A MULTI-SCALE SCENARIO APPROACH TO BIOLOGICAL INVASIONS
Two cases in the Ebro River

Beatriz Rodriguez-Labajos
Departament d'Economia i Història Econòmica, Universitat Autònoma de Barcelona,Spain,beatriz.rodriguez@uab.es

Abstract

Biological invasions are human-mediated processes contributing to global change. Governance of the responses to invasion processes must handle dynamic social understanding and agency. Mainstream policy guidelines embracing the precautionary approach advise the implementation of a hierarchical scheme starting from preventive strategies. This faces uncertainties inherent to such a socially and biologically complex phenomenon.

Taking this in mind, scenario development is proposed as a methodological approach for assessing biological invasions at different spatial scales. This way, the reflexive nature of biological invasions is explored in a non-reductionist fashion. This study examines two scales. At the local scale, the cases of two aquatic species invading the low Ebro River (zebra mussel and Wels catfish) are employed as empirical support for developing local scenarios. At the larger scale, the European Union is taken as governance unit for developing analytic narratives of alternative policy scenarios with implications in biological invasions. Scenarios obtained at both scales were integrated in order to evaluate consistency and plausible events from the overlapped contexts. Large scale scenarios may be employed as boundary conditions for local scenarios. But some elements point out to top-down and bottom-up influences, reflecting the ability of local contexts to react favourably or resist toward the large scale pressures.

Finally the usefulness of scenario development as assessment and management tool for governance of responses to biological invasions is examined.

1. Introduction

Biological invasions are human-mediated processes contributing to global change (Vitousek et al., 1997). Human involvement in biological invasions is framed in four relevant dimensions: history, causes, consequences and response to invasive species (McNeely, 2001). Thus, governance of the responses to invasion processes must handle dynamic social understanding and agency.

Conservation policy guidelines embracing the precautionary approach (e.g. the Convention on Biological Diversity (CBD, 2002)) advise the implementation of a hierarchical scheme starting from preventive strategies (Wittenberg and Cock, 2001).

Accordingly, many scientific efforts around invasive species focus on quantitative prediction of invasion processes in order to develop preventive policies (Daehler and Strong, 1996; Gilbert et al., 2004). But the complex interaction between factors makes each case unique, so making good predictions may prove to be

impractical (Heger and Trepl, 2003). Moreover, it has been said that *invasions just are unpredictable in the way that earthquakes are* (Williamson, 1999).

However, the human roots of invasions make them reflexive processes and thus subject of social learning. Therefore, while driving forces and desirable scenarios can be identified, communication with the involved actors can exploit favourably this reflexivity. Ordering the efforts around an objective of public policy implies to construct a 'big picture' that proves to be plausible and meaningful to the key audience. This guides the discussion towards scenario planning, which offers multiples perspectives on complex processes, helping to disclose the reason why things happen in a certain way (Chapman et al., 2001).

Taking this in mind, qualitative scenario development is proposed as a methodological approach for assessing biological invasions at different scales of governance. This way, the reflexive nature of the phenomenon is explored in a non-reductionist fashion. Particularly, the meaning of biological invasions and their driving forces are analysed taking into account stakeholders' different views.

This study examines two scales. At the larger scale, the European Union is taken as governance unit for developing analytic narratives of alternative policy scenarios. At the local scale, the cases of two aquatic species invading the low Ebro River are employed as empirical support for developing participatory local scenarios. Finally, both scales are integrated and the advantages and limitations of scenarios as assessment tools of biological invasions are outlined.

2. Scenarios and biodiversity

Interpretation of what scenarios are may differ according to their supporting goal, process design or content. After extensive review, van Notten et al. (2003) summarized the themes for classifying scenarios as it is shown in **Table 1**.

Table 1. Scenario typology
Source: van Notten et al. (2003)

Overarching themes	Characteristics
Project goal: Exploration vs decision support	*Inclusion of norms?:* descriptive vs normative *Vantage point:* forecasting vs backcasting *Subject:* issue-based, area-based, institution based *Time scale:* long term vs short term *Spatial scale*: global / supranational vs. national/local
Process design: Intuitive vs formal	*Data*: qualitative vs quantitative *Method of data collection*: participatory vs desk research *Resources*: extensive vs limited *Institutional conditions*: open vs constrained
Scenario content: Complex vs simple	*Temporal nature:* chain vs snapshot *Variables:* heterogeneous vs homogeneous *Dynamics*: peripheral vs trend *Level of deviation:* alternative vs conventional *Level of integration:* high vs low

In this paper, scenarios are understood as descriptions of alternative images of the future, created from mental models that reflect different perspectives on past, present and future events (Rotmans et al, 2000). They provide representations of plausible futures and typically include a storyline, sometimes supported by quantitative indicators (Berkhout et al., 2002).

