Biodiversity and Conservation
June 2009, Volume 18, Number 7, Pages 1719-1732
http://dx.doi.org/10.1007/s10531-008-9507-0

OECD pressure–state–response indicators for managing biodiversity: a realistic perspective for a French biosphere reserve

Harold Levrel[1, *], Christian Kerbiriou[2], Denis Couvet[2] and Jacques Weber[3]

[1] UMR CERSP, Muséum National d'Histoire Naturelle and IFREMER, UMR AMURE, Marine Economics Department, Centre de Brest, Z.I. Pointe du Diable, BP70, 29280 Plouzane, France
[2] Conservation des Espèces Restauration et Suivi des Populations—UMR 5173 Muséum National d'Histoire Naturelle, 55 rue Buffon, 75005 Paris, France
[3] CIRAD, 42 rue Scheffer, 75116 Paris, France

*: Corresponding author : H. Levrel, email address : Harold.Levrel@ifremer.fr

Abstract:

Sustainability is said to be the science of integration, be it integration of scale, discipline or of stakeholders' interests. One way to integrate such diverse elements is to develop sustainable development indicators. Numerous national and international organizations have attempted to develop such indicators, among which interaction indicators are of critical importance because they enable us to link up human activities, ecological dynamics, and social goals. Among the various ways to develop such indicators, the most common ones are the pressure–state–response (PSR) indicators, as well as others coming from this framework. With realistic methodology one shall observe how PSR indicators might appear as an operational tool to face rapid social and ecological changes within a French biosphere reserve in Brittany. Results suggest that such a framework is insufficient to describe, understand and manage social and ecological interactions.

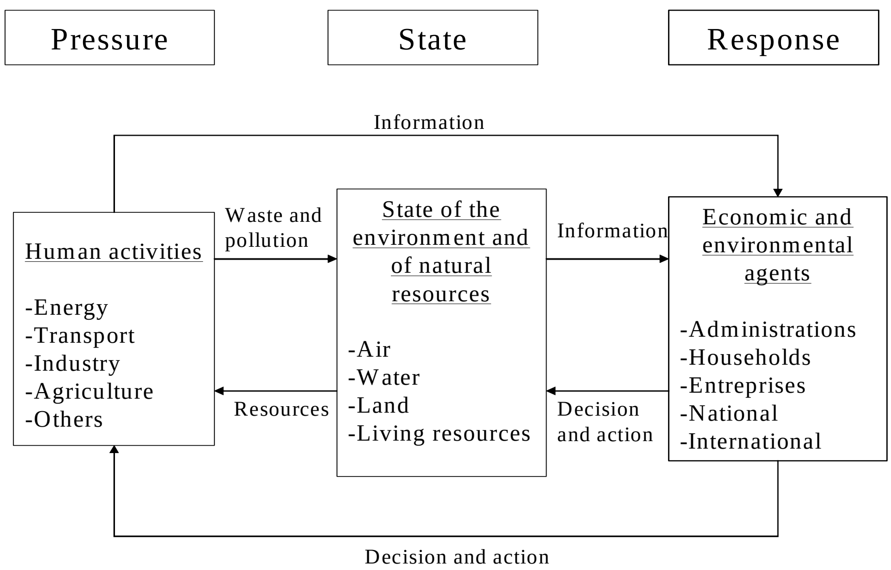
Keywords: Interaction indicators - PSR indicators - Adaptive management - Biodiversity

1. Introduction

Sustainable development may be compared to a journey. Everybody's heard about it and everybody agrees to say that it is a marvelous one. The problem is that nobody really knows how to get there and, actually, nobody knows the exact destination. It thus represents an "Eldorado" for development policy-makers. This is why sustainable development indicators are needed to give us some signals for identifying where we are going to. Among sustainable development indicators, the interaction indicators are of critical importance (Hukkinen 2003a). In the biodiversity management domain, interaction indicators address the question of the links between conservation issues, economical activities and social well-being (Levrel 2007). At the beginning of the 1990's, this indicator category did not exist. Yet, there was a need for it as stated by the Commission on Sustainable Development in the chapter 40 of Agenda 21 (1992, 40.4): "Methods for assessing interactions between different sectoral environmental, demographic, social and developmental parameters are not sufficiently developed or applied." So as to satisfy it, many international organizations have launched ambitious programs to develop interaction indicators.

Among the organizations that have developed interaction indicators is the Organization for Economic Co-operation and Development (OECD) with its successful and innovative Pressure-State-Response (PSR) framework (OECD 1994). The Driver-Pressure-State-Impact-Response indicators (DPSIR) (European Environmental Agency 2003), the Driving Force-State-Response indicators (DSR) (Commission on Sustainable Development 2001), the Pressure-State-Use-Response-Capacity (PSURC) (Convention on Biological Diversity 2003) all come from the OECD's original framework. The PSR indicators propose to evaluate the *pressures* of human activities on environmental *states* and to provide political *responses* in order to come back to a "desirable state" (Figure 1). This approach has recently been broadened to social, institutional and economical dimensions (CSD 2001). However, some recent works have shown that pressure and response indicators were not adapted – and not clear enough – to understand and manage interactions in both social and economical spheres (Briassoulis 2001; CSD 2001; Zaccaï 2002; Conseil National du Développement Durable 2003; Hukkinen 2003a).

