

Electronic Supplementary Material S1. Description of the Natura 2000 network in France.

1. Legal context of the Natura 2000 network and designation of Natura 2000 Sites

The Natura 2000 network is regulated by two directives. Following the Bird Directive of the European Union (79/409/EC), 384 Special Protection Areas (thereafter SPA, Fig. S1-1) were designated in France to protect endangered bird species from 1986 onwards. The other Natura 2000 areas are Special Areas of Conservation (hereafter SAC, Fig.S2), which are defined following the Habitat Directive of the European Union (92/43/EEC) to protect non-bird animals and plant species and habitats listed in Annexes I and II. These areas are identified as Sites of Community Importance (hereafter SCI, Fig.S1-2) and designated as SAC after approval by the European Union. To date, in France, approximately half of the 1369 SCI were further designated as SAC and thus effectively protected since 2005. As a whole (SCI/SAC and SPA combined), the Natura 2000 network represents 12.5% of the continental territory of France. Since the designation phase in 2000/2005, the Natura 2000 network is now engaged in a growing management process based on management plans, voluntary measures and impact assessment prior to new human activities.

Figure S1-1. Location of the 384 Special Protection Areas (SPA) in France

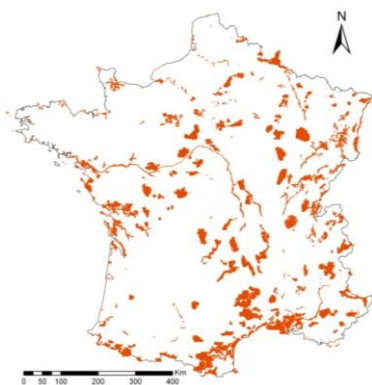
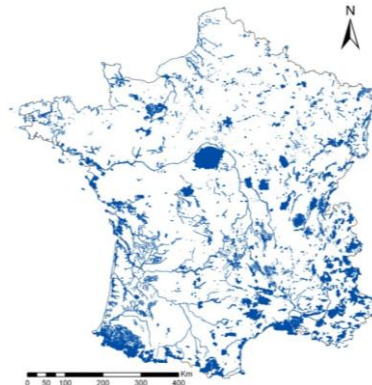


Figure S1-1. Location of the 1369 Sites of Community Interest (SCI) to be designated as Special Areas for Conservation by the European Union



2. Implementation of the management plan in a French Natura 2000 Site

Natura 2000 aims to conserve biodiversity by accounting for the economic, social, cultural and regional activities. Natura 2000 is helping to support local activities respectful of biodiversity in a sustainable development approach. For each French site, this objective leads to a management plan named DOCOB. It is prepared on the basis of

- an ecological and socio-economic diagnosis,
- a general orientation,
- a spatial inventory and quantified measures of conservation and the management of habitats and species of the two Directives (Bird Directive of the European Union and Habitat Directive of the European Union).

In France, the representative of the state at the department level (territorial division of the decentralised services of the state, 101 counties) nominates a committee (COPIL) responsible for leading the development of the DOCOB (state of places, objectives, specifications) and for following its implementation. The COPIL then nominates an operator responsible for the development of the DOCOB with the support of local working groups. Representatives of state departments, public institutions, communities, socio-professional organisations and associations concerned with the site are members of the COPIL. The DOCOB is reviewed under the same terms as those used in its preparation. The implementation of the DOCOB is supervised by COPIL, which assesses and reports on progress in its annual report. The assessment for obligations of the Habitat Directive of the European Union takes place every six years.

The actions to be implemented at the sites are

- habitat information and promotion actions,
- commitment to good practice with the Natura 2000 charter,
- regulatory tools,
- contractual management measures.

A host structure for the monitoring, activation and implementation of DOCOB is designated by the COPIL. In our case study, the Community of Municipalities of the Crozon peninsula (hereafter named Natura 2000 coordinator) is the body responsible for the activation. The project manager maintains contacts with stakeholders, collects data needed for writing technical documents, and prepares for and conducts meetings. Finally, the project manager submits reports to the steering committee and state services.

2. Site management

In France, a voluntary and contractual management of sites offers the opportunity for users to become involved in their management by signing Natura 2000 charters or management contracts. These contractual tools can be complemented by regulatory tools for authorisation to access certain areas or to develop certain sports or business. In all cases, the DOCOB is relied upon to ensure proper management of the site by maintaining or improving the conservation status of key natural heritage features.

The Natura 2000 contracts

For the purposes of the DOCOB, land owners and operators may enter into a Natura 2000 contract with the French State. Natura 2000 contracts are signed for a minimum period of 5 years. It is the structure responsible for the activation that identifies beneficiaries willing to implement the contractual measures via Natura 2000 contracts. The contract contains a set of commitments in accordance with measures outlined in the specifications included in the DOCOB on conservation; where appropriate, it includes the restoration of natural habitats and species that justified the creation of Natura 2000 and defines the nature and terms of public aid and services to be provided in return by the recipient. It can be established in agricultural and forest areas or in non-agricultural and non-forest areas.

The Natura 2000 charters

The Natura 2000 charter created by the relative development of rural areas (Law No. 2005-157 of 23 February 2005) is a document attached to the DOCOB and to which the holders of real rights over land within the site voluntarily adhere. It consists of a list of current commitments for the sustainable management of land and space and the return to sports or recreational sports respectful of natural habitats and species that help achieve the goals of

conservation and habitat restoration natural habitats and species identified in the DOCOB. It does not involve the payment of a financial contribution, but it does provide the right to benefit from the exemption from the property tax on undeveloped properties as well as access to public funds. Membership in the Natura 2000 charter does not preclude signing a Natura 2000 contract and vice versa.

3. Periodic assessment of the conservation status of habitats and species of Community interest

Conservation of the natural environment has required legal force with the publication in 1992 of the Habitat Directive (92/43/EEC), which introduced a definition of the concept of conservation status. In this framework, each member state is committed to the maintenance or restoration of natural habitats and species of wild fauna and flora of Community interest to a favourable conservation status to contribute to the maintenance of biodiversity.

Achieving and maintaining a favourable conservation status is the overall goal for all habitat types and species of Community interest. Such a status can be described as a situation where a habitat type or species thrives (qualitative and quantitative aspects: extent/population) and where the outlook for the vitality of the people or structures to favour habitats and ecological elements, intrinsic host or geo-climatic conditions are favourable to habitat ecosystems. The assessment consists of three components:

- Across each Natura 2000 site, assessing the conservation status of the habitats of Annex I and the species in Annex II (art R414-11 the Environmental Code).
- To assess nationally and for each biogeographic region the conservation status of habitats and species of Community interest (Annex I, II, IV and V) to inform the European Union. "Reporting" under Article 17 of the Habitat Directive.
- To assess the impact of projects and activities on the conservation status of the habitats of Annex I and the species in Annex II at the Natura 2000 network.

Electronic Supplementary Material S2. Details on stakeholders involve in the project

The Natura 2000 management plan, drawn up in 2006, allow to identify the stakeholders who play a role in the management of this area.

- The Natura 2000 Project Manager,

According to French Natura 2000 network, the representative of the State at the department level have nominates a committee (COPIL) responsible for leading the development of the DOCOB and for following its implementation (see *Supplementary Material S1*) , This COPIL then nominates an operator responsible for the development of the DOCOB, here community of Crozon Municipalities.

- People involve:

The Natura 2000 Project Manager was asked, from the early stage of the program, to build the conceptual model. He was also involved in the identification of all key actors and people according to his experience acquired during the implementation and management of the DOCOB. He participated in all workshops

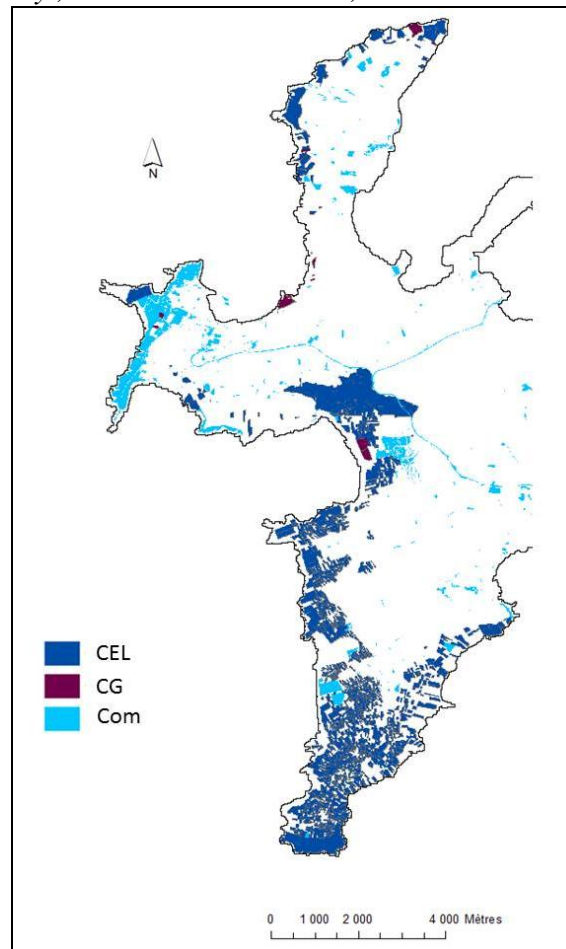
- Coastal Conservation Authority,

The Coastal Conservancy Authority is a public administrative institution of the State under the authority of the Minister of Nature Protection and is an officio member of the COPIL. It is generally perceived as a common organization of the State and local authorities, where the complementary qualities and roles of the one and the other combine and reinforce each other. The Coastal Conservancy Authority owns sites since 1975. Currently 700 sites (1600 Km²) are preserved representing nearly 13% of French coastal line. However it delegates the management of the sites partners. Site management is offered primarily to local authorities, but also sometimes to NGO concerned by nature conservation. The Coastal Conservancy Authority's sites of the Crozon peninsula (*Figure S2-1*) are co-managed with Crozon Municipality in partnership with the General Council of Finistère. The site of Crozon is the largest protected coastal area of Brittany. The conservatory conducted a pilot action consisting of the installation of a new farmer (goats and sheep farmer) on his land with the aim a restoration of meadows and heathlands at the expense of scrubs, ferns and blackthorn thicket.

- People involve:

The project manager of the Coastal Conservation Authority was involved during individual interviews to build the conceptual model, participation in the restitution workshop.

Figure S2-1. Location of sites managed by different owners. CEL: Coastal Conservation Authority, CG: General Council, Com: Communal properties



- Armoric Regional Nature Park,

According to IUCN Protected Areas Categories System French's Regional Nature Parks (ARNP) can be considered under Category VI (IUCN 2014) because they are created with the aim to protect and showcase large inhabited rural areas. Can be classified "Regional Park" a predominantly rural country whose landscapes, natural environments and cultural heritage are of high quality but whose balance is fragile. A regional nature park is organized around a concerted project of sustainable development, based on the protection and enhancement of natural and cultural heritage. All the Crozon peninsula is included in the perimeter of Armoric Regional Nature Park. The ARNP is a member of the COPIL.