Scenarios allow developing an integrated set of assumptions to expand insights into a situation and its potential evolution. For its flexibility and promotion of interlinking

between science and social actors in complex issues, they have been adopted within the methodological toolkit of approaches concerned by science-governance-policy interfaces in environmental matters, such as Social Multi-Criteria Evaluation (Munda, 2004) or integrated assessment (Kasemir et al., 2003).

Scenario development for assessing biodiversity is an emergent application. Related studies are presented in **Table 2**. Understanding of ecosystem change is addressed by considering the evolution of its drivers. Mainly focused on larger scales, both analytic and participatory methods have been employed.

Table 2 - Scenarios for biodiversity assessment

Source	Purpose	Type	Main scenarios
Biological invasions in South Africa (Chapman et al., 2001)	To anticipate and understand possible trajectories of plant invasions in South Africa in a frame of complexity	Analytic / Expert-based Qualitative storyline based on workshop activities with natural scientists	*Garden of Eden*: strongly performing economy and coherent policies and regulations *Another farmyard*: strong national economy but weak regulatory environment *Green desert*: weak national economy and weak regulatory environment *New mosaic*: weak economy but strong regulatory environment
GEO-3 (UNEP, 2002)	To provide to decision-makers a picture of what tomorrow might bring in terms of human well-being and environmental security and what the impact of their decisions is likely to be.	Analytic / Hybrid (model-based – expert based) Qualitative narratives take centre stage with the quantitative tools playing a supporting role	*Markets First:* market-driven developments converge on the values and expectations that prevail in industrialized countries; *Policy First:* strong actions are undertaken by governments in an attempt to reach specific social and environmental goals; *Security First:* great disparities, where inequality and conflict prevail, brought about by socio-economic and environmental stresses; and *Sustainability First:* new development paradigm emerges in response to the challenge of sustainability, supported by new, more equitable values and institutions.
Regional ecosystem services (Peterson et al., 2003)	To assess the sustainability of ecosystem services in a region in transition (Northern Highland Lake District, Wisconsin)	Participatory / Ecological scientist & stakeholders Qualitative narratives based on social and ecological processes that are known to take place	*Walleye Commons*. Development decrease and little effective lake management. *Northwoods.com*. Development increase, moderate vulnerability, protection of certain lakes. *Lake mosaic.* Development increase, management by groups of residents surrounding specific lakes.
Global biodiversity loss (Millennium Ecosystem Assessment, 2005)	To address the consequences of different plausible futures for global ecosystem services and human well-being	Analytic / Hybrid (expert based - model-based) Combination of qualitative storyline development based on interviews and literature review and quantitative modelling based on assumptions about the evolution of indirect drivers	*Global Orchestration*: global economic and social policies are the primary approach to sustainability. *Order from Strength*: protection through boundaries becomes paramount *Adapting Mosaic*: environmentally proactive local and regional management as the primary approach to sustainability *TechnoGarden*: potential role of technology in providing or improving the provision of ecosystem services.

3. The large scale dynamics

3.1. Methods and results

At the larger scale, socio-economic driving forces of biological invasions were identified by means of literature review. In order to appreciate the interactions between the socio-economic aspects and the biological domain, different levels of driving forces were categorized adapting an organizing scheme proposed by Spangenberg (2004). After that, the European Union was taken as unit of analysis for generating precise assumptions regarding the evolution of these drivers under alternative policy scenarios. Three scenarios developed by the European integrated project ALARM (see Omann and Stocker, 2005) were taken as reference. Results are presented in **Table 3**.

