2005) 11, 3–23

SPECIAL PAPER

Conservation Biogeography: assessment and prospect

Robert J. Whittaker*, Miguel B. Araújo, Paul Jepson, Richard J. Ladle, James E. M. Watson and Katherine J. Willis



Conservation Biogeography

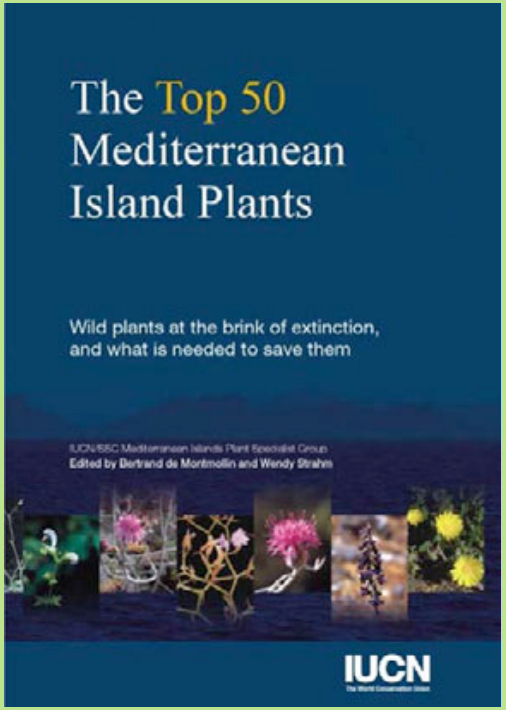
« Application of biogeographical principles, theories, and analyses, being those concerned with the distributional dynamics of taxa individually and collectively, to problems concerning the conservation of biodiversity »


