Universitat Autònoma de Barcelona

Water flows to multiple stakeholders

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An ecosystem services-based approach to conflicts in the Ter River basin

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A la gent del Ter.

PREFACE

I am Dídac Jordà Capdevila and am the author of this thesis. I hold a Bachelor degree in Biology (Autonomous University of Barcelona, UAB), a Master degree in Essential and Applied Ecology (University of Barcelona, UB) and a Postgraduate diploma in Geographical Information System (GIS) Technologies (Polytechnic University of Catalonia, UPC). My motivation for studying river functioning and management comes from my involvement in the *Projecte Rius* (River Project) in my hometown, Parets del Vallès. With this organisation, I participated in an internship Catalonia-Hessen on river restoration and environmental education in 2003 and 2004. Some years later, I gained experience in the environmental consultancy Tecnoma S.A., where I became specialised in environmental flow regimes, fish habitat and populations, river continuity and fish passes, and water management.

In September 2011, I started a PhD at the Institute for Environmental Sciences and Technology (ICTA), in the UAB, under the supervision of Dr. Beatriz Rodríguez Labajos and Dr. Joan Martínez Alier. This work has been funded by the project CSO2010-21979, focussed on social metabolism and environmental conflicts, from the Spanish National Program for Basic Research.

In particular, this thesis integrates ecological and socio-economic tools and perspectives for understanding water conflicts over river flows. By using an approach based on the ecosystem services concept, I scrutinise the variety of ecosystem services provided by the Ter River and question what effect water flow management has had and will have on the well-being of different stakeholders. In the title "Water flows to multiple stakeholders", we play with the word 'flows', as a verb, but also a noun. Likewise, the word 'stakeholders' refers to those groups of people interested in the management of water flows, as well as those that mark with stakes new water transfers as a persistent form of controlling water flows.

Part of this thesis is also done in collaboration with the James Hutton Institute, the King's College of London and the Université de Limoges. The experience at these institutions helped me to address certain parts of the thesis and to overcome some difficulties. Actually, this thesis has represented a major challenge and shift in my career, since it goes beyond the natural science of river ecology to embrace the socio-economic aspects of environmental flows. The performance of social research, including interviews, workshops and the search in historical archives, has been hard but also very rewarding. My understanding of environmental flows is now broader and deeper, but still there is a lot of research to be done.

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ABSTRACT

Water flows to multiple stakeholders: an ecosystem services-based approach to conflicts in the Ter River basin

Conflicts related to water flows are the subject of abundant intellectual outputs. However, analysis of their relation to the appropriation of instream flow–dependent ecosystem services (ES) is missing. Such analysis, undertaken with a proper regard for stakeholders' views and interests, is the objective of this thesis. As happens in other Mediterranean contexts, multiple water withdrawals from the Ter River (NE Catalonia, Spain), in particular for hydropower production and the supply of the metropolitan Barcelona, disrupt instream flows and hence damage the river ecosystem. Traditionally, this situation has triggered local and regional disputes, becoming a main issue for water management in the basin district.

This dissertation involves three types of ES applications. First, we identify and characterise multiple ways people use, enjoy and feel the river. This is done by a scrutiny of those hydrological alterations and components of nature that have an effect, positive or negative, on them. Second, an ES provision model is coupled with a water allocation model in order to quantify and establish a valuation of the ES under different water management and climate scenarios. Finally, the ES provision is studied for a period of 65 years, by analysing who has been who in the exercise of power for controlling the access to water flows and the ensuing ES. That historiographical research combines qualitative data from the archives (e.g., letters, news) and quantitative data of instream flows and dam management. In the course of the study, the engagement of all types of stakeholders – both key informants and water activist organisations – has been an essential aspect of the methodology. Field research undertaken between 2011 and 2015 included dozens of interviews with key stakeholders, the organisation of five workshops and two surveys.

The results show that, with the proper provisions, our ecosystem services-based approach: 1) helps to engage with stakeholders, reconnecting people to water management; 2) unveils less conspicuous ES, whose beneficiaries are usually misrepresented in decision-making spheres; 3) disentangles the complexity of societal-ecological relationships and shows the adaptation of river users to different levels of river alteration; 4) illustrates unequal distribution of benefits among different ES, over time and space and under different water management and climate scenarios; and 5) when used with a critical historical perspective, it discloses those power relationships that hamper the implementation of management measures that reduce the water extraction pressure on the river in support of an environmental flow regime.

Keywords: Catalonia, droughts, ecological distribution conflicts, ecological economics, ecosystem services, environmental flows, political ecology, river management, stakeholder participation, water allocation modelling, water conflicts

RESUM EN CATALÀ

Cabals que circulen vers múltiples interessos: un enfocament basat en els serveis ecosistèmics a la conca del riu Ter

Els conflictes relacionats amb la gestió dels cabals han sigut objecte d'abundant estudi. Tanmateix, manquen anàlisis que considerin l'apropiació d'aquells serveis ecosistèmics (SE) que depenen dels cabals circulants. Tal anàlisis, duts a terme incorporant les visions i els interessos dels actors locals, és l'objectiu d'aquesta tesi. De la mateixa manera que succeeix en altres contextos mediterranis, moltes extraccions d'aigua del riu Ter (NE de Catalunya, Espanya), particularment per a la generació d'electricitat i per a l'abastament de la Barcelona metropolitana, alteren els cabals circulant i malmeten els ecosistemes fluvials. Tradicionalment, aquesta situació ha comportat disputes locals i regionals, esdevenint un problema important en la gestió de l'aigua a escala de conca.

Aquesta dissertació incorpora tres tipus d'aplicacions de SE. En primer lloc, identifiquem i caracteritzem múltiples formes en les que el riu és utilitzat, gaudit i estimat. Això ho fem mitjançant l'escrutini d'alteracions hidrològiques i components de la natura que han tingut algun efecte, positiu o negatiu, sobre aquestes formes.

Segon, hem acoblat un model d'aprovisionament de SE a un model de distribució de l'aigua per tal de quantificar i valorar els SE sota diferents escenaris climàtics i de gestió.

Finalment, l'aprovisionament de SE és estudiat per un període de 65 anys, bo i analitzant qui ha estat qui en l'exercici del poder per a controlar l'accés als cabals i per tant als SE. Aquesta recerca més historiogràfica combina dades qualitatives d'arxius (per exemple, cartes i notícies) i dades quantitatives de cabals i de gestió de les preses. Al llarg de l'estudi, la incorporació d'actors locals, tant individus clau com organitzacions activistes, ha estat un aspecte essencial de la metodologia. El treball de camp realitzat entre 2011 i 2015 ha inclòs dotzenes d'entrevistes, la organització de cinc tallers i dues enquestes.

Els resultats demostren que el nostre enfocament basat en els serveis ecosistèmics: 1) incentiva a la participació d'actors, bo i reconnectant la gent amb la gestió de l'aigua; 2) revela SE menys evidents, els beneficiaris dels quals són normalment infrarepresentats en els àmbits de decisió; 3) desentortolliga la complexitat de les relacions socio-ecològiques i mostra l'adaptació dels usuaris dels rius a diferents nivells d'alteració; 4) il·lustra una distribució desigual dels beneficis entre SE al llarg del temps i de l'espai i en els diferents escenaris climàtics i de gestió; i 5) quan s'utilitza una perspectiva crítica històrica, permet comprendre les relacions de poder que obstaculitzen la implementació de mesures de gestió que redueixen l'extracció d'aigua en favor d'un règim de cabals ambientals.

Paraules clau: Cabals ambientals, Catalunya, conflictes d'aigua, conflictes ecològic distributius, ecologia política, economia ecològica, gestió fluvial, models de distribució de l'aigua, participació d'actors locals, sequeres, serveis ecosistèmics

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ACRONYMS AND ABBREVIATIONS

ACA: *Agència Catalana de l'Aigua* (Catalan Water Agency)

ACOS: *Arxiu Comarcal d'Osona* (Archive of Osona County)

AEEC: *Assamblea d'Entitats Ecologistes de Catalunya* (Assembly of Environmental Organisations of Catalonia)

AEMS-*Rius amb Vida*: *Associació per l'Estudi i la Millora dels Salmònids-Rius amb Vida* (Association for the Study and the Improvement of the Salmonidae-Rivers with Life)

AeV: *Aigua és Vida* (Water is Life)

Agbar: *Aguas de Barcelona, S. A.*

AHG: *Arxiu Històric de Girona* (Historical Archive of Girona)

ANG: *Associació de Naturalistes de Girona* (Naturalist Association of Girona)

ATLL: *Aigües Ter-Llobregat* (Waters of Ter-Llobregat)

BAU: Business-as-usual scenario

BOE: *Boletín Oficial del Estado* (Official Bulletin of the State)CCB: *Consorci Costa Brava* (Costa Brava Consortium)

CE: Choice Experiment

CHPO: *Confederación Hidrológica del Pirineo Oriental* (Hydrologic Confederation of the Oriental Pyrenees)

CICES: Common International Classification of Ecosystem Services

CiU: *Convergència i Unió* (Convergence and Union)

COCIG: *Cambra Oficial de Comerç i Indústria de Girona* (Official Chamber of Commerce and Industry of Girona)

COM: Compatibility-of-uses scenario

CV: Contingent valuation

DOGC: *Diari Oficial de la Generalitat de Catalunya* (Official Bulletin of the Government of Catalonia)

e-flows: Environmental flows

ECO: Ecosystem-priority scenario

Endesa: *Empresa Nacional de Electricidad, S.A.*

ERC: *Esquerra Republicana de Catalunya* (Left Republicans for Catalonia)

ES: Ecosystem service(s)

FCPEC: *Federació Catalana de Pesca Esportiva i Càsting* (Catalan Casting and Sport Fishing Federation)

GEDENA: *Grup d'Estudis i Defensa de la Natura* (Studies and Advocacy Nature Group)

GDT: *Grup de Defensa del Ter* (Advocacy Group for the Ter)

HA: Hydrological alteration

IC: Irrigation community

ICV-EUiA: *Iniciativa per Catalunya Verds-Esquerra Unida i Alternativa* (Initiative for Catalonia Greens-United and Alternative Left)

LHPP: Large hydropower plant

MA: Millennium Ecosystem Assessment

MOP: *Ministerio de Obras Públicas* (Ministry of Public Construction)

MuSIASEM: Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism

NEW: New-management-plan scenario

POT: *Plataforma d'Oposició als Transvasaments* (Platform of Opposition to Water Transfers)

PP: *Partit Popular* (Popular Party)

PSC: *Partit dels Socialistes de Catalunya* (Socialist Party of Catalonia)

PSCM: *Pla Sectorial de Cabals de Manteniment* (Sector Plan for Maintenance Flows)

PZBT: *Pla Zonal del Baix Ter* (Zonal Plan for the Lower Ter)

PZTS: *Pla Zonal del Ter Superior* (Zonal Plan for the Upper Ter)

RMB: *Regió Metropolitana de Barcelona* (Metropolitan Region of Barcelona)

SMCE: Social Multi-Criteria Evaluation

SGAB: *Sociedad General de Aguas de Barcelona* (General Society of Water for Barcelona)

SHPP: Small hydropower plant

SMS: Safe minimum standard

SPI: Service Provision Index

STP: Sewage treatment plant

TCM: Travel Cost Method

TEEB: The Economics of Ecosystems and BiodiversityWFD: Water Framework Directive

WFD: Water Framework Directive

WTP: Willingness to pay

Chapter 1

Introduction

1.1 BACKGROUND ON WATER FLOWS VALUE(S)

Freshwater ecosystems have been secularly linked with human lifestyle and ethical values (Acreman, 2001; Fagan, 2011), to the extent of being recognised as one foundation of social, cultural and economic well-being (Brisbane Declaration, 2007). Long-term human cultures could not exist without water (Naiman *et al.*, 2002). The human dependence on freshwater resources is extreme: 15.3% of global electricity production comes from hydropower (REN21 - Renewable Energy Policy Network for the 21st Century, 2012), 19.7% of cultivated land is irrigated, consuming 70% of water withdrawal (FAO, 2011), and 36% of world fisheries and aquiculture production comes from inland areas (FAO, 2012). Postel and Carpenter (1997) estimated that freshwater ecosystems provide benefits whose notional economic value could add up to several trillions of dollars (for comparison, Spain's Gross Domestic Product (GDP) is about 1.5 trillion dollars).

As a consequence of maximising those benefits from consumptive, and usually private, uses, the appropriation of freshwater resources has increased at alarming rates to the extent that the volume of worldwide water withdrawal has reached 35% of accessible runoff (Postel et al., 1996). The development of the required infrastructure for the control and distribution of water flows has then altered the normal functioning of the river ecosystems (Bunn and Arthington, 2002; Poff et al., 1997; Vörösmarty et al., 2010). Hydrological alterations cause the decline of aquatic species, as some key life-stage activities are linked to flow or flow-dependent elements such as temperature (Nesler et al., 1988; Whiting, 2002). The instream flow regime is actually the major determinant of physical habitat in streams (Poff and Ward, 1990); therefore, its alteration facilitates the invasion and success of alien and introduced species, and impairs the riparian biodiversity and resilience (Bunn and Arthington, 2002; Richardson *et al.*, 2007).

Subsequently, such changes have had an impact on local communities that strongly depend on the ecosystem's health (Vörösmarty et al., 2010), since a well-preserved river ecosystem also provides goods such as fish, waterfowl, fibre and timber (MA, 2003; Postel and Carpenter, 1997) and non-extractive services like space for recreation (Daubert and Young, 1981) or self-purification capacity (Wei *et al.*, 2009). Thus, social tensions are not rare when rivers are taken, e. g, for the construction of new dams (McCully, 1996; World Commission on Dams, 2000) or for sand mining (e.g., Singh et al., 2012, in India).

From that panorama, scientists from different disciplines, environmental organisations, local, national and international institutions and the business world have been calling for environmental flows (e-flows) that guarantee the preservation of the ecosystem (Brisbane Declaration, 2007; Dyson et al., 2008; Hirji and Davis, 2009).

Several strategies have been followed for the achievement of such a challenge. Already by the 70s, a few scientists studied dam management for restoring instream flows for fish communities and recreational activities (Tennant, 1976), with legal adversities (Lilly, 1980) and in competition with irrigators, among other technical and social issues (Orsborn and Allman, 1976).

Since then, multiple methods and frameworks have been developed in order to quantify instream flow requirements for environmental and economic purposes: the Instream Flow Incremental Methodology (IFIM) (Bovee, 1986; Cavendish and Duncan, 1986), the Building Block Methodology (BBM) (King and Louw, 1998), AQUATOOL, (Paredes-Arquiola et al., 2014), or the Ecological Limits of Hydrologic Alteration (ELOHA) framework (Poff et al., 2010). Besides the instream flow requirements, assessments have usually included an economic valuation for guaranteeing the social acceptability of the restoration project. The Travel Cost Method (TCM) (Getzner, 2015; Ward, 1987), Contingent Valuations (CV) (Johnson and Adams, 1988; Ojeda et al., 2008) and Choice Experiments (CE) (Martin-Ortega et al., 2011; Willis and Garrod, 1998) have been the most employed. The application of these methods generally aims to quantify the economic value of an incremental change in the instream flow level. Each new method or framework has contributed to broadening the scope of analysis in relation to the already existing ones. Thus, the newest methods work on the natural flow or on the management-based paradigms instead of on a minimum flow (see Table 1). They also consider a wider variety of purposes for restoring instream flows and include trans-disciplinary teams of scientists and policy-makers (Acreman et al., 2014a, 2014b).

At the institutional level, modern regulatory frameworks have adopted more inclusive and integrated approaches (Pahl-Wostl et al., 2013). The Water Framework Directive (WFD, European Commission, 2000), for instance, links quality with quantity, surface with groundwater, and environmental objectives with economic and social ones (Matthews et al., 2014). Although the WFD does not explicitly use the term ‘environmental flows’, it urges member states to achieve a good ecological status in all waterbodies by 2015, which actually includes guaranteeing an e-flow regime (Acreman and Ferguson, 2010).

However, most of the countries recognise that the directive had not been fully implemented by that year and hence needed to work to the extended timescale given in the WFD until 2027 (Ball, 2016). Such a target date is close to the global objective that the UN proposed by 2030 for water and sanitation, which includes “restoring and maintaining ecosystems to provide water-related services” (UN-Water, 2014).

Table 1. Concepts and paradigms on environmental flows

Concepts

- 'Instream flows' are defined as that body of water that flows within a river channel.
- 'Environmental flows' (e-flows) mean those maintained in a river system for the specific purpose of managing the condition of that ecosystem (King et al., 2003; Poff et al., 1997) to replicate natural processes (Whiting, 2002), to maintain their benefits (Dyson et al., 2008), in coexistence with agricultural, industrial and urban uses of water (Brisbane Declaration 2007).
- The 'minimum flow' concept is an outdated approach on the calculation of environmental flows that consists of a minimum level of flow that satisfies the ecosystem's basic requirements.
- In contraposition, the 'naturally variable flow regime' results from the aggregation of several flows that maintain different ecosystem features (Poff et al., 1997; Whiting, 2002).

Paradigms

- The 'natural flow regime paradigm' assumes that the modification of the natural flow regime can adversely affect riverine, riparian, and floodplain species and processes. This paradigm is based on recorded historical flow data that predates development in order to establish limits to hydrological change beyond which substantial (or unacceptable) ecological alteration takes place (Acreman et al., 2014a).
- The 'management-based paradigm' accepts that change in flow regimes is inevitable and that typically historical natural conditions cannot be reinstated, since water resource management, including major infrastructure such as dams, is s essential to alleviate poverty, mitigate flooding risks to people and property, and generate hydropower. This paradigm is based on a recognition of the ecosystem services provided by a river and the setting of a range of environmental objectives (Acreman et al., 2014a).

In this thesis environmental flows or environmental flow regime refer to the naturally variable flow regime. That is the scientific agreement on what is required for maintaining freshwater ecosystems – hence the ecosystem services they provide.

Despite the UN's optimistic goal, global threats to the freshwater ecosystems exacerbate the situation worldwide. Deterioration occurs as water sources are altered, e.g. by global change (Poff and Matthews, 2013) and water demands increase, e.g. due to population growth (UN-Water, 2014). Sometimes both processes are in place, e.g., when increased social metabolism facilitated by global trade translates into exports of virtual water and decline of water quality by pollution (Aldaya et al., 2010; Martinez-Alier et al., 2010; Muradian et al., 2012).

These threats are expressed through the local over-exploitation of rivers (Vörösmarty et al., 2015). As a consequence water-related conflicts appear around the world (Puigdollers et al., 2015). Currently, claims against dams and pressure for free-flowing rivers abound, both in the global South and in the global North (ENTITLE, 2016); and many environmental defenders involved in anti-dam movements have even paid for activism with their lives (e.g., El Espectador, 2013; Laval et al., 2014). In the Environmental Justice Atlas (EJAtlas, 2016) up to twenty-five cases of water management-related conflicts around the world (mostly in Latin America) involve deaths. The most recent is the murder of the indigenous leader Berta Cáceres for defending the Gualcarque River in Honduras against a hydropower project (Martins, 2016). That project was originally funded by the World Bank (among others), which on the other hand has also promoted the implementation of e-flows in many countries around the world (Hirji and Davis, 2009).

Why do the degradation rates of freshwater ecosystems persist after decades of methodological innovation for calculating and implementing e-flows? Most of the methodologies mentioned above propose improvements for water management as a technical challenge. Some of them also assume a negotiation among stakeholders. However, there are usually big differences in the capacity of stakeholders' influence. Actually, the lack of political will, the clash of interests – inherent to the complexity of socio-economic costs and benefits –, and legal and institutional barriers have been obstacles for the implementation of e-flows over and above other difficulties such as technical support, hydrological data availability and public acceptance (Le Quesne et al., 2010; Moore, 2004). Can another barrier be the lack of a collective thinking "outside of the box" dams? While understanding such obstacles on a case-by-case basis cannot necessarily help avoid water conflicts, it can facilitate turning them into pathways for a better management of water flows (Rodríguez-Labajos and Martínez-Alier, 2015b).

We selected the Ter River as the case study for this thesis because it provides an excellent opportunity for investigating the management of water flows and the associated social conflicts. Maintaining an e-flow regime in the Ter River is problematic due to the decrease of runoff in recent decades (Armengol and Dolz, 2009) and the river's connection to the hydrosocial cycle of the metropolis of Barcelona. Additionally, multiple withdrawals for domestic, agricultural and hydropower uses exist within the basin itself.

On paper, the Ter River's water authorities followed all the necessary steps for implementing an e-flow regime. After multiple tensions due to the overexploitation of the river, the WFD became an opportunity to guarantee the preservation of instream flows. An e-flow regime was designed, based on calculations using hydrological methods and habitat simulation for validation (ACA, 2005; Martínez Capel et al., 2007). After that, the implementation process sought the support from a process of stakeholder participation. Even monetary estimations of socio-economic benefits were made (Bardina et al., 2016). However, the problem has not been solved – nor it is foreseen to be solved in the coming years – and inter-stakeholder tensions for the e-flows remain.

In this thesis, we therefore study the persistent conflicts concerning ecological distribution in the Ter River regarding the management of water flows, in a way that transcends the technical and economic limits and moves into the social and political arenas. We analyse the diverse forms the river is used, exploited or enjoyed to benefit people; the forms of benefits that are promoted and those that have abated or even been discontinued; their performance over time and space; and the reasons behind the difficulties to achieve an implementation of e-flows. This is done by critically using the notion of *ecosystem services* (ES) under the perspectives of *ecological economics* and *political ecology*.

Ecological economics helps to frame social conflicts within the biophysical limits of water availability (Georgescu-Roegen, 1971), to go beyond the dichotomy between ecosystem and human needs and embrace the plurality of river values and interests in its management (Pahl-Wostl et al., 2013). It is also helpful for understanding the resistance against the negotiation of flow regimes that entail dam removal so as to enjoy the river in free-flowing conditions (Auerbach et al., 2014; Gowan et al., 2006). Political ecology challenges the neutrality of any water management approach, inviting an analysis of the role of different actors trying to promote or maintain the over-exploitation of rivers for their own benefit and based on their respective interests and influence (Molle et al., 2009).

Finally, an approach based on the notion of ecosystem services, despite the controversy it generates among ecological economists and political ecologists (Barnaud and Antona, 2014; Gómez-Baggethun et al., 2010; Kull et al., 2015; Norgaard, 2010), is arguably a useful methodological approach to analyse water conflicts (Rodríguez-Labajos, 2016). Therefore, this dissertation also aims to make a contribution for a better understanding of this methodological potential.

1.1.1 Theoretical frameworks: ecological economics and political ecology in the context of water management research

Wallace et al. (2003, p. 2019) explains the tradeoff issue about the implementation of e-flows as follows: "*The problem is to decide how much water should be utilised directly for people for domestic use, agriculture and industry and how much water should be used indirectly by people to maintain aquatic ecosystems that provide environmental goods and services*" (Fig. 1).