Figure 1: The Pressure-State-Response framework



Source : OECD, 1994

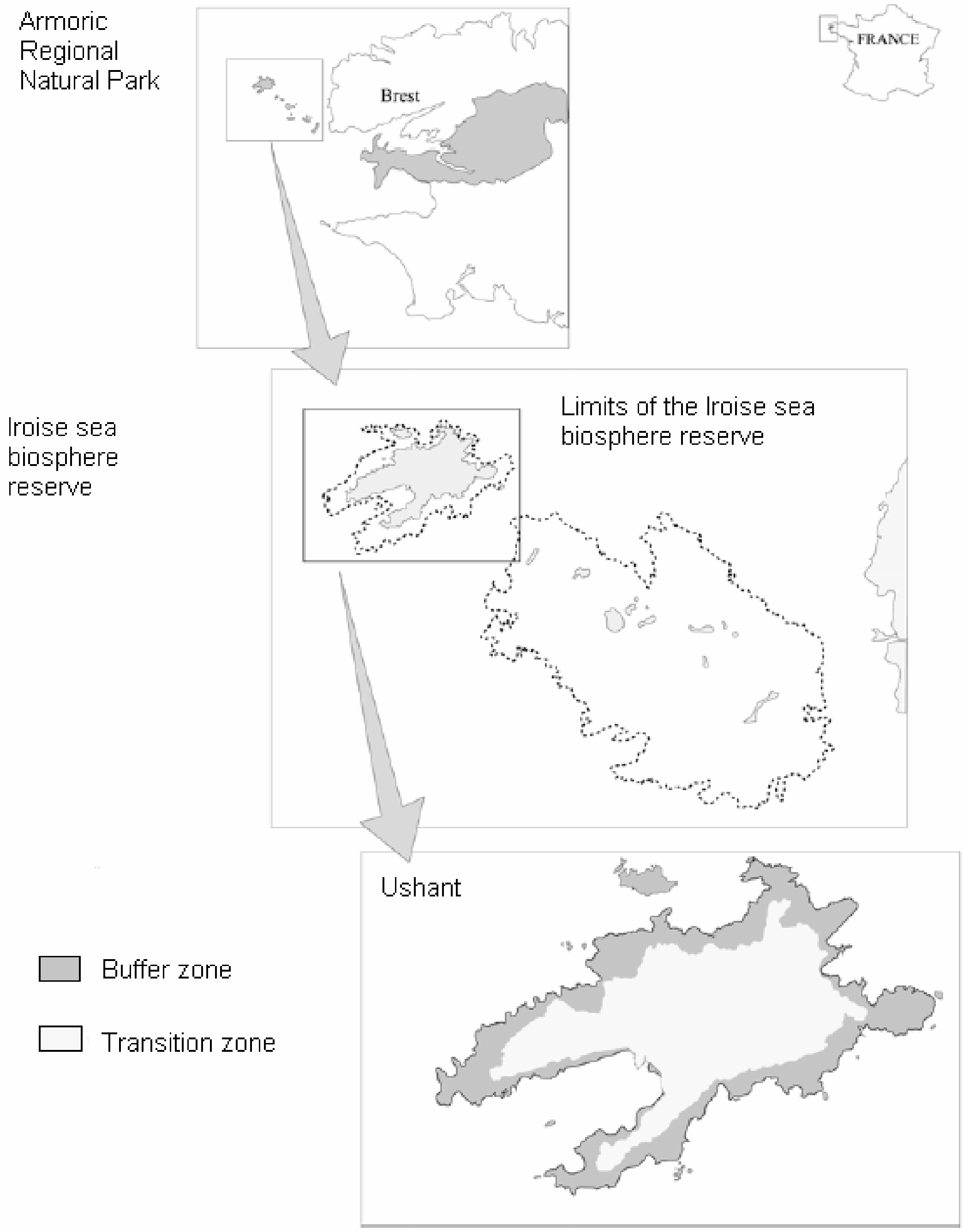
These indicators are often used in environmental reports as mentioned above. Indeed, PSR indicator system provides a useful and simple tool to formalize environmental problems due to its intuitive structure – human pressure on environmental state and political responses to adopt solutions. Environmental scientific programs have also adopted the PSR framework for developing interaction indicators. Except for the study of Kammerbauer et al. (2000), the PSR framework is most of the time developed as a control panel tool for experts (OECD 1994; Crabtree and Bayfield 1998; Firbanka et al. 2002; Liu 2007; Wolfslehner and Vacik 2007).

Since the publication of the first OECD report regarding PSR indicators, some criticisms have highlighted the theoretical limits of this framework (OCDE 1994; Hukkinen 2003b; Wolfslehner and Vacik 2007). In particular, the challenges associated with establishing cause-effect relationships between the three boxes and the PSR framework suggests an over-simplified representation of the complex social-ecological interactions and structures. As far as we know, there are few papers which propose an empirical assessment of such indicators on the ground. When a working group develops PSR indicators in a specific field, the focus is on underlining the limits of this framework without going further into their analysis. In particular, the key question of how it is possible to use PSR framework as an operational tool for managing social-ecological interactions is poorly discussed. Accordingly, we would identify traditional indicators of pressure, state and response in the field of biodiversity management and gather some empirical evidence in order to appreciate their relevance for park managers.