Some actions of ARNP linked with the study

- promote the implementation of agri-environmental measures or Natural 2000 contracts in its territory,
- carried conservation actions focus on restoration of heathlands (header of the EU INTERREG Program HEATH)
- promote and manage the sector of wood energy (i.e. in the study site the cutting of conifers and removal of conifers on heathland were used for wood energy)
- administer 3 ethnographic Museum which presents and showcases the natural and cultural heritage

People involve:

- *Deputy Head of the department Biodiversity of the ARNP*: involved for build the conceptual model during individual interview and participation in all workshops
- *Ornithologist of the ARNP*: present at all workshops
- *Landscape manager of the ARNP*: presents all workshops

- *General Council of Finistère*

In the context of the study, General Council of Finistère is mainly involved in the acquisition of natural areas (Figure S2-1), participates in the development of its land management plans and is members of the COPIL. The role of the *General Council of Finistère* officers involved on the site Natura 2000 is essentially administrative and coercive (monitoring measurements, budgets, contract management and Natura 2000 MAE organization of controls).

People involve:

- *Responsible for monitoring contracts natura 2000*: individual interview to build the conceptual model
- *Responsible for the territory mission and sustainable agriculture (monitoring MAE)*: individual interview to build the conceptual model.

- *The community of Crozon Municipalities (Department of Natural Areas),*

The community of Crozon Municipalities include Crozon, Roscanvel, Camaret-sur-Mer and Telgruc-sur-Mer municipality it includes more than 200 villages with a total of 13,541 inhabitants (2012). The natural, cultural and maritime elements of the region are attractive to tourists, in addition this local authority is the fourth of department of Finistère in terms of touristic accommodation possibilities.

The community of Crozon Municipalities owns coastal sites (Figure S2-1) and carried out management actions on its sites but also on sites of the General Council of Finistère and Coastal Conservation Authority:

- management of touristic frequentation (fences for prevent trampling of the vegetation),
- cutting of conifers and removal of conifers on heathland which prevents pine trees from overgrowing the low-lying heathlands,
- creation of patchwork areas, restoration of heathlands: medium overgrown heathlands are restored, high heathlands are maintained and gorse thickets are cut down.

In addition the community of Crozon Municipalities and especially the Department of Natural Areas became the operator responsible for the development of the DOCOB. Thus this local authority coordinate with members of the COPIL, the ecological and socio-economic diagnosis, the spatial inventory of habitats and species of the two Directives, quantified the measures of conservation needed and design the general orientations of management plan (see *Supplementary Material S1*)

People involve:

- *Service of Natural Areas Director in the town of Crozon*: individual interview to build the conceptual model, present at the validation workshop. However, he did not came to the first workshop dedicated to the model output, thus we made a feedback during an individual appointment at his office in the town hall.

- *Farmers,*

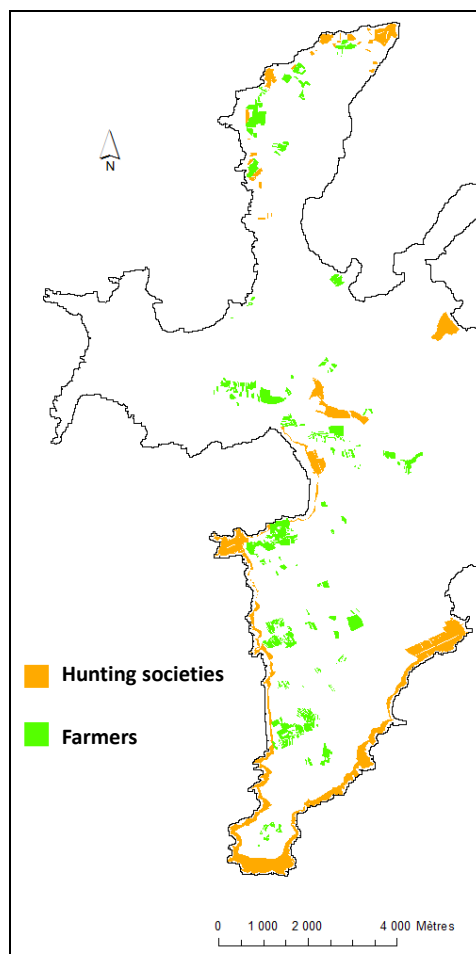
Following a very strong agricultural decline, only 16 farms are on the site (Figure S2-2). Agricultural activities can maintain habitats such as

- "Natural" pastures under extensive livestock (sheep, cattle) and horses breeding (1,314,694 m²)
- Artificial meadows (462,011 m²)
- Cultures in the production framework of cereals and vegetable (173,525 m²)
- "Medium" moor under extensive livestock production (8974m²)

People involved:

- *A breeder*: individual interview to build the conceptual model, present in all workshops. This breeder was involved in a heathland restoration project in partnership with the *Coastal Conservation Authority* (owns the land).

Figure S2-2. Location of sites managed by farmers and hunting societies



- NGO concerned by nature conservation

- *Crozon Hunting Society*,

The Crozon Hunting Society is involved in actions which are intended to the maintenance of paths and meadows (Figure S2-3). Hunters also cultivated crops dedicated to game (blend of corn, buckwheat and various cereals). The Crozon Hunting Society is a member of the COPIL and also contracted agreements for management of Coastal Conservation Authority's sites.

People involved:

- *President of the Crozon Hunting Society* and *another hunter*: individual interview to build the conceptual model.

- *Society for the Study and Protection of Nature in Brittany*,

Founded in 1959, the Society for the Study and Protection of Nature in Brittany played a pioneering role by creating bird sanctuaries along the coast. It brings together nearly 3000 members and today manages a network of more than 100 protected natural areas in Brittany. On the Natura 2000 site Crozon its action is mainly focused on the naturalist expertise (identification and localization of heritage issues, i.e. rare plants).

People involved:

- Representative of the Society for the Study and Protection of Nature in Brittany: individual interview to build the conceptual model, present in all workshops
- *Responsible for birds study to the Society for the Study and Protection of Nature in Brittany:* involved in chough population monitoring: present at the validation workshop

References

IUCN 2014. IUCN Protected Areas Categories System

http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpa

Electronic Supplementary Material S3. Species of EU Community interest on the site

Plant species of EU Community interest

Annex II of the Habitats Directive:

- *Liparis loeselii* (L.C.M. Rich), Natura 2000 code : 1903
- *Rumex rupestris* (Le Gall), Natura 2000 code: 1441
- *Trichomanes speciosum* (Wild), Natura 2000 code: 1421

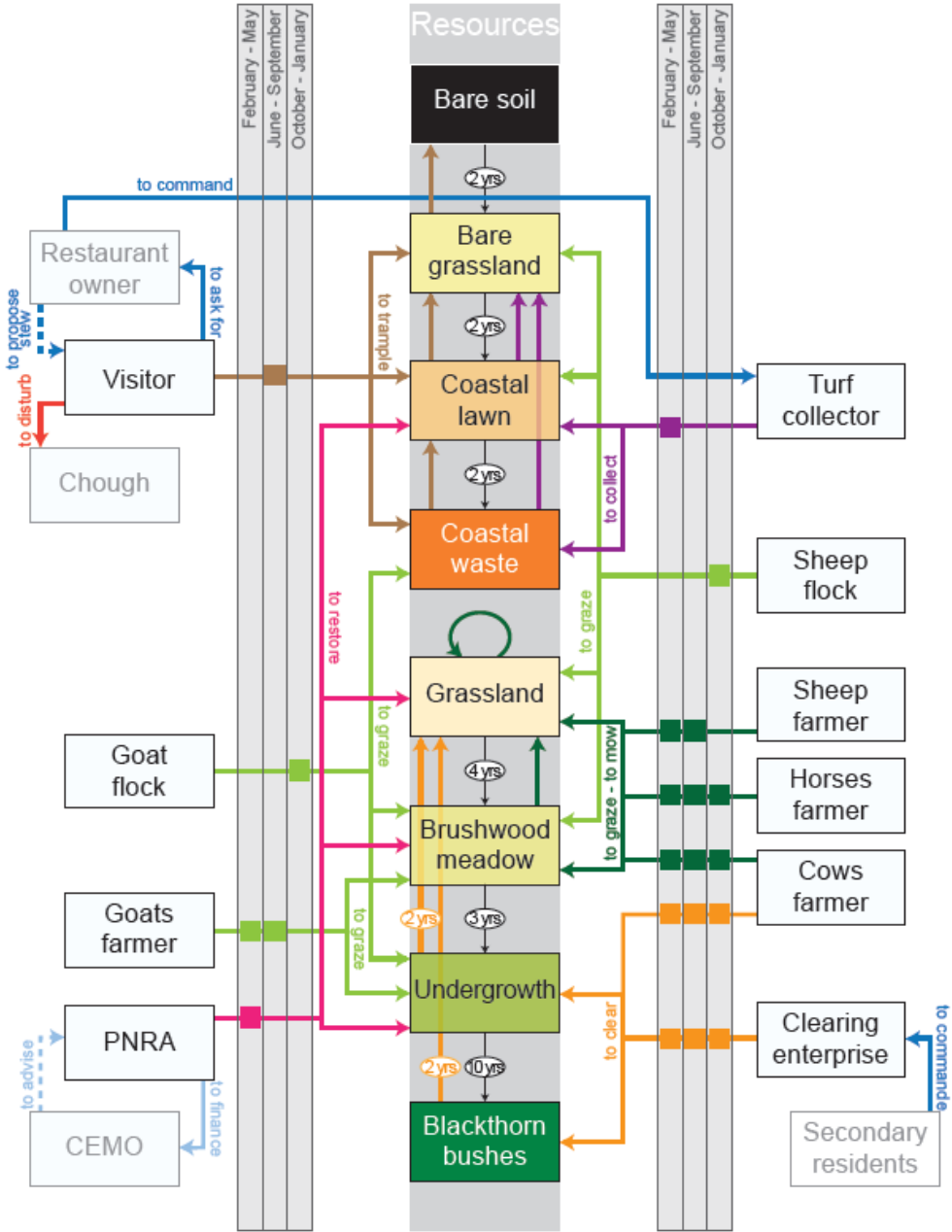
Annex IV of the Habitats Directive

- *Spiranthes aestivalis*

Animal species of EU Community interest

- *Coenagrion mercuriale* (Charpentier, 1840), Natura 2000 code: 1044
- *Oxygastra curtisii* (Dale, 1834), Natura 2000 code: 1041
- *Euphydrias aurinia* (Rottemburg, 1775), Natura 2000 code: 1065
- *Euplagia quadripunctaria* (Poda, 1761), Natura 2000 code:1078
- *Lucanus cervus* (L, 1758), Natura 2000 code: 1083
- *Elona quimperiana* (Férussac, 1822), Natura 2000 code: 1007
- *Rhinolophus ferrumequinum* ((Schreber, 1774), Natura 2000 code: 1304
- *Barbastella barbastellus* (Schreber, 1774), Natura 2000 code: 1308
- *Myotis emarginatus* (Goeffroy, 1806), Natura 2000 code: 1321
- *Lutra lutra* (L, 1758), Natura 2000 code : 1355
- *Halichoerus grypus* (Fabricius, 1791), Natura 2000 code: 1364

Electronic Supplementary Material S4. The conceptual model of Ouessant



For more details see Rouan et al. 2010.