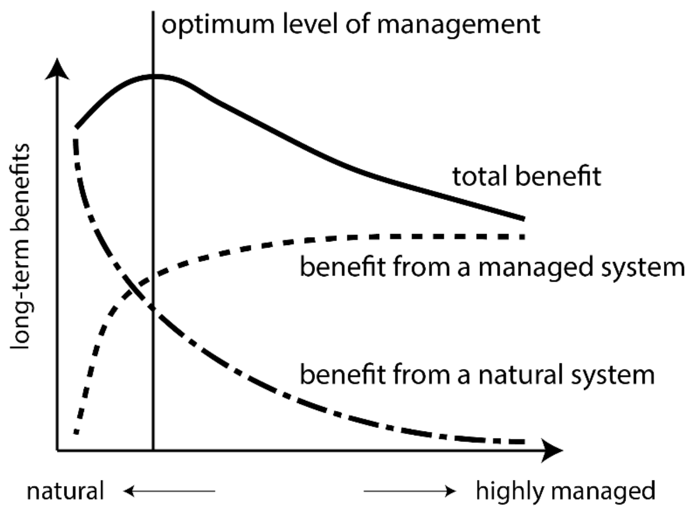


Fig. 1. Maximising benefits from freshwater ecosystems. Based on Wallace et al. (2003).

This idea inherently leads to that of how the different uses are valued in relation to each other. Indeed, the logic behind valuation is to unravel the complexities of socio-ecological relationships, to make explicit how human decisions would affect ES values and to express these value changes in units (Kumar, 2010). In this respect, according to some perspectives, the valuation of ecosystems – and of the services they provide – is based on the understanding of changes to human well-being from marginal changes to ecosystems.

Different fields of academic research approach economic valuation differently, and this can be exemplified by the problem of social choice presented by Wallace et al. Environmental and natural resources economics, which are branches of neoclassic economics, would assign a monetary value to the river by means of measuring the society's willingness to trade off for preserving an e-flow regime. Benefit from diverted flows and benefit from instream flows would be compared in a cost-benefit analysis and, in accordance to the curves presented in Fig. 1, one could easily find an optimal level of flow regulation that would produce a maximum level of long-term benefits.

Instead, ecological economists are sceptical about monetary valuation in the context of nature protection (Kallis et al., 2013; Rodríguez-Labajos and Martinez-Alier, 2013). They tend to warn against the use of a unique metric of value as in cost-benefit analysis that would mean simplifying the complexity inherent in a river ecosystem, favouring immediate benefits and distant costs over long-term benefits and immediate costs, and escaping uncertainty issues (Espeland and Stevens, 1998; Hanley and Spash, 1993). In fact, incommensurability (i.e., "the absence of a common unit of measurement across plural values") has even been proposed as the foundation of ecological economics (Martínez-Alier et al., 1998, p. 280).

Thus, grounded in an ecological economics point of view, this thesis will not provide a unique solution for the Ter River management that can be argued as the optimal one. Rather, we aim at producing a multi-dimensional map of ES provision for decision-makers to find a balanced compromise solution among the different conflicting ES demands. With similar arguments of those given by Spangenberg and Settele (2010), we avoid calculating the monetary value of ES provided by water flows, which should be restricted to the implementation process with politically defined targets.

From an ecological economics perspective water conflicts can be seen as ecological distribution conflicts, where tradeoffs occur in multiple dimensions (e.g., temporal, spatial, beneficiary, service). Table 2 shows some examples of different types of tradeoffs generating water conflicts. Nevertheless, with our study we want to explore the idea that water conflicts not only exist because of the tradeoffs among water flow demands, but also because of people's decisions on how they will pursue their stakes (by pushing for laws, demonstrations, purchases, etc.). Therefore, the implementation of e-flows – like other water policies – would not depend only on the technical capacity to do so or on an achievement of inter-stakeholder equity, but also on the interests of powerful firms, states and organisations.

Rodríguez-Labajos and Martínez-Alier (2015) describe the political ecology as that discipline that, in water conflicts, studies who has the power (by custom or by law) to use the available water from a river excluding others. Political ecology studies struggles over resource access and control (Paulson et al., 2003; Ribot and Peluso, 2003). A common topic in political ecology is the study of the political construction of water crises in order to manage water for urban speculation or water privatisation, with the subsequent overexploitation of water resources, which triggers further water crises (Bakker, 2000; Otero et al., 2011; Swyngedouw, 1997).

Table 2. Types of tradeoffs

Type	Definition	Example of related water conflicts	References
Temporal tradeoffs	Benefits now – costs later	In the Aral Sea basin, short-term profit for the cotton industry was prioritised against a sustainable use of water	(Micklin, 1988; Deng et al., 2012)
Spatial tradeoffs	Benefits here – costs there	In the Ebro basin (Spain), downstream areas complain against the overexploitation of the resources upstream	(Martínez-Alier, 2002)
Beneficiary tradeoffs	Some win – others lose	In Chile, the privatisation of water facilitates the appropriation of water flows by big landowners	(Camacho, 2012)
Service tradeoffs	Manage for one service – lose another	In Australia indigenous groups defend the non-market value of instream flows in opposition to productive water extractions	(Jackson, 2005)

Notes: Based on the classification of tradeoffs in Kumar (2010). While beneficiary tradeoffs occur among stakeholders of different type (e.g., big landowners *versus* smallholder farmers), service tradeoffs occur among different type of stakeholders (e.g., irrigators *versus* hydropower producers).

Coming back to the problem presented by Wallace et al. about social choice, a political ecologist would make us consider three additional points. First, they would ask who benefits from the managed system, who benefits from the natural system and, the most important, who benefits from the alleged optimum. Second, they would question how the curves have been developed and whether these represent real needs or, rather, if the design process has been influenced by the desire to satisfy specific interests. Finally, they would analyse the discourses of the main beneficiaries in their effort to convince the general public about the optimality of their approach to water-flow management.

Both ecological economics and political ecology disciplines require methodologies that perform comprehensive assessments with a multi-criterial perspective in order to materialise ecological distribution conflicts (Martinez-Alier, 2003). Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) is an interesting tool developed by Giampietro et al. (2009), which provides a characterisation of the performance of socio-economic activities and ecological constrains at different levels and scales in order to represent patterns of metabolism of socio-economic systems. Social Multi-Criteria Evaluation (SMCE) is an inclusive framework for decision-making presented as an alternative to cost-benefit analysis (Munda, 2004). Both frameworks have timidly applied in water issues (e.g., Cabello, 2016; De Marchi et al., 2000).

In this thesis, particularly because it is not widely tested, we believe that the notion of ecosystem services (ES) can be a useful methodological approach to analyse water conflicts from both the ecological economics and political ecology perspectives.

1.1.2 Methodological approach: the notion of ecosystem services

Ecosystem services (ES) are "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life" (Daily, 1997) or, a more straightforward definition, "the benefits people obtain from ecosystems" (MA, 2003). Since the publications of Daily and Costanza et al. (1997), this concept has been especially used in the context of ecosystems valuation, as it has been demonstrated to be suitable for linking ecosystem management and socio-economic benefits. It also has been used for decision-making (Daily et al., 2009), water resources management (Brils et al., 2015), and even business (Houdet et al., 2015). However, few publications have affirmed the potential of ecosystem services for studying ecological distribution conflicts, and none of them for conflicts over water flows at a watershed level.

Rodríguez-Labajos (2016) shows some of ES's virtues for the understanding of water conflicts: 1) they enhance the awareness of socio-environmental linkages; 2) they identify distributional issues; and 3) they perform practical evaluation of tradeoffs. Moreover, analysing the variety of ES provided by instream and diverted water flows can also integrate the natural flow paradigm with the management-based paradigm in order to help scientists and decision-makers to implement a socially sustainable river management (Acreman et al., 2014b; Pahl-Wostl et al., 2013).

As the ES notion is central for the development of the study, the following two chapters will develop it in depth. This will be done in connection with management decisions related to water flows and related conflicts.

1.2 OBJECTIVES AND RESEARCH QUESTIONS

After this background, it is worth clarifying that water conflicts are well studied by ecological economists and political ecologists, but little comprehensive work has been done by using ES as criteria for a multidimensional assessment of such conflicts. This dissertation is motivated by the idea that ES-based approaches may help to analyse the capture of the highest share of water flows by some stakeholders at the expense of others. Assuming that this causes ecological distribution conflicts, we would like to contribute to reinforcing the links between the study of material processes in the ecosystems and the understanding of how power is used to shape such processes through concrete management interventions.

In particular, **our main objective is to test an application of ecosystem services to understand ecological distribution conflicts related to water flow management**. To this end, the specific objectives are 1) the development of specific methodologies for assessing water flow-dependent ES, 2) the exploration of past, current and forthcoming tradeoffs in relation to different scenarios of water management and 3) the understanding of materialities behind sociocultural, political and economic causes of conflicts over water flows. All in all, this thesis attempts to contribute to the ecological economics and political ecology theoretical frameworks by demonstrating the usefulness of ecosystem services-based approaches for analysing ecological distribution conflicts and the associated power relations.

Such objectives mirror research questions that are addressed in three different applications, presented in Chapters 5-7 of this dissertation. These questions are:

- Do the identification and characterisation of ecosystem services by linking water flows and socio-economic benefits help to understand potential inter-stakeholder tensions? (**Chapter 5**)
- How can participatory modelling for the valuation of ES provision explain current inter-stakeholder tensions over time and space and potential conflicts under alternative water management scenarios and climate change conditions? (**Chapter 6**)
- Through which mechanisms (e.g. regulations, discourses, etc.) has power been exercised in order to gain, legitimise and defend a particular manner of water management for preserving the current flow of ES provision? (**Chapter 7**)

A case study application

In order to answer such research questions regarding theoretical and methodological epistemologies, an empirical assessment of ecosystem services in a conflictive river basin needs to be addressed. We selected the Ter River basin (NE Catalonia, Spain), a case that is *typical* and *influential*, according to the types of selection methods presented by Seawright and Gerring (2008).

The Ter is a typical river because it offers the possibility of studying practically all the representative intra- and inter-basin socio-economic processes linked to e-flows in a Mediterranean context, such as water transfers, small hydropower conflicts, expansion of irrigated areas and riverbank urbanisation, inter alia. This case is also an influential one because about 5,220,000 inhabitants (ACA, 2015) from the Metropolitan Region of Barcelona (RMB), actually located in other river basins, depend on the Ter's water flows. Two consecutive droughts in 2005-2006 and in 2007-2008 not only affected the riparian communities but also produced economic losses to the irrigators, the hydropower producers and the Catalan government (Martin-Ortega et al., 2012). Thereafter, the Ter became the first river in Catalonia where a strategy for implementing e-flows were taken seriously (Bardina et al., 2016), notwithstanding the subsequent failure.

1.3 OUTLINE OF THE THESIS

This thesis consists of eight chapters (see Fig. 2), whose information has been published (or is in the stages of revision) in different peer-review journals and books, and has been presented in several seminars and international events (see Box 1).

After this introduction to the background and research objectives, Chapters 2-3 elaborate on the conceptual and methodological basis of the research. **Chapter 2** provides a conceptual framework for the use of the *ecosystem* services concept, by analysing the origins and evolution of the term and proposing a broad definition of ecosystem services-based approaches (Martin-Ortega et al., 2015). **Chapter 3** proposes an analytical framework that structures, in different steps, the assessment of water flow management for the case of the Ter River, after having previously reviewed different case-specific valuations (Jorda-Capdevila and Rodríguez-Labajos, 2016).

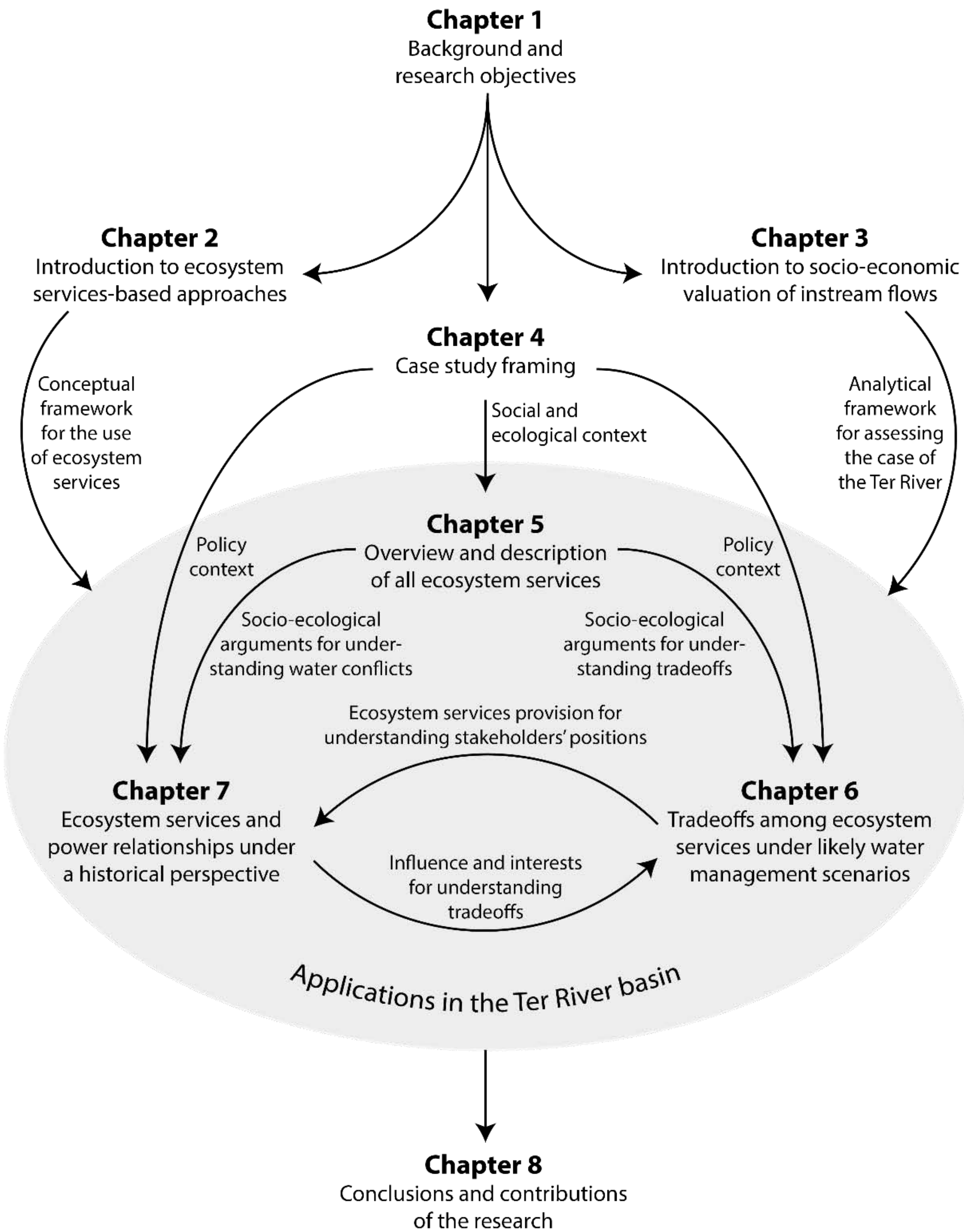


Fig. 2. Organisation of Chapters 1-8 throughout the thesis.

Chapter 4 introduces the Ter River, its watershed with its biophysical and social attributes, and its management including the available resources, the main water uses and the regulations in force. This chapter also describes four specific study areas in the Ter River basin where the fieldwork has been undertaken.

Chapters 5-7 include three applications of ecosystem services-based approaches in the Ter River basin (Jorda-Capdevila et al., 2016a). **Chapter 5** presents an overview of multiple ecosystem services provided by the Ter River and analyses their biophysical and social contradictions by developing a cause-effect network (Jorda-Capdevila and Rodríguez-Labajos, 2015). **Chapter 6** develops a coupled model in order to simulate ecosystem services provisioning under different water management and climate scenarios (Jorda-Capdevila et al., 2016b). **Chapter 7** maps the five most important conflicts in the Ter basin through a historiographic analysis, and relates them to the power of different actors for preserving their stakes in terms of ecosystem services provision.

Finally, **Chapter 8** concludes by summarising the responses to the different research questions introduced above. This final chapter also discusses major findings in light of the existing literature in the areas of ecological economics and political ecology, and to ES-based approaches. Some final proposals for further research and for non-academic applications are also provided.

Box 1. Derived publications

Publications in peer-review journals or books

- Jorda-Capdevila, D., Rodríguez-Labajos, B., 2015. An ecosystem services approach to understand conflicts on river flows – local views on the Ter River (Catalonia). Sustain. Sci. 10, 463–477. doi:10.1007/s11625-014-0286-0
- Jorda-Capdevila, D., Rodríguez-Labajos, B., 2016. Socioeconomic value(s) of restoring environmental flows – systematic review and guidance for assessment. River Res. Appl. (under revision).
- Jorda-Capdevila, D., Rodríguez-Labajos, B., Bardina, M., 2016. An integrative modelling approach for linking environmental flow management, ecosystem service provision and inter-stakeholder conflict. Environ. Model. Softw. 79, 22-34.
- Jorda-Capdevila, D., Rodríguez-Labajos, B., Bardina, M., 2016. Une évaluation en cinq étapes des services écosystémiques des rivières pour modeler la gestion conflictuelle des cours d'eau: le cas de la rivière Ter. VertigO (in press).
- Martin-Ortega, J., Jorda-Capdevila, D., Glenk, K., Holstead, K., 2015. What defines ecosystem services-based approaches?, in: Martin-Ortega, J., Ferrier, R., Gordon, I., Kahn, S. (Eds.), Water Ecosystem Services: A Global Perspective. Cambridge University Press, Cambridge, pp. 3–13.

Presentations in international events

- Jorda-Capdevila, D., Rodríguez-Labajos, B., 2013. Conflicts on River Flows - Who Captures the Highest Share of the Ecosystem Services? At the 10th biennial conference of the European Society for Ecological Economics, Lille, June 2013.
- Jorda-Capdevila, D., Rodríguez-Labajos, B., 2014. Analyse de l'approche des services écosystémiques comme un outil pour faire face à la gestion de l'eau à la rivière Ter. At the the academic workshop "Services écosystémiques et gestion durable des cours d'eau", Limoges, Juin 2014.
- Jorda-Capdevila, D., Rodríguez-Labajos, B., 2015. Assessing ecosystem services of instream flows: the case of the Ter River. At the EcoHydrology' 2015, Lyon, September 2015.
- Jorda-Capdevila, D., Rodríguez-Labajos, B., 2015. Dam removal: new environments and new landscapes? Social, cultural and political issues. At the academic workshop "Dam removal: new environments and new landscapes? Social, cultural and political issues", Poitiers, December 2015.
- Jorda-Capdevila, D., Rodríguez-Labajos, B., Bardina, M., 2015. Poster presentation. Modelling Ecosystem Services from River Flows – Does it help to understand conflicts? At the World Water Congress XV, Edinburgh, May 2015.
- Martin-Ortega, J., Glenk, K., Jorda-Capdevila, D., 2015. What defines ecosystem services-based approaches? At the World Water Congress XV, Edinburgh, May 2015.
- Rodríguez-Labajos, B., Jorda-Capdevila, D., Sisteré, C., 2012. Environmental conflicts and the use of rivers in Catalonia. At the Summer School on Environmental Conflicts. Barcelona, July 2012.

Seminars in different institutions

- Aberdeen Center for Environmental Sustainability, University of Aberdeen (Scotland, UK)
- Diputació de Tarragona (Catalonia, Spain)
- Institut Català de Recerca de l'Aigua (Catalonia, Spain)
- Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona (Catalonia, Spain)
- James Hutton Institute (Scotland, UK)
- Universitat de Vic – Universitat Central de Catalunya (Catalonia, Spain)

Chapter 2

An ecosystem services-based approach for the analysis of water flows

2.1 INTRODUCTION

Since the publication of the Millennium Ecosystem Assessment (MA, 2003), economic approaches to the understanding and management of natural resources based on the notion of ecosystem services have been increasingly discussed in the scientific literature (Fisher et al., 2009; Norgaard, 2010; Ojea et al., 2012). The MA was followed by a number of other initiatives to assess ES at different levels: global, the most significant assessment being "The Economics of Ecosystem Services and Biodiversity" (Kumar, 2010), state, as in the United Kingdom (Bateman et al., 2011) and Spain (EME, 2011), and local, e.g., in New Jersey (Costanza et al., 2006) and Barcelona (Chaparro and Terradas, 2009). Although incorporation of these assessments into water policy making is not yet well established, there is clear interest in very diverse contexts across the world. For example, there are ongoing discussions about how to incorporate ES in the upcoming river basin planning cycles within the Common Implementation Strategy of the European Water Framework Directive (Blackstock et al., 2015), since ES have proved useful to scrutinise the contribution of freshwater ecosystems to human well-being (Brauman et al., 2007; Postel and Carpenter, 1997; Russi et al., 2013).

The ES in research has spread through multiple applications. From mapping exercises for land use planning in specific sites (Egoh et al., 2008) to assessments for alerting of socio-economic impacts of ocean acidification in the Mediterranean Sea (Rodrigues et al., 2013) or meta-analysis for analysing effectiveness in multiple ecological restoration projects worldwide (Benayas et al., 2009).

In parallel to the popularisation of the idea of ES, some concerns have arisen. Thus, this rapid and widespread adoption of the term in the scientific literature and in the policy domain resulted in a lack of clarity about the meaning of 'ecosystem services' and in confusion about terminology. It also carries the risk of its use becoming arbitrary and detached from any specific meaning (Seppelt et al., 2011). Gómez-Baggethun *et al.* (2010)

express that mainstreaming ES may result in applications that diverge from the original purpose as an utilitarian concept to increase public interest in biodiversity conservation (Peterson et al., 2010), towards an emphasis on the commodification of nature for trade in potential markets (Corbera and Pascual, 2012; Kosoy and Corbera, 2010). Norgaard (2010) also state that we might be 'blinded' by the 'ecosystem services metaphor' and thus not see the ecological, economic, and political complexities of the challenges we actually face. In addition, excessive, uncritical faith in the potential of management approaches based on some form of an ecosystem services framework to address complex and conflict-laden resource management problems is likely to result in disillusion if solutions prove to be unsatisfactory (Martin-Ortega et al., 2013).

Despite all controversies around the use of ES, we believe in the potential of the concept for raising alternative views on the exploitation of nature and consider them for a conflict analysis. Thus, the objective of this chapter is to review the origins and evolution of the notion of ES (see **Section 2.2**) and to define 'ecosystem services-based approaches'[1] in a comprehensive way that multiple articulations of the notion could fit in (see **Section 2.3**). The purpose here is not to provide an ultimate definition of 'the' ecosystem service approach, but rather to establish a basis for characterising its applications (in policy initiatives or research projects). At the end of this chapter, because we acknowledge that definitions and classifications of ES are case-specific and purpose-driven, **Section 2.4** builds our own approach to analyse the water conflicts in the Ter River basin.