Table 3 - Driving forces of biological invasion under the ALARM scenarios

Driving forces of biological invasions		**GR**owth **A**pplied **S**trategy	**B**usiness -**A**s- **M**ight- **B**e-**U**sual	**S**ustainable **E**uropean **D**evelopment **G**oal
Primary DF Management	**Transport practices**	↑	↗ →	↘
	Trade activities	↑	↑	↘
	Travel and tourism	↗	→	→
	Changing agricultural practices	↗	→	→
	Fauna management	→	→	↘
	Expanding human-made infrastructure	↑	↗	↗ →
	Options available for alien invader control	↑	↗	↘
Secondary DF Policy	**Policy transformation**	→	→	↗
	Trade policy	↑	↗	→ ↘
	Changes in laws, policies and regulations	↗	→	→
	Agricultural policy	→	→	↘
	Environmental policy	→	→	→
Tertiary DF Ideology and lifestyle	**Global trends**	↑	↗	↗
	Internal economic trends	↑	→	→
	Emerging social interests	↑	→	↘
	Changing perspectives and paradigms in nature conservation	↑	→	↘
	Knowledge / information	↗	↗	→
Base - Short term 'exogenous'	**Human population dynamics (size and time of occupation)**	↗	↗	↗

Narratives were developed for each scenario according the formulated assumptions.

1. In the GRAS scenario, intensification of most drivers accentuates the phenomenon of biological invasions in the midst of generalized social indifference. Only its economic impacts are perceived and generate some reactions. Responses toward invasive species damaging economic assets (infrastructures, commercial crops and harvests) are required. They adopt those 'easy' solutions that, inside the soft regulatory framework, match with the mainstream economic interest (pesticides, GMO). Impacts on human health of both biological invasion and their control are tolerated except for the few incidents where liabilities are clearly

demonstrated. Defined by business opportunities, research agenda focuses on innovative technical solutions for fighting against pests, namely biotechnology.

2. In the BAMBU scenario, most drivers also intensify. Incoming flow of invasive species is constant. However, the species find some barriers for establishing. Although the trend to urbanization favours bioinvasions, the aim of nature conservation pushes some policies, like CAP, towards landscape maintenance. The network of protected areas is extended. Preventive policies are pursued by supporting weakest-link countries. Although social concern enhances preventive actions, prevalence of economic interests lessens the priority of biological invasions as a matter of intervention. Research agenda on biological invasions focuses on technical control solutions. Educational programmes supporting nature appreciation are also required by a part of the society.

3. In the SEDG scenario, driving forces of biological invasions decline dramatically owing to a higher social awareness. Sense of place and resources in environmental education have made of sustainability a basic ideological guideline for acting towards invasions. Two kinds of response are taken. On the one hand, each specific invasion is systematically assessed with stakeholders' support. Vigorous control and effective mitigation measures are taken only in some cases. On the other hand, the very concept of biological invasions is deconstructed. The capability of adaptative management takes the place of a general bioinvasions policy.

3.2. Lessons of the large scale

Identification of driving forces at the large scale reveals those aspects of the invasion phenomenon that can be managed by public policies and those that only can be approached from a consensus with the relevant actors. In this sense, fundamental driving forces, including both ideology and basic population dynamics, operate as general influences for all the system. Meanwhile, the policy and the management levels affect more specifically certain taxa, or certain species inside the taxa. Thus, the more direct the causal association, the easier the development of specific actions. However, interventions at the last link of the drive chain make likely the re-emergence of the invasion process.

On the other hand, analysis of pathways can be synthesized in sectoral economic trends. This way, the increase of transport due to trade and travel, new globalized patterns of consumption and the transformation of hosting ecosystems emerge as main drivers of biological invasions. The kind of exerted pressure is different between sectors. While trade and transport increase the movement of the species, some activities enhance their establishment by transforming the host ecosystems. In any case, they are especially relevant in terms of management. Among them, trade, tourism and travel and other highly impacting economic activities can be highlighted.

Qualitative scenarios allowed the recognition of plausible outcomes in terms of bioinvasions from diverse socio-political contexts in Europe. They are flexible assessment tools that allow a transparent account of assumptions, including:

- exposition of trends and sequences of events;
- indication of species and taxa prone to participate in the invasion process;
- possible policies and social responses to those policies (e.g. conflicts for the use of pesticides);
- social tensions and cultural and ideological developments around biological invasions.

Consistency of scenarios has been tested by expert assessment. However, a real test of consistency would be to put these scenarios under the scrutiny of stakeholders.

3. Strangers in the Ebro River

3.1. Methods

This section describes local scenarios based on the social perceptions around the invasion processes of *Dreissena polymorpha* (zebra mussel) and *Silurus glanis* (Wels catfish) in the low Ebro River. Participatory methods are employed to involve relevant stakeholders in key activities of scenario development from the identification of driving forces to the setting out of the storylines. Methodological procedure includes the steps specified in **Figure 1**.