Electronic Supplement S5. Details on the conceptual model of the Crozon peninsula

1. Modelled resources

Resources are the habitats considered in the study. Wetlands and the foreshore were not considered in this study, in part because they are less affected by the dynamics studied here (fallow encroachment and tourism) and due to the lack of data about their status and dynamics.

The implementation of spatial multi-agent models, based on a cellular automaton generated, require GIS layers for creating the model's space. The information used for natural habitat was provided by National Botanical Conservatory of Brest (CBNB). The typology used to describe natural habitats is based on phytosociology approach (Braun-Blanquet 1928), a formal framework for naming and organising vegetation types within a syntaxonomic hierarchy of associations, alliances, orders and classes (Barkman et al. 1986,). The CBNB vector layer contain true « associations » from a phytosociology approach (for example the “*Ulici maritimi-Ericetum*” but also transitional forms such as “*Ulici maritimi-Ericetum with Schoenus nigricans*”). However this typology was partially inadequate for our goal: modelling human activity at a Natura2000 site, because

- (i) This typology is relative complex while it used by botanist, it is not appropriate for discussions with all stakeholders.
- (ii) There are too many categories, some of which are redundant according to the issue of this project.

The typology used by the CBNB is more detailed than the Corine code and Natura 2000; some codes were used for several habitats (Table S4-1)

Table S4-1. Correspondences between the typology used for the conceptual model and Corine Natura 2000 codes.

Habitats	Corine code	Natura 2000 code
Short grassland	18.21	B3.3 (1230-1,2,3,6)
Aerohaline grassland	18.21 ; 31.231	B3.31 (1230-3)
Short heathland	18.21	F4.232, F4.235 (4030-2, 4030-3)
Medium heathland	31.85	F4.231 (4030-2)
Medium-overgrown heathland	31.85	F4.23, F4.231
High heathland	31.85 ; 31.86 ; 38 ; 44.92	F3.15
Conifer heathland	31.2352 ; 83.31	-
Pine forest	83.31 ; 83.32	-
Cropland	82	-
Meadow	38	-
Uncultivated meadow	38.2	-
Scrub	31.831	-
Fern	31.86	E5.3
Blackthorn thicket	31.8112	F3.1112
Gorse thicket	31.8112	F3.15

A match was made between the typology used by the National Botanical Conservatory of Brest (CBNB) and habitat classes identified by local agents for the conceptual model groups. Thus, without altering the spatial boundaries of the polygons of the vector layer provided by the CBNB we merged some vegetation categories of the CBNB. From meetings, which lasted on average two hours, a conceptual model was extracted, which was the most exhaustive possible in relation to the issue of tourist traffic and the fencing in of vegetation, including stakeholders, resources (semi-natural habitats and landuses), the dynamics and conditions of

change in vegetation in relation to the actions of stakeholders. The conceptual model (validated by stakeholders), set the final vegetation typology. This new and rduced typology allow

- (i) Include the CBNB GIS vector layer,
- (ii) Take into account Natura 2000 management goals,
- (iii) Discussions between all stakeholders

Table XX: Example of vegetation merging.

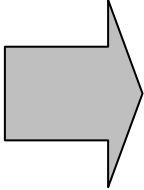
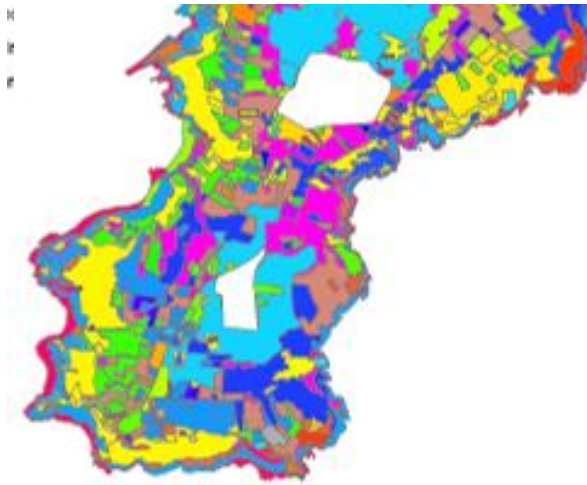
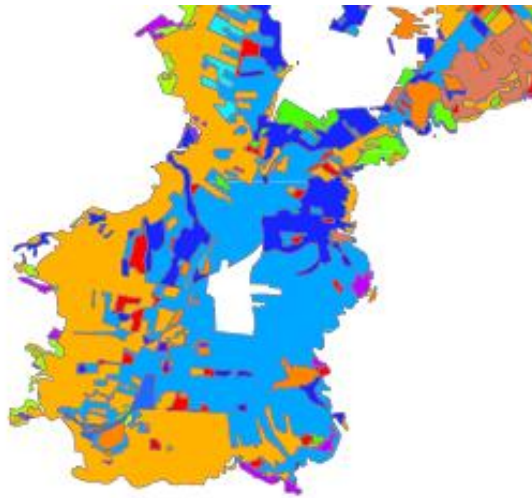
CBNB typology	Retain typology
<i>Ulici maritimi-Ericetum cinereae</i>	
<i>Ulici maritimi-Ericetum cinereae ericetosum ciliaris</i>	
<i>Ulici gallii-Ericetum ciliaris</i>	
<i>Ulici gallii-Ericetum cinerae</i>	
<i>Ulici gallii-Ericetum ciliaris</i> with <i>Schoenus nigricans</i>	
<i>Ulici maritimi-Ericetum cinereae</i> with <i>Schoenus nigricans</i>	
<i>Ulici maritimus - Erica ciliaris</i>	
	Short heathlands (4030-2, 4030-3)

Figure S4-1: Vegetation map of the South of Crozon peninsula with CBNB typology



- | | | | |
|---|--|---|--|
|  | Gorse thickets on rocky outcrops |  | short grassland (<i>Juncus bufonius</i>) |
|  | short grassland (cliff and therophytic facies) |  | Cliff vegetation (<i>Crithmum maritimum</i> , <i>Spergulara rupicola</i>) |
|  | Short grassland (on rocky outcrops with gorse thicket) |  | Garden |
|  | Aerohaline grassland (with gorse thicket) |  | Medium heathland(<i>U. maritimus</i> , <i>E. ciliaris</i>) |
|  | Pine forest (sparse) |  | Aerohaline grassland (<i>Daucogummiferi</i> - <i>Armerietum maritimae</i>) |
|  | Pine forest (planting pine) |  | Aerohaline grassland (with <i>U. maritimus</i> , <i>E. cinerea</i>) |
|  | Pine forest (overgrowth) |  | Short grassland |
|  | Urban area |  | Short grassland (with <i>U. maritimus</i> , <i>E. cinerea</i>) |
|  | Campground |  | Coniferous planting |
|  | Croplands (vegetable growing) |  | Kitchen garden |
|  | <i>Dactylo oceanicae</i> - <i>Sarothamnetum maritimi</i> |  | Uncultivated meadow with <i>Dactylis glomerata</i> |
|  | <i>Orobanch</i> - <i>Hederetum</i> |  | Mesophilous meadow |
|  | Rocky foreshore |  | Ferns |
|  | Sandy foreshore without phanerogamic vegetation |  | Bramble |
|  | Gravel foreshore without phanerogamic vegetation |  | Willow |
|  | Cliff without phanerogamic vegetation |  | <i>Scillo verna</i> - <i>Ericetum cinerea</i> |
|  | Gorse thickets overgrowth |  | Bare soil |
|  | <i>Ulici maritimi</i> - <i>Prunetum spinosae</i> dominated by <i>Ulex europaeus</i> |  | <i>Ulici humilis</i> - <i>Ericetum cinerea</i> <i>ericetosum ciliaris</i> |
|  | <i>Ulici maritimi</i> - <i>Prunetum spinosae</i> dominated by <i>Prunus spinosa</i> |  | <i>Ulici humilis</i> - <i>Ericetum cinerea</i> |
|  | Thicket (with <i>P. spinosa</i> , <i>Crataegus monogyna</i> , <i>Sambucus nigra</i> ...) |  | <i>Ulici humilis</i> - <i>Ericetum cinerea</i> (inland mesophilous heathlands) |
|  | Thicket (with <i>Salix atrocinerea</i> ...) |  | <i>Ulici humilis</i> - <i>Ericetum cinerea</i> (inland xerophilic heathlands) |
|  | Thicket (with mesophilous meadows) |  | <i>Ulici humilis</i> - <i>Ericetum cinerea</i> |
|  | Thicket (with ferns) |  | <i>Ulici maritimi</i> - <i>Ericetum cinerea</i> |
|  | Thicket (with <i>P. spinosa</i> , <i>U. europaeus</i>) |  | Town with garden |
|  | Thicket (with <i>P. spinosa</i> , <i>U. europaeus</i> , <i>S. atrocinerea</i>) | | |
|  | Thicket (with ferns, <i>P. spinosa</i> , <i>U. europaeus</i>) | | |
|  | Thicket (with ferns, <i>P. spinosa</i>) | | |
|  | Thicket (with <i>U. europaeus</i> , <i>S. atrocinerea</i>) | | |
|  | Gorse thicket (with patch of meadows) | | |
|  | Gorse thicket (with patch ferns) | | |
|  | Gorse thicket (with mesophilous littoral heathlands <i>U. galli</i> , <i>E. ciliaris</i>) | | |
|  | Gorse thicket (with dry littoral heathlands <i>U. galli</i> , <i>E. cinerea</i>) | | |
|  | Gorse thicket (with dry littoral heathlands <i>U. galli</i> , <i>E. cinerea</i> , <i>E. ciliaris</i>) | | |
|  | Gorse thicket (with mesophilous inland heathlands <i>U. galli</i> , <i>F. ciliaris</i>) | | |
|  | Gorse thicket (with dry inland heathlands <i>U. galli</i> , <i>F. ciliaris</i>) | | |
|  | Blackthorn thicket | | |

Figure S4-2: Vegetation map of the South of Crozon peninsula with the retain typology