Sardinia


Corsica


Malta

The need to a better estimate of plant species threats



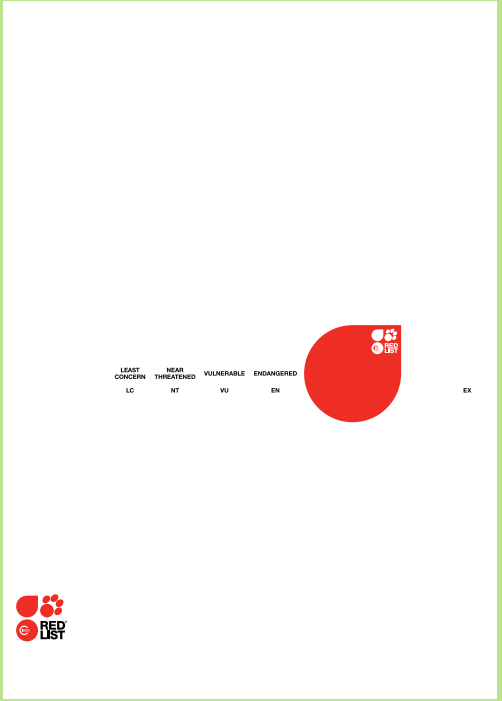
➔

➔

➔

IUCN

SSC
Species Survival Commission



The need to develop / renforce cooperative networks

Importance to favour international projects between Mediterranean islands

Some Life projects devoted to insular plant conservation

Life Natura - EOLIFE '99

TUTELA DELLE SPECIE VEGETALI PRIORITARIE DELLE ISOLE EOLIE

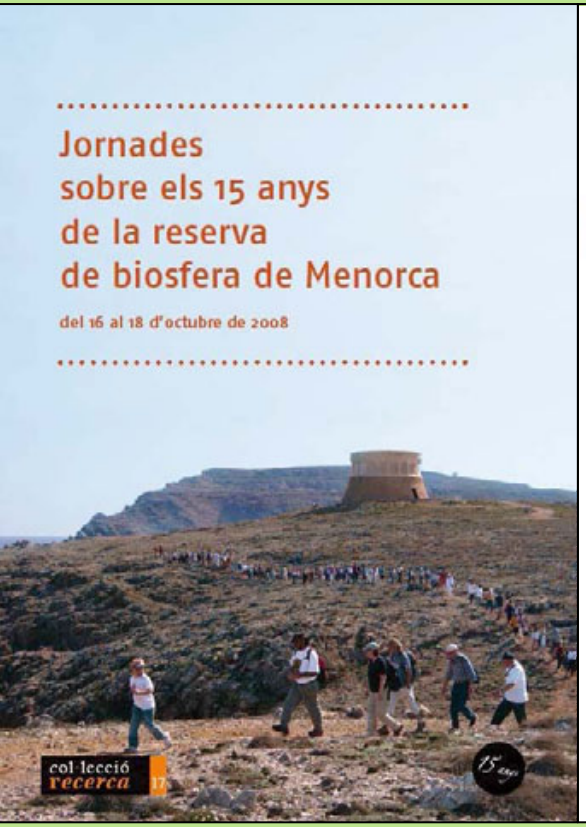
"Conservation of Priority Plant Species in Aeolian Islands"

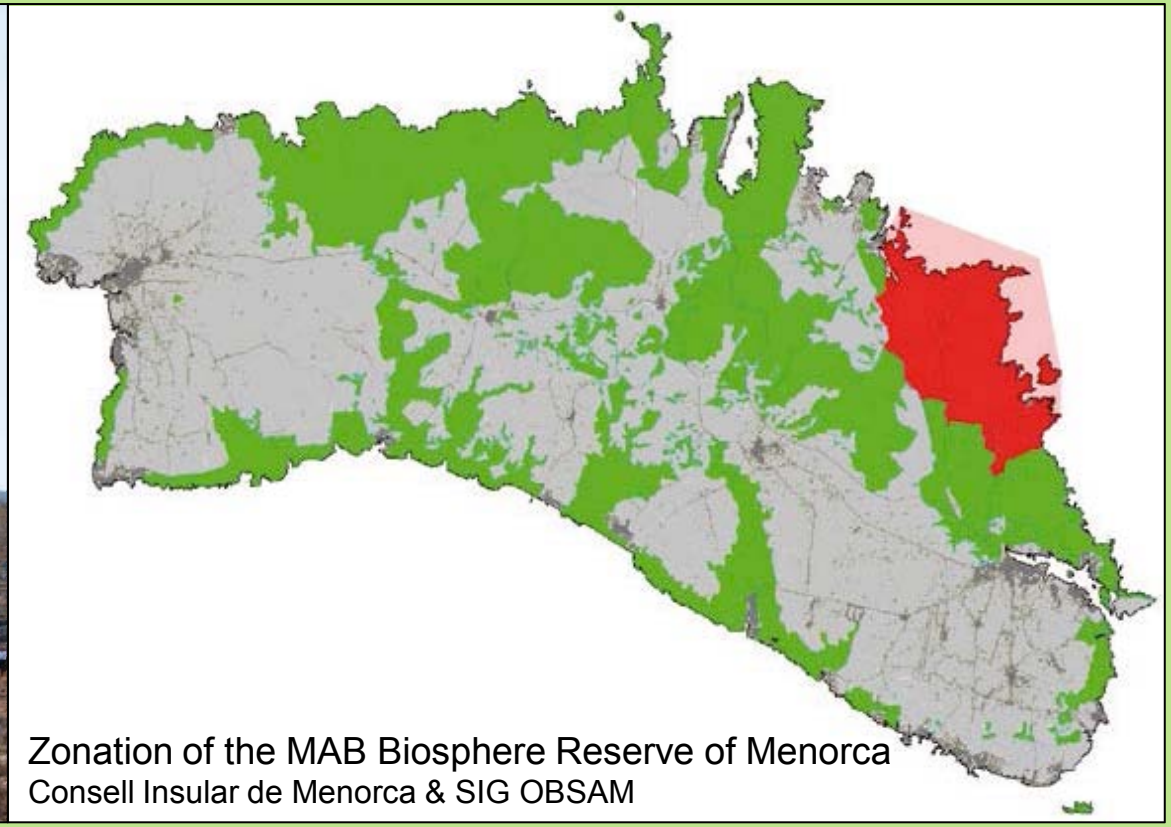
Some proposals for the future conservation of Mediterranean islands' plants and habitats