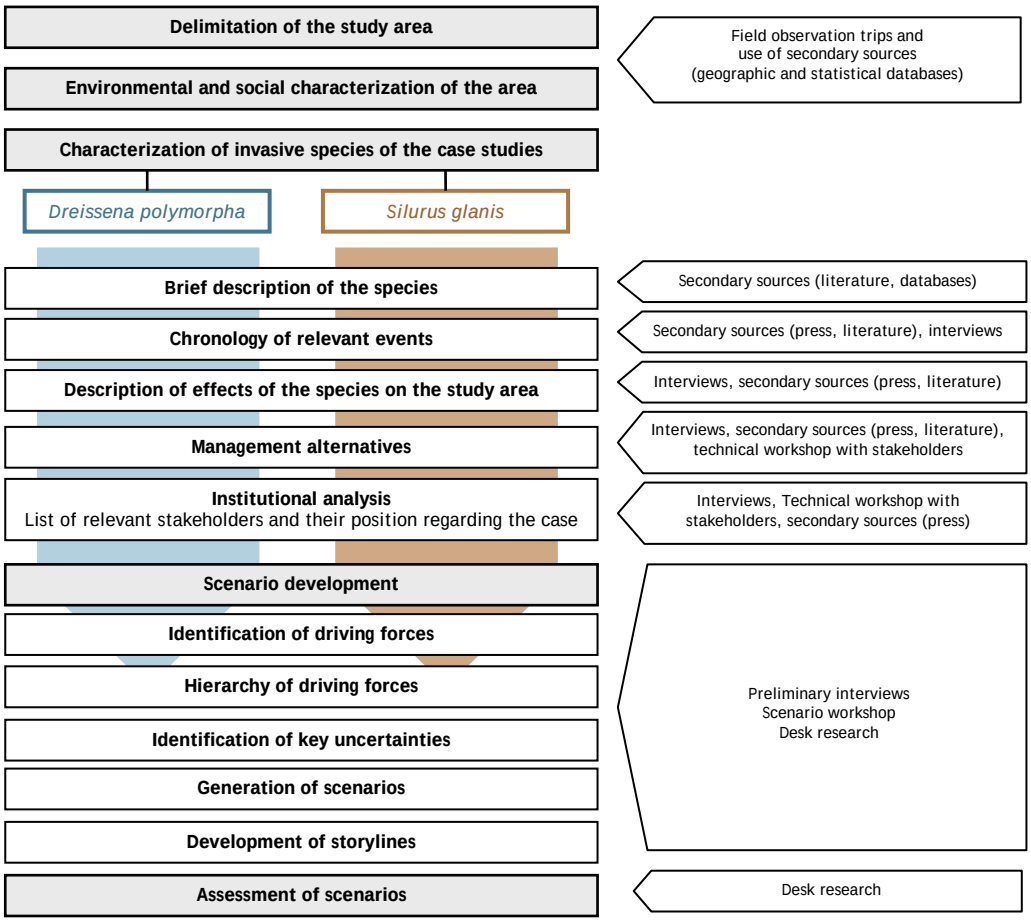


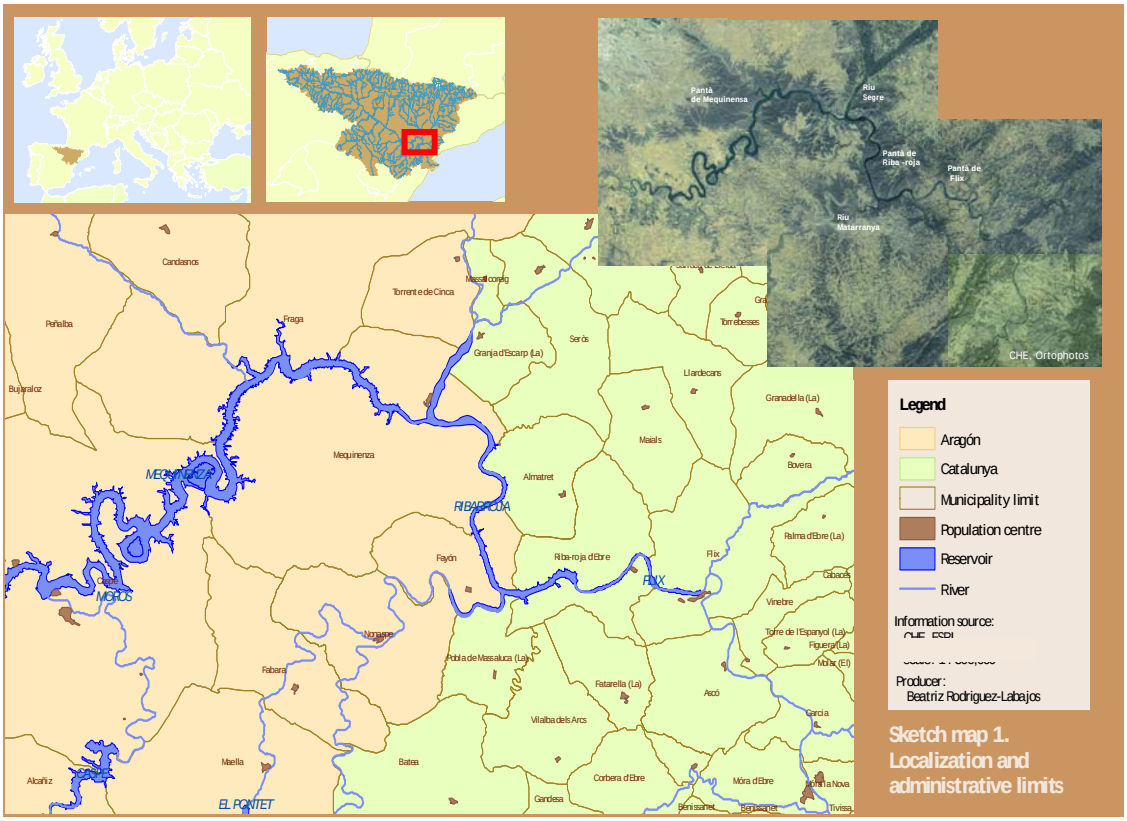
Figure 1 – Methodological procedure for the local scenario development

3.2. The region

The Ebro River drains the largest Iberian watershed. The lowest course of this river comprises three successive reservoirs - Mequinenza, Riba-roja and Flix - where the water is employed in a variety of purposes (CHE, 2005a):

1. *Direct use*: municipal water supply; irrigation; hydropower production and refrigeration of a nuclear power plant (Asco).
2. *Indirect use*: angling; restricted recreational navigation, and recreational attraction for leisure facilities.

In spite of the physical transformation of the watershed, most of this low density population region is already protected and other parts are projected as Natura 2000 sites (CHE, 1998; Generalitat de Catalunya, 2004). Administrations present in the area are the whatershed authority, Confederación Hidrográfica del Ebro (CHE), two regional administrations, the Governments of Aragon and Catalonia, and several municipalities.



Sketch map 1. Localization and administrative limits

3.3. Invasive species in the Ebro River

In this area, the Ebro is currently affected by the invasions of two aquatic invasive species: zebra mussel (*Dreissena polymorpha*) and Wels catfish (*Silurus glanis*).

Zebra mussel [*Dreissena polymorpha*] is a bivalve mollusc occurring in freshwater habitats such as estuaries, rivers and lakes. Its high reproductive capability and ability to survive in air for several days has contributed to facilitate its spread (Olenin et al., 1999). Additionally, anthropogenic factors promoting dispersal are long-distance transport through shipping activities (ballast