2. Material and method: a realistic methodology to test PSR indicators: the case of the Ushant island

A realistic methodology consists in comparing theory with practice within a specific context (Collier 1994). Most of the time, conservation programs adopt an ecosystem approach (Convention on Biological Diversity 2000; UNESCO Man And Biosphere 2000; Millenium Ecosystem Assessment 2005). Therefore, we have attempted to test PSR framework at a small ecosystem scale: the Ushant Brittany island (1541 ha.) localized in western France (48° 28' N, 5° 5' W) (Figure 2). The island of Ushant is recognized as an European biological hotspot for ecosystem, sea birds (Cadiou et al. 2004), plants (Annezo et al. 1998, Kerbiriou et al. 2008) (Tables 1 and 2).

Figure 2 : Location and zoning of Ushant island and Iroise sea biosphere reserve



Source: Kerbiriou, 2006, p.18

Table 1: Indicators of bird community trends in Ushant[1]

[1] Grey tint indicate breeding bird population at this period. **European conservation status** : **SPEC2** species whose global population are concentrated in Europe and which have an unfavourable conservation status in Europe ; **SPEC3** species whose global population are not concentrated in Europe but which have an unfavourable conservation status in Europe ; **Non-SPEC** species whose have a favourable conservation status in Europe (source Burfield & Bommel 2004). **Listed Ann I** : Annex 1 of the European Community Directive 79/409 on the Conservation of Wild Birds. Article 4 of this Directive requires members States to designate Special Protection Areas (SPAs) in which biotopes used by species on Annex 1 are maintained. Fr R species considered as Rare in France; Fr M specie whose need a

Birds species indicators	1900	1950	1960	1971	1984	1992	2002	Listed	European conservation Status	European threat status
Dartford warbler (*Sylvia undata*)	■	■	■	■	■	■	■	Ann I ; FrM	SPEC2	Depleted
Linnet (*Carduelis cannabina*)	■	■	■	■	■	■	■		SPEC2	Declining
Common kestrel (*Falco tinnunculus*)	■	■	■	■	■	■	■	FrM	SPEC3	Declining
Northern house-martin (*Delichion urbica*)	■	■	■	■	■	■	■		SPEC3	Declining
Barn swallow (*Hirundo rustica*)	■	■	■	■	■	■	■	FrD	SPEC3	Depleted
Northern wheatear (*Oenanthe oenanthe*)	■	■	■	■	■	■	■		SPEC3	Declining
Red-billed Chough (*Pyrrhocorax pyrrhocorax*)	■	■	■	■	■	■	■	Ann I ; FrM	SPEC3	Declining
House sparrow (*Passer domesticus*)	■	■	■	■	■	■	■		SPEC3	Declining
Skylark (*Alauda arvensis*)	■	■	■	■	■	■	■		SPEC3	Depleted
Mallard (*Anas platyrhynchos*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Common cuckoo (*Cuculus canorus*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Common swift (*Apus apus*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Winter wren (*Troglodytes troglodytes*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Hedge accentor (*Prunella modularis*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Meadow pipit (*Anthus pratensis*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Rock pipit (*Anthus petrosus*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Common stonechat (*Saxicola torquata*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Common whitethroat (*Sylvia communis*)	■	■	■	■	■	■	■		Non-SPEC	Secure
Raven (*Corvus corax*)	■	■	■	■	■	■	■		Non-SPEC	Secure
White wagtail (*Motacilla alba*)	■								Non-SPEC	Secure
Peregrine falcon (*Falco peregrinus*)	■							Ann I ; Fr R	Non-SPEC	Secure
Crested lark (*Galerida cristata*)	■							Fr D	SPEC3	Depleted
Common quail (*Coturnix coturnix*)	■	■							SPEC3	Depleted
Northern harrier (*Circus cyaneus*)	■	■	■					Ann I ; Fr M	SPEC3	Depleted
Corn bunting (*Milaria calandra*)	■	■	■	■					SPEC2	Declining
Yellow hammer (*Emberiza citrinella*)	■	■	■	■				Fr M	Non-SPEC	Secure
Yellow wagtail (*Motacilla flava*)	■	■	■	■					Non-SPEC	Secure
Sand martin (*Riparia riparia*)				■					SPEC3	Depleted
Great spotted woodpecker (*Dendrocopos major*)		■							Non-SPEC	Secure
Zitting cisticola (*Cisticola juncidis*)				■	■		■		Non-SPEC	Secure
Grasshopper-warbler (*Locustella naevia*)			■	■			■		Non-SPEC	Secure
Magpie (*Pica pica*)		■							Non-SPEC	Secure
Blackbird (*Turdus merula*)		■	■	■	■	■	■		Non-SPEC	Secure
Common reed-warbler (*Acrocephalus scirpaceus*)		■	■	■	■	■	■		Non-SPEC	Secure
Common starling (*Sturnus vulgaris*)			■	■	■	■	■		SPEC3	Declining
Song thrush (*Turdus philomelos*)			■	■	■	■	■		Non-SPEC	Secure
Great tit (*Parus major*)			■	■	■	■	■		Non-SPEC	Secure
Bullfinch (*Pyrrhula pyrrhula*)			■	■	■	■	■		Non-SPEC	Secure
Common moorhen (*Gallinula chloropus*)				■	■	■	■		Non-SPEC	Secure
Common wood-pigeon (*Columba palumbus*)				■	■	■	■		Non-SPEC	Secure
Eurasian collared dove (*Streptopelia decaocto*)				■	■	■	■		Non-SPEC	Secure
Robin (*Erithacus rubecula*)				■	■	■	■		Non-SPEC	Secure
Sedge warbler (*Acrocephalus schoenobaenus*)				■	■	■	■		Non-SPEC	Secure
Willow warbler *(Phylloscopus trochilus*)				■	■	■	■		Non-SPEC	Secure
Goldfinch (*Carduelis carduelis*)				■	■	■	■		Non-SPEC	Secure
Greenfinch (*Carduelis chloris*)				■	■	■	■		Non-SPEC	Secure