- scrub
- cropland
- dune
- Gorse thickets
- Blacthorn tickets
- Conifer heathlands
- High heathlands
- Medium heathlands
- Medium overgrown heathlands
- short heathlands 1
- short heathlands 2
- aërohaline grassland
- short grassland 1
- short grassland 2
- short grassland 3
- Pine forest
- Meadows (cultivated)
- Uncultivated meadows
- Meadows (semi_natural)
- Ferns
- bare soil

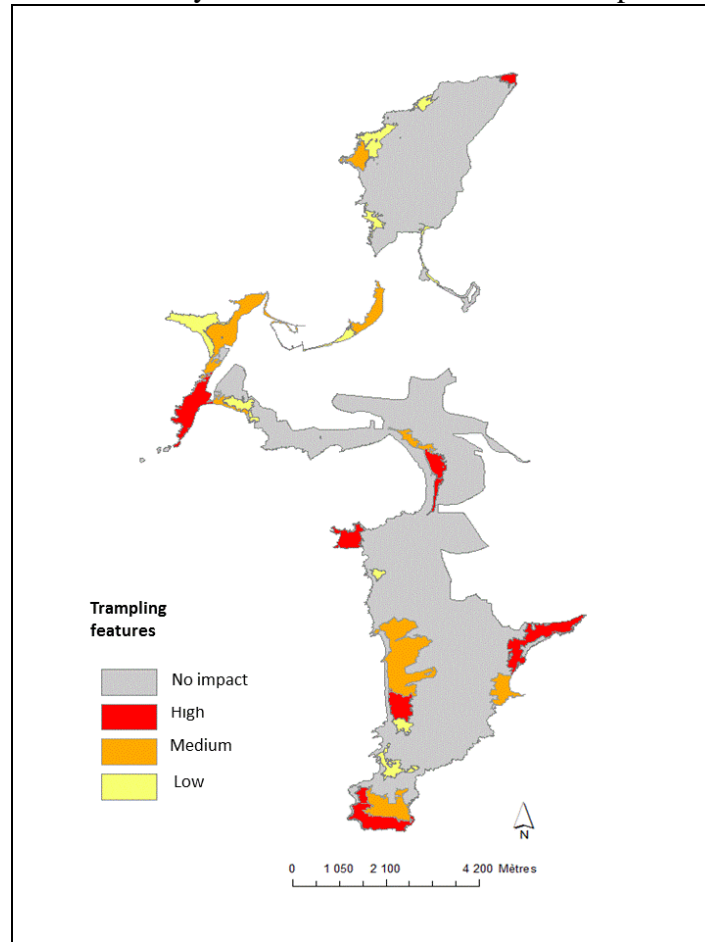
2. Dynamics of resources based on human actions

2.1. Tourists:

- Spatial and temporal variation of tourist's frequentation

The Natura 2000 coordinator has identified sites where tourists impact vegetation and has also determined the intensity of traffic associated with each site (Fig. S4-3). The annual number of tourists visiting is used to document urbanisation. Seasonal variation in tourist frequency was estimated from an INSEE study (National Institute of Statistics and Economic Studies) and verified using 3 logger passing located in Crozon.

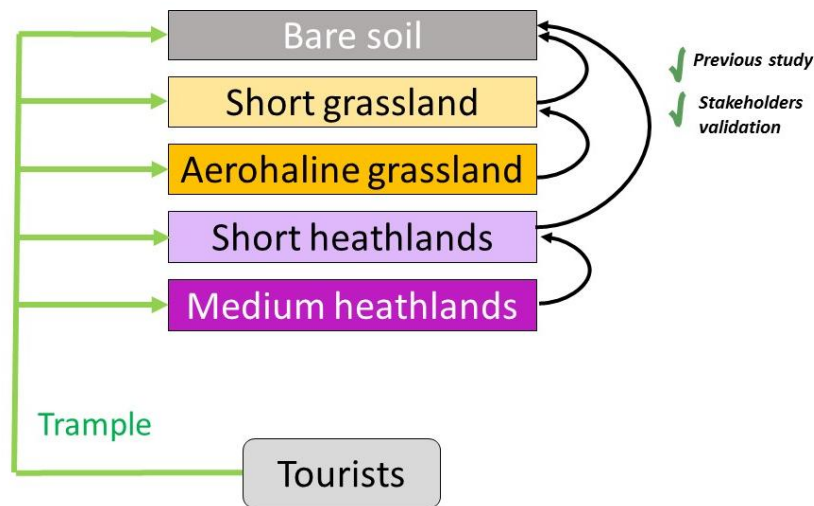
Figure S4-3. Intensity of tourist traffic on the Crozon peninsula site.



- Impact of tourist trampling on coastal habitats

One of the first degradation resulting from the presence of tourists is vegetation trampling, which often affects ecosystems of high conservation value (Yorks et al., 1997). Coastal cliff vegetation is very similar to alpine grasslands (close species such as *Armeria* sp, *Festuca* sp., *Scilla* sp, *Jasione* sp, *Sedum* sp...), is characterized by a growth on thin soil and poor productivity, so that trampling could potentially generate major, long-lasting damage to this vegetation as well as noticed on alpine grassland (Whinam and Chilcott, 2003). Human trampling of short grassland and short heathland leads to soil erosion (apparition of “bare soil”), while trampling of Aerohaline grassland and medium heathland leads to other vegetation type, respectively short grassland and short heathland (Fig XXXXX). Short grassland were classified in three vegetation types (short grassland 1, 2 & 3) according to soil depth and presence or not of indicator species that do not resist trampling, such as thallophyte, succulent or perennial woody-stems species (see Kerbiriou et al. 2008).

Figure S4-4 Resources and dynamics linked to tourist trampling. Transitions were implemented thanks to 1) “Previous study”: Kerbiriou et al. 2008, 2) Empirical information from stakeholders’ fields observation “Stakeholders validations”



Empirical surveys conducted on Ushant (Kerbiriou *et al.* 2008) established a relationship between the number of tourists visiting an area, the impact of trampling (number of cells, the spatial unit area model) and the percentage of bare soil. In the model, therefore, the number of impacted cells depends on the number of tourists to the area. The impacted cells are selected according to 2 types of priority criteria: proximity to roads and habitat types (grass and heath). The impact of trampling varies depending on the type of vegetation: on short grassland, soil increases +0.07, while on aerohaline grassland and short heathlands, the increase is +0.04 (Kerbiriou et al. 2008). When the vegetation cover reaches a critical value, a change occurs in the vegetation type.

- When the vegetated area is between 40% and 60%, a cell of medium heathland becomes a cell of short heathland. When a cell of aerohaline grassland has a cover less than 40%, this cell becomes a cell of short grassland. When a cell of short heathland or short grassland has a cover less than 40%, it becomes a cell of bare soil.

2.2. Farmers

Meadows and cultures are maintained by agricultural activities and those of hunting societies. These activities also create wide paths through the shrub and thicket vegetation (blackthorn thickets, gorse thickets, shrub and fern) of coastal land owned by the Coastal Conservation Authority or municipalities (see *Supplementary Material Figure S2-1*).

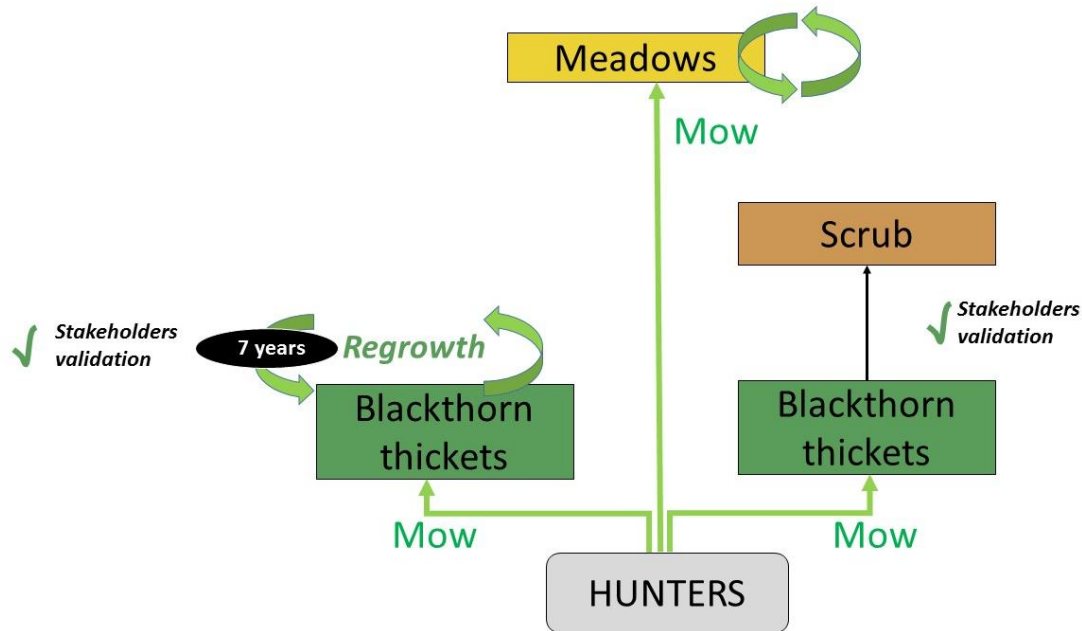
Figure S4-5 Resources and dynamics linked to agriculture practices



2.3. Hunters

Hunter's activities mow meadows, blackthorn thickets and Gorse Thickets, they also create wide paths through the shrub and thicket vegetation (Fig S4-6) of coastal land owned by the Coastal Conservation Authority or municipalities (see *Supplementary Material Figure S2-1*).