water, hull fouling) and the creation of invasion corridors (canals) (Carlton, 1996). Impacts of the species are due to two distinctive capabilities, namely: attaching to solid surfaces in very high densities and removing planktonic organisms and particulates by pumping water (Johnson and Padilla, 1996). Thus, they damage human equipment and infrastructure, and affect other aquatic organisms and communities. Due to the

previous considerations, this species has been listed *among 100 of the "World's Worst" invaders* by the Global Invasive Species Programme (www.gisd.org/database).

In the Ebro River, release of zebra mussel in the reservoirs was accidental. According to local actors, it probably took place in the late 1990s associated with fishing practices. The spread of the species comprises dams and lengthens downriver. Local stakeholders point out to the following key aspects of the invasion process:

- In spite of the warnings of the environmentalist associations after the initial detection of the species (in the summer of 2001), a general concern did not arise until the case was politically employed during the debate of for the National Hydrological Plan (end of 2001), and when economic impact is evident (middle of 2002).

- In 2002 the watershed authority developed a normative response focused in navigation restrictions and disinfection of the boats. However, the implementation of the actions has been limited by the lack of coordination among different administrations, especially by the disconnection between the regional and the local authorities. Additionally, the response has been diverse in Aragon and Catalonia. The normative has failed to prevent the spread of the species to the immediate risk areas.