On a global scale

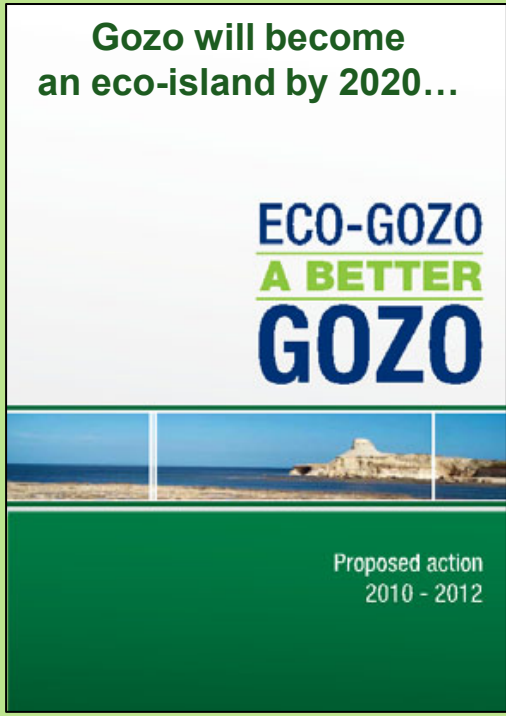
- An inter-islands analysis of conservation priorities (with common DB) including comparatives perspective of territorial dynamics between islands

- Inclusion of medium-size islands within the MAB Biosphere Reserve network





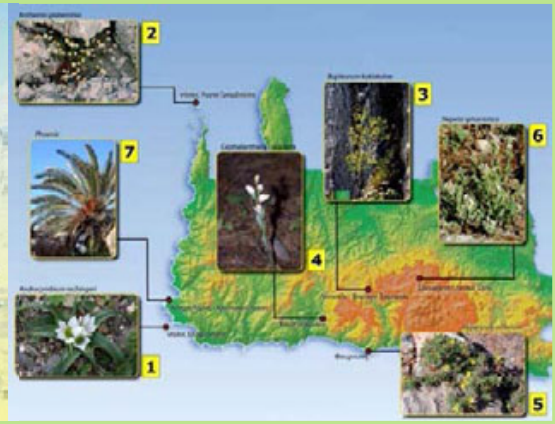
Zonation of the MAB Biosphere Reserve of Menorca
Consell Insular de Menorca & SIG OBSAM



Some proposals for the future conservation of Mediterranean islands' plants and habitats

On a local scale

Establishment of a peri-Mediterranean network of insular Plant Micro-Reserves (PMRs), as already performed in Menorca (24 PMRs), W. Crete (7 PMRs), Croatia and ongoing in Cyprus (5 PMRs)



Expansion of some efficient national initiatives:

- Protected coastal areas of the Conservatoire du Littoral in France

Corsica: 68 sites for 18,062 ha, ca. 295 km of coasts i.e. 20% of the coastal linear of the whole island