Figure S4-6 Resources and dynamics linked to hunters practices

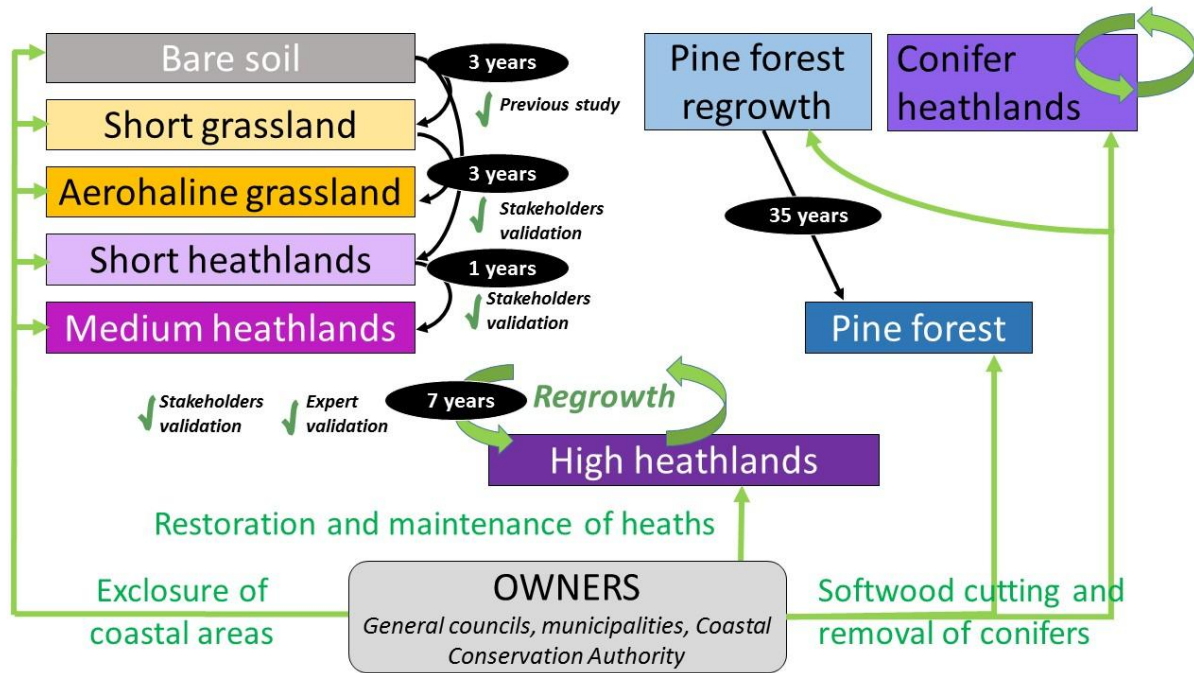


2.4. Owners' conservation actions:

Conservation actions are performed by the municipalities, the Coastal Conservation Authority and General Council on their respective properties (*Supplementary Material Figure S2-1*).

- Exclosures of coastal areas/development of paths.
Exclosures of coastal areas do not suffer from trampling; the vegetation grows again with the transitions and time described in the schema of the conceptual model to a sustainable and stable state (Figure S4-7). For each cell of the model (spatial unit), this state corresponds to the habitat mapped in 1999 and is considered as a stable state
- Softwood cutting and removal of conifers on conifer heathland.
- Following a softwood cutting, a pine forest becomes a pine forest regrowth. Heathland with conifers remains a heathland with conifers in the sense that the seed bank soil always contains the seeds of conifers. This cutting merely delays the development of conifer heathlands to pine forest.
- Heath management and creation of mosaic of habitats. When medium-overgrown heathlands are restored this habitat is transformed into medium heathlands. When high heathlands and gorse thickets are mowed, the vegetation regrowth attains its respective category in 7 years.

Figure S4-7 Resources and dynamics linked to owners' conservation actions. Time transitions were implemented thanks to 1) knowledge provided by published study (Kerbiriou et al. 2008): "*Previous study*"; 2) expertise from Coastal Conservation Authority & *The community of Crozon Municipalities (Department of Natural Areas)*: "*Stakeholders validation*" and 3) expertise from two botanists ("*Expert validation*").



3. Natural dynamics and passive restoration.

Somme vegetation could be considered as « perennial » such as Pine forest, High heathlands, Medium Hightlands, Short heathlands, Aerohaline grassland, Short grassland, Ferns, Gorse thickets and Blackthorn thicket. These vegetation are assumed not to change or evolves very slowly and on large period of time (Figure XX).

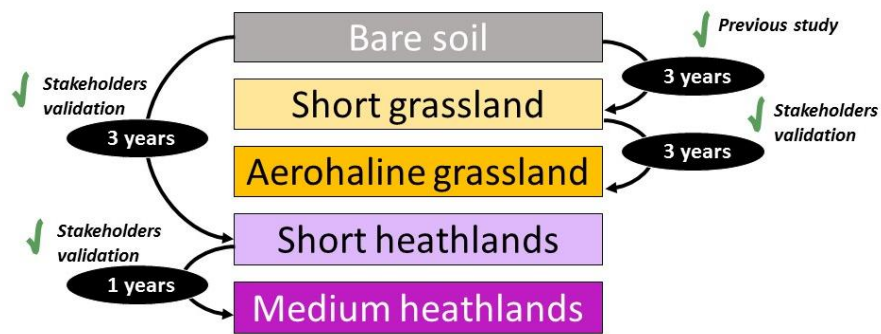
However, some of these vegetations category could be also an altered form of other vegetation category, for example Short grassland or Short heathland could correspond respectively to trampled Aerohaline grassland and trampled Medium heathland, without tourist trampling pressure they recover their “initial” state (Aerohaline grassland and Medium heathland) see Figure XXX

Finally, some vegetations categories are only transitional stages of a dynamic such as Uncultivated meadows, Scrub, Conifer heathlands, Pine Forest regrowth, medium overgrown heathlands.

3.1 Trampled vegetation and passive restoration

Fenced in coastal areas do not suffer from trampling; the vegetation grows again and recover initial state

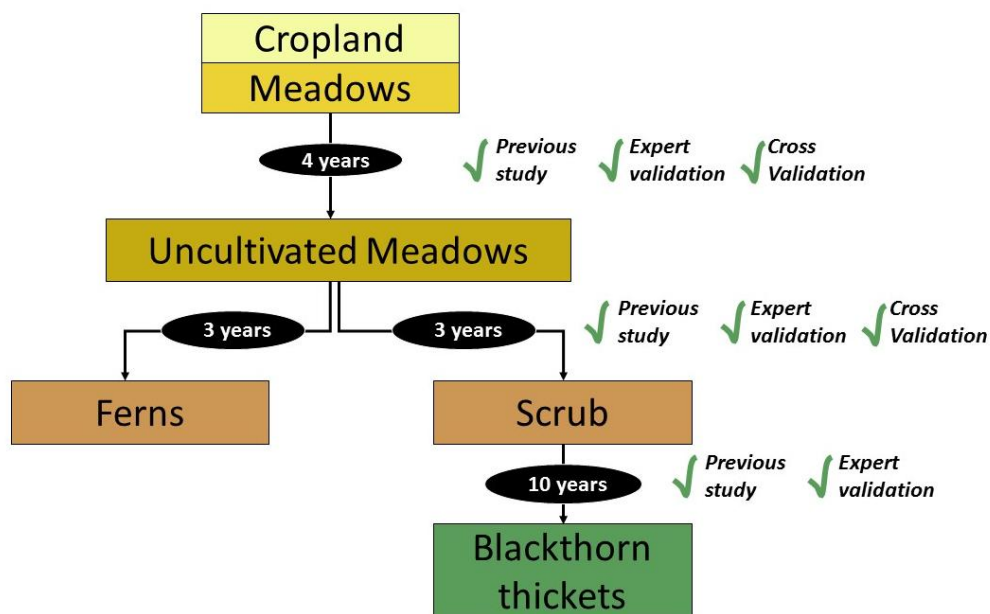
Figure S4-8 Resources and dynamics linked to the fencing in coastal areas and passive restoration dynamics. Time transitions were implemented thanks to 1) knowledge provided by published study (Kerbiriou et al. 2008): “Previous study”; 2) expertise from Coastal Conservation Authority & The community of Crozon Municipalities (Department of Natural Areas): “Stakeholders validation”



3.2. Recent Agriculture abandonment

Without management, meadows and culture (two transitional stages of a dynamic) evolves into stages of shrub and thickets.

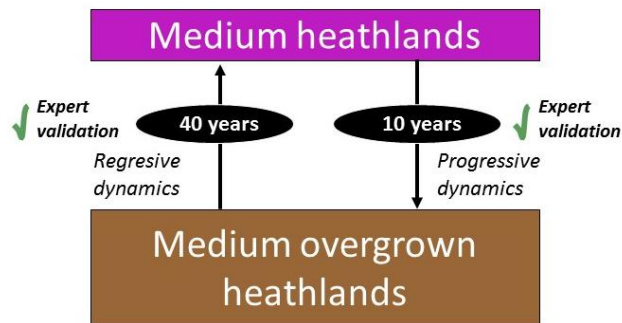
Figure S4-9 Resources and dynamics linked to encroachment. Time transitions were implemented thanks to 1) knowledge provided by the pre-establish model in Ushant (“*Previous study*”, Rouan et al. 2009, Gourmelon et al. 2013); 2) expertise from two botanists (“*Expert validation*”); 3) feedback from confrontation between field observations 1999 and 2013 (see 2.2.4 Validation of software prototype).”



3.3 Dynamics linked to past agriculture practices

In the past the coast was cleared for the development of culture and especially of sheep grazing, currently some medium heathlands are witnesses of this past and evolve slowly (Fig. S4-10). The dynamics of medium-overgrown heathlands may be stable, progressive or regressive depending on their location (distance to the sea, soil depth...etc.). When the dynamics are stable, medium heathlands cannot evolve to the stage of medium-overgrown heathlands; when the dynamic is progressive, this transition takes place in 10 years. The regressive dynamics of heathlands led to medium-overgrown heathlands returning spontaneously to medium heathlands in 40 years (Figure S4-10).

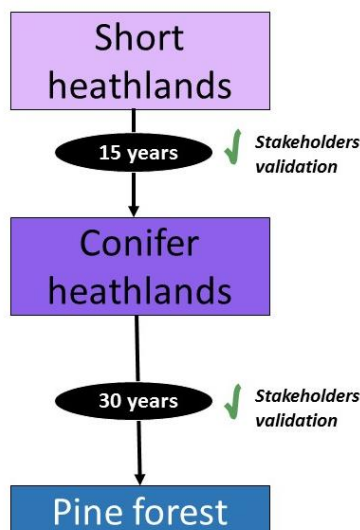
Figure S4-10 Resources and dynamics linked to medium-overgrown heathlands (“witnesses of past agricultures practices”). Time transitions were implemented thanks to expertise from two botanists (“*Expert validation*”).



3.4. Dynamics of pine encroachment.

Several coniferous species were planted include the genres to which they belong: *Abies* (fir), *Picea* (spruce), genre *Cupressus* (cypress) and *Pinus* (pine), but the majority of the plantations were made for the benefit of maritime pine (*Pinus pinaster*) (Gueguen 2006). Maritime pine were planted in the last century between the two wars, matured for 3-4 decades, they currently colonized Short heathlands in the eastern side of Crozon peninsula (Fig. S4-11).

Figure S4-11 Resources and dynamics linked to *pine encroachment*. Time transitions were implemented thanks to expertise from Coastal Conservation Authority & *The community of Crozon Municipalities* (Department of Natural Areas): “*Stakeholders validation*”



4. Dynamic resources taking into account the spatial structure

A cell of short heathlands is colonised by pine; if a neighbouring cell is a pine forest, then it becomes a cell conifer heathland after 15 years.

A cell of uncultivated meadows is colonised by ferns; if a neighbouring cell is ferns, it becomes a cell of ferns itself after 3 years.