Wels catfish [*Silurus glanis* (Linnaeus, 1758)] is a fish belonging to the family of Siluridae. Considered as the largest freshwater fish in Europe, it reaches up to 2,5 m length and more than 100 kg weight. It is sedentary, occurring in freshwater ecosystem such as deep and turbid rivers or big lakes and dams (Carol, 2004).

Due to its big dimensions and voracity Wels catfish affects remarkably the trophic structure of the ecosystems where it is introduced. Thus, it is a risk to autochthonous fishes and other vertebrates (amphibians, small mammals and aquatic birds) (Doadrio, 2002). Also it can affect the water quality of reservoirs (Carol, 2004).

However the species has commercial and recreational uses. Native to Eastern Europe (Danube, Dnieper and Volga rivers) (Caza y pesca, 01/1984), it has been introduced in different European countries for angling purposes. Since 1985, there are records of introductions to Algeria, Tunisia and China from different European countries (Kobayakawa, 1989).

The release of Wels catfish in Ebro during the middle 1970s was deliberate. A German biologist and angler, Roland Lorkowsky, declared himself as the introducer of 32 juveniles from Danube River in 1974. He stated that the introduction was justified by an imminent ecological disequilibrium due the abundance of other fish predators (Caza y pesca, 07/1988). It is likely than further introductions took place during those years in both Mequinenza and Riba-roja reservoirs. Towards the beginning of the 80s, the emergence of Wels catfish was regarded with concern for local fishing associations, considering it a major menace for local species' survival at the long term (Correo Catalán, 24/11/1984; Diario Español 10/10/1985). Nowadays there is a local tourist industry based in the presence of this species together with other alien fishes like Black bass (*Micropterus salmoides*) or Pike-perch (*Sander lucioperca*).

3.4. Participatory scenario development

After a series of preparatory interviews with stakeholders, a group dynamics for scenario development was conducted adapting the methodology of the IDON Scenario Thinking (Galt et al., 1997). An important component of this methodology is the facilitation of stakeholders' reflection by means of visual language in every step of the dynamics. Next results of every step are displayed.

1. Identification of driving forces

   Common drivers of both invasion processes involve changes in the configuration of the watershed due to the creation of dams, and the growth of recreational activities.

   Introduction of both species is related to previous alterations in the ecological characteristics of the river due to human intervention. Thus, Wels catfish was introduced after many other alien fishes used for angling. International anglers, attracted by these other catches, pondered the feasibility of importing Wels catfish into the region, and justified it by the excess of alien predators lacking of a controlling species. In the case of zebra mussel, angling of Wels catfish was the catalyst. Boats movement from affected countries and, overall, transport of living bait are the likely sources of introduction. In particular, the hitchhiking of larvae during the deliberate introduction of an exotic species used for bait, *alburno* (bleak, *Alburnus alburnus*) is highlighted as pathway. This was introduced after the decrease of the native species employed for the same purpose, *madrilla* (French nase, *Chondrostoma miegii*).

   Responsibility of 'foreign' actors is underlined in both cases. External users of the river press local conditions by demanding transformations in the watershed features and by transporting the species.

2. Hierarchy of driving forces according to its relevance and uncertainty

   In spite of the different points of view, discussions for classifying the factors revealed a considerable agreement. The classification was carried out following the criteria presented in **Figure 2**.

   According to participants' appreciation, most relevant drivers compelling the invasion process are:

   - difficulties for the eradication of the species,
   - scarce knowledge of the territory by the population,
   - lacking means for the institutional response, and
   - the kind of uses of the river, especially those carried out by external actors.

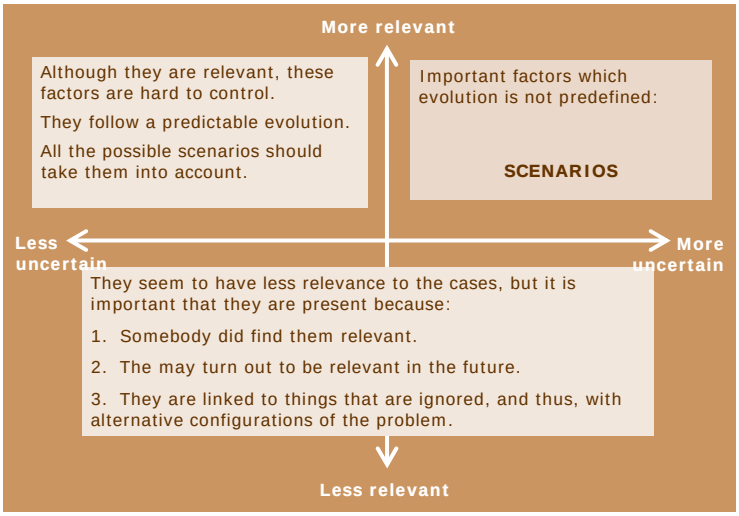


Figure 2 - Classification of driving forces

   Most uncertain topics refer to those whose evolution is not predetermined. Participants pointed out to drivers such as practices of ecosystem management, including illegal introductions of alien species and those changes in the configuration of the river that can be managed, like the water level and the water flow.