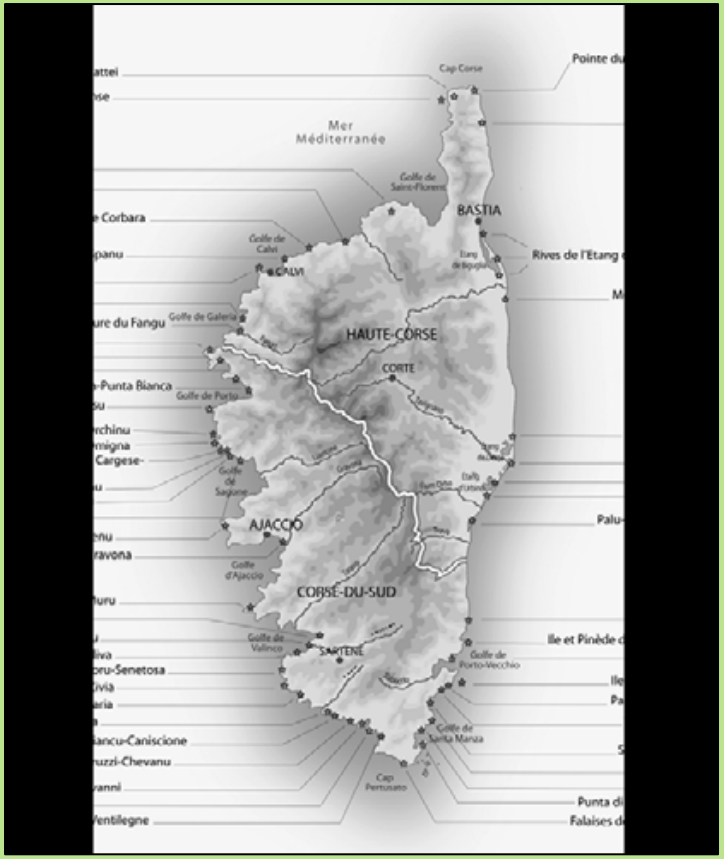
- Conservatoires botaniques nationaux

Conservatoire botanique national de Corse

Conservatoire de l'espace littoral et des rivages lacustres

Conservatoire Botanique National

C O R S E



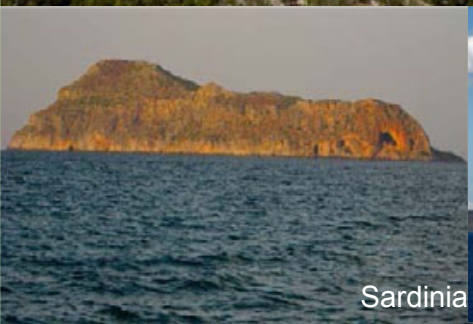
... But smaller islands and islets need much more attention and studies to preserve this fragile biological heritage!