5. Biodiversity Indicators

The impact of different socio-ecological dynamics on biodiversity according to the management scenarios were examined in terms of several indicators of biodiversity status.

Two main types of indicators were hence used:

i) the surfaces of different habitat types, characterizing the closed over status of the areas,
ii) indices characterising the diversity and heritage quality of communities of plants and birds: hereafter the species richness, the community rarity and the community specialisation indices per habitat. Calculated at the community level as the average value of the species belonging to the community, these rarity and specialisation indices hence reflect the responses of a large number of species, in interaction, to changes in environmental conditions.

Species richness of flora (S_f) is the number of species/m² per habitat. It was calculated from botanical surveys (n = 433, Table S4-2) using a standardized method (five 1 m² quadrats per homogeneous habitat).

The community specialisation (**CRI_f**, **CRI_a**, **CSI_a**) were calculated at the level of each habitat: each index obtained per habitat corresponds to the average of index values obtained from samplings of the community within this habitat.

Rarity index of plants community (CRI_f) is calculated as the arithmetic mean of the species rarity. The degree of rarity of each plants species (Table S4-3) was calculated by counting the grid units of the distribution atlas for the flora of the county (Quéré et al. 2009) for which the species was known. The rarity index of the community was obtained by weighting the rarity of each species by its frequency measured on the five quadrats

Rarity index of avian community (CRI_a) is calculated as the arithmetic mean of the species rarity. The degree of rarity of each birds species (Table S4-3) was calculated by counting the grid units of the distribution for the breeding bird atlas of Brittany (GOB 2012)

Specialisation index for avian community (CSI_a) is calculated as the arithmetic mean of the species specialization index (SSI, Table S4-3) weighted by the abundances (Julliard et al., 2006) (Eq. (1)). The SSI (Table S4-3) is the coefficient of variation of the abundance of a species across 18 habitat categories (Julliard et al., 2006; Devictor et al., 2008a). It is calculated from the French BBS (2001-2008) (Jiguet et al., 2012) and the French BS (2006-2012), which is the matching volunteer).

$$CSI_j = \frac{\sum_{i=1}^n a_{ij} (SSI_i)}{\sum_{i=1}^n a_{ij}} \quad (2)$$

where n is the total number of species recorded, a_{ij} is the abundance of individuals of species i in plot j , and SSI_i its specialization index.

Thus, this indices of specialisation of bird communities per habitat were calculated, from the degree of specialisation in the habitat of species (Julliard et al. 2006), weighted by the abundance of each species in each habitat (Julliard et al. 2006). In that cases the abundance by habitat was obtained using data from French monitoring of common birds 1 (Jiguet et al; 2012).

Table S5-2. Habitat sampled

Habitat	Number of sampling
Aerohaline grassland	19
Blackthorn regrowth	13
Blackthorn thicket	10
Conifer heathland	14
Cropland	14
Ferns	16
Gorse thicket	10
High heathland	44
High heathlands regrowth	15
Meadow	77
Medium heathland	45
Medium overgrown heathland	23
Pine forest	11
Pine forest regrowth	12
Scrub	20
Short grassland	43
Short heathland	35
Uncultivated meadows	12

Table S5-3: species rarity and specialization value

Plants	rarity	Birds	specialization (SSI)	rarity
<i>Acer pseudoplatanus</i>	0.209	<i>Accipiter nisus</i>	0.7874	0.3854
<i>Achillea millefolium</i>	0.082	<i>Acrocephalus schoenobaenus</i>	2.2975	0.8073
<i>Agrostis stolonifera</i>	0.027	<i>Acrocephalus scirpaceus</i>	2.1941	0.7463
<i>Acer pseudoplatanus</i>	0.027	<i>Aegithalos caudatus</i>	0.6232	0.2293
<i>Ajonc de Le Gall</i>	0.245	<i>Alauda arvensis</i>	1.1554	0.2976
<i>Ajuga reptans</i>	0.155	<i>Anthus petrosus</i>	NA	0.7902
<i>Anacamptis morio</i>	0.755	<i>Anthus pratensis</i>	1.3746	0.7098
<i>Anagallis arvensis</i>	0.045	<i>Buteo buteo</i>	0.4949	0.1780
<i>Anagallis arvensis parviflora</i>	0.891	<i>Linaria cannabina</i>	0.6968	0.2317
<i>Angelica sylvestris</i>	0.100	<i>Carduelis carduelis</i>	0.7043	0.2659
<i>Anthoxanthum odoratum</i>	0.036	<i>Chloris chloris</i>	0.6572	0.1829
<i>Anthoxanthum sp.</i>	1.000	<i>Certhia brachydactyla</i>	0.6220	0.3780
<i>Anthyllis vulneraria</i>	0.691	<i>Cettia cetti</i>	1.3581	0.6585
<i>Armeria maritima</i>	0.418	<i>Circus aeruginosus</i>	2.0570	0.8585
<i>Arrhenatherum elatius</i>	0.091	<i>Cisticola juncidis</i>	2.1481	0.6122
<i>Arum italicum</i>	0.255	<i>Coluba oenas</i>	1.2908	0.7293
<i>Asphodelus albus</i>	0.945	<i>Columba palumbus</i>	0.3000	0.0707
<i>Avena fatua</i>	0.327	<i>Corvus corone</i>	0.2811	0.0927
<i>Avena sativa</i>	1.000	<i>Corvus monedula</i>	0.9598	0.3878
<i>Bellis perennis</i>	0.018	<i>Corvus corax</i>	1.2282	0.8780
<i>Brassica nigra</i>	0.800	<i>Cuculus canorus</i>	0.4335	0.4976

<i>Bromus ferromii</i>	0.800	<i>Dendrocopos major</i>	0.6379	0.3073
<i>Bromus hordeaceus</i>	0.282	<i>Dendrocopos minor</i>	0.9135	0.7561
<i>Calamagrostis epigejos</i>	0.991	<i>Emberiza cirulus</i>	0.5855	0.4098
<i>Calluna vulgaris</i>	0.182	<i>Emberiza citrinella</i>	0.7113	0.3439
<i>Carex paniculata</i>	0.200	<i>Emberiza schoeniclus</i>	2.3901	0.6659
<i>Castanea sativa</i>	0.155	<i>Erithacus rubecula</i>	0.4840	0.0927
<i>Catapodium loliaceum</i>	0.564	<i>Falco peregrinus</i>	2.1170	0.9585
<i>Centaurea erythrea</i>	0.164	<i>Falco tinnunculus</i>	0.6808	0.2122
<i>Cerastium diffusum</i>	0.555	<i>Fringilla coelebs</i>	0.2717	0.0732
<i>Cirsium campeste</i>	0.055	<i>Garrulus glandarius</i>	0.4435	0.2976
<i>Cirsium vulgare</i>	0.027	<i>Locustella luscinioides</i>	NA	0.9610
<i>Cochlearia danica</i>	0.464	<i>Locustella naevia</i>	1.2360	0.8951
<i>Convolvulus arvensis</i>	0.191	<i>Miliaria calandra</i>	1.4643	0.9390
<i>Corylus avellana</i>	0.209	<i>Motacilla alba</i>	0.6933	0.2659
<i>Crataegus monogyna</i>	0.109	<i>Motacilla cinerea</i>	1.6446	0.4780
<i>Cruciata laevites</i>	0.309	<i>Muscicapa striata</i>	0.9674	0.6415
<i>Cuscuta epithymum</i>	0.491	<i>Oenanthe oenanthe</i>	1.7036	0.9561
<i>Cytisus scoparius</i>	0.100	<i>Panurus biarmicus</i>	NA	0.9854
<i>Dactylis glomerata oceanica</i>	0.955	<i>Parus ater</i>	1.3863	0.9463
<i>Dactylis glomerata</i>	0.000	<i>Parus caeruleus</i>	0.3509	0.0610
<i>Dactylorhiza maculata</i>	0.291	<i>Parus cristatus</i>	1.6167	0.5707
<i>Daucus carota</i>	0.055	<i>Parus major</i>	0.2949	0.0902
<i>Digitalis purpurea</i>	0.118	<i>Parus palustris</i>	0.9876	0.5805
<i>Dipsacus fullonum</i>	0.545	<i>Passer domesticus</i>	1.2636	0.0659
<i>Echium vulgare</i>	0.918	<i>Phoenicurus ochruros</i>	1.1169	0.6390
<i>Erica ciliaris</i>	0.318	<i>Phylloscopus collybita</i>	0.4600	0.1610
<i>Erica cinerea</i>	0.118	<i>Phylloscopus sibilatrix</i>	1.1175	0.8659
<i>Erica vagans</i>	1.000	<i>Pica pica</i>	0.7022	0.1585
<i>Erigeron acer</i>	0.936	<i>Picus viridis</i>	0.3842	0.4195
<i>Erigeron annuus</i>	1.000	<i>Prunella modularis</i>	0.4953	0.1463
<i>Eryngium campestre</i>	0.591	<i>Pyrrhula pyrrhula</i>	1.0525	0.5073
<i>Eryngium maritimum</i>	0.718	<i>Pyrrhocorax pyrrhocorax</i>	2.8557	0.9659
<i>Eupatorium cannabinum</i>	0.127	<i>Regulus ignicapillus</i>	1.0805	0.7829
<i>Euphorbia paralias</i>	0.764	<i>Regulus regulus</i>	1.4598	0.5390
<i>Euphorbia portlandica</i>	0.582	<i>Saxicola torquata</i>	0.7758	0.2024
<i>Festuca arundinacea</i>	0.136	<i>Serinus serinus</i>	0.7767	0.6000
<i>Festuca rubra</i>	0.100	<i>Sitta europaea</i>	0.9229	0.3659
<i>Festuca rubra pruinosa</i>	0.709	<i>Streptopelia decaocto</i>	0.9920	0.1805
<i>Frankenia laevis</i>	0.700	<i>Streptopelia turtur</i>	0.4003	0.3049
<i>Fumaria capreolata</i>	0.564	<i>Sturnus vulgaris</i>	0.5706	0.0634
<i>Galium aparine</i>	0.018	<i>Sylvia atricapilla</i>	0.3163	0.1488
<i>Galium mollugo</i>	0.091	<i>Sylvia borin</i>	0.6939	0.3537
<i>Galium saxatile</i>	0.364	<i>Sylvia communis</i>	0.6540	0.4073
<i>Galium verum</i>	0.945	<i>Sylvia undata</i>	2.0649	0.7146
<i>Gd brome</i>	1.000	<i>Troglodytes troglodytes</i>	0.3716	0.1024
<i>Geranium dissectum</i>	0.027	<i>Turdus merula</i>	0.2336	0.0195
<i>Geranium molle</i>	0.009	<i>Turdus philomelos</i>	0.4017	0.1707
<i>Hedera helix</i>	0.009	<i>Turdus viscivorus</i>	0.5179	0.2902