3. Identification of key underlying themes

A discussion on the relevance and the controllability of the driving forces allows focussing the analysis in the critical uncertainties. They are important factors whose evolution are not predetermined and underlie the progress of biological invasions.

Those topics considered as key themes were *water use management* and the character of *administrative framework*. The first one clusters all these factors related to the specific economic practices using water resources. This comprises irrigation, domestic consumption, energy production and, very especially, recreation activities. The second one refers to the nature of the administrative response to the invasion. It involves elements as institutional responsibility, mechanisms of control and inspection, normative performance and prevention culture, among others.

4. Generation of scenarios

Stakeholders distinguished an administrative / normative framework where the institutional lack of coordination prevails (*Status quo*) versus another where the intervention is organized under common purposes (*Integrated intervention*). On the other hand, the water use management can be guided by the demand made by different economic actors (*Leisure – business*) or a more ecosystem management is carried out (*Environmental*).

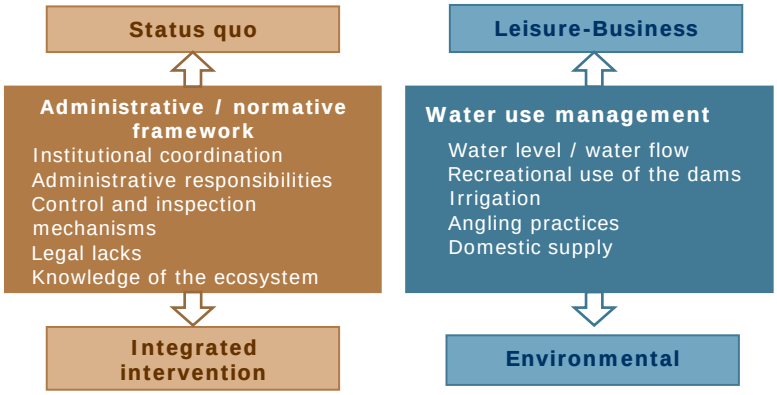


Figure 3 - Key uncertainties and generation of scenarios

The combination of each alternative for both key themes allows generating the niches for the scenarios to be described, as it is shown in the **Figure 3**.

5. Development of storylines.

Contents are provided by joint deliberation about the plausible evolution of each driver under the specified scenario. This way, storylines are built up and a number of indicators were derived. A scheme of ensuing narratives is presented in **Figure 4**.

		Administrative / normative framework	
		Status quo	**Integrated intervention**
Water use management	**Leisure / Business**	**Every man for himself!** Utilitarian focus Spread of both bioinvasions 'Easy solutions' Local ecosystems strongly affected	**Politically correct business** Management, subordinated to political will (social agreement) Certain control of the species, shared costs
	Environmental	**Administrative chaos with good intentions** Passive lack of cooperation Reduced spread of the species, high costs	**Shangri-la** Real control from shared guardianship Conflict

Figure 4 - Generation of scenarios

3.5. Lessons from the local scale

When issues are complex, diversity of perspectives cannot be reduced, but scenarios rise as effective bridges of understanding. Thus, this approach produces images that stakeholders may fill with meaning from their respective experience about past events and from their expectations about the future. The role of scenarios as integrative tool for different languages of valuation must be underlined.

Through the development of scenarios, stakeholders could share their views in the problem definition, and framed their local concerns in the larger underlying dynamics. In this way, two elements were promoted: support to shared responsibility and a contribution to empowerment (based on an extended knowledge of the processes).

In the Ebro, stakeholders are not homogeneous in terms of their concerns and effective power on the watershed resources. Through scenarios local actors are given an opportunity to react towards the potential situations by unveiling and exploring key uncertainties around the invasion processes.

Specifically, each participant could:
- recognise factors driving the invasion process according to his or her own views and other stakeholders' perspectives;
- define relevant key uncertainties of the cases;
- identify criteria for the assessment;
- include the obtained information in their decisions.