special population monitoring (source from the French Red List, Berthelot & Rocamora 1999).

Carrion crow (*Corvus corone*)									Non-SPEC	Secure
Garden warbler (*Sylvia borin*)									Non-SPEC	Secure
Common chiffchaff (*Phylloscopus collybita*)									Non-SPEC	Secure
Blackcap (*Sylvia atricapilla*)									Non-SPEC	Secure
Eurasian sparrowhawk (*Accipiter nisus*)									Non-SPEC	Secure
Chaffinch (*Fringilla coelebs*)									Non-SPEC	Secure
Marsh-harrier (*Circus aeruginosus*)								Ann I ; Fr M	Non-SPEC	Secure
Water rail (*Rallus aquaticus*)									Non-SPEC	Secure
Long-eared owl (*Asio otus*)									Non-SPEC	Secure
Long-tailed tit (*Aegithalos caudatus*)									Non-SPEC	Secure
Cetti's warbler (*Cettia cetti*)									Non-SPEC	Secure
Bird community indicators[2]										
SPEC2	**3**		**3**				**2**			
SPEC3	**11**		**8**				**7**			
Listed species	**8**		**6**				**5**			
Total rare species	**22**		**17**				**14**			
Specific Richness	**27**		**30**				**46**			

Table 2 : Plant species richness among habitats in Ushant and their amount in term of presence of rare species station[3].

Habitat	Number of sampling	Plant species richness by sampling	Percentage of rare species plots
Short grassland (1230-6)	51	14.12 ± 0.57	77
Maritime grassland (1230-3)	62	11.06 ± 0.53	0
Short dry heaths (4030-2)	52	14.67 ± 0.57	6
Medium dry heath (4030-3)	55	10.56 ± 0.55	3
Pasture	277	8.31 ± 0.36	0
Pasture in earlier stage of fallow land encroachment	39	13.15 ± 0.63	0
Fallow land dominated by bracken and blackberries	137	8.17 ± 0.29	0
Fallow land dominated by shrub (gorse and blackthorn)	44	7.55 ± 0.60	0
Marsh dominated by herbaceous	42	9.00 ± 0.98	2
Marsh dominated by willow	14	8.02 ± 0.61	0

Moreover, Ushant is located in the Iroise Sea Biosphere Reserve[i], a protected area harboring marine, terrestrial and coastal ecosystems which aim to reconcile biodiversity conservation with its sustainable use. Besides, participatory processes involving local stakeholders are a prerequisite for implementing conservation policy regarding UNESCO's

---

[2] **SPEC2** species whose global population are concentrated in Europe and which have an unfavourable conservation status in Europe ; **SPEC3** species whose global population are not concentrated in Europe but which have an unfavourable conservation status in Europe ; **Non-SPEC** species whose have a favourable conservation status in Europe (Burfield & Bommel 2004). **Listed Ann I** : Annex 1 of the European Community Directive 79/409 on the Conservation of Wild Birds.

[3] The total of percentage did not reach 100% due to presence of some rare species in habitat not considered in this study (cliff and maritime caves). When habitats are one of the Annexe I directive habitat their *EUNIS* code is indicate into bracket.

MAB label (see web site of MAB-UNESCO programme: http://www.unesco.org/mab/). In this context, interaction indicators should be a privileged governance tool improving dialogue between people and facilitating collective decisions regarding interaction between conservation and development issues. We are here questioning the capacity of PSR indicators to provide a means of communication for park managers concerned by the impacts on biodiversity of recent rapid social-ecological changes.
To that end, we have reviewed literature and carried out several interviews (n=30) that took place between 2003 and 2004 with park managers, local stockbreeders, island residents and scientists living or working on this island for a long period of time. This enables us to test how it is possible to implement the PSR framework through a three step diagnostic regarding respectively "state indicators", "pressure indicators" and "response indicators".