2.2 ORIGINS AND EVOLUTION OF THE NOTION OF ECOSYSTEM SERVICES

Gómez-Baggethun *et al.* (2010) link the historic development of the concept of ecosystem services to the evolution of general economic concerns about nature, and the emergence and expansion of environmental economics as a discipline. In this context, the authors describe the evolution from the original economic conception of nature's benefits as use values in Classical economics; their conceptualisation in terms of 'exchange values' in Neoclassical economics; and the expansion of monetary valuation to what they call the "mainstreaming of the new economics of ecosystems", in which the notion of ES is

[1] The terminology adopted here has been carefully considered. We refer to approaches and not frameworks, because we refer to the way complex relationships between humans and the environment are understood, and not to a formalised supporting structure. We use the plural because we consider ecosystem services-based approaches to be based on a paradigm that encompasses different ways of articulating that understanding. These different articulations can take the form of conceptual theoretical frameworks, such as the ones proposed by the UK National Ecosystem Assessment (Bateman et al., 2011; Schaafsma et al., 2015), the Valuing Nature Network or the well-established ecosystem service's cascade from Haines-Young and Potschin (2010); frameworks of action such as the Ecosystem Approach and Integrated Water Resources Management (Niasse and Cherlet, 2015); or classification or accounting frameworks, such as the Common International Classification of Ecosystem Services (CICES) developed by the European Environment Agency.

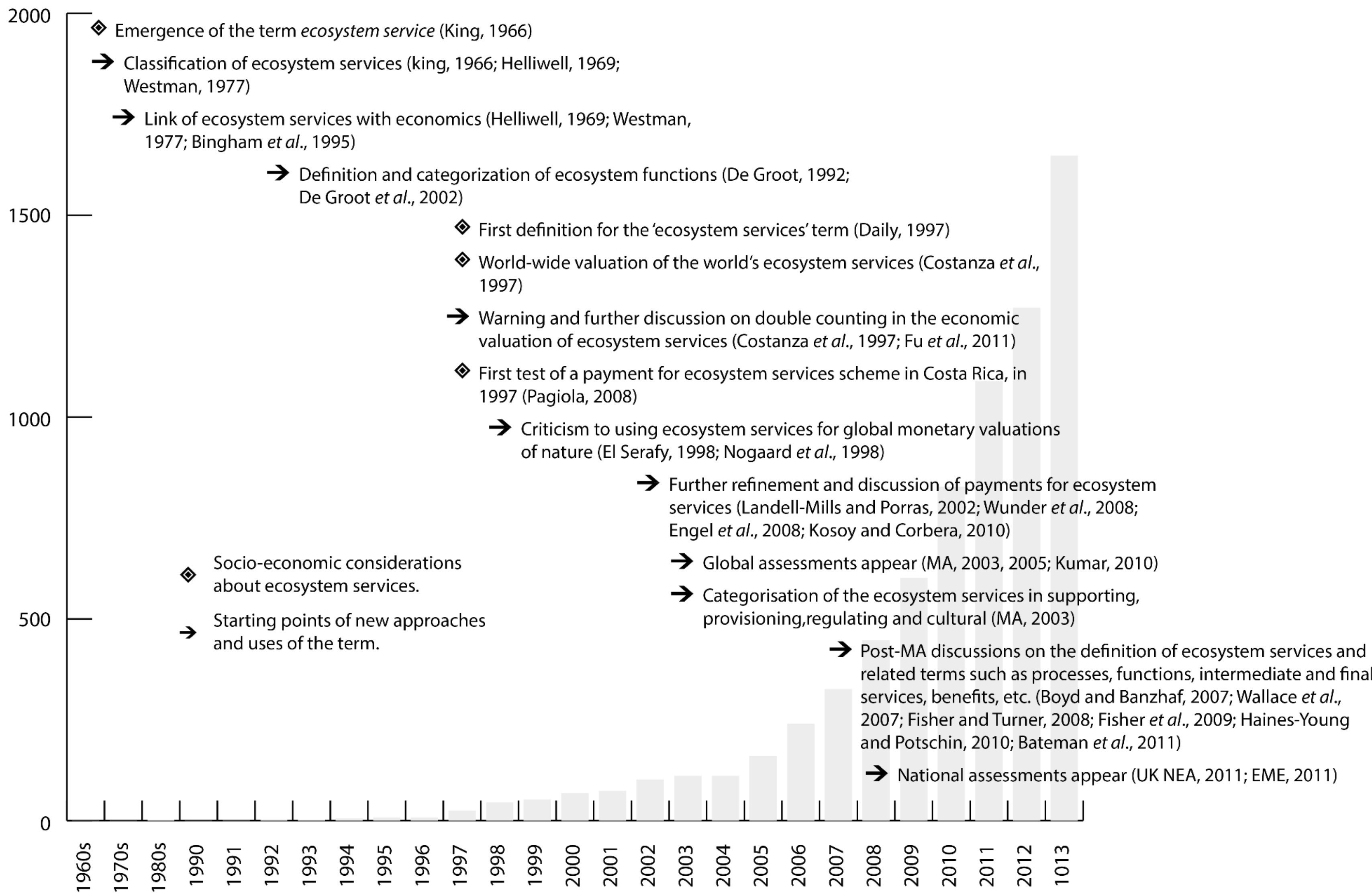


Fig. 3. Timeline representing the evolution of the notion of ecosystem services. Note: The bar chart illustrates the increase of publications using the term ecosystem services. It is based on a computerised search of the ISI Web of Science database during the time period up to 2013.

embedded. Here we focus on the emergence of the term 'ecosystem service' itself, and the evolution of its meaning and use (see Fig. 3 for a graphical representation).

The term 'ecosystem services' was first mentioned in the 1960s. King (1966) was concerned with the interaction between ecological and economic relationships of humans, and defined six values associated with wildlife that are "*positive to people*"[2]. Helliwell (1969) identifies recognisable benefits from wildlife and proposed the monetisation of values to incorporate them into conventional cost-benefit analysis. Westman (1977, p. 961) discusses the importance of accounting for the benefits of nature's 'services', understood as the "*dynamics of ecosystems*" that "*impart to society a variety of benefits*", and differentiated them from ecosystems' standing stock or nature's free goods. In their article "Extinction, Substitution and Ecosystem Services", Ehrlich and Mooney (1983) highlight that extinctions of species would result in the loss of services to humanity, which could range from trivial to catastrophic. Further publications appeared in the early 1990s (Bingham et al., 1995; Costanza and Daly, 1992; Ehrlich and Wilson, 1991). Bingham *et al*. in particular discuss the relationship between ES and economic valuation. These studies used the term ecosystem service, but none gave specific definitions.

Key milestones were the publication of Daily's book "Nature's Services: Societal Dependence on Natural Ecosystems" (Daily, 1997) and the seminal work of Costanza et al. (1997) "The Value of the World's Ecosystem Services and Natural Capital". Daily provides the first definition of the term ecosystem services, as "*the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life*". She also highlights that failure to foster delivery of ES undermines economic prosperity, forecloses options, and diminishes other aspects of human well-being. Costanza *et al*. set the ambitious goal of assigning a monetary value to the world's ecosystems and estimated an aggregated value of the entire biosphere. Costanza *et al*.'s work has been subject to criticism; El Serafy (1998) raises concerns about the comparison between the world's ES values and the global gross national product; Norgaard *et al*. (1998, p. 37) focus their criticism on the use of marginal values "*when the total collapse of some services seemed not only plausible but the driving concern*". Both highlight the fact that separate valuations of ES could result in double counting (a fact that had been acknowledged by Constanza *et al*. themselves). Despite these criticisms, this work contributed significantly to placing the valuation of ES very high on the research agenda.

From the late 90s onwards, the literature on ES grew rapidly (Fisher et al., 2009). In particular, De Groot *et al*. (2002) made a critical contribution by emphasising the role of the 'ecosystem functions' underlying the provision of services and goods. They list and describe a set of ecosystem functions as "*the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly*" (de Groot et

[2] The six values listed by King (1966) are commercial, recreational, biological, aesthetic, scientific and social.

al., 2002). Based on an earlier book (de Groot, 1992), four general types of ecosystem functions were defined: regulation, habitat, production, and information functions.

These publications provided the foundation for the Millennium Ecosystem Assessment (MA, 2003), which is undoubtedly the turning point in the popularisation of the ES concept. The assessment aimed to demonstrate how the decline in biodiversity (and degradation of ecosystems more generally) directly affect ecosystem functions that underpin services essential for human well-being. It provided a broad definition of ES as "the benefits people obtain from ecosystems" (MA, 2003) and the most frequently quoted typology of services: provisioning (production), regulating (regulation), supporting (habitat), and cultural (information) services. The Millennium Ecosystem Assessment explicitly promoted the use of the notion of ES to inform decision-makers across the globe, and has clearly inspired the development and application of different forms of ES-based approaches.

Since publication of the MA publication, different interpretations and critiques of the definition and classification of ES have emerged. Ojea *et al*. (2012) review the range of definitions that have been proposed, and found that interpretations differ according to the nature and types of services that are considered to have value for society. One post-MA definition is that of Boyd and Banzhaf (2007), who define 'final ecosystem services' as "*the components of nature directly enjoyed, consumed, or used to yield human well-being*". The authors consider services as the end products of nature (and hence the term 'final' ES), and distinguish them from 'intermediate natural components' and from 'benefits'. Boyd and Banzhaf propose to value only services as defined above, and exclude benefits in which anthropogenic inputs are involved (e.g. recreational angling would have non-natural inputs such as tackle and boats), and intermediate components, which they define as part of the process resulting in ES. Wallace (2007) and Fisher and Turner (2008) highlight that the same service can be either intermediate or final depending on the context (e.g. primary production to regulate water, or to benefit directly as food). According to Fu *et al*. (2011b), the exclusion of intermediate services in economic valuation does not indicate that they have no value, but that their values are realised through the value of the final ES; and Fisher *et al*. (2009) also point to the importance of stakeholders' perceptions in defining whether a service is intermediate or final.

A further distinction is that of final services and 'goods'. The UK National Ecosystem Assessment defines goods as the objects (both of use and non-use character) that people value (Bateman et al., 2011), while services are the flows that originate from ecosystems and contribute to the provisioning of goods. The most accepted conceptual framework for linking ecosystems and human well-being is that called 'service cascade', elaborated by Haines-Young and Potschin (2010) and adapted by De Groot et al. (2010). As its name indicate, it is a cascade of elements from biophysical structures and processes to functions, services, benefits and values (see Fig. 4).

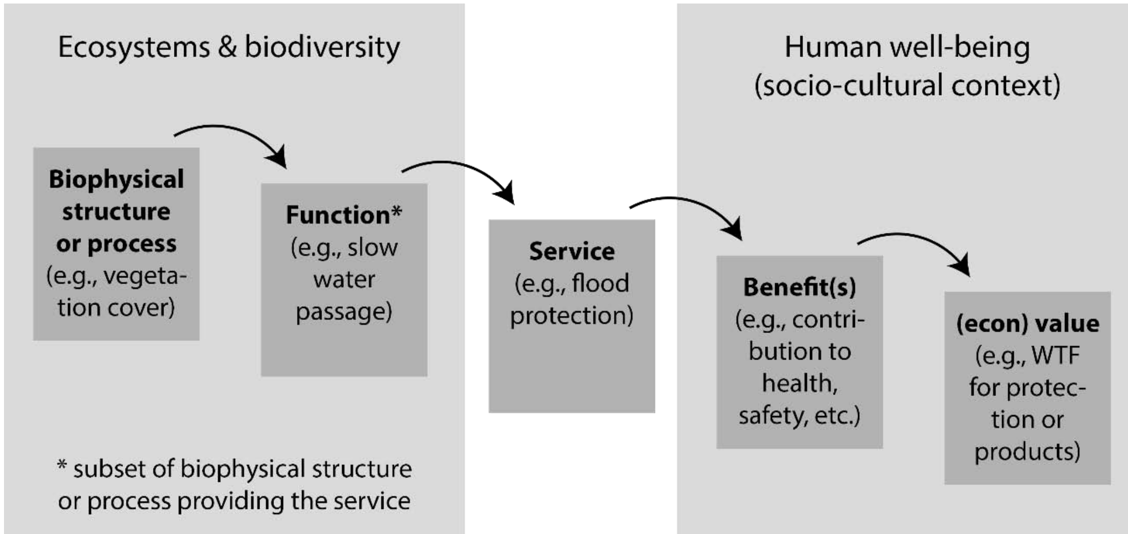


Fig. 4. Service cascade for linking ecosystems to human well-being. Source: De Groot et al. (2010), adapted from Haines-Young and Potschin (2010).

A parallel discussion has developed around the monetisation of the value of ES. In environmental economics, the predominant paradigm for the interpretation of the notion of value of ES has been that of Neoclassical economics (Gómez-Baggethun et al., 2010). Within this paradigm, the value of ES is measured in terms of the welfare change associated with changes in ecosystem status in monetary units (Pearce and Turner, 1989). The need for and validity of monetary assessments of ES values has been, and continues to be, heavily criticised, particularly from ecological economics perspectives (Azqueta and Delacámara, 2006; Martínez-Alier et al., 1998; Joachim H. Spangenberg and Settele, 2010). Even though alternative indicators of well-being that do not rely on monetary values have been suggested and applied (Byg, 2014), they have only recently found their way into actual assessments of ES. For example, Kenter *et al*. (2013) investigated the recreational use and non-use values of UK divers and sea anglers in potential marine protected areas in the context of the UK National Ecosystem Assessment, using a combination of monetary and non-monetary valuation methods and an interactive mapping application to assess site visit numbers.

2.3 ECOSYSTEM SERVICES-BASED APPROACHES: DEFINITION AND CORE ELEMENTS

As demonstrated above, there is no clear consensus on how exactly ES should be defined and classified, and as research on ES evolves, further interpretations might emerge. Major differences between definitions arise from the purpose the ecosystem service concept is expected to serve (Fisher and Turner, 2008; Fisher et al., 2009). A purely descriptive objective, for example, illustrating human-nature relationships, can use the most generic and broad definitions, such as those given by the MA and Daily (1997). For the specific purpose of creating an ES inventory that can be balanced against economic national accounts – and therefore an evaluative use of the term –, it is useful to think beyond aspects that are 'valued' and define ES more narrowly, as in the CICES developed from the work on environmental accounting by the European Environment Agency. Frameworks of identified ES will then differ depending on the specific descriptive or evaluative objectives behind the task (Fisher et al., 2009).

Instead of drawing upon extensive but generic lists of services such as the ones published in the MA, the selection and definition of relevant ES should be on a project-by-project basis to avoid a mismatch of purpose and underlying conceptual framework. Research papers should make clear the underlying purpose of the work and how the term ecosystem service is defined. Unlike Nahlik et al. (2012), we understand that specific projects should define and operationalise frameworks to achieve their own specific targets. As stated previously, rather than trying to provide an ultimate definition of The Ecosystem Services Framework, we propose a set of common guiding core elements of generic ES-based approaches that underpins the characterisation of research and policy applications.

Broadly then, an ecosystem services-based approach is a way of understanding the complex relationships between nature and humans to support decision-making, with the aim of reversing the declining status of ecosystems and ensuring the sustainable use/management/conservation of resources. An ES-based approach entails the following core elements:

1. **The focus on the status of ecosystems, and the recognition of its effects on human well-being.** An ES-based approach takes a viewpoint of anthropocentric instrumentalism, placing the emphasis on the benefits that humans obtain from nature, and recognising that humans are the ones who assign value to aspects of ecosystems. This is in contrast to alternative ways of interpreting the relationships between humans and nature, which consider the human system to be part of a broader ecological system and reject the idea of decision-making being purely driven by anthropocentric views, including notions of intrinsic value and bio or eco-centric viewpoints.
2. **The understanding of the biophysical underpinning of ecosystems in terms of service delivery.** This represents a new way of understanding and describing ecosystems in terms of the biophysical structures, processes, and functions leading to the delivery of services to humans (production chain). Traditionally, ecologists and other natural scientists have not thought about ecosystems in terms of human well-being but rather in terms of biogeochemical cycles, energy flows, species behaviour, and population dynamics, etc. An ES-based approach implies that there should be a re-phrasing of science in terms of how nature delivers to humans and what roles humans play in that delivery. Moreover, it requires the description and adequate quantification of the interactions of an ecosystem's components and their

effects upon a single service or a range of services (acknowledging complex interdependencies), across temporal and spatial scales.

3. **The integration of natural and social sciences and other strands of knowledge for a comprehensive understanding of the service delivery process.** An ES-based approach is, by definition, transdisciplinary in nature; this requires the integration of different academic disciplines, for example, via jointly developed models, which inevitably tradeoff precision in disciplinary approaches to achieve outcomes that are of use to decision making. An ES-based approach also requires the consideration of non-academic strands of knowledge, including the views and perceptions of stakeholders at the relevant scales. Co-construction of knowledge with stakeholders is essential to understand the variety of ways in which ecosystems generate well-being, and to establish the legitimacy of decisions based on the valuation of ES.
4. **The assessment of the services provided by ecosystems for its incorporation into decision-making.** An ES-based approach inherently implies an assessment (qualitative or quantitative) of the services delivered by ecosystems, and the identification of the (social) values of services in monetary and/or non-monetary terms. This is motivated by the need to incorporate these values into decision-making processes.

The above core elements are logically related to each other in a nested structure. Core element 1 is a necessary condition for core element 2 to apply. Similarly, core elements 1 and 2 are implied in the integrative work of core element 3, and for the assessment established in core element 4, i.e. as pre-requisites for the assessment of ES and the incorporation of their values into decision making. Fig. 5 illustrates this.

The nested structure of the core elements accommodates variations in the application of ES-based approaches. Our proposition is that an ES-based approach necessarily implies that the core elements are present, but that different research or policy case studies vary in how the core elements are represented. According to the nested structure, any ES-based application is necessarily grounded in the acknowledgement that ecosystem status and human well-being are linked (core element 1). However, the effects on human well-being can be perceived in a comprehensive manner, or be focussed on specific dimensions of well-being only (for example, whether solely economic welfare effects are considered, or whether shared social values, happiness, health, security, etc., are included as well). In core element 2, variation may arise from the way that the biophysical underpinning of service delivery is established. For example, biophysical analysis can be predominantly based on either measurement or modelling. In addition, some applications might be based on a more complex, site-specific biophysical analysis than others that, for example, rely on transferring knowledge on biophysical effects of ecosystem changes from similar contexts. Similarly, the integration of knowledge across disciplines and domains (core element 3) can also be examined along a range of dimensions. The degree of knowledge integration can involve only a few scientific disciplines and domains, or co-generation of knowledge can involve many disciplines and domains. Integration can be either static, following pre-defined paths in which knowledge flows between all the parties involved, or dynamic, allowing for feedback loops and adjustments in the conditions and assumptions underlying knowledge creation. Adherence to core element 3 can be achieved through (quantitative) surveys or (qualitative) participatory processes with stakeholders that aim to co-construct knowledge. Finally, the assessment of services (core element 4) can be quantitative or qualitative, or be conducted in monetary or non-monetary terms. The suggestions for characterising adherence to the four core elements (see Fig. 5) are not meant to be comprehensive. Rather, we hope that the idea of the nested core elements will stimulate discussions among researchers and policy makers about plausible and useful characterising terms. Furthermore, any characterisation may be adjusted over time to accommodate any novel development in ES-based approaches methodology or application.

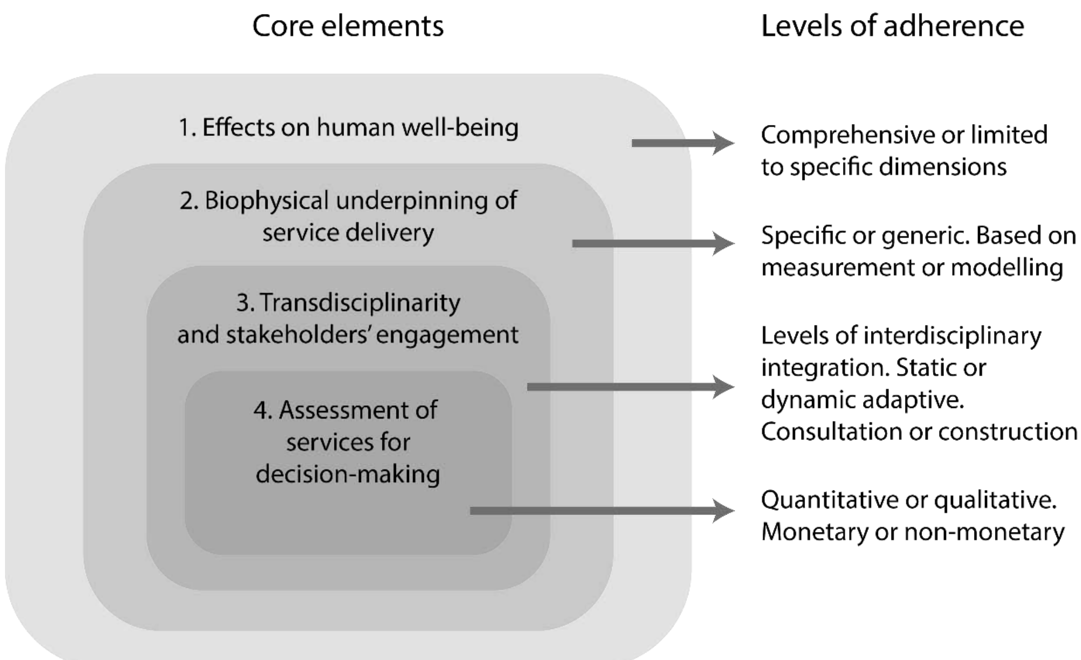


Fig. 5. Nested core elements characterising an ecosystem services-based approach.

2.4 TOWARDS AN ECOSYSTEM SERVICES-BASED APPROACH FOR THE CASE OF THE TER RIVER

In a context of conflicts over water flow management, and for the specific case of the Ter River, we develop our own ES-based approach. This ES-based approach builds on Fisher and Turner's (2008) definition as the ecological function (usually a set of ecological functions) required to provide one specific benefit. This is related to what Farley and Costanza (2010) categorise as *ecosystem fund-services, sensu* Georgescu-Roegen (1971), i.e. fund as a particular configuration of stock-flow resources with distinctive physical characteristics that guarantee the supply of a given benefit, i.e. an increase of people's well-being from using, consuming or enjoying water flows. As both sides of the same coin, we understand that one fund-service is equal to one benefit, and that these two concepts represent the notion of ES from either a biophysical or a socio-economic point of view.

Throughout this dissertation, we rather use the term 'ecosystem services', already commonly used in many fields of research. The term 'fund-service' is only used when we emphasise biophysical attributes of the service required to benefit (e.g., a specific flow of cold water, needed for cooling industrial processes). The term 'benefit' is especially used when we talk with stakeholders, since it is a more understandable term, or when we discuss about old studies that did not use the ES concept. Fig. 6 shows our terminological distinctions in a graphical way.