Asymmetries of power regarding decision-making capabilities (either financial or administratively based) restricted the organization of local initiatives around common positions. In general, the focus on common specific issues was more valued than the dispersion of initiatives around ambitious environmental plans.

During the interaction process, the purpose of each stage was presented in order to enhance transparency. In this way, participants shared their points of view in a structured way. Some topics generated interaction between stakeholders with asymmetric knowledge (for instance, the meaning of water quality or the local implications of new regulatory framework). Two-way communication boosted learning focussed on specific topics around the invasion process (like the current distribution of the species and the management measures around them).

Additionally, during the workshop local stakeholders repeatedly expressed a need for extending the role of participation of civil society concerning the management of local resources.

4. Inter-scale integration

A discussion on scales and biological invasions leads to draw attention to two key elements:

- Highlighting the relevance of stakeholders as prime actors of the process. Both the case study and the analysis at the large scale have pointed out the interaction of different groups of interest. The nature of the linkage between interests and the role of those actors playing a role at different scales must be understood when facing multi-level governance of biological invasions.

- Distinguishing the assortment of indicators that correspond to the same process. Specifically, the same driver (e.g. transport practices, tourism) has different translations depending on the scale of analysis. Reducing the analysis to synthetic indicators may help to provide explanations but not to accompany governance. Then, indicators for every level should be examined together with stakeholders, also at different levels.

Large scale scenarios may be employed as boundary conditions for local scenarios. But some elements point out to top-down and bottom-up influences, reflecting the ability of local contexts to react favourably or resist toward the large scale pressures. Taking this into account, scenarios obtained at both scales were integrated in order to evaluate consistency and plausible events from the overlapped contexts.

To this end a hypothetical overlapping of scenario levels will be attempted under the following questions: Are both levels consistent? If they are not, does the inconsistency reveal any specific kind of tension between scales? Which kind of trends can be expected from those tensions? In other words, the procedure for the integration includes:

1. Hypothetical overlapping of scenario levels
2. General link between scenarios: assessing consistency and identifying sources of inconsistency
3. Assessing conceivable dynamics highlighting likely top-down and bottom-up effects and tensions

Next, an example is presented for the case of the GRAS scenario (**Table 4**).

Table 4 - Inter-scale integration of scenarios. Example: GRAS

Local scenario	**Every man for himself**	**Politically correct business**	**Administrative chaos with good intentions**	**Shangri-la**
Consistency?	Yes	Consistency between the large scale trends and the preferences of domestic economic actors	Consistency between the large scale trends and the institutional conditions.	None
Tensions?	No	Demands from the national / regional administrations towards the UE institutions Political tension but social indifference	Citizens' demands are neglected by the administrations.	Tension regions – UE Why some regions are able to defend themselves in front of the large scale dynamics?
Plausible trends?	Described trends emphasize in both levels. Vicious circle.	Possible downloading towards a GRAS profile	Dynamics towards degradation of social profile. Social concern - Protests	Resistance Alliance of regions (e.g. GMO-free regions)

5. Conclusions

Outcomes and tensions at different levels are recognized thus illustrating the potential of scenarios as assessment tools of biological invasions. Usefulness of scenario development as assessment and management tool for governance of responses to biological invasions can be summarized as follows (**Table 5**).

Table 5 - Advantages and disadvantages of scenario development

	Advantages	Limitations
Scenario development in general	Scenarios support a precautionary view to the uncertain futures, even when the assessment has been done *ex post*. They help to face complexity directly, becoming the only possibility when uncertainty is irreducible. They are flexible tools: They integrate many languages and forms of knowledge. Scenario development enhances learning: new information is added to the old knowledge in a meaningful way. Assumptions are stated transparently.	They do not provide crisp results. Assumptions are restricted by the frames of reference of the participants, either stakeholders or the analysts themselves. Information constraints and underlying discourses will be reflected in the outcomes. Assumptions are difficult to test. When they are strictly qualitative, scenarios may be lacking in meaning to those audiences used to crisp results.
Analytic scenarios	Less time consuming, only dependent on analyst agenda	Information is restricted to available publications and databases
Participatory scenarios	Consistency is warranted by stakeholders' participation. Trust building enhances their role as tools for transition. When scenario development meets stakeholders' needs, they contribute with their time and effort. Research cost can be reduced in time and money.	Time and resource consuming Preparatory tasks, including strengthening of trust and creation of the working atmosphere, are crucial.

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