Djerba islet



Ibiza islets


Santorin



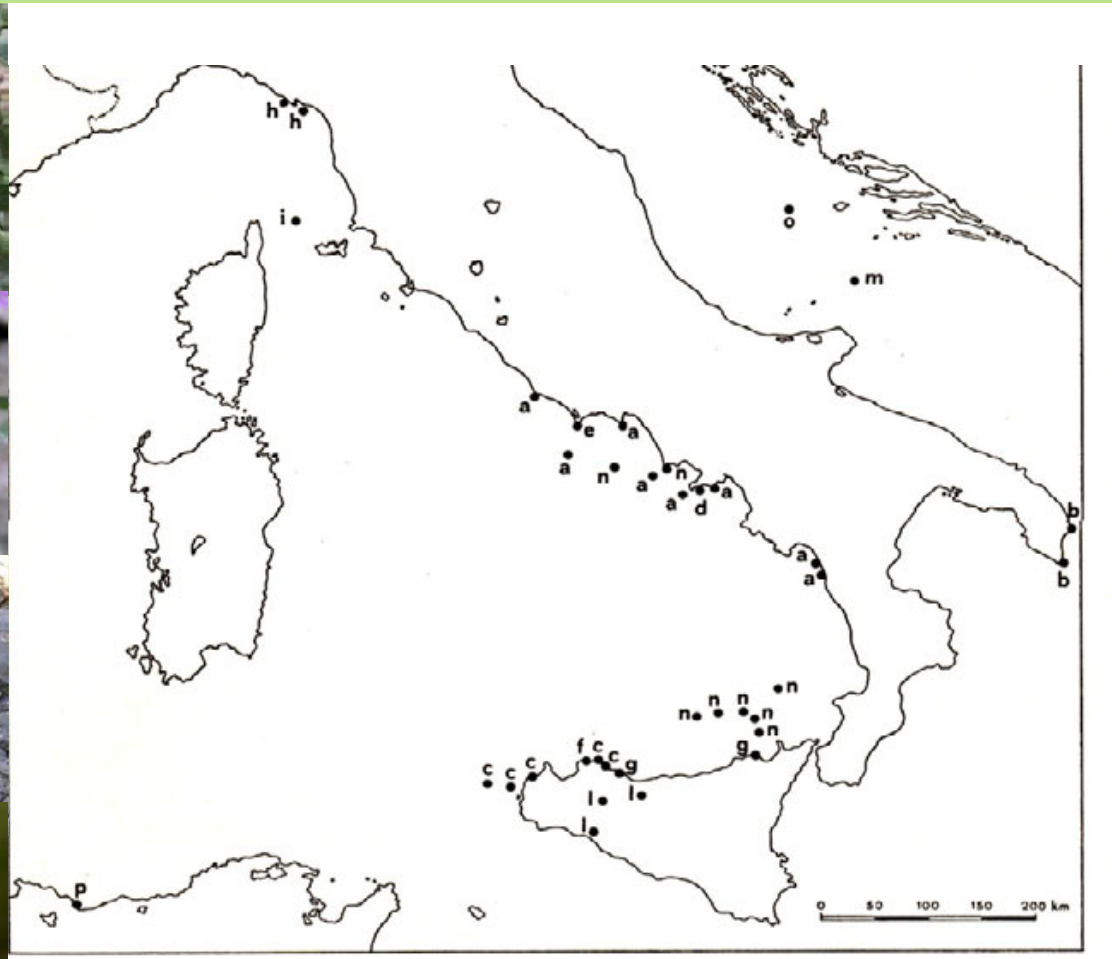
Sardinia islets


Pilau islet (Tunisia)

Small islands: privilegied areas for micro-evolution studies

« Each island population is an evolutionary unit with ecological changes occuring independently on each »

Ricklefs & Cox, 1978. *American Naturalist*, 112.



- Distribuzione delle 14 varietà di *Centaurea cineraria* (secondo Fiori, 1927); *a*: var. *typica*; *b*: *leucadea*; *c*: *sicula*; *d*: *sirenium*; *e*: *circae*; *f*: *umbrosa*; *g*: *todari*; *h*: *veneris*; *i*: *gymnocarpa*; *l*: *busambarensis*; *m*: *friderici*; *n*: *aeolica*; *o*: *jabukensis*; *p*: *gymnocarpa* subvar. *papposa* (secondo Quezel e Santa, 1963).
- Distribution of the 14 varieties of *Centaurea cineraria* (according to Fiori 1927): *a*: *var. typica*; *b*: *leucadea*; *c*: *sicula*; *d*: *sirenium*; *e*: *circae*; *f*: *umbrosa*; *g*: *todari*; *h*: *veneris*; *i*: *gymnocarpa*; *l*: *busambarensis*; *m*: *friderici*; *n*: *aeolica*; *o*: *jabukensis*; *p*: *gymnocarpa* subvar. *papposa* (according to Quezel et Santa, 1963).

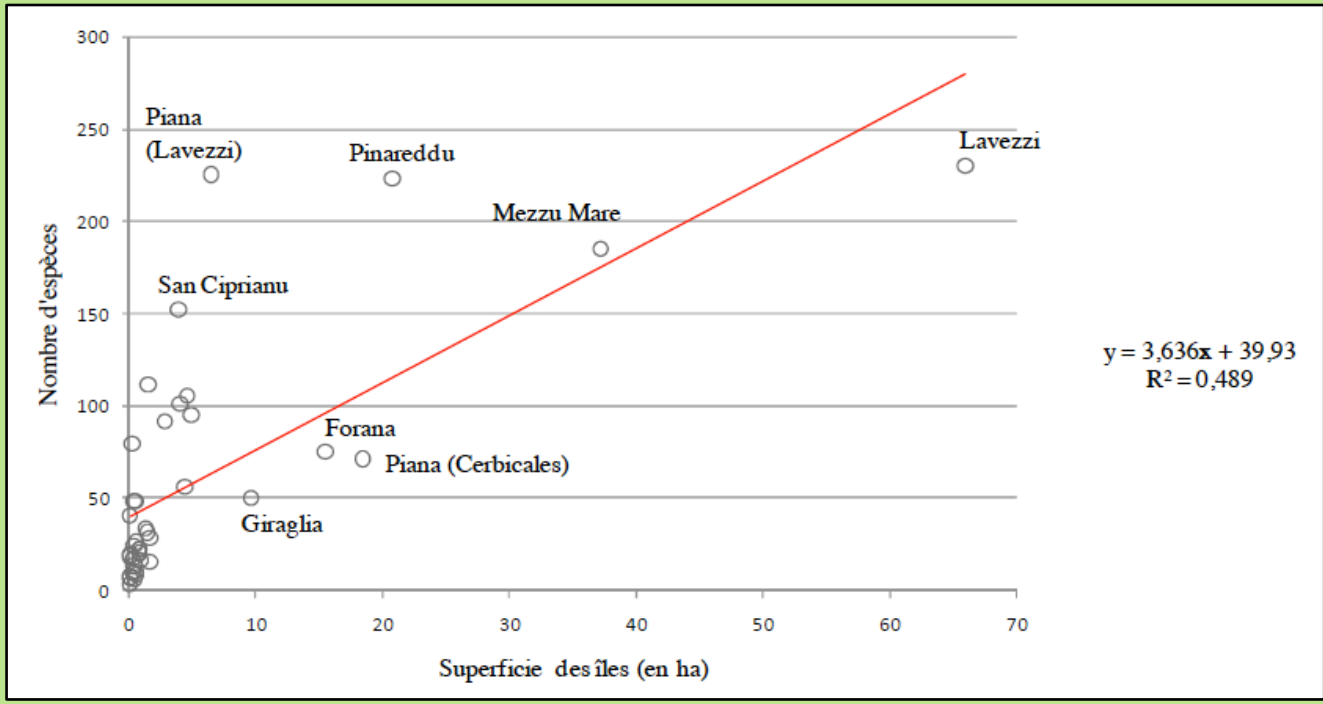
Ferrarini E., 1971. *Giornale Botanico Italiano*, 105.