3. Results

3.1. The states

To construct PSR indicators, it is necessary to define a desirable – or a reference – state. Identifying the desirable state for biodiversity is a delicate task because it is related to a variety of ecological scales – from the genetic to the landscape level, including that of the Biosphere. However, it is possible to tackle this diversity of scales thanks to the set of state indicators: number of Red List Species or endemic species, population size, habitat heterogeneity, agricultural plant varieties, etc. Even if this approach appears useful, there are some tensions between these different parameters. For example, habitats on Ushant are more heterogeneous today than they were fifty years ago (Gourmelon et al. 1995). In the middle of the fifties, the landscape of Ushant consisted of open grasslands, but fallow land encroachment during the following 50 years was a source of habitat heterogeneity.
However, regional park managers perceive this process as a source of biodiversity loss. Habitat fragmentation and loss due to fallow land encroachment led to reductions in population sizes for many terrestrial bird species (Skylark (*Alauda arvensis*), Chough (*Pyrrhocorax pyrrhocorax*) and to species extirpation for some (Montagu's Harrier (*Circus pygargus*), Crested lark (*Galerida cristata*), Quail (*Coturnix coturnix*), Corn bunting (*Emberiza calandra*), Yellowharmmer (*Emberiza citrinella*). Yet, arrival of new species occurred simultaneously (Marsh Harrier (*Circus* aeruginosus), Chaffinch (*Fringilla coelebs*), Goldfinch (*Carduelis carduelis*), Greenfinch (*Carduelis chloris*), Carrion crow (*Corvus corone*), Robin (*Erithacus rubecula*), Great Tit (*Parus major*) which lead to an increase in the total species richness ($y = 0.1848x – 328.36$; $R^2 = 0,71$; Table 1). In fact, in Northern developed countries, the loss of open habitat due to changes in agriculture practices is often perceived as detrimental to biodiversity (Lovett-Doust et al. 2003; Grand et al. 2004; Laiolo et al. 2004). Such perceptions materialise because most new species are common, generalist and opportunistic whereas threatened species are specialists of open landscape, most often with restricted ranges, and are considered as rare (Table 1) (Tucker and Heath 1995). The same pattern has been observed for plant communities on Ushant (Table 2).
The next step to build PSR indicators is to identify pressures, which are the source of current dynamics.

3.2. The pressures

A period of rapid changes is ideal for analysing social-ecological interactions because the driving forces are easy to identify. Rapid social changes on the island of Ushant are characterized by a decreasing human population and an ever–increasing number of tourists. At the beginning of the 20^{th} century, there were 2661 inhabitants but only 956 at the last census. In fact, in 1952, there were always agro-pastoral activities ran by households for their own consumption with crops in the middle of the isle (34% of the area of the isle), and pastures in the coastal and wetland meadow areas (38%) grazed by 4500 sheep and 350 cattle (Gourmelon et al. 2001). In 1992, crops disappeared (1%), while pastures (31%) were localized in the middle of the isle and sheep livestock number stood at around 1000. Sheep livestock was around 650 in 2003. Cattle livestock had disappeared in 1992 but a small livestock (60) was introduced in 2000. Between 1952 and 1992, fallow land encroached on the major part of the isle – from 0 % to 43 % of the total area (Gourmelon et al. 1995). At the same time, the number of tourists has dramatically increased as shown by the evolution of the number of ferry passengers: from 10 000 in 1950 to 250 000 in 2000 (Le Viol 2002), with a continuous annual growth of about 2 500 passengers during the last twenty years (ANOVA $F_{1,17}$ = 708.365 P<0.0001; GAM, P = 0.356). This double dynamic is due to the growth of leisure activities and the decline of agro-pastoral activities, as well as changes in ecosystem services – from provisioning services (agro-pastoral activities) to cultural services (tourism activities) (Millenium Ecosystem Assessment 2005).

Fallow land encroachment lead to the decrease of rare species as previously mentioned (Kerbiriou 2001). Tourists represent a source of pressure for the local ecosystem due to coastal trampling and disturbances to the local fauna (Kerbiriou et al. 2005).

In our example, it is important to underline that human activities have some positive effects on biodiversity and are not only a source of pressure. From an economic perspective, externalities are not necessarily negative in the case of Ushant where it is the lack of human agro-pastoral activities which has led to fallow land encroachment and to potential ecological problems. Even if tourists represent a source of pressure for ecological viability, they are also a source of ecological opportunities. First of all, coastal trampling by tourists has a double effect. It leads to the degradation of the vegetation but it also maintains open landscape for local red list species, including some birds (Wheatear and Chough) and plants (*Ophioglossum lusitanicum*, *Isoetes histrix)*. Secondly, tourists are a source of opportunities for the natural park because tourists pay a transport tax (“Barnier Tax”) which generates income directly allocated to environmental management such as fallow land control. Tourists staying at least one night in Ushant have also to pay a sojourn tax, managed by the municipality.