<i>Heracleum sphondylium</i>	0.036
<i>Holcus lanatus</i>	0.009
<i>Hordeum murinum</i>	0.436
<i>Hyacinthoides non scripta</i>	0.082
<i>Hypericum humifusum</i>	0.155
<i>Hypochaeris radicata</i>	0.018
<i>Ilex aquifolium</i>	0.164
<i>Jasione montana</i>	0.073
<i>Juncus glaucus</i>	1.000
<i>Juncus inflexus</i>	0.582
<i>Lathyrus nissolia</i>	0.900
<i>Lathyrus aphaca</i>	0.882
<i>Laurier sauce</i>	0.555
<i>Leucanthemum vulgare</i>	0.064
<i>Linum bienne</i>	0.364
<i>Lolium perenne</i>	0.036
<i>Lolium perenne italicum</i>	0.036
<i>Lonicera periclymenum</i>	0.082
<i>Lotus corniculatus</i>	0.055
<i>Lotus parviflorus</i>	0.891
<i>Luzula campestris</i>	0.127
<i>Lystera ovata</i>	0.464
<i>Matricaria recutita</i>	0.555
<i>Medicago arabica</i>	0.191
<i>Medicago lupulina</i>	0.209
<i>Medicago sativa</i>	0.591
<i>Melampyrum pratense</i>	0.445
<i>Mentha suaveolens</i>	0.418
<i>Myosotis arvensis</i>	0.191
<i>Ononis repens/riclinata</i>	0.573
<i>Ophrys apifera</i>	0.800
<i>Origanum vulgare</i>	0.664
<i>Ornithopus perpusillus</i>	0.118
<i>Pedicularis sylvatica</i>	0.227
<i>Phlomis fruticosa</i>	0.009
<i>Picris echioides</i>	0.336
<i>Picris hieracioides</i>	0.845
<i>Pilosella officinarum</i>	0.173
<i>Pinus maritimus</i>	0.009
<i>Plantago coronopus</i>	0.045
<i>Plantago holostea</i>	0.009
<i>Plantago lanceolata</i>	0.009
<i>Plantago major</i>	0.045
<i>Poa annua</i>	0.027
<i>Poa trivialis</i>	0.055
<i>Polygala serpyllifolia</i>	0.291
<i>Polygala vulgaris</i>	0.673
<i>Polypodium vulgare</i>	0.155

<i>Potentilla anserina</i>	0.245
<i>Potentilla recta</i>	0.109
<i>Potentilla repens</i>	0.009
<i>Potentilla reptans</i>	0.164
<i>Prunella vulgaris</i>	0.073
<i>Prunus spinosa</i>	0.045
<i>Pteridium aquilinum</i>	0.018
<i>Pulicaria dysenterica</i>	0.355
<i>Quercus pedunculatus</i>	0.100
<i>Quercus petraea</i>	0.636
<i>Quercus robur</i>	0.100
<i>Ranunculus bulbosus</i>	0.345
<i>Ranunculus ficaria</i>	0.091
<i>Ranunculus parviflorus</i>	0.864
<i>Ranunculus repens</i>	0.018
<i>Rosa canina</i>	0.409
<i>Rosa microcantha</i>	0.991
<i>Rosa pimpinellifolia</i>	0.755
<i>Rubia peregrina</i>	0.582
<i>Rubus fruticosus</i>	0.018
<i>Rumex acetosa</i>	0.009
<i>Rumex acetosella</i>	0.064
<i>Rumex obtusifolius</i>	0.045
<i>Sagina sp.</i>	1.000
<i>Salix cinerea</i>	0.064
<i>Sambucus nigra</i>	0.082
<i>Sanguisorba minor</i>	0.664
<i>Sanguisorba officinalis</i>	0.009
<i>Scilla autumnalis</i>	0.818
<i>Sedum anglicum</i>	0.091
<i>Senecio jacobaea</i>	0.027
<i>Sherardia arvensis</i>	0.136
<i>Silene maritima</i>	0.418
<i>Silene vulgaris</i>	0.927
<i>Silene vulgaris var. maritima</i>	0.418
<i>Simethis mattiazzii</i>	0.964
<i>Sinapis arvensis</i>	0.364
<i>Solanum dulcamara</i>	0.055
<i>Sonchus oleraceus</i>	0.045
<i>Spergula subulata</i>	0.482
<i>Taraxacum gr. Ruderalia</i>	0.036
<i>Teucrium scorodonia</i>	0.064
<i>Tragopogon pratensis</i>	0.973
<i>Trifolium dubium</i>	0.045
<i>Trifolium incarnatum</i>	0.009
<i>Trifolium pratense</i>	0.036
<i>Trifolium repens</i>	0.009
<i>Tuberaria guttata</i>	0.864

<i>Ulex europaeus maritimus</i>	0.782
<i>Umbilicus rupestris</i>	0.009
<i>Urtica dioica</i>	0.009
<i>Veronica arvensis</i>	0.082
<i>Veronica chamaedrys</i>	0.145
<i>Veronica hederifolia</i>	0.227
<i>Vicia bithynica</i>	0.891
<i>Vicia sativa</i>	0.173
<i>Vicia sylvatica</i>	0.009
<i>Vinca minor</i>	0.545
<i>Vincetoxicum hirsutinaria</i>	0.009
<i>Viola riviniana</i>	0.082

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Electronic Supplementary Material S6. Geographic information used to create the spatial grid.

Source information	Information used
GIS National Botanical Conservatory of Brest	- Natura 2000 areas - Natural habitats according to the conceptual model category
BD Carto IGN [http://professionnels.ign.fr/gratuit]	- Municipality - Paths
MNT IGN [http://professionnels.ign.fr/gratuit]	- Areas with steep slopes
GIS of Natura 2000 coordinator (Community of Municipalities of the Crozon peninsula)	- Intensity of tourist frequentation among the different areas - Natura 2000 sectors - Areas where conservation actions were performed between 2006 and 2012
Plans of the Department of Natural Areas of the town of Crozon	- Cutting areas softwood performed before 2013
GIS DREAL	- Agricultural parcels (2004, 2010, 2012) - Properties of Coastal Conservation Authority
GIS Coastal Conservation Authority	- Areas agreement with hunting association and farmers
Géobretagne [http://cms.geobretagne.fr/]	- Communal properties, properties of General Council
our GIS	- Chough's breeding sites - Priority area for cutting softwood

Electronic Supplementary Material S7. Additional elements of the model validation Crozon.

Figure S6-1: Vegetation map obtained by simulation

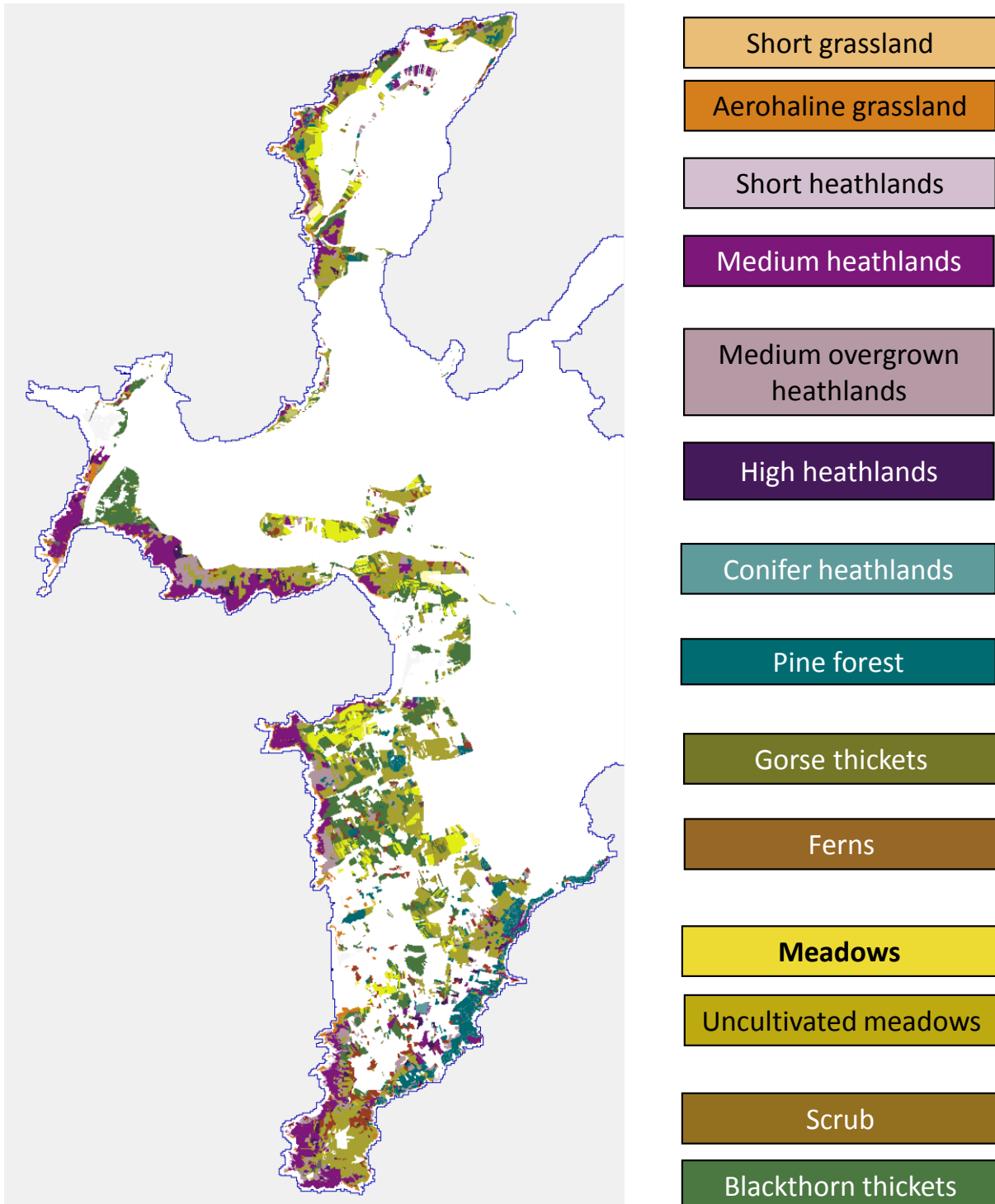



Table S7-1: model validation Crozon.