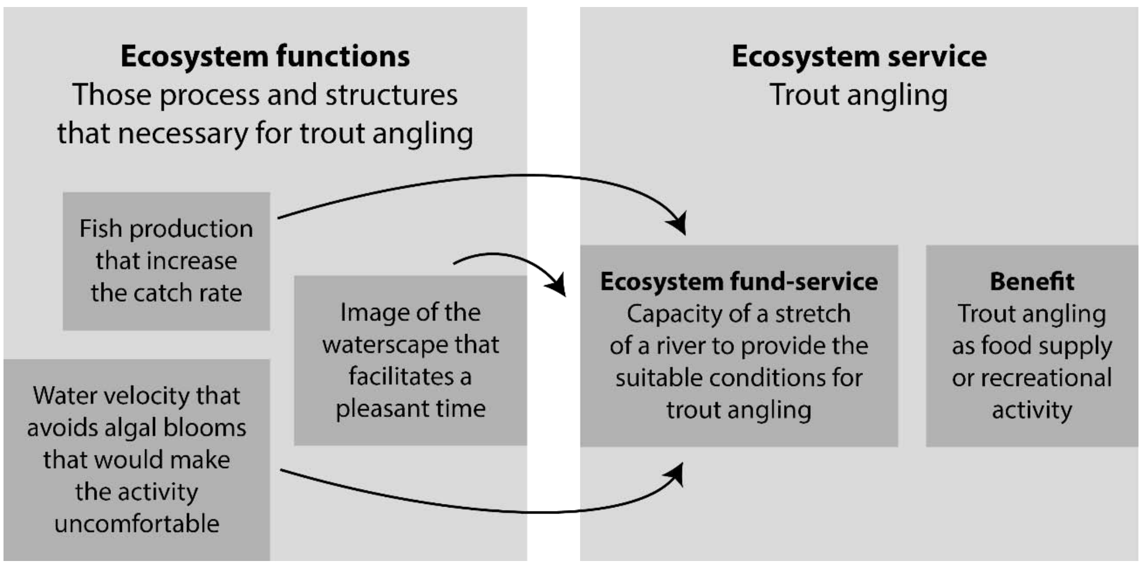


Fig. 6. Terminology employed in our ecosystem services-based approach.

Regarding the classification of ES, we use MA's categories of provisioning, regulating, cultural and supporting services. We do not think that the mentioned classification is essential for addressing water conflict, but we understand that may enhance the identification of ES. In relation to the discussion about the use of supporting services in assessments (Fu et al., 2011a; Wallace, 2007), we think that they could be very useful to recognise the intrinsic values of the river ecosystem itself, as well as of other associated ecosystems (e.g., floodplain wetlands or coastal ecosystems).

In relation to the four principles, our ES-based approach:

1. … recognises that structural changes to water flow management can influence several ecosystem processes in different ways and that, in turn, these changes result in multiple kinds of impact on human well-being (e.g., economic cost of water purification, pleasure of contemplating a river spot, feelings towards the biodiversity loss, the catch rate of brown trout) – core element 1.

2. … requires the understanding of the biophysical processes that determine the way water and sediment dynamics, etc. affect the different components of the ecosystem (quality of freshwater, riparian forest structure, habitat configuration) to the extent that it has impact on human well-being (through use or non-use) by the beneficiaries – core element 2.
3. … combines knowledge of the service delivery processes that are based on natural sciences (particularly hydrology and ecology) with information from social sciences (ecological economics and political ecology) and (local) stakeholder knowledge (e.g. farmers, drinking water users, floodplain residents, hydropower companies, regulators) that jointly help to understand, for example, where benefits arise in relation to where ecosystem change takes place – core element 3.
4. … requires at least some degree of quantification of changes in the final services delivered (e.g., the amount of water overflowing from the weir) coupled with a qualitative interpretation of the implications for human well-being, or the valuation of associated benefits (e.g., the satisfaction degree of ramblers with regard to the aesthetics of the waterscape) – core element 4.

Chapter 3

Socio-economic valuation of restoring environmental flows – review of case studies and roadmap for applications

3.1 INTRODUCTION

As mentioned in **Chapter 1**, freshwater is the foundation of human well-being. One the one hand, of the multiple benefits obtained from rivers, there is the water supply for domestic uses, irrigation and the production of electricity. All these benefits are provided by water withdrawal and their role in our well-being is well studied. On the other hand, since recent decades, multiple governments are incorporating environmental flow regimes in their water plans in order to guarantee a good ecological status of rivers. However, the socio-economic implications of costly river restoration measures are less studied, so there is an increasing interest of policy makers to understand them. Disregarding such benefits may turn into inter-stakeholder conflicts.

This chapter aims to review empirically-based literature assessing environmental flows and proposes a methodological framework for case-specific applications. **Section 3.2** offers the state-of-the-art on three aspects: 1) what motivations drive the socio-economic evaluation of instream flows (policies and alternative instream flow regimes); 2) what values and benefits are associated with instream flows (e.g., the sheer existence of a well-preserved river, productive assets, cultural attributes); and 3) what methods are employed to undertake such assessments (e.g., scenario development, monetary and non-monetary valuations, and stakeholders engagement). Building on this, we develop a roadmap for applications (**Section 3.3**) and propose an analytical framework for our case study (**Section 3.4**). Our proposal combines increased stakeholder participation, better understanding of ecosystem functioning, awareness of the plurality of values and an accurate choice of valuation methods.

3.2 A REVIEW OF CASE STUDIES

Various methodologies have been developed for optimising either ecological (Tharme, 2003) or socio-economic benefits (Ko et al., 1992) of managing dams or water diversions. Notwithstanding, they leave some gaps of understanding that have to be filled. One of the most conspicuous gaps is the socio-economic benefit provided by instream flows that is not commonly commoditised nor valued economically (through other methods). There are several difficulties to do so. First, while costs of implementing e-flows are typically quantified in financial terms, their benefits remain difficult to measure accurately (Dyson et al., 2008; Naiman et al., 2002; Postel and Carpenter, 1997). Second, tradeoffs between consumptive and non-consumptive uses of water flows involve ethical issues (Acreman, 2001). Third, the assessment of non-market benefits depends on perception, and perception is heterogeneous, context-dependent and dynamic (Binimelis et al., 2007).

Due to the increasing social recognition of instream flows, there have already been attempts to fill these knowledge gaps. Since Daubert and Young (1981), several works have been undertaken to value marginal changes in perceived instream flow states. Two reviews, by Wilson and Carpenter (1999) and Brown (1991), help to summarise advances in this respect. Wilson and Carpenter compare different methods used in the valuation of freshwater ES. Seventeen out of thirty reviewed studies took place in river ecosystems, of which only four attempted to value the water quantity. In the early 1990s, Brown specifically reviews the state-of-the-art of valuations of instream flows. Nevertheless, no updates from Brown have been published since, while significant progress has been made about ES-based approaches.

3.2.1 Selection of case studies for reviewing

The gathering of publications was carried out through a systematic search at Web of Science™ database. Combining the keywords 'instream flow/s', 'streamflow/s' or 'environmental flow/s', with the keywords 'economic valu/ation', 'benefit/s' or 'ecosystem service/s' yielded 558 articles. Then, to ensure that the selected literature fitted our objectives, some selecting criteria were specified.

1. Guarantee of empirical applicability. The analysis was restricted to case study-based papers, neither theoretical studies nor methodological proposals were included.
2. Policy relevance. Policies related to the management of instream flows had to be explicitly included in the valuation scenarios. This precluded interesting studies that see instream flows as the presumptive benefit or detriment from other kind of policies, e.g., land use and floodplain restoration policies for flood control (Brouwer and van Ek, 2004).
3. Assessments of socio-economic benefits from instream flows. There are already plenty of studies assessing ecological benefits of e-flows, e.g., improvements in aquatic habitat (Hickey *et al.*, 2015); and plenty of studies on socio-economic benefits provided by diverted water such as irrigation (Sisto, 2009), hydropower

(Guo *et al.*, 2012), urban supply (Medellín-azuara *et al.*, 2007). All of them were rejected.

After the ensuing filtering, 33 publications for the period 1987-2016 resulted as suitable references for the review, although we acknowledge that the economic discussion on the benefits and costs of altering river flows is much older (Krutilla, 1967). Fig. 7 shows the spatial distribution of analysed cases. Interestingly, most of the case studies are located in latitudes that present a semi-arid climate and throughout all continents, with the exception of South America, which is not actually exempt from conflicts related to water flows, e.g., in Peru or Chile (Camacho, 2012).

Table 3 presents a list of questions about the selected case studies. The next subsections explore the state-of-the-art of river restoration and socio-economic benefits through these questions.

Table 3. Questions in the review

Objectives of the case studies (**Section 3.2.2**) ▪ What are the stated objectives of the assessment of socio-economic benefits of instream flows? ▪ What type of policy measures are associated with the implementation of e-flows? ▪ What alternative flow regimes are proposed there?
Instream flow-dependent ES (**Section 3.2.3**) ▪ What values and ES are attributed to these instream flow regimes? ▪ How are such values and ES being identified? ▪ How is the provision of ES discussed in biophysical terms?
Valuation processes: scenarios, methods and performance (**Section 3.2.4**) ▪ How are the valuation scenarios being developed to evaluate e-flows restoration policies? ▪ What methods have been used in socio-economic assessments? ▪ Who are the stakeholders and how are they involved in the valuation process?

3.2.2 Objectives of the case studies

The multiple reasons bringing researchers to study the socio-economic benefits of instream flows can be classified in two groups: those aiming to support certain policy measures and those aiming to design an optimal flow regime for specific benefits. The first type of studies has a policy component and assesses a measure that includes the implementation of e-flows or new water withdrawal, for an impact assessment or a cost-benefit analysis. Such policies include the purchase of irrigation water rights (Mullick *et al.*, 2013), the construction/removal of a dam (Loomis, 2002; Skoulikaris *et al.*, 2009), the replacement of a wastewater outflow (Halaburka *et al.*, 2013), or an integrative hydromorphological restoration project (Loomis *et al.*, 2000; Morrison and Bennett, 2004). Of course some of these policies entail the restoration of elements of river ecosystems other than instream flows: riparian vegetation, longitudinal continuity, water quality (Becker *et al.*, 2014).

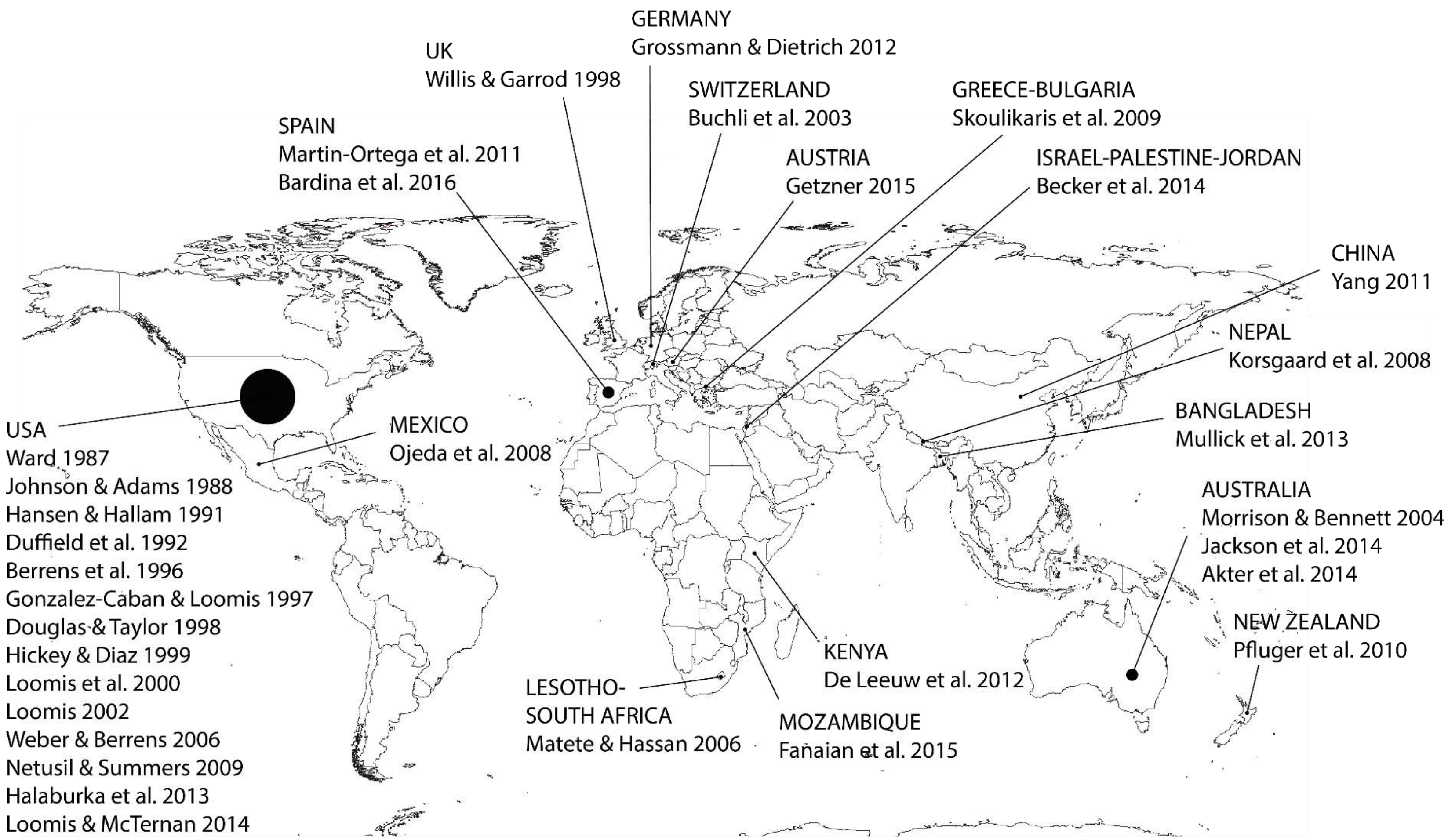


Fig. 7. Location of the 33 studies valuing the socio-economic benefits of instream flows.

The policy measures assessed are either for future implementation or already implemented. Getzner (2015) compares the non-market benefits from free-flowing stretches to those benefits from stretches currently affected by water withdrawals. Some studies are based on plans – not yet implemented – proposed by public administrations, e.g., the U.S. Army Corps of Engineers (Loomis, 2002) or the Catalan Water Agency (Bardina et al., 2016); non-governmental organisations, the Oregon Water Trust (Netusil and Summers, 2009); or private companies (Skoulikaris *et al.*, 2009). In these cases, the alternative instream and diverted flow levels are usually well defined. In most studies, however, the policies are hypothetically constructed, based on the current legislation, e.g., the Water Framework Directive (Martin-Ortega *et al.*, 2011), on the stakeholders' interests (in the case of the Ter River), or on some background literature from the study area (Loomis *et al.*, 2000). Finally, some studies assess diferent instream flow levels even without fully-stated bases. Willis and Garrod (1998), for instance, do not specify any amount of instream flow to be valued, and the term 'acceptable flow levels' is used instead.

The second group of studies seek those instream flow levels that provide the greatest benefit. These studies are more technical and provide departure points for planning a restoration project of e-flows. They involve a wide range of ensuing alternative flow states, based on either scientific expert judgment or observational data. Such range is also expressed with either a variety of defined levels (Hickey and Diaz, 1999; Pflüger *et al.*, 2010; Ward, 1987) or arranged in a continuum (Duffield *et al.*, 1992; Johnson and Adams, 1988).

With very few exceptions, in the existing studies there is an evident lack of an integral view regarding what an e-flow regime means. Neither the sediment nor organic debris transport appears as a key aspect of e-flows. The notion of environmental flows as a variable flow regime is also rarely represented. Only Johnson and Adams (1988), Loomis (2002) and Grossmann and Dietrich (2012) consider the seasonal dynamics of rivers for providing provided benefits.

3.2.3 Instream flow-dependent ecosystem services

What are then the benefits that rivers provide to the human well-being? ES-based approaches raise just timidly in the valuation of e-flows. While the link between nature and human well-being is always implicit, the reviewed literature not always profits from the ES concept. 18 out of the 33 selected publications use the term, mostly since 2005 (see Fig. 8). Some other studies used the notion without mentioning the term itself. An example is 'fishery production' in Johnson and Adams (1988), considered as a valuable attribute for fishermen and directly provided by nature.

For the purpose of this review, we consider that whenever benefits provided by river ecosystems appear, they can be interpreted as a form of ES, even though they are not reported as such in the respective publication. With this consideration, studies such as Ward (1987), Hansen and Hallam (1991), Douglas and Taylor (1998) or Loomis and McTernan

(2014) evaluate one particular ES, usually fishing or boating. Meanwhile, studies openly employing an ES approach usually include a more comprehensive variety of ES (Fig. 8). Recently, some works have focussed on multiple ES of the same type, for instance, food (e.g., provision of different species of aquatic wildlife in Jackson *et al.*, 2014) or recreation (Getzner, 2015).

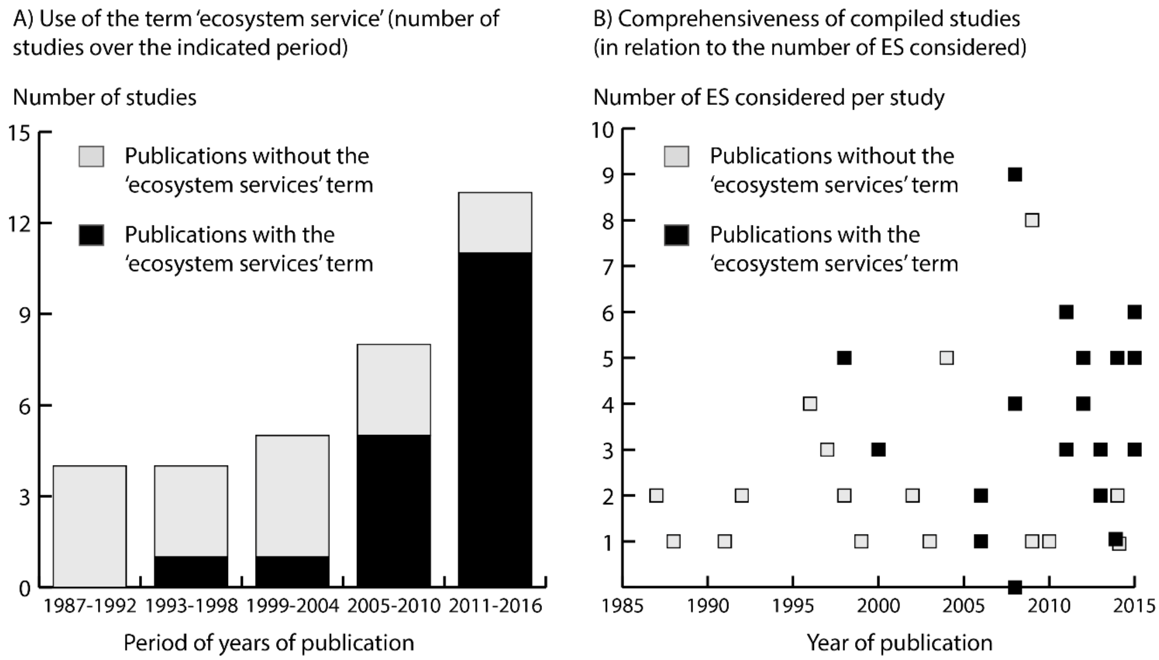


Fig. 8. Presence of the term 'ecosystem services' over the time.

In order to identify the ES that the river provides and select those to be assessed, several studies use participatory methods, requesting stakeholders' reasons to give it rivers importance. These methods are either surveys (Jackson *et al.*, 2014), interviews (the choice for our case study, in **Chapter 5**) or focus groups (Morrison and Bennett, 2004). Other studies use the existing literature for the ES identification and selection (Becker *et al.*, 2014; Loomis *et al.*, 2000). Yet, most studies just choose ES of interest without specifying any identification method (Halaburka *et al.*, 2013; Mullick *et al.*, 2013).

The MA classifies ES in the provisioning, regulating, cultural and supporting categories, and describes in depth the most relevant services provided by inland water systems (i.e. hydrological regulation, sediment retention and water purification, recharge/discharge of groundwater, climate change mitigation, products from inland water systems, recreation and tourism, and cultural value). Surprisingly, only few studies seem to build on the MA's insights. Fig. 9 brings the diverse ES found in the selected studies into line with the MA categories. The relevance of cultural ES (especially fishing and boating) and supporting ES (e.g., biodiversity) is noticeable at first sight. Instead, provisioning services usually depend on diverted flows or on other kind of policies (e.g., timber extraction or waterfowl hunting on floodplain management, rather than on water flow management). Regulating services are usually associated with an indirect use value hence are too unfamiliar for being identified by participatory methods.

Beyond rivers, Yang (2011), De Leeuw *et al.* (2012), Grossmann and Dietrich (2012) and Akter (2014) assess multiple ES provided by variations in water flows through wetlands, which also appear in Fig. 9 as supporting ES.

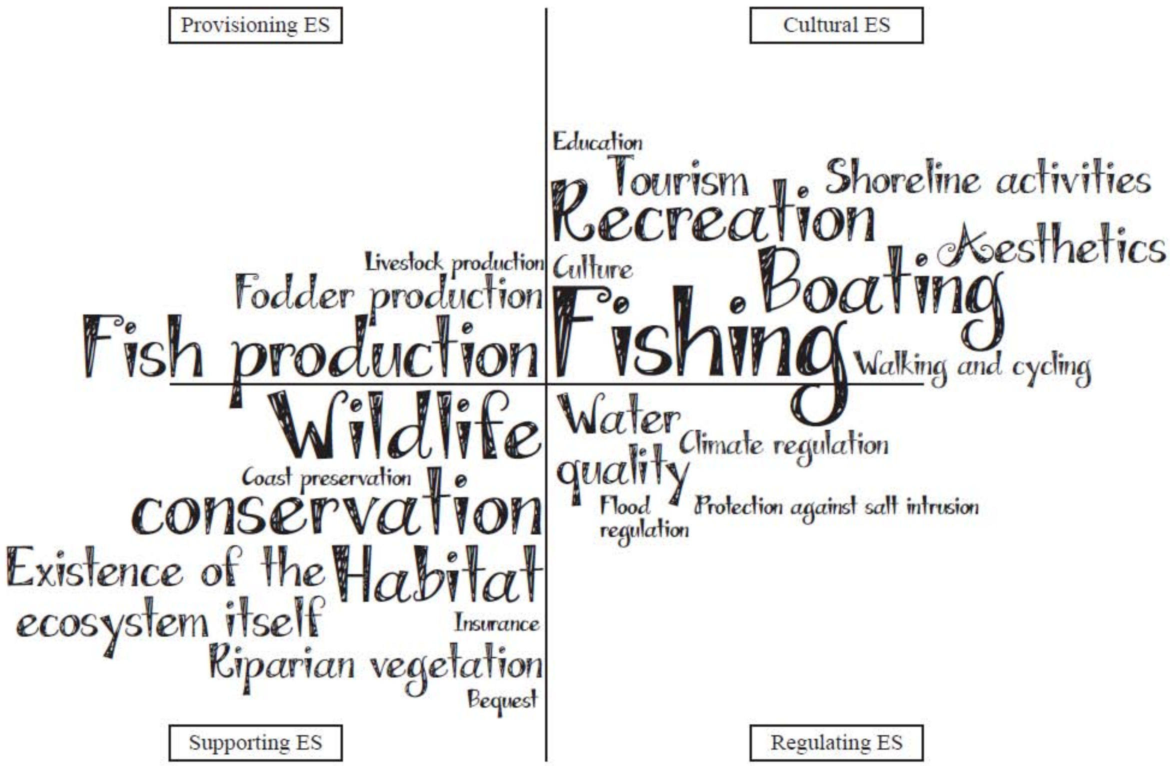


Fig. 9. Ecosystem services from instream flows, according to the MA categories. Note: Ecosystem services identified in the literature are ordered in size by number of articles that mention them, being 'fishing' named fourteen times and 'bequest' or 'education' only one. Within each sector, the disposition is random. 'Water quality' includes 'dilution of pollutants'; 'wildlife conservation' includes terms mentioned in the literature as 'fish species', 'aquatic birds' and 'biodiversity'; 'riparian vegetation' includes 'adjacent wetlands'; 'shoreline activities' includes 'swimming' and 'picnicking'; and 'existence of the ecosystem itself' includes 'the ecological status of the river'.