The impact of these pressures on biodiversity is difficult to assess because ecological, social and economical parameters do not evolve at the same time scales. With respect to ecological dynamics, crop fields become meadows after one or two years. Resilience of seed-eating bird populations for two decades decreases (such as Buntings (*Emberiza sp*) and colonization of new species led to the increase of species richness in the short term. However, at medium term, extinction of seed-eating bird species, potential disappearance of open grassland habitat with its consequences on other bird species and new species interactions could lead to species richness decrease (Pimm and Harvey 2001). In addition, changes in economic activities are very fast – e.g. new business opportunities associated with tourism – whereas social institutions are particularly slow to change – e.g. access and use rights. Therefore, it seems difficult to evaluate the medium-long term net effect of human impacts on present social-ecological system reorganization (Gunderson and Holling 2002).

In fact, social-ecological driving forces are diverse and complex. They are interconnected and difficult to discriminate. For instance, tourists consume a traditional dish based on sheep meat, which is proposed by restaurants and requires using some sods of turf for cooking. This dish is very successful and represents an important source of income. It contributes both to the maintenance of open landscape and the increase in coastal erosion because sods are harvested from the coastal grasslands. Tourists also create a pressure on local accommodation prices (92 % between 1995 and 2002) (Buhot 2004) which can be related with decreases in both human population and traditional agro-pastoral activities. At the same time however, the increasing number of tourists maintains minimum public services on the island and supplies jobs to the local population. There are 5 hotels, 3 guest houses, 17 houses who rent rooms for tourists, 30 furnished houses to rent, 1 camping with 50 places, 1 youth hotel with 44 beds, and 1 naturalist centre with 40 beds, for a total capacity of 600 tourists. There are 10 restaurants, 3 taxis and 4 bicycle renting companies.

Now we need to explore the potential social responses allowing to counterbalance negative effects coming from pressures and to develop new indicators.