Insular situations on small islands represent understudied laboratories to better infer adaptative or evolutionary capacities of plant populations according to:

- Biogeographical history
- Isolation pattern
- Population's size
- Environmental constraints

Important concentration of plant richness on islets

Les Petites Iles de Méditerranée (Initiative PIM) : Elaboration d'une base de données et premiers éléments de gestion



Species-area relationships for 39 satellite islets of Corsica

Corsica island

2468 native plant species on 8748 km^2
≈ 130 satellite islets

- ✔ 39 islets properly censused
- ✔ 534 plant species on a total surface of 2.15 km^2

➔ 21.6 % of the whole Corsican flora, on only 0.025% of the total surface of Corsica

Serrano M., 2008. Master EEGB, Université Paul Cézanne Aix-Marseille III.

Rapid and severe impacts of disturbances on plant richness and composition

ELSEVIER

Biological Conservation, Vol. 84, No. 3, pp. 235–243, 1998

Printed in Great Britain
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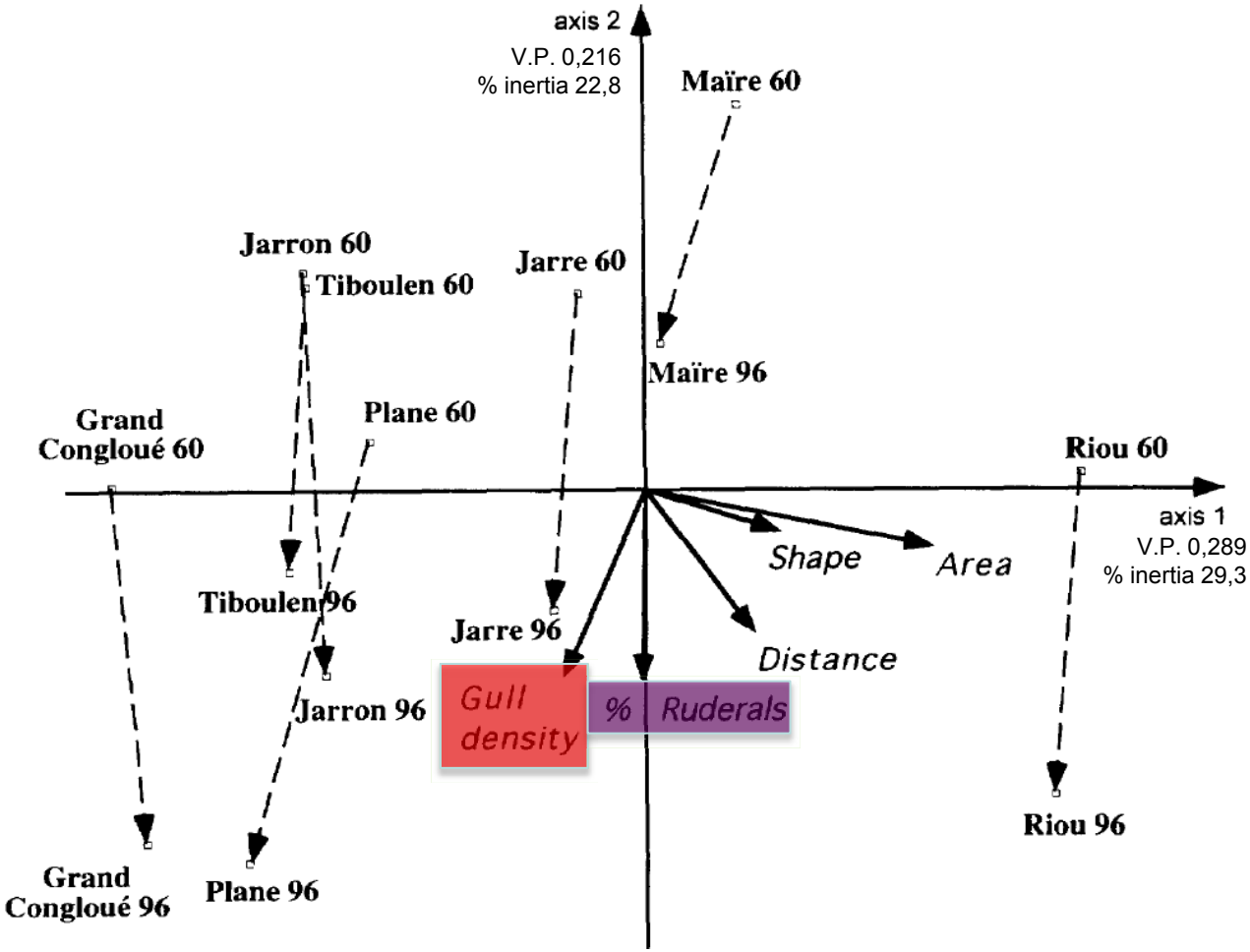
PII: S0006-3207(97)00130-4

IMPACT OF GULL COLONIES ON THE FLORA OF THE RIOU ARCHIPELAGO (MEDITERRANEAN ISLANDS OF SOUTH-EAST FRANCE)

Eric Vidal,[a]* Frédéric Médail,[a] Thierry Tatoni,[a] Philip Roche[a] & Patrick Vidal[b]

Floristical changes on the Riou archipelago (Marseilles) in relation to gull (*Larus cachinnans*) densities