The use of ES-based approaches crucially entails the clarification of causalities from which ES stem (Fu et al., 2011b), which necessarily links to the domain of natural sciences. This is particularly necessary for valuing socio-economic benefits hard to perceive by stakeholders (Fisher *et al.*, 2009), such as CO_2 regulation or disease control.

The studies in our review explore this biophysical underpinning of the relationship between instream flows and ES in four varying degrees.

1. Blatant disregard. Some studies do not account for biophysical foundations and directly rely on other statements to explain ES delivery, usually on the stakeholders' interests or beliefs. For instance, Buchli *et al.* (2003, p. 586) rely on the fishermen's

complaint: "*the absence of fish is a consequence of the absence of water*"; and Ward (1987) and Getzer (2015), on the stakeholders' real preferences for the season when and the stretch where the flow is suitable for fishing.

2. Expert-based hypothesis of appropriate causal links. Loomis *et al.* (2000) argue that adequate flows are important for diluting pesticides, wastewaters and other pollutants, hence, for ensuring that the river is not toxic to fish and is safe for water-based recreation. Ojeda *et al.* (2008) assume that conditions of delta ecosystem before a dam construction, which are well-known, will be recovered after a restoration of water flows.
3. Quantification (by estimations) of the consequences of alternative instream flow regime choice. For instance, Grossmann and Dietrich (2012) offer details of ES provision as a result of the increase of the groundwater level and the benefits it provides in wetland areas. Loomis (2002) use geomorphologic parameters such as water depth, islands appearance, vegetation coverage and number of rapids.
4. Use of modelling tools and mathematical functions that precisely determine the service provision in relation to the flow level. E.g., Johnson and Adams (1988) (whose established relations are represented in Fig. 10) and Hickey and Diaz (1999) look at fishery production, and De Leeuw *et al.* (2012) at a variety of services. Korsgaard *et al.* (2008) use the called service suitability curves to quantify the ES provision, an approach commonly used to study the preferential hydraulic conditions for river fish (Bovee, 1986; Raleigh *et al.*, 1986).

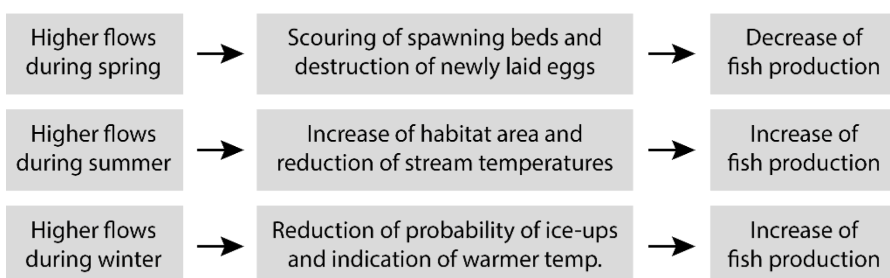


Fig. 10. Links between the ES *fish production* and seasonal instream flows used by Johnson and Adams (1988).

3.2.4 Valuation process: scenarios, methods and performance

By definition, valuation scenarios are those options different enough to be distinguished in a valuation process. According to the service provisioning cascade (Haines-Young and Potschin, 2010), a given policy measure has an effect on the instream flow level, which in turn has an effect on different components of the river ecosystem, which in turn provide a variety of ES. Then, one could ask: what should be valued? Some studies put the focus on only one of the stages of this cascade (see Fig. 11), while others evaluate more than one. For example, Pflüger et al. (2010) gives information about the instream flow level and the aesthetics of the waterscape through pictures, but does not specify under what type of management those scenarios would be performed. Although it would be desirable, none of the studies gives detailed information about the four stages. Besides, such information also depends on the valuation method selected.

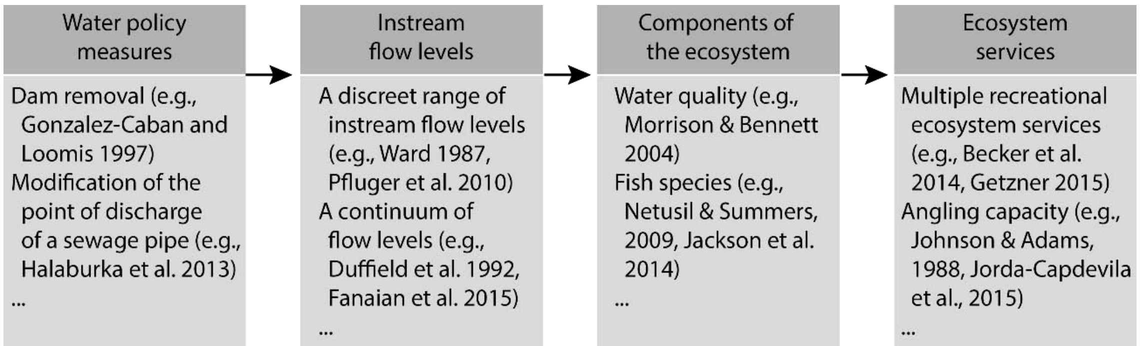


Fig. 11. Types of information that are introduced to be valued in any assessment of instream flows.

Methods on economic valuations of instream flow benefits have evolved a lot since 1987. By exploring the selected articles, one could argue that it is because of the evolution of the valuation methods themselves, together with the incorporation of the notion of ES in economic disciplines. As already mentioned, the oldest studies were much focussed on knowing more about specific recreational benefits valued by the respective stakeholders. The Travel Cost method (TCM) (see Table 4) was the preferred approach for such first type of assessments. Then, the Contingent Valuation method (CVM) was the most employed when non-use values (e.g., existence value of the ecosystem, aesthetic value) were incorporated. Douglas and Taylor (1998) use both methods for evaluating ecotourism-based river management and concluded it compared “apples versus oranges”, as the CVM refers to nearly pristine waters while the TCM estimates benefits for the current degraded state. Around 2000, the Contingent Behaviour Travel Cost method, a mix of the previous two methods, started to be used in substitution of the TCM. It allows the calculation of travel costs in hypothetical scenarios. Choice Experiments (CE) distinguishes the value of different attributes (e.g., ES) in broader assessments.

Other non-market methods like hedonic pricing have also been used, albeit less frequently. Netusil and Summers (2009) use that method to estimate the effect of the presence of various species of fish on the annualised price per transaction of buying water rights to implement e-flows.

Additionally, some benefits are actually recognised in markets hence facilitate the employment of market-based methods. This is the case of Mullick *et al.* (2013), who calculate the marginal benefit of fishery and small-scale navigation in current markets. Another example of market valuation method is the Replacement Cost. Jackson *et al.* (2014) look for the local-market price of different fish species from Australian rivers, usually captured by indigenous groups.

Table 4. Methods on economic valuation of environmental flows

Method	Examples	Description
Production based		
Market price	Fanaian *et al.* (2015)	Looks for the price of a commodity in the local/international markets that represents a particular ES (e.g., the price of timber)
Net factor income	Yang (2011); Grossmann & Dietrich (2012); Mullick *et al.* (2013)	Estimates the value of a commoditised ES by calculating the income of benefited people (e.g., the salary of a kayak instructor)
Cost based		
Avoided cost	Fanaian *et al.* (2015)	Calculates the damage cost of a possible hazard (e.g., floods) in order to estimate the value of an ES that avoids such hazard
Replacement cost	Yang (2011); Jackson *et al.* (2014)	Uses cost of artificial substitutes for environmental goods or services to estimate the costs incurred by replacing them (e.g. the cost of building a water treatment plant in substitution to a riparian forest)
Marginal abatement costs	Grossmann & Dietrich (2012)	Calculates the shadow price of carbon by estimating the costs of meeting a specific reduction target for certain political jurisdiction
Revealed preference		
Travel cost	Ward (1987); Weber & Berrens (2006); Getzner (2015)	Constructs marginal recreation benefit functions at several instream flow states, measuring the willingness to incur travel costs by the level of participation of trips and their length
Hedonic pricing	Netusil & Summers (2009)	Isolates the value of an environmental amenity from the observed value of other benefits in specific markets (e.g., prices of houses with different views over the river)
Stated preference		
Contingent valuation	Berrens (1996); González-Cabán & Loomis (1997); Ojeda *et al.* (2008)	Estimates use and non-use values through surveys, asking people about their willingness to pay (WTP) for protecting instream flows or their willingness to accept for a water withdrawal
Contingent behavior travel cost	Loomis (2002); Buchli *et al.* (2003); Loomis & McTernan (2014)	Elicits travel costs as well as expected travel costs by including scenarios with hypothetical instream flow levels in surveys among recreationists
Choice experiment	Willis & Garrod (1998); Morrison & Bennett (2004); Martin-Ortega *et al.* (2011)	Allows to choose one set of attributes that include, besides the WTP, either the instream flow level or states of different elements of the river dependent on instream flow regimes (e.g., number of fish species, status of the riparian vegetation)
Benefit transfer		
Benefit transfer	Bardina *et al.* (2016); Halaburka *et al.* (2013); Akter *et al.* (2014)	Is the procedure of estimating the value of an ecosystem service by transferring the results of an existing valuation with similar parameters to overcome the lack of time / money for performing a primary valuation
Non-monetary methods		
Environmental perception rating scales	Pflüger *et al.* (2010)	Makes the surveyees arrange different pictures of a landscape that represent different states of the ecosystem (e.g., different instream flow levels) according to their the aesthetic perception

In relation to non-monetary valuation, it has rapidly emerged since some arguments were exposed against the idea of using only monetary terms for economic valuation. However, only one of the studies on e-flows restoration dares use this type of valuation. Pflüger *et al.* (2010) perform a survey where respondents rank different instream flow levels according to their preferences on the aesthetics of shown pictures.

The demarcation of the study area is closely related to the selected valuation method. The accounting of the number of trips that recreationists do to the river does not imply to consider the same area as asking for the WTP by telephone. Then, the levels of demarcation range from a little stretch of the river, a wetland or a delta to a set of river basins or a whole State. Grossmann and Dietrich (2012) even define a different area for different ecosystem service being assessed. Fig. 12 shows the variety of areas considered in the literature to be evaluated. This is not a minor decision. The perception of an inter-basin water transfer will diverge whether a water donor, a water receptor or an outsider are asked. As a natural mean of transport for water, sediments, wildlife, seeds, nutrients, etc., river ecosystems provide services that can be produced and consumed in different areas and scales. Few studies take that into account, e.g., Hansen and Hallam (1991) consider the cumulative effects of increasing the instream flow discharge downstream and Yang (2011) the role of freshwater management for the climate regulation worldwide.

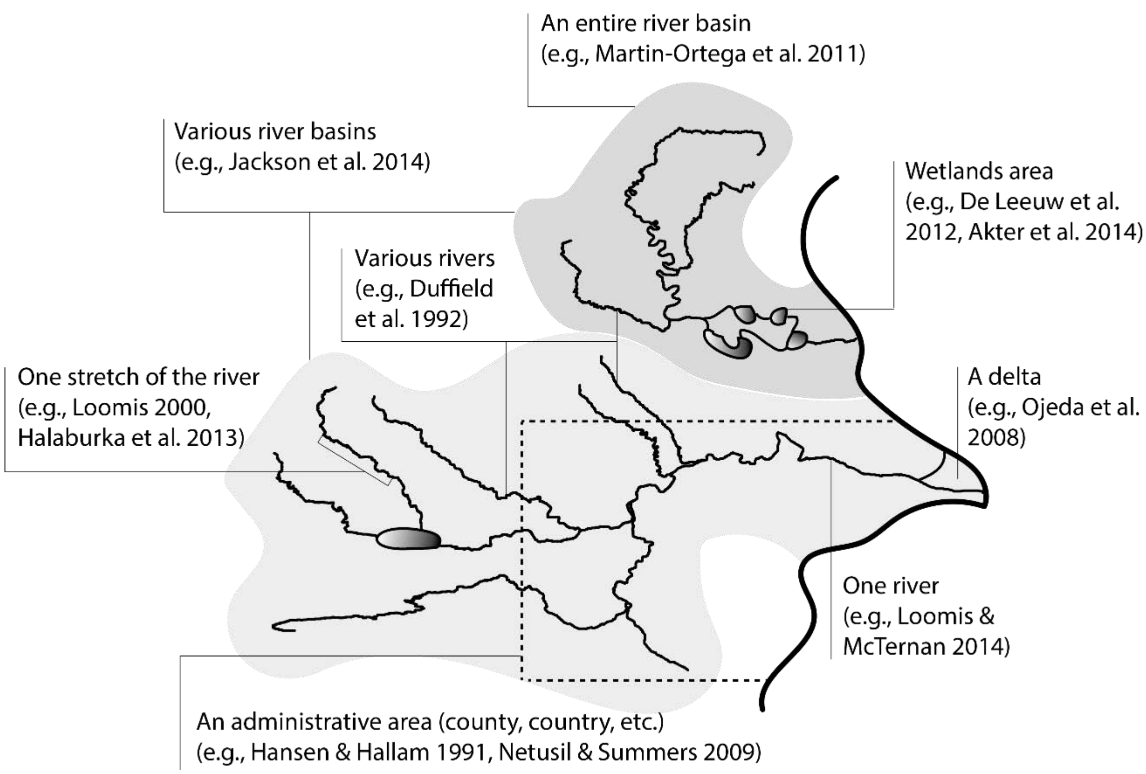


Fig. 12. Study areas considered to undertake the assessments.

3.3 A ROADMAP FOR APPLICATIONS

Informed from the above, this section presents some insights that may be of interest for the specialised researchers. Acknowledging the methodological contributions in previous studies, this section sets the basis for consistent economic valuations of e-flows restoration projects.

Our proposal is structured in four steps: 1) the case study framing – an initial definition of objectives well-grounded in empirically supported background –, plus three sequential steps of evaluation, adapted from Jenkins *et al.* (2010): 2) identification and characterisation (encompassing localisation) of ES, 3) biophysical quantification, and 4) economic valuation. This roadmap will be used in **Section 3.4** to develop the analytical framework for our ES application.

3.3.1 Case study framing

The objectives of the assessment are crucial to frame the case study. When the objective is to provide technical information to restore an e-flow regime, a relevant distinction to be made is whether the goal is a 'natural' or a 'designed' flow regime. Acreman *et al.* (2014a) defend a natural flow regime for those cases whose aim is for a re-naturalised ecosystem; whereas a designed regime can be useful when the goal is to make certain ecosystem status and the provisioning of certain services compatible. The first type of assessments may basically rely on ecological criteria, but the second type requires a socio-economic perspective and an ES-based approach would be recommended.

Assessments with a technically-generated range of instream flows provide a useful guide to design and implement policy measures, overall when water managers start the assessments from scratch. This information base may be helpful to search a balance between benefit maximisation and the realistic options on flow regime implementation. It is unlikely to maximise all benefits at once in multi-services assessments. In the face of tradeoffs from water management options, the equilibrium model[3] may exacerbate the lack of water for downstream users as well as for the environment. Meanwhile the non-equilibrium model tends to boost sharing principles (Lankford and Beale, 2007). Another option is the establishment of a safe minimum standard (SMS), i.e. a level of key ES delivery below which should not be permitted to fall (Margolis and Nævdal, 2004). SMS are argued to promote equity between stakeholders (Farmer, 2001).

When the objective is to evaluate water policy measures, the assessment should focus on contrasting the current situation with either a water extraction or a reallocation of instream flows. This type of studies usually assesses projects that include other policy measures beyond those referred to instream flows management. Different alternative policies should

[3] The equilibrium model is a representation of the economy based on the stability of variables when economic forces are balanced and in the absence of external influences (Berck et al., 1990).

be either detailed in current plans or hypothetically constructed from stakeholder demands, existent regulations or scientific studies.

If the measures are integrative (e.g., including the management of sediments, floods, droughts, etc.), the assessment becomes more realistic but also more complex to undertake. Indeed, the more limited an assessment is to instream flows, the better its results can be used for benefit transfer. Wilson and Hoehn (2006) argue that one specific measure allows to characterise simply the so-called ecosystem commodity (e.g. water discharge), contributing to the reliability and validity for benefit transfer. Nevertheless, the isolated measure of discharging an environmental water flow regime may be useless or even detrimental (Dyson et al., 2008). The lack of sediment even in free-flowing rivers may cause sediment-hungry, resulting in downstream erosion (Kondolf, 1997; Ligon *et al.*, 1995). Hence, a sand mining ban or dam removals can be complementary measures to the implementation of e-flows for preserving the native fish species (Olaya-Marín *et al.*, 2012).

3.3.2 Identification and characterisation of ecosystem services

The identification step is basic to recognise those ES produced under free-flowing conditions to then integrate them into assessments (Auerbach *et al.*, 2014). This step should not be restricted to the ES present in the literature (e.g., the ones listed by the MA or other classification systems), but to expand on the whole set of perceived benefits. In cases with water conflicts, less conspicuous services could be argued as important reasons for instream flow restoration.

Maestre-Andrés *et al.* (2015) recommend three complementary ways to obtain the maximum range of ES: a literature review, non-participant observation and interviews with stakeholders. The engagement of stakeholders through both the interviews (key informants) and the observation (general public) facilitates to deal with minority stakeholders. As many features of freshwater ecosystems are relevant for people who daily live with rivers, the lack of recognition of some ES can contribute to the absence of public participation of marginalised actors (Schlosberg, 2007), so undoubtedly bringing to an unequal distribution of the resources (Guha and Martínez-Alier, 2013). This is particularly important in river basins where non-profit benefits are abundant, e.g., ES linked to indigenous values in Australian rivers (Jackson *et al.*, 2014; Poirier and Schartmueller, 2012). This is why we think ES approaches are also useful to examine environmental justice issues.

The characterisation step consists in the ecological and economic determination of ES attributes (Daily, 2000). This step distinguishes the ecological functions that support ES provisioning, classifies the public-private good aspect and observes different –sometimes divergent– views from the locals (Fisher et al., 2009; Kremen, 2005). Localisation entails both the spatial (cartographic) and temporal representation of perceptions and preferences of valued ES over space and time (Plieninger et al., 2013). Mapping exercises are essential for limiting where and when ES are beneficial (e.g., swimming in pools and in summer) and for understanding their provision at different scales (Burkhard *et al.*, 2013).

From this step, a large set of entangled ES may emerge, as it is illustrated in **Chapter 5** for the case of the Ter. The prioritisation and the selection of the suitable ES for the valuation process is therefore necessary for making an efficient use of research resources. However, focussing the research may leave aside useful information. The exclusion of ES from valuation should then be well justified and explained (e.g., the educational service is surely interesting but has poor correlation with the instream flow level).

3.3.3 Biophysical quantification of service provision

The quantification step describes the interactions between the physical control of water flows, the ecosystem functioning and ES in order to provide numeric (quantitative or semi-quantitative) estimations of ES provisioning. Modelling exercises are argued to effectively represent these complex interactions (Jakeman and Letcher, 2003; Volk, 2013). Water allocation models calculate the amount of water discharged or diverted for instream or out-of-stream uses, while hydraulic models explore hydraulic factors (depth, width, velocity, etc.) derived from instream flows. The outcomes from this modelling can be transformed into ES provision by means of the selection of suitable indicators, e.g., tonne of food (irrigation) or KWh (hydroelectricity), and of mathematical models that relate these indicators to the instream flow level (Fanaian et al., 2015; Johnson and Adams, 1988). Usually, it is necessary to couple various models for this quantification step.

The ES provision highly depends on when and where the instream flow is discharged. Different types of flow turn on different ecological functions. For instance, in a Mediterranean stream, high flows in spring help to oxygenate the spawn and spread the seeds, but in summer, it can remove the fry and swamp the seedlings. Various methodologies (King and Louw, 1998; King et al., 2003) respond to this complexity in ecological assessment. However, this complexity is usually not recognised in economic valuation, which should be more open to the natural flow regime paradigm.

The biophysical quantification put numbers on the links between policies, instream flow levels, components of the river and ES, which are not evident for the general public. The necessity of connecting the ES provision with their biophysical underpinning is inversely proportional to the degree of expertise that evaluators have. For example, fishermen may directly know their preferable flow level without knowing the fish production rates. The biophysical quantification is also argued to provide a perceived neutral atmosphere for discussing political disputes when they are caused by water scarcity, growing consumption and non-equitable distribution of resources (Gaddis et al., 2010; Homer-Dixon, 1994).

3.3.4 Economic valuation

The economic valuation is a process by which the beneficial ways that ecosystems affect people are calculated, in the light of prevalent value systems. There is a massive amount of literature on valuation (Kumar, 2010; Mendelsohn and Olmstead, 2009; Wilson and Carpenter, 1999). This step is particularly complex and keeps creating controversy among researchers, as it is not technically easy to estimate values per flow units; and also because the use of monetary values may be perceived as too reductionist.

An attempt to extract a value per stretch of the river, catchment area or amount of flow from the reviewed literature resulted totally unsuccessful. Enormous differences in monetary terms appeared among the different cases, ranging between 12.51 USD[4] (Martin-Ortega et al., 2011) and 428.52 USD (Buchli et al., 2003) per household, or between 0.32 (Willis and Garrod, 1998) and 569.34 (Loomis, 2002) millions of USD per project. Many factors explain that variability, from biophysical aspects (e.g., natural flow level, improvement degree of the restoration project) to socio-economic elements (e.g., income per household, environmental awareness, proximity to the river). Under such conditions, the benefit transfer method may be easy to apply but highly misleading. Bardina *et al.* (2016) are cautious in the development of their benefit transfer. There is the need to conduct beforehand original valuation studies in similar contexts so that the results can be precisely transferred.

Moreover, the value is closely related to the use of the river, but also to the non-use. Less tangible ES have been evaluated by calculating the willingness of stakeholders to pay for them. This let the resulting monetary value be incorporated to cost-benefit analyses, together with the mentioned market values. However, such analyses may present a lack of ethical, political, social, historical or ecological considerations in water issues (Acreman, 2001). Different types of value can be incommensurable (Martinez-Alier et al., 2010) – some people do not simply accept the construction of a dam, even if they receive some money as a compensation. As it is mentioned in **Chapter 2**, concerns regarding ecosystems commoditisation are frequent (Kosoy and Corbera, 2010; Peterson et al., 2010). A comprehensive use of ES-based approaches in valuation should be able to capture the plurality of values related to instream flows offering a response to such concerns.

3.3.5 Stakeholder participation

Stakeholder participation deserves special consideration. Although it is not a step considered in the roadmap, it is an element that can be present – and we recommend so – in all steps. In relation to the objectives and to the time and money availability, there are different levels of participation, e.g., ‘continuous engagement’, ‘punctual involvement’, ‘based on stakeholders’ opinions’. In any case, different reasons for engaging with stakeholders are here presented:

- Stakeholder participation helps to better understand complex socio-ecological processes hence facilitates the identification of relevant ES**.** In their revision, Seppelt et al. (2011) report a lack of comprehensiveness because only 50% of the studies consider five or fewer ES simultaneously. One likely reason could be the absence of stakeholder involvement in 61% of the studies revised.