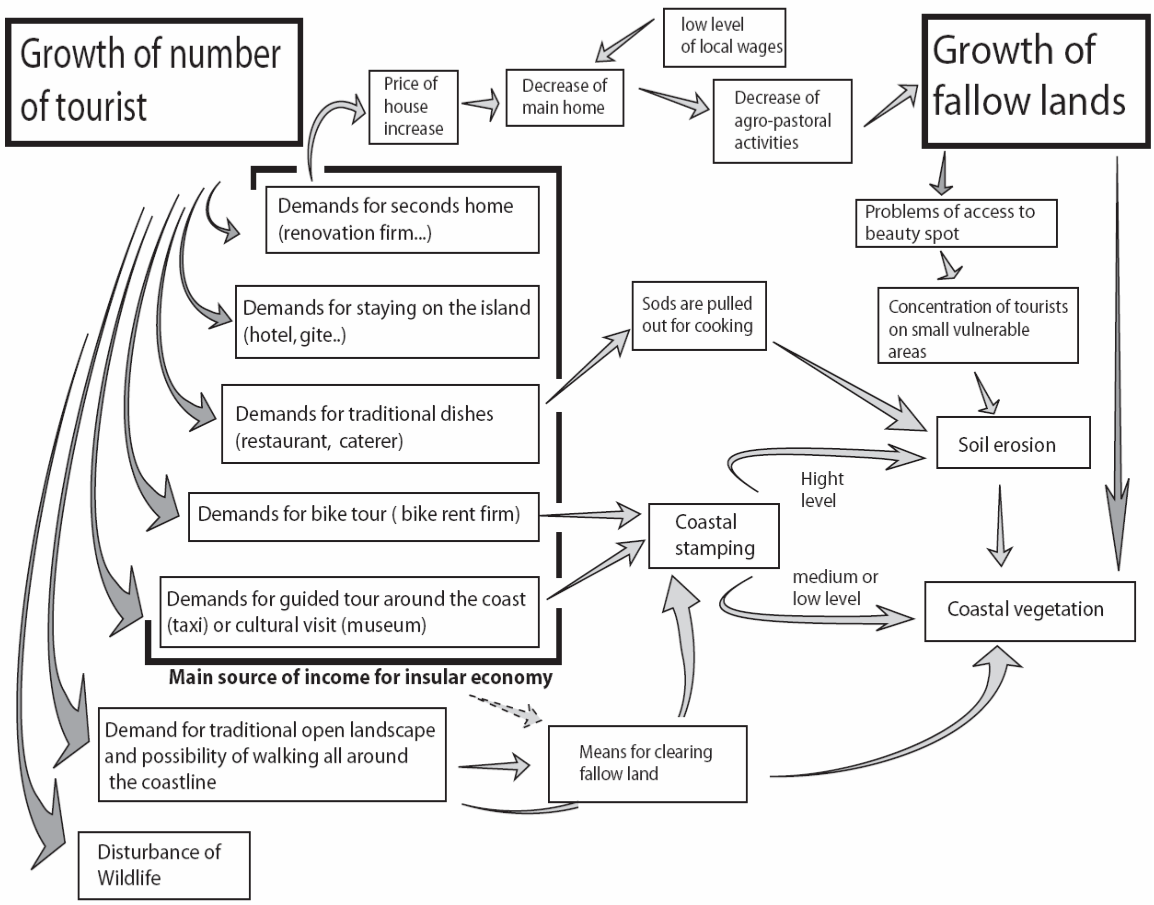
3.3. The responses

Response indicators are often the percentage of protected area, the total number of protected species and the expenditure in nature conservation (CSD 2001; EEA 2003; CBD 2003). Such indicators are used because they can easily be documented, in particular because they correspond to well-established responses or policies. New, more ambitious responses, like agro-environmental measures, or eco-labelling, are not represented yet through indicators (although it is in project, see web site of CBD: http://www.biodiv.org). In the case of Ushant, these traditional conservation measures exist. Ushant is located within the Armoric Regional Park and the Iroise Sea Biosphere Reserve. The coastal zone has received the status of "Site Classé[ii]" in 1979, which has led to the total protection against any human construction. Moreover, Ushant is within a Natura 2000 area. These measures could provide an adapted response to the tourism boom but are useless with respect the fallow land encroachment problem. Today, only the Armoric regional park provides some responses to the fallow land encroachment problem by promoting the clearing of some fallow parcels. Such a response is useful but, if there are not any other responses to fight the source of the problem – i.e. the real driving force is the decline of agro-pastoral uses, this ex-post response will have an important cost and will neither be efficient nor sustainable.

4. Discussion

It is possible to develop state, pressure and response indicators for the isle of Ushant in accordance with those proposed by CSD (2001), EEA (2003) or CBD (2003) (Figure 4).

Figure 4: Interactions between fallow land encroachment and tourist increase



Yet, is it useful for describing, understanding and governing current rapid social-ecological changes?

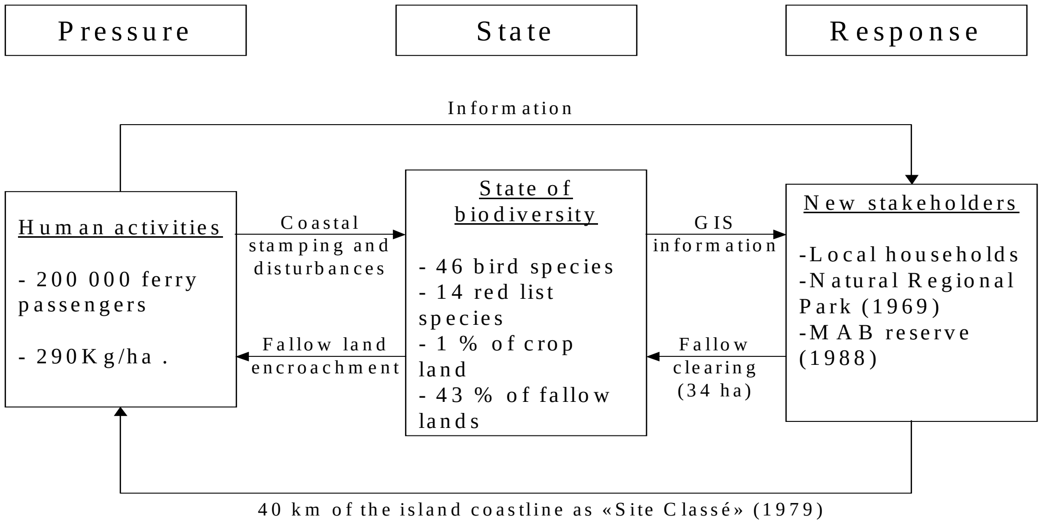
State indicators?

As illustrated by this example, it is difficult to determine critical indices for decision-making because there are many criteria – richness or abundance of rare species for example – which can be in conflict at different ecological scales (Tables 1 and 2). Decision-makers usually adopt trade-off thanks to implicit social conventions – such as to maximize the number of red list species, satisfy public opinion or optimize habitat heterogeneity. Accordingly, choosing a desirable state is not a strictly scientific and objective question. It is partly subjective and depends on various individual and collective preferences (Westley et al. 2002): it is essential to take into account stakeholders' perceptions of biodiversity. Classifying them in order to characterize biodiversity's desirable state is the next step so as to identify workable conservation goals. For the same reasons, there is not a single social or economic desirable state but many alternative ones. If there are conflicts between different ecological objectives, it is even more difficult to balance them with social and economical ones.

Pressure indicators?

Fallow land encroachment and the tourism boom are interrelated through many ways and there is a great uncertainty concerning their net effects on the biodiversity. The initial "pressure issue" is becoming a complex problem with many interconnections (Figure 3).

Figure 3: PSR indicators for Ushant island in 2006



Practices' classification in a "pressure box" at a local scale is equivalent to showing who's responsible for the problem. Stakeholders can not accept to be a simple source of pressure for the social-ecological system (Levrel and Bouamrane 2008): the pressures always result from the activities of others. Consequently, the pressure classification process is more a source of conflict than one of dialogue between local stakeholders.

Response indicators?

Response indicators are mainly focused on technical solutions and don't take into account the political dimensions of these responses. Responses are always the result of (long) negotiations in a specific social context: they exhibit an emergent and a consensual property.

Park managers are not alone on the island and their response capacity is limited. They don't command and control the social-ecological system. As a result, it is not possible to develop efficient response indicators without taking into account the social process that leads to select them. For the moment, local stakeholders are not interested in participating to the biosphere reserve management and they have simply no idea or suggestion for managing the rapid changes. In this context, the first step to develop response indicators that contribute to the management of social-ecological interactions is to improve communication between local stakeholders. Subsequently, interaction indicators could help understanding how the system works and how potential responses, based on trade-off that are socially acceptable, could change the dynamics of the system.