Figure S7-1: Sampling point for model validation



Error type	Remarks
<p>rasterisation (111 plots)</p>	<p>During rasterisation, the information stored in a cell (model space unit) relates only to the habitat which has the largest surface area in the cell. 111 georeferenced plots mentioned "erased during rasterisation" because these habitats were the minority in terms of area across the cell. The rasterisation step is necessary, though the bearing requires an attempt to adapt to the spatial resolution of the average size of the patch-type of vegetation.</p> 
<p>Effect of the random allocation of age during initialisation (163 plots)</p>	<p>The evolution of one habitat to another depends on the type of habitat and the time. The time dimension is modelled by a variable "age" assigned to each cell and incremented each year. At initialisation, the value of this variable is randomly selected between two bounds corresponding to the age of the potential habitat. For example, the age of a <i>meadow</i> will be set between 0 and 4 years; the age of an uncultivated meadow will be set between 4 and 7 years. If the meadow is not maintained, it becomes an uncultivated meadow after 7 years. Thus, this relatively random assignment of age value to cells generates a bias with respect to the real age of a habitat, and therefore to the moment of transition to another habitat (ahead of or behind reality). For example, in the model, 33 out of 110 points that we observed as pine forest correspond to cells in which the habitat is conifer heathlands, while 24 of 49 points that we observed in conifer heathlands match pine forest. This bias is related to the difficulty of knowing precisely the stages of the plant population and / or very local geophysical constraints (wind, spray, soil type).</p>
<p>Inconsistency between the 1999 vegetation (e.g., pine forest) and vegetation type observed in the field in 2013 (e.g., shrub), because under the conceptual model the transition from pine forest to <i>shrub</i> does not exist</p>	<p>Regarding a transition not included in the conceptual model, this type of error can be challenging. Special cases may exist and may be derived</p> <ul style="list-style-type: none"> - A human action not known and therefore not included in the simulations, - An error in vegetation identification in 1999 or 2013, - An error related to the accuracy of the location in 1999 or 2013 (the field is a mosaic of a medium composed of small patches of habitat often less than 200 m²).

Electronic Supplementary Material S8. Scenarios

1. Scenario current trend

Management	
Tourist trampling	Tourist frequentation considered stable
Exclosure	Sectors and dates envisaged in the management plan of the Coastal Conservation Authority ¹
Mowing heathland	Areas and periods in the same patterns as the mowing actions since 2006. These actions are performed by municipality of Crozon, the Coastal Conservation Authority and General Council ² . The sectors are drawn randomly on medium-overgrown heathlands, high heathlands and gorse thickets on their respective properties.
Cuts softwood	Areas and periods in the same patterns as the softwood cut actions since 2006. These actions are performed by the Coastal Conservation Authority and the municipality of Crozon ³ . The sectors are drawn randomly on pine forest and conifer heathlands on their respective properties and excluding areas with important slopes
Agricultural activities	Maintenance of existing farms in 2013
Activities of hunting societies	Maintenance of geolocalised meadows and the creation of paths according to the pattern of surfaces since 2006

¹ *An area under development (Dinan 2013); an area planned (Cap de la Chèvre 2019)*

² *Identified since 2006: a mowing event of 0.45 ha by the Coastal Conservation Authority, an event of 2.3 ha by the General Council, an event of 1.3 ha and 0.25 ha of two events by the municipality of Crozon. Surfaces and intervals between events were retained and applied in simulations on a time horizon of 15 years.*

³ *Identified since 2006: a cutting event of 1.72 ha, a cutting event of 8 ha by the Coastal Conservation Authority, and a cutting event of 4.64 ha by the municipality of Crozon. In the same way as for the heathland, the surfaces and periodicity between events were retained and applied in simulations on a time horizon of 15 years.*

2. Sustained Management Scenario

Actions corresponding to the Current Trends scenario, to which are added conservation measures advocated in the target document. Exclosure and softwood cuttings made according to sectors and priorities are defined in the target document. Priority 1 is made at a time corresponding to year 1, priority 2 to 5 years, and priority 3 to 10 years.

Actions: i) restoration of heathlands, ii) maintenance of heathlands iii) creation of a mosaic of habitat are not related to a predefined site and are modelled in terms of effort area per year. Each of these 3 actions concern 20 ha / year. The sectors are randomly selected on medium-overgrown heathlands, high heathlands and gorse thickets.

3. Agricultural-stopping Activities Scenario.

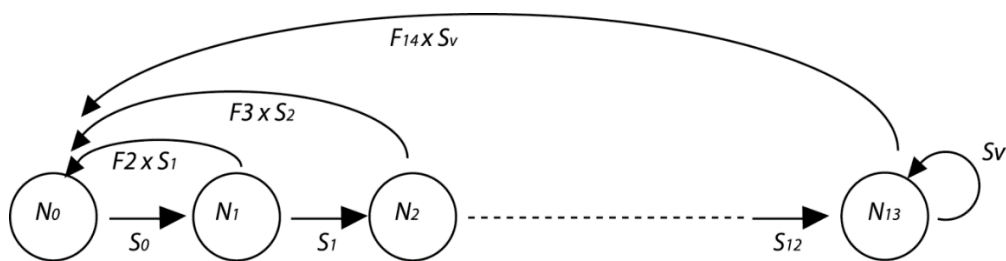
Actions included in this scenario correspond to the Current Trends scenario excluding agriculture from the beginning of the simulation.

4. Without Agriculture and Without Conservation Actions Scenario.

Trampling is the only action represented.

Electronic Supplementary Material S9. Modelling Chough population dynamics

- *The development of an individual-centred model* was necessary because the number of choughs is extremely low: 9 breeding pairs for a total population of 40 individuals in 2013. This approach was used to examine the effects of the stochastic results due to the low number of breeding birds and environmental stochasticity (Judson 1994). This type of model has led to a complete description of all individuals: sex, age and reproductive status. These models are more accurate than the predictions of the deterministic models, especially when the population size is small or the population trend is close to balance (Travis & Dytham 1998). This model was defined using the following inputs: complete census of breeding pairs on the site, fledging success (assessment based on the period 1995-2005 for the population of Ushant, located within 50 km (Kerbiriou 2006)) and survival (assessment based on the 1998-2005 period, and also on Ouessant (Kerbiriou *et al.* 2009)). In addition, some data are not available for Ouessant such as female fertility by age or survival rates of adults, and it is necessary to mobilise the results of similar studies conducted on the island of Islay in Scotland for over 20 years (Reid *et al.* 2003).

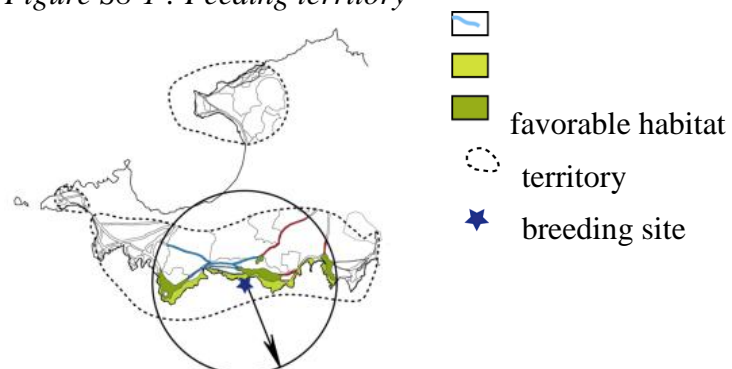


The spatially explicit population modelling is open to empirical knowledge (Grimm 1999) and allows linking the population dynamics for dynamic environments (landscape, land use) (Letcher *et al.* 1998; Railsback & Harvey 2002). This type of model is particularly suitable for this species and this research question because it permits taking the spatial data into account: *Breeding site* limited to 24 breeding sites, including 10 historic sites and additional sites currently used. This resource does not change and is not affected by other agents; *Feeding habitats*, the chough is a specialist species using foraging habitats whose main requirement is low vegetation height: grassland and heathlands, dunes and pasture.

This type of model allows us to take into account the high territoriality of this species (Kerbiriou *et al.* 2006). Omitting spatial heterogeneity in the distribution of these resources or pressures (fallow land encroachment, tourists) would make this model of chough population dynamics unrealistic.

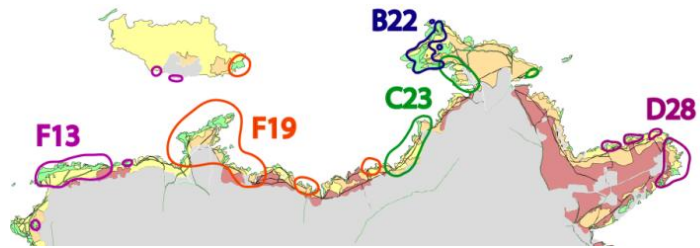
In addition, reproductive success is linked to the quality of the territory during the breeding season. This quality is a combination of habitat quantity adjacent to the nest and has been included in the territory of the breeding pair (Kerbiriou *et al.* 2006).

Figure S8-1 : Feeding territory



Territoriality of breeding pairs requires considering the territorial interactions between reproductive couples: the choughs, in the breeding season, segment space in territory. The choughs were then considered communicating agents in the multi-agent modelling.

Figure S8-2 : layout of 5 feeding territory



The connection between the population dynamics of choughs and other agents (managers, farmers, and tourists) are based on the impact of these agents upon the dynamics of habitats used by Chough: short grassland 1, 2 &3, short heartlands (1&2), dune. .

Differences with the model developed for Ouessant.

Field observations on the Crozon peninsula allowed us to identify a new resource in terms of food habitat for chough dune systems (Coastal stable dune grassland “grey dunes”). In the model, this resource is considered as non-progressive in the simulations and not impacted by the agents.

A second difference is the foraging radius, which was increased from 300 to 500 meters. This change is a result of field observations at the Crozon site. Preliminary simulations showed that the population dynamics were more sensitive to the number of available breeding sites than to the foraging radius. Modelling conducted with 14 rather than 24 breeding sites affected the annual population growth rate, which decreased from 6% to less than 1%. While modelling with a foraging range radius of 300 meters instead of 500 meters does not affect the growth rate, no significant change was recorded. According to these results, the number of nesting sites therefore appears to be a factor that limits population growth, a finding also obtained on Ouessant (Kerbiriou 2006).

Table S8-1 : Summary of the model settings

Parameter	Estimation	Reference
First year survival probability S_0^f	$S_0 = 0,32$	Kerbiriou <i>et al.</i> 2009 Reids <i>et al.</i> 2003a
second year survival probability (S_1)	$S_1 = 0,82$	Kerbiriou <i>et al.</i> 2009
Survival probability of 3-12 years old adults (S_2 à S_{12})	S_2 à $S_{12} = 0,82$	Reids <i>et al.</i> 2003b
Survival probability of 13+ years old adults (S_v)	$S_v = 0,27$	Reids <i>et al.</i> 2003b
Mean female productivity	Depends on the age of the females, the quality of the territory within a radius of 500m around the nest	This study, Kerbiriou <i>et al.</i> 2006, Reids <i>et al.</i> 2003a
Initial population size	40	This study
Maximum number of nesting sites	24	This study
Initial population age structure	Obtained from a matrix model using the same life cycle	This study

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