[4] All resultant monetary values have been converted to 2013 USD from other currencies and years.

- Through the diversity of knowledges and values, it avoids oversimplification of environmental problems when complex and dynamic nature exists (Reed, 2008, p. 1), as in river management issues.
- It also allows the development of different management options and their evaluation, either by ranking them or by assigning weights of importance to different services (Ananda and Herath, 2009; Seppelt et al., 2011).
- It enables the acceptance of results and the ensuing policy measures when the assessment is related to a specific decision-making context (Hage et al., 2010), Subsequently, it addresses the achievement of a social sustainability goal (Andre, 2012).
- Stakeholder participation is also consistent with regulatory guidelines of water management, such as the WFD.

As we have seen in **Section 3.2**, the selection of the stakeholders that need to be involved in a valuation process is not a trivial matter. River ecosystems provide services that are enjoyed and consumed at different sites, even at different scales and with different intensity. This is due to their role as transport channel and the complexity of their functioning (Poff et al., 2010). The provision of biological products concerns local people, while the water supply can be a regional issue and the CO_2 cycling global. To what extent does this depend on factors such as place of residence, influence capacity, interest, or forms of river use? In this context, who has the right to value what? Does the weight of the valuation should change in relation to such parameters? There is not a unique response, and the decision should come from the objectives of the research. A systematic stakeholder analysis and consistent use of participatory methods that are inclusive with diversity of knowledges can help to tackle these challenges (Reed, 2008; Reed et al., 2009). In any case, the limitations of stakeholder participation should always be openly acknowledged.

3.4 APPLYING THE ROADMAP TO THE CASE OF THE TER RIVER

The roadmap for socio-economic assessments of water flow presented above is applied for the case of the Ter River (see Table 5). The case study framing, identification, characterisation, quantification and valuation are necessary steps to assess the current situation, as well as some alternative scenarios proposed. Although most of the studies previously reviewed aim to obtain a few numbers to incorporate them in cost-benefit analyses, ours go beyond the valuation itself. Instead, we use the outcomes from the different steps of the assessment to achieve the objective of understanding inter-stakeholder conflicts. Actually, we perform three coupled assessments, related to each other through this roadmap applied as analytical framework. Thus, in **Chapter 5** we undertake the identification and characterisation of ES for analysing competition for water flows, divergent views and hot spots of activity. In **Chapter 6** a coupled model helps to quantify and value the ES provision under different water management scenarios in order to find tradeoffs and synergies among ES. In **Chapter 7**, all results are somehow used to analyse the ES provision through the recent history of the management of the river under the influence of actors and their interests.

Table 5. Roadmap for assessing socio-economic benefits of instream flows

Information required	Application to the case of the Ter River
Case study framing	
Natural flow regime or management-based paradigm	Management-based due to the anthropic level of the river channel and the dependence of many sectors on the Ter's waters.
Purpose of the assessment (to evaluate or to develop a policy measure)	To evaluate the current management of the water flows from the Ter River, and alternative scenarios, in order to understand inter-stakeholder conflicts.
Type of policy measures proposed	Only policy measures related to the water flow management.
Development of valuation scenarios	Four water management scenarios, based on the reduction of the water transfer to the RMB, the increase of the efficiency in irrigation systems and a change of priorities among water uses; and two climate scenarios.
Scope of the study (spatial, temporal, key informants).	Spatial: river basin delimitation (zooming in on four study areas) and other areas supplied by the inter-basin water transfers. Temporal: Past (1950-2015 period), current and future scenarios. Key informants: stakeholders identified through a snowball sampling, representing four different policy cultures: public sector, private sector, civil society and academia.
Identification and characterisation of ecosystem services	
Identification of all ES that somehow benefit people	28 ES of all four categories (supporting, regulating, provisioning and cultural) provided by 43 different ecosystem functions.
Characterisation of ES	Different hydrological alterations and different stakeholders' views of nature associated with each ES.
Localisation: spatial and temporal representation of ES provision	Maps and graphs that illustrate the stretches of the river where and the seasons and water-year types when an ES is provided.
Selection or prioritisation of ES	15 ES selected to be valued because of their salience and correlation with the instream flow levels
Biophysical quantification of service provision	
Selection of indicators	Monthly median of water flows passing through the river channel (instream flows) or through canals (diverted flows).
Description of the relationship between instream flows and the ES indicators	Distribution of water flows under the valuation scenarios previously developed thanks to a water allocation model.
Economic valuation	
Election of the valuation method and organisation of its performance	Suitability curves-based method. It relates water flows obtained from the water allocation model to the level of satisfaction, and calculates the called Service Provision Index (SPI).
Performance of the valuation process and arrangement of the results	SPI of different ES, which are aggregated by season, water-year type and stretch of the river, and illustrate tradeoffs and synergies
Validation	A return meeting with stakeholders, which is used to contrast the outcomes of the assessment.

3.4.1 Stakeholders as information providers

In this dissertation, we do not use participation as a continuous process of stakeholder engagement. Rather, our case is clearly one of those that stakeholders are merely used as information providers. Thus, stakeholders do not participate in any decision of the research process, but their knowledges and values are the pillars of the study. At the same time, there was a concern for keeping stakeholders aware of the results obtained so return exercises where also performed (see **Chapter 6**, **Section 6.5.4**)

Different techniques were used to select the suitable stakeholders as information providers and to extract information. Similarly as other examples of water management assessments (e.g., Whitfield and Reed, 2012), we performed a snowball sampling (Goodman, 1961) to identify key actors related to the water management or to the provision of specific ES (see **Chapter 5** for more information). The fieldwork comprised in the Ter River basin involved thirty-three interviews, five workshops and two surveys. Table 6 specifies each participatory method in relation to the different steps of the assessment. The entire structure of the fieldwork is detailed in **Appendix A**.

Table 6. Stakeholder engagement in the assessment

Method	Information gathered	Steps
Semi-structured interviews with key informants (N= 20)	Description of current, past and desired relationship with the river	Identification
	Identification of components of nature	Characterisation
	Opinion on the current water management in relation to the ES	Characterisation
Workshops (32 stakeholders involved in 4 workshops along the river) and supplementary interviews with key informants (N = 13)	Conditionings (biophysical, infrastructural, management or legal) for ES provision	Characterisation
	River stretches related with a specific ES provision highlighted in a map	Localisation
	Features of the water flows required to provide – null, minimally acceptable, and optimal – levels of ES, thus configuring the ‘suitability curves’ for each ES.	Valuation
Surveys (among 26 non-governmental organisations struggling for a better water management in Catalonia and a 10 key stakeholders already interviewed)	Opinion on the current management of the dams, the water supply to the RMB and regulation of the hydropower plants	Quantification and valuation
	Sort of the different uses of water according to their priority.	Quantification and Valuation
One validation workshop (with 12 stakeholders, specialised in different ES)	Agreement and disagreement about the results obtained	Validation

Chapter 4

The Ter River, a representative case in the Mediterranean basin

4.1 INTRODUCTION

"*Human influence on the Ter started in the Middle Ages with iron industries, which caused great deforestation in large areas. During the Industrial Revolution, cotton mills and paper mills proliferated along its banks, attracted by the quality of its water. An inheritance of this period is the presence of small dams [weirs] and channels directing the water to the production of hydraulic power. Regulation of the Ter was completed during the 1950's by the construction of two large reservoirs in the middle stretch of the river [Sau and Susqueda]. Since then, the high development of industrial facilities and, in general, the unplanned growth of urban centres have caused the affluence of enormous sewage inputs to the river. Human pressure on the river is diverse and has increased in recent times. Intensive farming, urban development and industry depend on its waters. Up to now the Ter remains undisturbed only in some of its first and second order tributaries*" (Sabater et al., 1992).

The text above, written in 1992, shows a scene that does not differ substantially from the situation of many rivers in the industrialised Europe at that time. Yet the magnitude of the hydrological alterations, the diversity of stakeholders competing for water flows and the tight connection with water metabolism of what is now the sixth urban area in the European Union, the *Regió Metropolitana de Barcelona* (Metropolitan Region of Barcelona, RMB) (Demographia, 2016), make the Ter River a unique case that deserves to be explored in depth.

This chapter provides first some general data of the Ter River and its basin. This is followed by an explanation of how water flows are managed, including a description of available water resources, demands of different water uses, and regulations and policies. Finally, the chapter presents the four study areas selected for the fieldwork.

4.2 GENERAL DESCRIPTION OF THE RIVER BASIN

The Ter is a typical Mediterranean river. Located in NE Catalonia, Spain, it is a 208-km-long river that springs at 2,400 meters, in the Eastern Pyrenees, and from there flows south to the inland Vic Plain. Then, it turns east, passes through a hilly area and forms a flat and marshy area at the mouth. Finally, it drains into the sea with an average natural discharge of 844.94 hm^3/year (ACA, 2005).

Throughout its course, the Ter receives a large number of tributaries (Fig. 13). The largest in the upper part is the Freser River (4th order[5]). The upper basins of the Ter and the Freser receive a high number of small streams feeding into them in the Pyrenees. The Ritort, Rigat and Merdàs are the most important. In its middle stretch, the Ter receives small 2nd to 3rd order streams, coming from middle-mountain sub-basins: the Vallfogona, Ges, Rupit, Brugent and Llémena streams are left bank tributaries, while the Sorreigs, Méder, Major and Osor are right bank tributaries. Before it reaches the sea, the Ter receives the Onyar River, a 4th order stream, which has a marked Mediterranean regime, but does not highly alter the Ter hydrography. Other tributaries below the Onyar-Ter confluence are the Terri and Farga streams – both on the left bank. When the Ter flows out into the Mediterranean Sea, it is a 5th order stream (Sabater et al., 1992).

Girona is the largest city in the area and the capital of the province where most of the basin is located. The important towns that the Ter flows through are Camprodon, Sant Joan de les Abadesses, Ripoll, Sant Quirze de Besora, Torelló, Manlleu, Roda de Ter, la Cellera de Ter, Anglès, Bescanó, Salt, Girona, Sarrià de Ter, Sant Julià de Ramis, Celrà and Torroella de Montgrí (Fig. 13).

4.3 THE MANAGEMENT OF WATER FLOWS

According to the Statue of Autonomy of Catalonia, the Government of Catalonia is the public organism in charge of managing the water flows of the Ter River, as of all internal basins of Catalonia. In Catalonia, there are also interregional basins whose management is shared with the Government of Spain and other regional governments. These are the Ebro, the Garonne and the Sénia basins. In 1998, the Catalan government created the *Agència Catalana de l'Aigua* (Catalan Water Agency, ACA), the current watershed authority.

The Ter basin, together with the Llobregat River and other smaller rivers, becomes part of the Ter-Llobregat system, established as a single management unit by the Water Management Plan 2009-2015 (ACA, 2010). This means that the water resources of all these rivers are accounted together with the purpose of satisfying the estimated population needs. The Ter-Llobregat Discharge Commission meets twice per year and determines the distribution of water resources for meeting the variety of needs: urban supply, irrigation and environmental uses.

[5] The stream order hierarchy was officially proposed in 1952 as a way to define the size of perennial and recurring streams. The sizes range from a first order stream all the way to the largest, a 12th order stream.

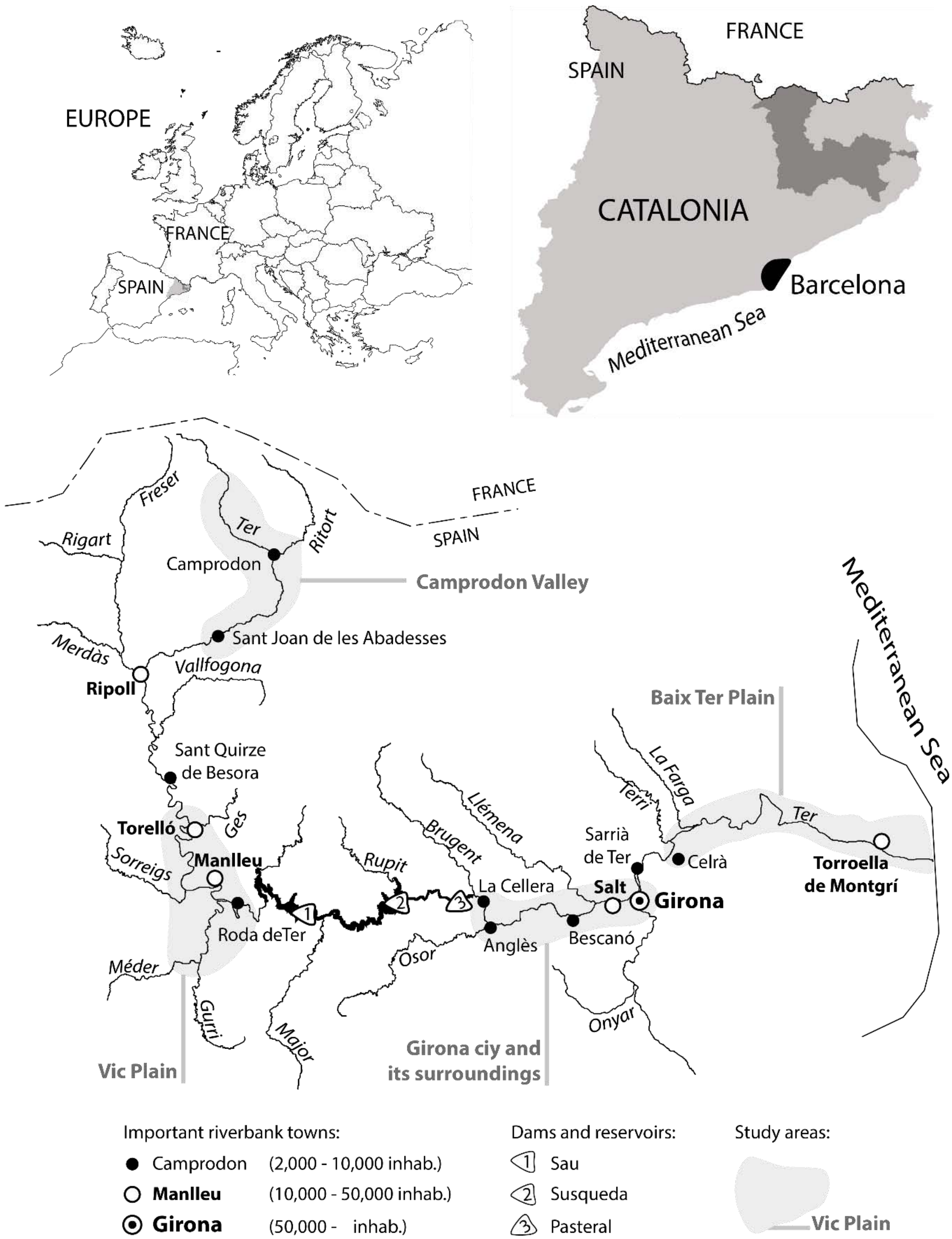


Fig. 13. Location of the Ter River basin. **A.** Location of Catalonia within Spain and Europe. **B.** Location of the Ter River basin and Barcelona within Catalonia. **C.** The Ter River with all its tributaries, the dams and the riverside towns. Note the selected four study areas highlighted in grey.

Within the Ter-Llobregat system, the largest part of water supply correspond to the Aigües Ter-Llobregat network[6], which is managed by the licensee Aigües Ter-Llobregat (ATLL). ATLL supplies drinking water to about 5,220,000 inhabitants and covers an area of 4,233 km^2, mainly in the RMB. Water demand for this area is estimated about 370 Hm^3 annually (ACA, 2015).

4.3.1 Water resources

Instream flows

The Ter, as with other Mediterranean rivers, has a very variable flow regime, from year-to-year and also within a year. The Ter is a snow- and rain-fed river. Summer is the driest season throughout the basin. However, the flows in winter are also low in the headwaters, where the influence of snow is major (see Fig. 14). Regarding the inter-annual variation, the average annual flow was 816 Hm^3 between 1940 and 2008, while the maximum was 2,252 Hm^3 and the minimum 322 Hm^3 (ACA, 2015).

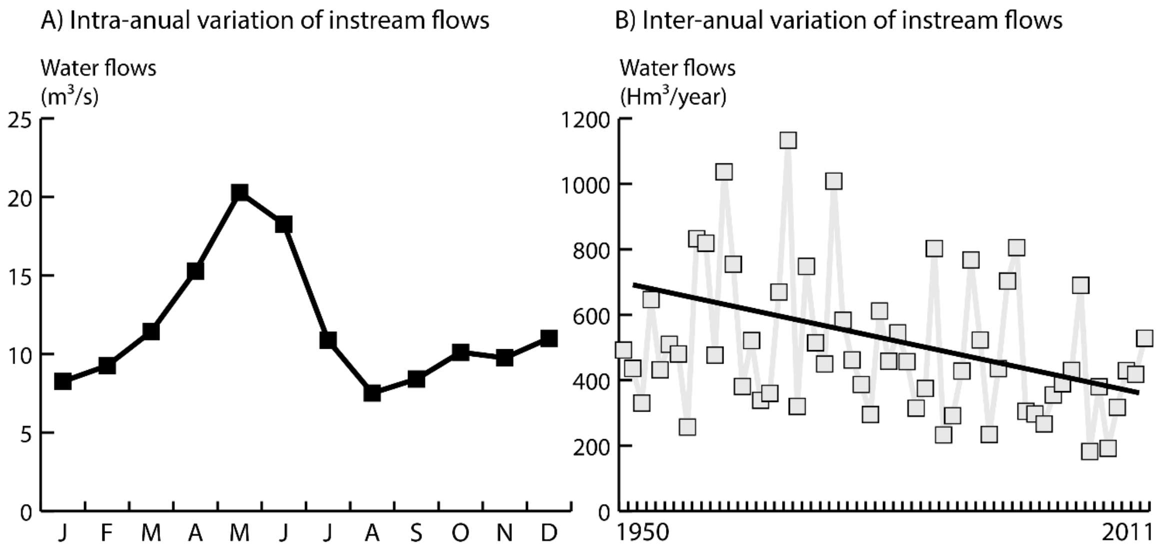


Fig. 14. Intra-annual and inter-annual variation of the Ter River instream flows (series from 1950 to 2011), at the gauging station of Roda de Ter, upstream of the Sau reservoir. **A.** Monthly median flow. **B.** Contribution of a hydrological year. Source: ACA.

Variation of instream flows has not been homogeneous in recent decades either. Armengol and Dolz (2009) showed that the average flow has decreased by about 40% since the construction of the Sau reservoir (see Fig. 14). The decrease of the precipitations (-65% between 1971 and 2013), the afforestation (+6.0% between 1971 and 2005) and the crop abandonment (-1.6% between 1971 and 2005) in the basin are likely causes of that fall (Vicente-Serrano et al., 2016).

[6] In order to avoid confusion, throughout this thesis we refer to the Metropolitan Area of Barcelona to actually mean the area supplied by the Ter-Llobregat network, which are almost coincident.

Sau, Susqueda and Pasteral reservoirs

In the middle course of the river a chain of three reservoirs (Sau, Susqueda and Pasteral) divide the basin into two sub-basins (see Pic. 1 and Pic. 2), which are de facto managed as different units: hereafter the 'Lower Ter' and the 'Upper Ter'. The dams regulate water flows of the Lower Ter in order to prevent floods, while at the same time storing water reserves mainly for domestic and irrigation uses, and for producing hydroelectricity.

The Sau-Susqueda-Pasteral chain has a joint capacity of 402 hm^3 and the average residence time of the water is 117, 143 and 1.7 days respectively. From the Pasteral reservoir the water is diverted to supply urban areas of the RMB. The diverted flow can range between 26% (in 2011) and 115% (in 2007) of the annual water quantity flowing into the Sau reservoir. Thus, the reservoirs exert a direct influence on the Lower Ter, severing the continuity of the river ecosystems, and altering the flow regime. While in some months the dams discharge a minimal flow, especially after severe droughts (3.1% in May 2008), in other months, particularly in the summer, the discharge may double or triple the flow upstream of the reservoirs (238.9% in August 2004) (See Fig. 15).

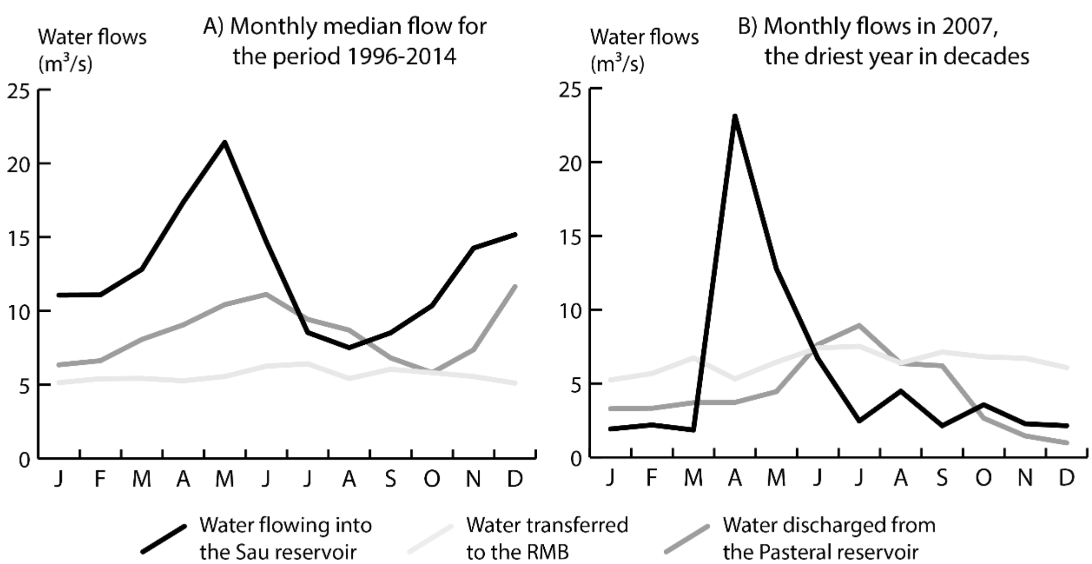


Fig. 15. Effect of reservoirs on water flows. Source: ACA.

Pic. 1. Susqueda dam.
In the picture, we can see that there is very little discharge. This is because most of the water runs through an underground pipe to a hydropower station.

Pic. 2. Pasteral reservoir.
This 2-Hm^3 reservoir buffers the impact of the Susqueda discharges, which vary a lot between day and night because of electricity demands, hence minimising the daily hydrological alteration downstream.

The reservoirs have also proved effective for purifying the polluted water coming from upstream, with a phosphorus and nitrogen sink capacity of 81% (Puig et al., 1987).

4.3.2 Water uses

Domestic use

The domestic use of the Ter's waters is very important, especially since the construction of the Sau-Susqueda-Pasteral system. Most of the water stored in this reservoir system goes to the RMB, but also to coastal towns of the central Costa Brava, and to Girona and its outskirt. Still, the majority of municipalities in the Lower Ter consume groundwater.