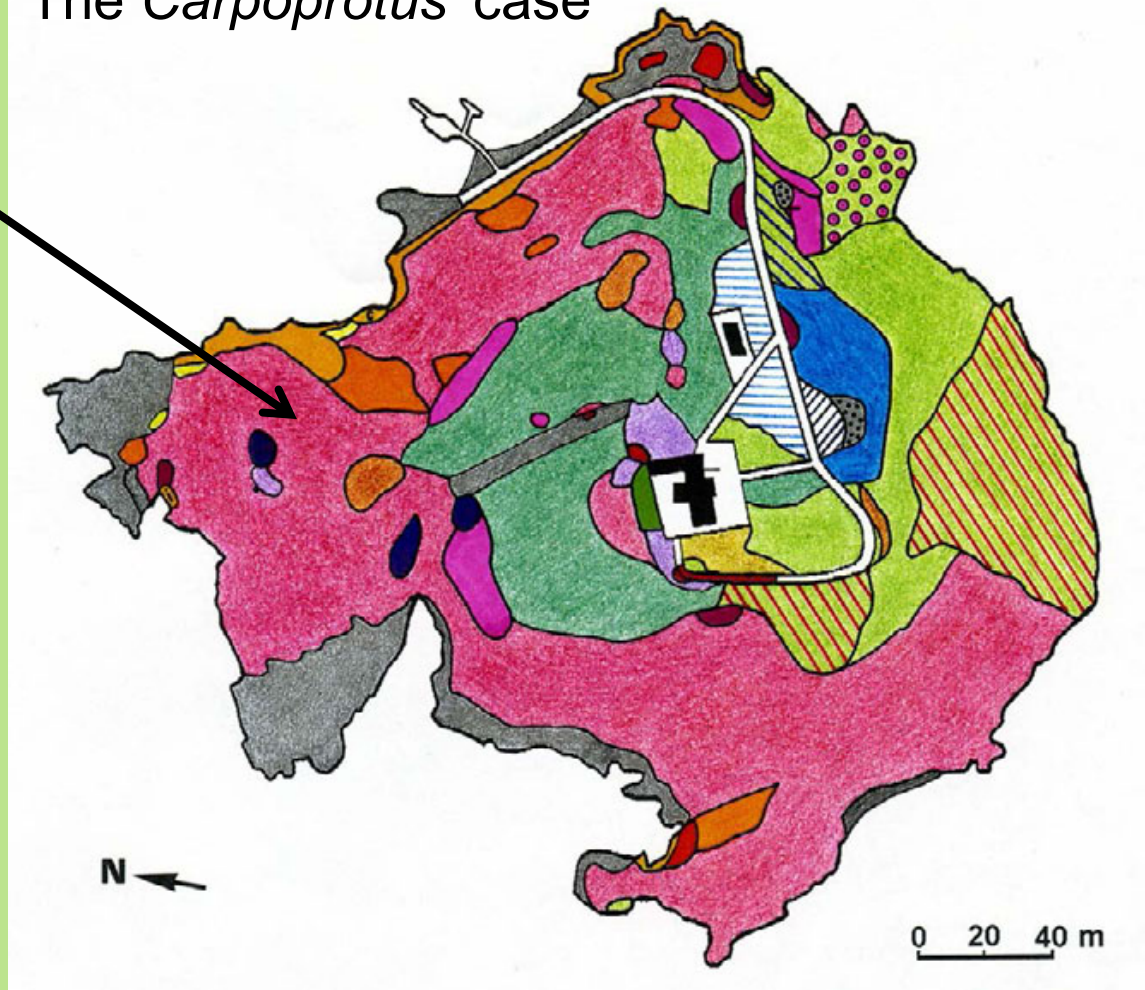


A significant plant turnover correlated with:
- Gull densities (r = -0.395)
- % of ruderal plants (r = -0.405)
- Distance to continent (r = 0.300)

Tremendous success of biological invasion on small islands

Disproportionate effects of biological invasions on small islands / species diversity / ecosystem functions

The *Carpoprotus*' case



Vegetation map of the Grand Rouveau island - 5.5 ha (Provence)

Médail F., 2000. *Bull. Soc. Bot. Centre-Ouest,* 31.

The Mediterranean small islands initiative (PIM)

An international program devoted to the conservation of small islands (surface < 1,500 ha).

Sources: Initiative PIM

Thematic programs
of the Mediterranean small islands initiative (PIM)

Since 2005, the PIM initiative is focused on 6 programmes

- Sentinel Islands
- Albatros
- Terra Cognita
- Island Workshop
- Ileum
- Pharos

www.initiative-pim.org

Some proposals for the future conservation of Mediterranean islands' plants

Conservation framework, in summary

✓ To combine

- reactive approaches on the most threatened (often biggest) islands
- proactive approaches on relatively less threatened islands (notably small islands and islets)

✓ To develop together European and IPAs programmes concerning the whole Mediterranean islands, and the PIM initiative for the smallest ones

✓ To increase North-South collaborations between scientists and managers

Needs of long term biodiversity monitoring
Prioritise actions according to threats

Zembra (© L. Malherbe & J.-P. Lassort, atelier Moss)

Owing to their uniqueness and fragility, Mediterranean islands, even the smallest ones, urgently need some integrated and proactive conservation planning for the long-term preservation of this outstanding biotic heritage.

MEDITERRANEAN ISLANDS:
A DISPROPORTIONATE CONSERVATION VALUE
WITH REGARD TO SUCH REDUCED SURFACES!