Comments on relevance and the theoretical background of PSR indicators.

PSR indicators can provide a quick description of interactions but do not indicate precisely how social and ecological issues are related. The PSR framework is focused on the environmental issue where ecological system dynamics depend exclusively on human activities.

PSR indicators seem useful for national administrative monitoring purposes due to their intuitive design (human pressure on environmental state) and because they can provide initial information to disentangle the different components of the environmental problem. At a local scale, it is not the case: social-ecological interactions are numerous but easily identifiable. It is possible to take into account the complexity of the social-ecological dynamics. However, the PSR framework seems inappropriate to inform about this complexity because it provides economical, ecological and social sector-based ad-hoc desirable states that are in conflict and lead to an oversimplification of social-ecological interactions. In other words, the PSR framework is built upon a simple scenario of how anthropogenic pressure creates environmental disturbances. It could be possible to link together several PSR frameworks corresponding to several points of view: some "states" would represent some "pressures" for others and so on. But this would go beyond a PSR framework and amount to building a systemic one.

Indeed, the PSR framework background is based on an analytic approach which looks for an optimal solution by using simplified constraints on anthropogenic pressures, environmental states and social responses. This optimal perspective where humans are the problem and have the solution is not in accordance with the sustainability indicator problematic (Hukkinen 2003a, 2003b; Reed et al. 2006; Levrel and Bouamrane 2008). There is a long history of social-ecological collapses due to the use of "optimal modelling methodology" for managing ecosystem services (Carpenter et al. 2002). The key problem for PSR indicators is that, within this framework, the ecological system and people are passive – not adaptive – with the exception of the "manager". This manager has the capability to collect all information, to analyse it and to take the optimal decision in response to any environmental change. The construction of PSR indicators is currently based on neoclassical decisional theory leading to a "command and control" perspective not adapted to assessing interactions between environmental, demographic, social and developmental parameters or providing solid bases for decision-making at a local scale (Arrow et al. 2000; Yorque et al. 2002; Kinzig et al. 2003).

A core property of an indicator is to have a scientific dimension as tool of proof and a political one as tool for decision. It is a scientific as well as a social object (Latour 1987, 1998). An indicator must be considered as a compass and a gyroscope that give accurate and relevant signals about sustainable development trajectories (Lee 1993).

Therefore, it could be more useful to use a systemic and reference scenario approach for launching simulations in which interaction indicators are connected by non-linear relations (Hukkinen 2003a; Levrel and Bouamrane 2008). System dynamics models (SDM), Multi-agent systems (MAS) and Role-playing game (RPG) are particularly adapted for it (Vennix 1996; van Eeten M. and Roe 2002; Janssen 2003; Boulanger and Bréchet 2005). With these categories of models, one can develop artificial socio-ecosystems where human and ecological entities co-evolve, and test alternative “what if” scenarios in order to explore the possible futures and to facilitate negotiations between local stakeholders. They have been used successfully in many contexts for managing natural resources, understanding better how social-ecological interactions work and improving discussion quality (Costanza and Ruth 1998; Rouwette et al. 2002; Etienne et al. 2003; Bousquet and Le Page 2004; Gurung et al. 2006).

These categories of models use interaction indicators in many ways:

they use some reference indicators in order to compare different scenarios at various time and spatial scales;

these models have a very flexible interface which can produce alternative sense-making indicators corresponding to alternative points of view for the same phenomenon;

as the simulation progress with very different scenarios, key interaction indicators that determine different outcomes emerge;

these models permit to articulate micro-indicators used for decentralized decision-making with macro-monitoring indicators.

In this approach, interaction indicators can facilitate discussions and collective learning, balance arguments and provide information to carry-out trade-off analyses for social, ecological and economical aims (Reed et al. 2006). In our example, interaction indicators should highlight interactions between economic dimensions (price of houses, demand for traditional dishes, etc.), social questions (proportion of main home vis-à-vis second home, motivations for agro-pastoral activities, etc.), ecological dynamics (invasive species, habitat heterogeneity changes, etc.) and individual representations (of the island, fallow land encroachment or biodiversity, etc.) in order to understand better the current biodiversity dynamics and to clarify the social, ecological and economic stakes in relation with the biodiversity issue.

Moreover, these interaction indicators must inform about economics constraints (tourist as the main source of income for the isle), ecological constraints (vegetal structure which creates problems of access for tourists and breeders) and social constraints (local institutions and conventions concerning breeding activities) as well as the social relations (conflicts between different stakeholders about natural resource uses) to understand how this social-ecological system works. Taking into account all these parameters, and in particular tensions between different social-ecological components, is essential for governing biodiversity in the Ushant Island. It requires models and interaction indicators adapted to this complex task.

---

[i] “Biosphere reserves are sites recognized under UNESCO's Man and the Biosphere Programme which innovate and demonstrate approaches to conservation and sustainable development […]There are 531 sites worldwide in 105 countries.” (http://www.unesco.org/mab/BRs.shtml)

[ii] Natural sites requiring authorization for any new construction which can impact state or appearance of this protected area.