In the Upper Ter, the consumption of water for domestic supply is smaller although increasing due to the groundwater pollution in the Vic Plain related to to pig farming. In the past, the only city supplied with waters from the Upper Ter was Manlleu. In the Pyrenees, the municipalities use water from springs and wells instead.

Agricultural use

Irrigated land is important in the Lower Ter (see Pic. 3), where the irrigation communities manage the diverted flows (see Table 7). There, irrigated land occupies 13,889 ha, in which maize (23.44%), wheat (16.29%) and barley (12.29%) are the most extended crops. Rice (4.27%) and apple trees (6.59%), despite their relatively low extension, are emblematic crops in the region and have a cultural added value. The water needs at the diversion points are estimated to be about 85 Hm^3 (ACA, 2009a).

Pic. 3. Gardens in the floodplain of the Ter River, close to Anglès town.

Table 7. Seven most important irrigation communities (IC)

	Surface (ha)	Irrigated surface (ha)	Water extraction need (Hm^3/year)	Main crops
La Pardina	249,47	76,90	0.377	Oat
Salt-Bescanó i Vilablareix	617,18	383,51	1.823	Maize and barley
Sèquia Monar	313,22	115,51	0.387	Barley and rapeseed
Sant Julià de Ramis-Cervià de Ter-Sant Jordi Desvalls-Colomers i Jafre	1.361,61	533,52	2.709	Maize and common wheat
Sèquia Vinyals	840,37	465,81	3.530	Common wheat and maize
La Presa de Colomers	5.007,52	3.979,95	27.106	Maize and alfalfa
Molí de Pals	3.105,31	2.390,37	19.742	Rice, alfalfa and maize

Source: ACA (2009a).

Industrial use

The Sau, Susqueda and Pasteral dams produce hydroelectricity. Their water flow capacity is 70, 50 and 30 m^3/s and their installed power is 55, 85 and 6.5 GW, respectively. In addition, eighty two small hydropower plants (SHPP) spread throughout the Freser and Ter courses constitute the major utilisation of the potential energy for electricity production. These are run-of-the-river plants, that is, hydroelectric plants that cannot regulate the flow. Although they do not consume water, their water rights licenses allow them take up to 150-20,000 l/s (see Fig. 16), sometimes even exceeding the average instream flow levels under undisturbed conditions. Pic. 4 shows a conflictive dam in the Ritort tributary.

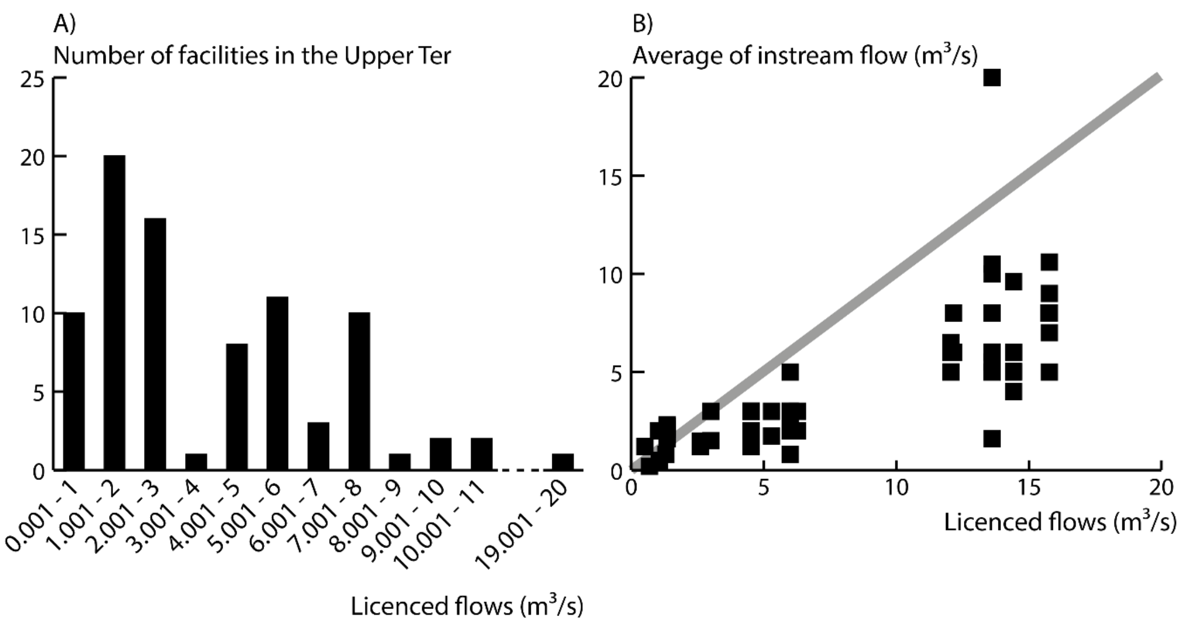


Fig. 16. Representation of the eighty-five small hydropower plants currently working in the Upper Ter. **A.** Number of facilities arranged by licenced flows. **B.** Comparison between licenced flows and average flows under undisturbed conditions. Grey bar indicates when both are equal. Source: ACA.

Other important industrial uses correspond to the textile, chemical, wood and agri-food sectors. Main industrial areas are in Girona, but also in Sant Joan de les Abadesses, Ripoll, Torelló, Manlleu, Roda de Ter, Anglès, Salt, Sarrià de Ter, Celrà and Torroella de Montgrí.

Pic. 4. Molló dam.
It was built to supply electricity to the Molló village. After a long judicial process, the court ruled in favour of removing this dam because, when it was working, it was not discharging even a minimum flow.

Pic. 5. Santa Eugènia wetlands.
In Girona city, these wetlands are fed by the outflows of the irrigated fields in the area.

Environmental, aesthetic, health and other uses

Besides the main uses detailed above, water is also diverted for environmental, aesthetic, health and multiple other purposes. These uses may not generate a high economic benefit, at least directly. However, their effect on the well-being of the locals is significant.

A paradigmatic infrastructure employed for multiple uses is the Monar Canal, which crosses the cities of Salt and Girona. Most of the water that flows through is used by three SHPP and a little portion irrigates the fields of the *Horta de Salt IC*. Some of the water used for irrigation also feeds some floodplain wetlands (see Pic. 5), a spot of biodiversity that attracts visitors interested in nature. At its mouth, the Monar canal flows into the final stretch of the Onyar River, which has traditionally used for collecting debris from the city. Now, it creates the iconic waterscape that has become one of the symbols of Girona.

4.3.3 Water policy in the European Union, Spain and Catalonia

Water Law

The Spanish *Law 29/1985, of August 2, on Water*, also called Water Law, aims to regulate the public hydraulic domain and the powers related to its management. In particular, the Water Law requires that Autonomous Communities (i.e. administrative regions of Spain), whose Statutes give them authority over watersheds fully contained within their territory, adjust their legal system to the following principles:

1. Unity of management, integrative treatment, water economy, no concentration, decentralisation, coordination, efficiency and users' participation.
2. Respect for the unity of the watershed, of the hydraulic systems and the hydrologic cycle.
3. Compatibility between the public management of water and the land use policy, the conservation and protection of the environment and the restoration of nature.

In practice, this means that the Ter River is fully managed by the Government of Catalonia and that environmental flows are not considered a use itself, but a previous restriction to any use.

Water Framework Directive

As explained in the first chapter, the WFD does not set the objective of implementing e-flows. However, by targeting a *good ecological status* for all water bodies, the Directive compels European countries to include e-flows in the water policy agenda. The necessity to implement e-flows particularly affects Mediterranean countries, which suffer a greater threat on water scarcity, although other countries, like the UK, are also making an effort in this respect (Acreman and Ferguson, 2010).

The transposition of the WFD took place in Spain through the *Law 62/2003, of December 30, 2003, on Tax, Administrative, Labour and Social Security Measures*. This Law imposed the obligation to develop an inventory of water resources, a diagnosis of anthropic pressures on water bodies, and action measures to achieve a good ecological status, integrated in a river basin management plan for each river basin district. For the Ter River, this responsibility lay with the Catalan government and the ACA, which made a great effort to accomplish its objectives (Munné et al., 2016).

The WFD also calls for the involvement of stakeholders in the planning process. The ACA was actually one of the first departments of the Catalan government to formally undertake processes of stakeholder engagement. A structured series of workshops have been tooking place throughout Catalonia since 2006 for the development of the management plans, as well as other sector plans, such as those for implementing an e-flow regime.

Sector Plan for Maintenance Flows

In order to comply with the WFD's mandate of achieving a good ecological status of Catalan rivers, the ACA elaborated the *Pla Sectorial de Cabals de Manteniment* (Sector Plan for Environmental Flows, PSCM) (ACA, 2005). This ambitious plan establishes different hydro-regions in relation to the type of flow regime. Then it applies hydrological methods, e.g., the Basic Flow Method (Palau and Alcázar, 2012), to estimate e-flow regimes and, ultimately, it validates such regimes with fish habitat simulation models

(Martínez Capel et al., 2007). However, in order to have the e-flows implemented at a basin or sub-basin level, the ACA requested specific zonal plans in agreement with stakeholders.

The zonal plans seek the compatibility between e-flows and existing water concessions, mainly held by hydropower companies. The take-off point of the Ter in terms of instream flows was particularly bad in the Catalan context. Thus, the Zonal Plan for the Upper Ter (Bardina et al., 2016) and the Zonal Plan for the Lower Ter (ACA, 2009a) were the first to be designed (together with those for the Llobregat basin). However, the Catalan government has never legally approved them, so the e-flow proposal for the Ter River remained and technical guidelines are yet to be implemented. Those facilities that ask for changes in their licenses and those that sign new water concessions with the ACA are the only ones to have the e-flows enforced.

Management Plan for the river basin district of Catalonia

Two management plans have been written in compliance with the calendar established in the WFD. The first one was for the 2009-2015 period (ACA, 2010), and the second one, for the 2016-2021 period, is currently in the review phase and pending until the approval (ACA, 2015). They define e-flows not as a use, but as a prior restraint to any use. However, the manner in which these plans have considered the e-flow management has changed. The former establishes that the e-flows have to be negotiated with stakeholders and approved by the zonal plans. The latter enforces implementation in all cases, but bringing the flow regime down to about 60% of the e-flows established in the PSCM. With this revised approach, the ACA aims at a progressive implementation of e-flows, but there is not any document that foresee a fully implementation.

Other provision regarding the water flow management in the management plans are:

1. For hydrological planning purposes in the Ter-Llobregat system, the order of precedence for the consent of water concessions will be in accordance with the following uses: 1) domestic uses; 2) industrial uses, excluding those of the point 4; 3) irrigation; 4) industrial uses for the production of hydroelectricity; 5) recreational uses; 6) aquaculture; 7) navigation and river transport; and 8) other uses, which would include the preservation of wetlands and historical canals.
2. The estimates of water demand supplied by the Ter-Llobregat system remain at 370 Hm^3/year for the year 2021, but they are about to increase 8% for the horizon 2033-2045.
3. Policy measures undertaken during between 2009-2015 in order to diversify the water sources are new desalination plants (70 Hm^3/year), improvement in infrastructure (18 Hm^3/year), recovery of aquifers (43 Hm^3/year) and water reuse (11 Hm^3/year + 30 in emergency situations).
4. The water deficit of the Ter-Llobregat system is currently about 2 m^3/s. In the near future, this deficit can increase up to 5 m^3/s, depending on the scenarios of water demand and how they consider demography and climate change.

4.4 STUDY AREAS IN THE TER RIVER BASIN

In a relatively small area (3,010 km^2), the Ter basin includes a variety of landscapes, river uses, views and struggles that make it an ideal case for studying ecological distribution conflicts related to water flows. Specifically, we have chosen the Ter River for the following reasons:

1. The types of benefits people receive from the river are as diverse as its landscape.
2. The dependence of social and economic assets on the Ter's water resources is very strong, not only for the Ter basin inhabitants, but also for extra-basin urban areas where the majority of the population of Catalonia currently lives.
3. There are dozens of weirs and dams that divert water, hence causing serious impact on the instream flow regime and related ES.
4. The Ter River has an emotional significance for the people in the basin and historically they have engaged in struggles for defending the river .

During the stage of field research, four sites located along the river course help us to represent the diverse socio-environmental landscapes throughout the river basin: the Camprodon Valley in the Pyrenees, the fertile Vic Plain, the city of Girona and its hilly and forested outskirts, and the rural Baix Ter Plain, with the Mediterranean Sea influence (See Fig 13).

4.4.1 Camprodon Valley

The Camprodon Valley (Pic. 6), at the core of the Pyrenees, is one of the rainiest areas in Catalonia. It is in Ripollès County and its main town is Camprodon (2,359 inhab.). The green and mountainous landscape, the low density of urban areas and a good transport infrastructure make it a perfect spot for receiving tourists. Alpine sports (e.g., skiing, hiking, climbing and fishing), architectonic heritage (e.g., old towns, churches, bridges, weirs and other ancient monuments) and gastronomy are the main tourist attractions. Along the river, several industries use freshwater for their processes. In this area there are also a lot of small hydropower stations (i.e. those without capacity to dam the flow).

The area is also a popular place for family-oriented environmental activities. There is an ecomuseum, an environmental education centre, a summer camp and a naturalist association, i.e. *Grup d'Estudis i Defensa de la Natura* (Studies and Advocacy Nature Group, GEDENA).

4.4.2 Vic Plain

The Vic Plain (Pic. 7) is a flat and fertile depression, core of Osona County. Intensive agriculture and intensive pig farming are economically important. These activites have blended so well that manure from the farms is regularly used for fertilising the fields despite existing regulation. As a result the groundwater bodies in the area are polluted by an excess of nitrates, and many natural springs have been disabled.

Vic is the main town of the plain (41,956 inhab.) and Manlleu is the largest riparian town (20,279 inhab.). Actually, Manlleu considers itself as the Capital of the Ter. This is mainly because is the home of the *Grup de Defensa del Ter* (Advocacy Group for the Ter, GDT), one of the most active group in the basin, which has been engaged in a struggle for the good quality of the water bodies and their associated ecosystems. A major success for the group was sending a businessman to prison for polluting a water source. The Industrial Museum of the Ter and the Centre of Studies of Mediterranean Rivers are also located in Manlleu. Both institutions contribute to the study and dissemination of the river's biodiversity and age-old industrial uses, mainly hydropower for producing textiles and now electricity.

4.4.3 Girona city and its outskirt

Located downstream of the chain of reservoirs, Girona city (97,586 inhab.) is the capital of the province of the same name. Girona consists of a small metropolitan area (see Pic. 8) surrounded by rural outskirts with patches of woodlands and agriculture. The irrigated lands produce forage, maize and fruit trees. Industrial activities in the sectors of food, chemical, wood and textile are quite extended.

The city is a relevant tourist destination and the Onyar River is one of the main attractions. The Ter is a bit off the beaten tourist path, but the number of people enjoying the river is increasing. Certainly, it is not rare to see people kayaking, fishing or jogging along the river.

Girona also houses the Universitat de Girona (University of Girona, UdG), which has generated a number of publications about natural and cultural aspects of the Ter River. The UdG Research Group on Ecology of Inland Waters and the UdG Institute of the Environment are well-known institutions on these topics. In addition, several environmental associations and civic platforms disseminate information about water management and the conservation of the river ecosystem, as well as leading protests – mainly regarding the Ter transfer.

4.4.4 Baix Ter Plain

Located in Baix Empordà County, the Baix Ter Plain is an eminently rural flat area around the river mouth (see Pic. 9). The plain is considered the granary of the province. Most of the cultivated land is irrigated, with rice and fruit trees being the most iconic crops.

Besides the agricultural sector, tourism is a key activity, particularly on the coast, and this has resulted in the construction of hotels and camp sites. Although most tourists stay by the coast, the awareness about the Ter has increased related to its role as the source of water supply and in environmentally sensitive tourism. Actually, the lower stretch of the river, the historical (millennial) irrigation canals and wetlands are included in a natural park.

In terms of flow, this is the area that has suffered most, since there the river accumulates water withdrawals for domestic, industrial and irrigation purposes. In the main town

(Torroella de Montrgrí, 11,381 inhab.), two active environmental groups operate: the GDT and *Gent del Ter* (People from the Ter). The Museum of the Mediterranean, which promotes the study and dissemination of cultural and natural knowledge about the plain, is also located in Torroella.

Pic. 6. Sant Joan de les Abadesses.
This municipality in the middle of the Pyrenees is visited for its architectonic heritage. Moreover, it is also an important town in terms of industry, where companies such as Fibran and multiple SHPP are placed. Source: Espencat (Wikimedia Commons).

Pic. 7. View of the Vic Plain.
Source: Antonio Gil (Flickr).

Pic. 8. The statue '*Les llúdrigues*' ('The Otters').
This artwork is placed in the municipality of Salt, in the metropolitan area of Girona. Source: Jofre Ferrer (Flickr).

Pic. 9. L'Estartit and the wetlands of *Ter Vell*.
L'Estartit is a tourist village located close to the mouth of the Ter. In the picture we can appreciate the old mouth of the river, which now corresponds to the historical canal and lagoon of the Ter Vell.
Source: Cnestertit (Wikimedia Commons).

Chapter 5

Local views on the Ter River: ecosystem services from biophysical and social perspectives

5.1 INTRODUCTION

In previous chapters we highlighted the ample recognition to the fact that ecosystems provide both market and non-market benefits to sustain human well-being. ES provided by rivers include water supply, fish production, space for recreation, beauty, electricity, waste disposal, etc. Within this context, a lot has been analised through global assessments such as the Millennium Ecosystem Assessment (MA, 2003) and The Economics of Ecosystems and Biodiversity, the TEEB Project (Kumar, 2010); even in particular for the water context (Russi et al., 2013). However, a purpose-driven case study application requires more detailed understanding of the local views, since the social and ecological contexts highly influence the ES provision. This is missing in most of the ES literature, which usually takes the ES categories by the influential works just mentioned above as given.

Thus, this chapter addresses, in a critical perspective, 1) the biophysical realism by which the ecosystem functioning provides multiple ES, and 2) the stakeholder work, which includes the local views in instream flows management assessments. These two elements are actually considered as facets of potential research on ES (Seppelt et al., 2011). This is done bearing in mind the four core elements of an ES-based approach (see **Chapter 2**). Although Seppelt et al. acknowledge that some attempts already exist in this direction, a broad exploration of local views on tradeoffs among ES is still missing.

A major outcome of this work is a methodological proposal based on the involvement of relevant stakeholders to draw ES tradeoffs generated by water withdrawals. In particular, the study is done with the specific objectives of: 1) characterising benefits from river ecosystems from a comprehensive stakeholders' perspective; 2) clarifying the links between the production of benefits and the hydrological alterations (HA) from management options currently put in place; and 3) analysing such links through an exploration of potential tradeoffs and synergies among ES.

5.2 METHODS

5.2.1 Data gathering

We started from a thorough scrutiny of multiple stakeholders' positions in order to gather the necessary data. This involved the selection of key informants representing the variety of stakeholder types, and data collection through semi-structured in-depth interviews in 2012.

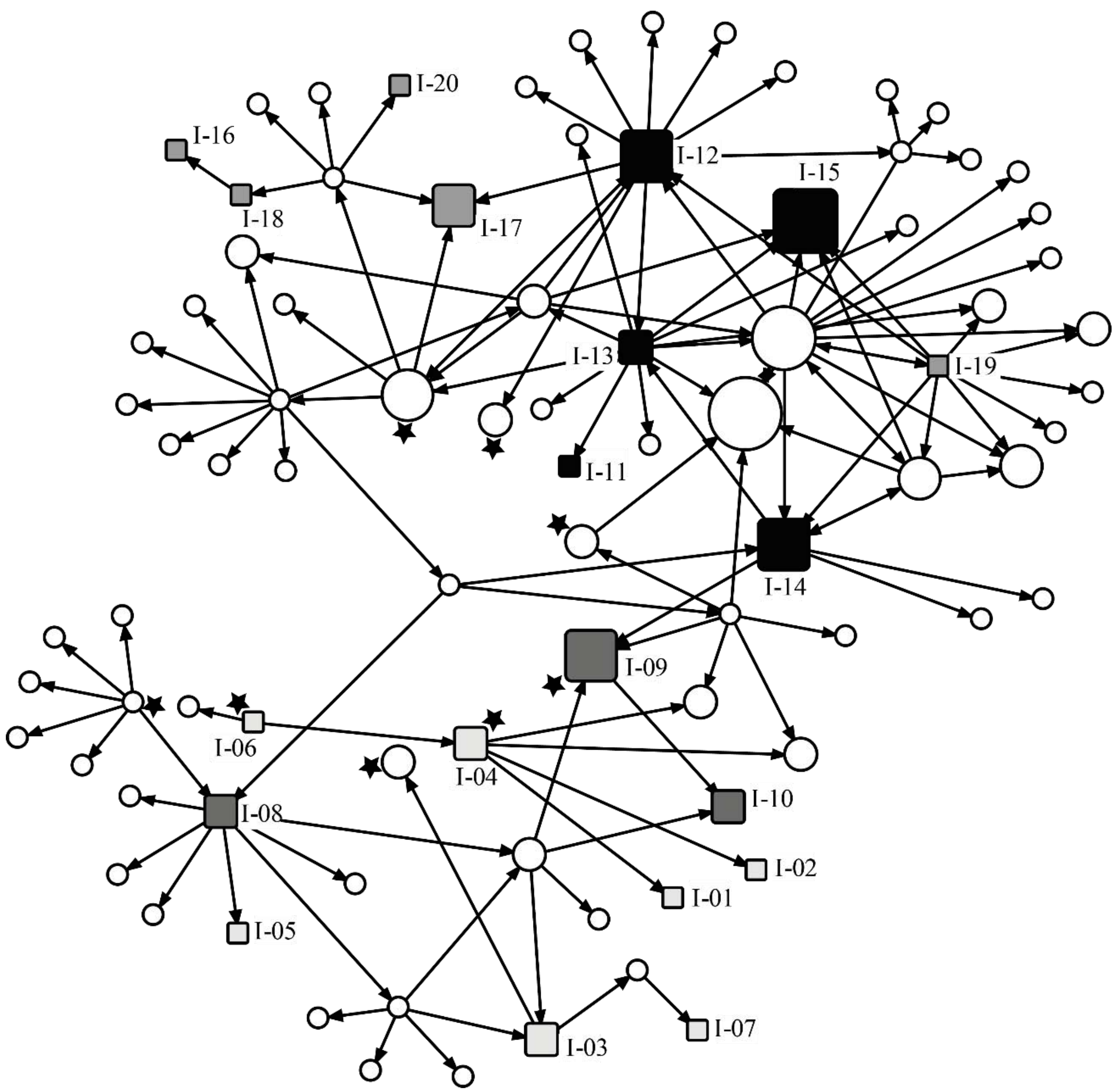


Fig. 17. Snowball sample with links between stakeholders. Note: Each stakeholder is represented by either circles or squares, sized by in-degree centrality, as the number of other stakeholders that have cited them. The colour identifies the location of the interviews: Camprodon Valley in light grey, Vic Plain in dark grey, Girona in black and Baix Ter Plain in intermediate grey. White circles represent other contacted stakeholders but not interviewed. Likewise, stakeholders with black stars are the starting points of the snowball sampling.

A snowball sampling[7] started from eight well-known stakeholders, mainly activists and scientists, interested in the Ter River in terms of either personal or professional motivations. They were the gateway to a network of up to 87 stakeholders before the sampling process was deemed as exhausted.

We represented the network by NetDraw software (Fig. 17), and then selected key informants with a high in-degree centrality, i.e. an indicator of the number of ties received by a given stakeholder. Specific stakeholders representing a particular and uncommon view were also selected, always trying to comprehend all types of policy cultures (public sector, private sector, civil society and academia). An additional criterion was based on excluding highly similar profiles. These criteria allowed selecting twenty key informants that were contacted and then interviewed (see Table 8). The number of interviewees was also determined by the information obtained, as described below.

Table 8. List of interviewed stakeholders

Interviewees' code	Interviewees' profile	Policy culture	Localisation
I-01	Primary school teacher and children	Civil society	Camprodon Valley (UT)
I-02	Nature photographer	Civil society	Camprodon Valley (UT)
I-03	Fly-fishermen and activist	Civil society	Camprodon Valley (UT)
I-04	Tourism worker and hiker	Public sector	Camprodon Valley (UT)
I-05	Industrial biochemist	Private sector	Camprodon Valley (UT)
I-06	Kayak instructor for children	Private sector	Camprodon Valley (UT)
I-07	Hydropower producer	Private sector	Camprodon Valley (UT)
I-08	River inspector	Public sector	Vic Plain (UT)
I-09	Biologist and museum technician	Academia	Vic Plain (UT)
I-10	Activist group	Civil society	Vic Plain (UT)
I-11	Environmental council technician	Public sector	Girona (LT)
I-12	Hydrogeologist consultant	Academia	Girona (LT)
I-13	Consultant and naturalist	Academia	Girona (LT)
I-14	Biologist and activist	Academia	Girona (LT)
I-15	Water management technician	Public sector	Girona (LT)
I-16	Environmental educator	Civil society	Baix Ter Plain (LT)
I-17	Meteorologist	Academia	Baix Ter Plain (LT)
I-18	Museum Director	Public sector	Baix Ter Plain (LT)
I-19	Farmer and activist	Private sector	Baix Ter Plain (LT)
I-20	Fishermen, farmer and restaurateur	Private sector	Baix Ter Plain (LT)

Notes. The interviewees' code is useful to see in **Appendix B** the links between hydrological alterations, natural elements and benefits found during the each interview. UT means Upper Ter; LT means Lower Ter. Usually, although the interviewees live or work in a specific area, their knowledge reaches the entire lower or upper Ter.

A basic interview script was designed based on the steering questions related to the following topics of interest: 1) relationship between the Ter and the informants in terms of profession, association, leisure, etc.; 2) benefits that the river provides – or provided in the past, or should provide in the future – to the respondent or to the general public; 3)

[7] The snowball sampling method consists in asking to informants for 5-10 contacts to become new informants in order to get other new contacts from them and so on. See Goodman (1961) and Biernacki and Waldorf (1981) for further information.

infrastructure and natural components required to maintain those benefits, referring specifically to the instream flows; and 4) problems arising from the lack of flow (see **Appendix A** for the entire script). Unfamiliar terms such as 'ecosystem fund-services' and even 'ecosystem services' were avoided during the fieldwork, so the term 'benefit' was preferred to approach the interviewees.

The naming of benefits was used as an indicator of saturation of the given information. After the fifteenth interview, no new benefits were described, so twenty interviews were considered enough for the information required.

5.2.2 Data organisation and analysis

From the interview transcripts, we identified different 'objects', i.e. items implicitly found within the discourse, categorised either as 'hydrological alterations' (HA), 'components of nature', or 'provided benefits'. This was done in order to construct a network of cause-effect relationships between objects (as in Lelièvre and Sérodes, 1995) aiming at finding tradeoffs and synergies. A detailed explanation of the procedures involved is provided in the following paragraphs.

As indicated in **Section 3.1**, provided benefits are improvements coming from the river to the well-being of stakeholders. Hydrological alterations are anthropogenic disruptions in the magnitude or timing of a naturally variable flow regime (Rosenberg et al., 2000). Finally, we define components of nature as those elements that constitute the river ecosystem, including biological communities such as fishes or the riparian vegetation and immaterial attributes such as water quality or the waterscape beauty.

The data is organised and analysed in three phases, related to the three specific research objectives mentioned in **Section 5.1**. First, F4 software was employed to transcribe the interviews and ATLAS.ti to organise the information to be analysed. All quotations of interest were coded in terms of the categories of objects mentioned. The process identified all provided-benefit objects from the Ter River. With the description made by the informants, we could then analyse the ES that sustain them, the production and consumption locations and divergent views. **Section 5.3.1** explores this benefit characterisation.

Second, quotations with more than one associated object were employed to create a link between them and thus to build a cause-effect matrix using Microsoft Excel. Links were classified as positive, negative or unclear. This matrix allowed to describe the impact of various types of hydrological alterations on the components of nature and provided benefits either directly or indirectly. The outcome of this phase is discussed in **Section 5.3.2**. Complementary information from the literature regarding the same links was added with comparative purposes.

Third, we developed a cause-effect network from all the links represented in the cause-effect table by using NetDraw software. Codified objects were used as nodes and links as ties. In order to simplify the analysis, two kind of items were removed: a) benefits barely mentioned (e.g., water consumption for artificial snow production) or redundant benefits already included in other items (e.g., tourism, included in the appreciation of beauty or recreational activities). We also removed indirect relations explained via other links, as well as relations scientifically contested. **Appendix B** shows the complete list of relationships selected.

The resulting network was used to identify potential tradeoffs and synergies using the following procedure. Each HA has an impact to some benefits either directly or through the alteration of certain components of nature. The account of effects indicates the number of means by which one object impacts on another. Tradeoffs are pointed out when particular activities cause hydrological alterations that generate negative impacts to other uses; while synergies arise when those impacts are positive. The magnitude of those effects cannot be quantified from the interviews. The quantification of the effect of HA on ES is performed in **Chapter 6.** So, instead of actual tradeoffs, the chapter identifies potential tradeoffs in order to illustrate competition or harmony among stakeholder groups. These are actually described in **Section 5.3.3**.

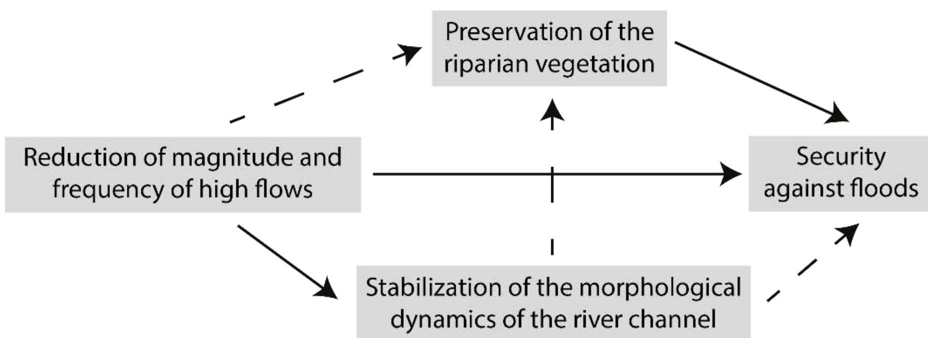


Fig. 18. Example of accounting effects of instream flows on benefits. Note: Solid ties are positive effects; broken ties are negative effects. The account of 'effects of the reduction of high flows on security against floods' includes one positive effect and three negative effects.

Fig. 18 illustrates an example of this procedure of accounting for tradeoffs. The 'reduction of magnitude and frequency of high flows' is a hydrological alteration with a positive impact on the benefit 'security against floods'. However, the reduction of high flows can also have a negative impact by stabilising the 'morphological dynamics of the river channel' and not preserving the dynamics of the 'riparian vegetation', both components of nature closely related to the security against floods.

5.3 RESULTS

5.3.1 The ecosystem services provided by the Ter River

From the interviews, 28 ways of benefiting from the river were identified. Fig. 19 shows the frequency of benefit identifications in the Upper and Lower Ter, separately. The most recurrent were fishing, appretiation of the beauty and biodiversity, the security against floods, tourism and the appreciation of the cultural heritage. Hydropower, which produces electricity now, but anciently ran mills, forges and looms, was especially mentioned in the Upper Ter. Meanwhile, irrigation and the transfer to the RMB are noted in the Lower Ter. Water supply was also mentioned for domestic uses, factory farming and industry. Locals described extinct river uses such as otter hunting for getting fur, and washing clothes nearby the canals. Riverbanks grazing and timber gathering still occur, but have diminished during last decades, while the use of the river channel for collecting litter and extracting aggregates have been banned for their destructive effects on the ecosystems.

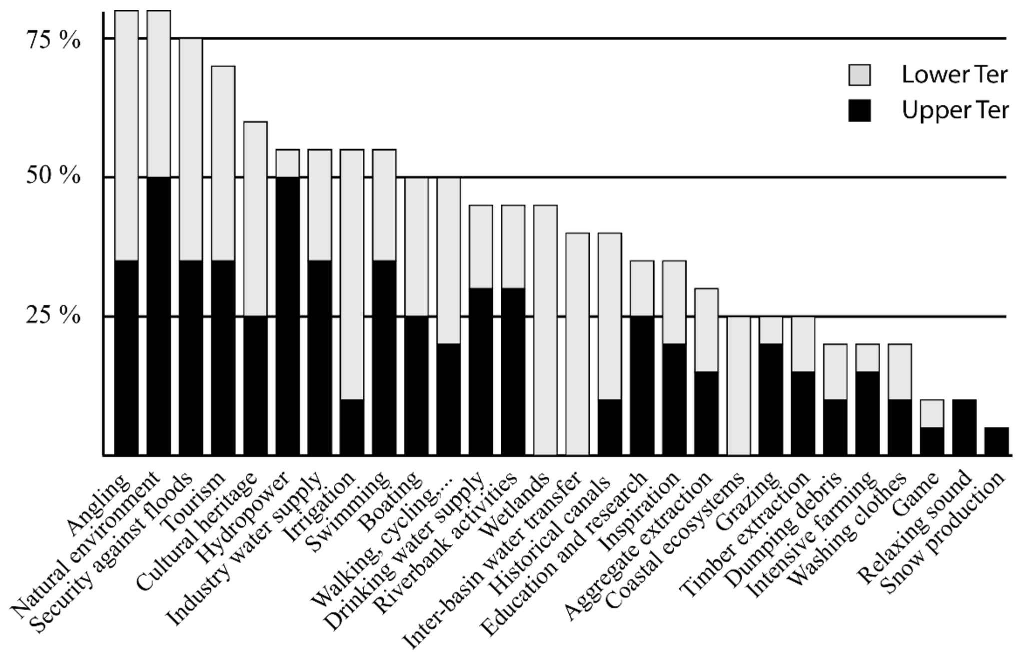


Fig. 19. Percentage of interviews where each benefit has appeared. Note: In black, interviews in the Upper Ter; in grey, interviews in the Lower Ter.

Culturally, the river matters. It is a source of inspiration, particularly where architectonic heritage in the area closely related to the river, and an object of research and learning. Many recreational and sports activities are practiced along the river: kayaking, boat riding, swimming, walking, dog walking, jogging, cycling, or sitting down on the riverbanks. Among the less usual, but locally relevant, there are the romantic scenery of the river and the relaxing sound of water running. The use of water for snow production in a ski station in the headwaters is barely mentioned too.

Furthermore, the preservation of adjacent ecosystems included in a protected natural park was also considered as a service. These other ecosystems are historical canals (see Box 2 for a further description), with their own particular habitat and endemic species, wetlands and the coast, all of them supported by water coming from the Ter.

Box 2. The historical canals

According to Ribas et al. (2011) and Montaner (2010), the *Sentmenat* and *Molí de Pals* irrigation canals have been completely integrated into the landscape of the Baix Ter Plain for centuries. Both canals deliver water to a network of multiple minor canals, the *Sentmenat* throughout the left bank and the *Molí de Pals* in the right bank.

These canals illustrate the history of the plain. Hydrographically, the *Sentmenat* follows the ancient mouth of the Ter (a few kilometres north of the current mouth), while the *Molí de Pals* joins the Daró, a coastal stream that ends up in the same delta. They also remind the colonisation of the plain, anciently insalubrious and little inhabited. The cultural heritage of these canals also include ancient infrastructure such as bridges and public washing places. In addition, the historical canals represent actual freshwater ecosystems, including their own riparian vegetation and aquatic fauna. There are even some protected species of naiads or freshwater mussels (e.g., *Unio elongatulus* and *Potomida littoralis*) and fish, e.g., the three-spined stickleback (*Gasterosteus aculeatus*). Part of the historical canals are also included in the natural park of *El Montgrí, les Illes Medes i el Baix Ter*.

Notwithstanding their protection and beauty, the historical canals are currently in a much-damaged situation. New pipes have been constructed underground to transport water for irrigation in a more efficient way. Despite the protests of socio-environmental organisations (e.g., *Gent del Ter*) and the legal protection of an instream flow regime, such canals are now neglected, their waters eutrophicated and their flora and fauna harmed.

43 ecosystem functions sustain the 28 ES (Table 9). Interestingly enough, 18 out of these 28 ES involve diverging views, as some stakeholders relate them to damages to the ecosystem or to certain aspects of their well-being. Analysing their geographical location, it is possible to elicit that approximately half of the ES needs to be transported along the river or outside the ecosystem – even out of the river basin – in order to generate some benefit; while the other half does not require any transportation. Our results show some differences among benefit categories (see Fig. 20). Support and provision clearly require some transportation between distinct areas (e.g., sand and gravel are extracted from floodplains and brought to other places out of the river to generate benefit; and downstream coastal wetlands are fed by water from the river). Cultural and regulation benefits are practically all generated and consumed *in situ*, especially those that are more closely-dependent on water flows (e.g., boating, hydropower production, security against floods).

Table 9. Identification and characterisation of benefits provided by river flows

Ecosystem services	Ecosystem functions	Divergent views between stakeholders	
		Arguments for	Arguments against
Supporting[A]			
Preservation of coastal ecosystems[B]	Supply of sediments; supply of nutrients		
Preservation of historical canals[B]	Supply of a certain amount of water flows	Cultural and natural heritage. Recharge of aquifers and wetlands	Inefficiency of water transport
Preservation of wetlands[B]	Supply of a variable flow regime; maintenance of the aquifers level; maintenance of the salt wedge away		
Provisioning[A]			
Aggregate (sand and gravel) extraction	Supply of sand and gravel sediments	A local resource for construction	Damage of the river morphology
Artificial snow production	Supply of a minimum water flow	No water consumer	Water demanding
Drinking water supply	Supply and storage of clean water; maintenance of the salt wedge away		
Game	Provisioning of otters for their skin and meat	Profit from nature	Otters depleted
Grazing	Supply of a minimum water flow for the livestock	An ancient tradition	Competition with riverbank uses for the space
Industry water supply	Supply of a minimum water flow	Employment	Pollution
Intensive farming	Supply and storage of clean water	Wealthy activity	Pollution into the aquifers
Inter-basin water transfer	Supply and storage of clean water	Basic needs	Highly water demanding
Irrigation	Supply and storage of clean water in summer; maintenance of the aquifers level; maintenance of the salt wedge away	Recharge of aquifers, landscape preservation and economic source	Inversion of the flow regime, inefficiency of water consumption and pollution
Timber extraction	Provisioning of wicker, alder and poplar timber for basketry, turnery and shoddy wood respectively	Flood damage prevention	Riverbank destruction
Regulating[A]			
Dumping debris	Transport of a water flow with certain velocity		
Hydropower	Transport of a certain amount of water flow	Basic needs. Clean, sustainable and local energy. Architectonic heritage	Very highly water demanding
Security against floods	Transport of flood flows (disservice); maintenance of a river channel clean of vegetation; maintenance of the natural riparian forest in the floodplain		
Washing clothes	Transport of a minimum water flow of clean water		

Cultural[A]			
Fishing	Production of either healthy and edible species or big fishes for recreation Contribution to the beauty	Respectful with the fish and the natural environment	A source of exotic species
Appreciation of the natural environment	Contribution to the beauty Support of biodiversity with autochthonous flora and fauna	Beauty of nature	Subjectivity of what is beautiful or ugly
Boating	Transport of a water flow with certain conditions of depth and velocity	People closer to the river	Very demanding for artificial instream flows. Source of exotic species
Education and research	No specific services for education and research		
Inspiration	Maintenance of the either very good or very bad ecological conditions of the river; support of emblematic species such as otters		
Relaxing sound of the flowing stream	Production of relaxing sound by certain water flow and velocity		
Riverbank activities	Contribution to the beauty		
River-related cultural heritage	Those services related to ancient benefits such as hydropower, textile industry and irrigation.	Weirs and canals appreciated as heritage by locals	Weirs change completely the riparian habitat, stop sediments and fishes and other fauna to move
Swimming	Provisioning of a water flow with certain water quality, depth, velocity and temperature; avoidance of dangerous exotic species; maintenance of a heterogeneous morphology with beaches, pools and waterfalls; contribution to the beauty	Without chlorine, cheap, fresh, natural and peaceful	Not secure due to dangerous and disgusting animals
Tourism	Those services related to recreational benefits such as boating or swimming	Great source of wealth	Ecosystem degradation
Walking, jogging and cycling	Contribution to the beauty	People closer to the river. Increase of awareness	Difficulties to preservation of sensitive fauna

A. We use the MA classification of ecosystem services to classify benefits. **B.** One of the main functions of river ecosystems is the transport of water, sediments and nutrients to other ecosystems. Although those ecosystems are not directly used as benefits, their preservation is taken into account as a set of all multiple benefits they deliver.

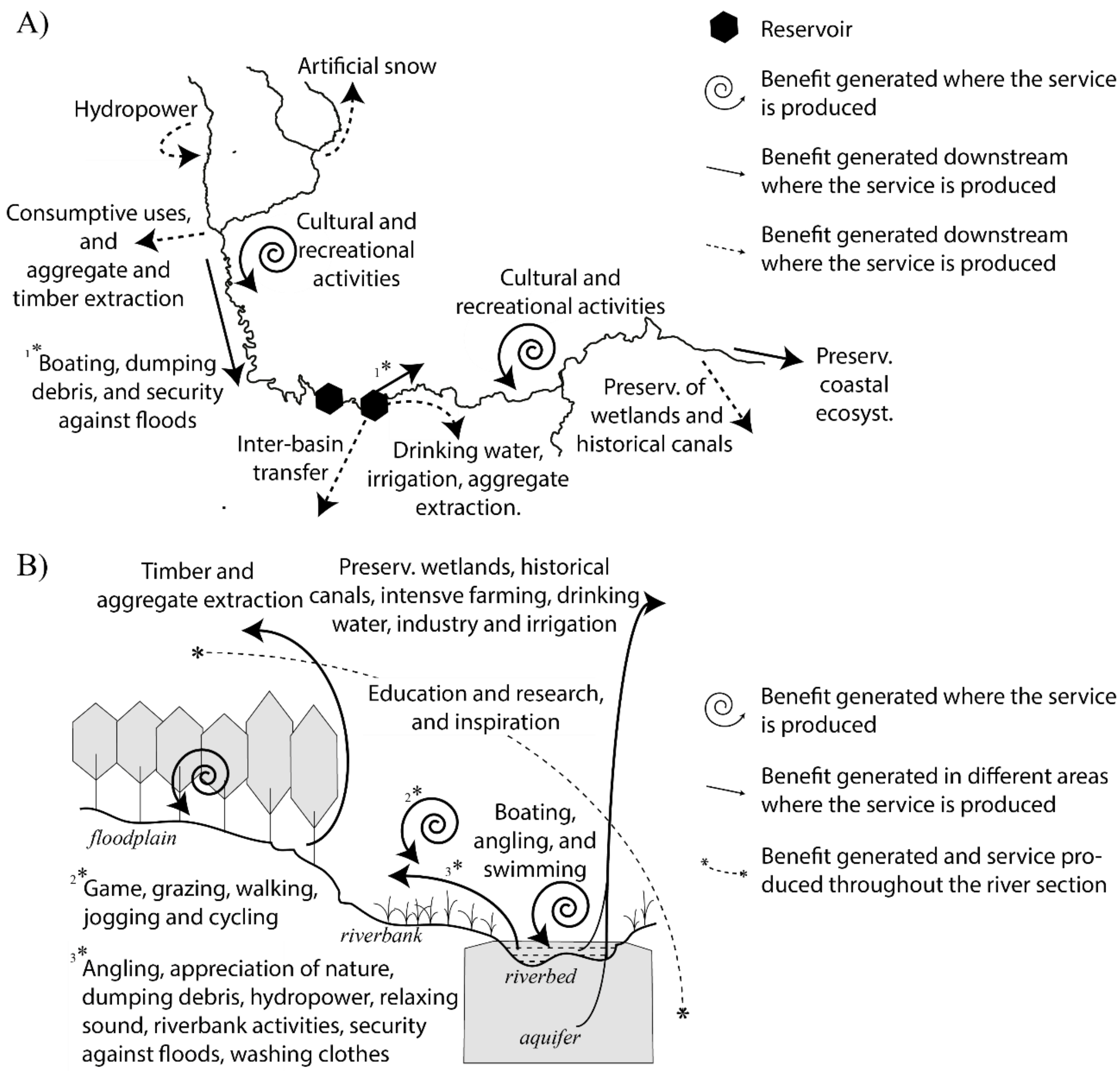


Fig. 20. Production of ecosystem services and their transport to generate benefits. **A.** At a watershed scale, a map of the Ter River course presenting longitudinal transport of ecosystem services (upstream, downstream and outwards from the basin). **B.** At a smaller scale, a river section showing the transversal transport outwards from the river and among areas within the river system (riverbed, riverbank, floodplain and aquifer).

5.3.2 A cause-effect matrix for defining HA-ES relationships

The next step in the analysis was to identify prevalent hydrological-alteration objects (coded as HA), and the effect they produce, as perceived by the interviewees, on the other objects: ‘components of nature’ and ‘provided benefits’.

A total of 9 HA were distinguished from the stakeholders’ responses. There were agreement that the most striking alteration in the Ter River is the reduction of the current and the annual flow magnitude (HA1 and HA2, respectively). These are caused by all kind of withdrawals. Stakeholders confirmed that current and annual flows dilute pollutants, ensure aquatic habitat features and contribute to the river beauty, and their alteration affects all consumptive uses.

Two other perceived HA are related to the variability of natural regimes. On the one hand, irrigators demand higher flows in summer (HA3), which is consistent with the management of reservoirs to prevent floods in the rainy autumn; however, this can remove the native fry or swamp the seedlings. On the other hand, flow stabilisation (HA4) to increase hydroelectric production can facilitate the proliferation of invasive species, as it has so conspicuously happened in the Ebro River (Prats et al., 2009).

In other cases, alterations were related to extreme events. While such events are typical of Mediterranean rivers, the Ter suffers remarkable prolonged low flows (HA5) during dry periods due to the regular diversion for the water supply of Barcelona. Prolonged low flows are detrimental for the entire ecosystem and damages all water-consumptive uses located downstream. At the same time, as a result of its regulation, the river suffers reduced high flows in terms of magnitude and frequency (HA6), which are important to maintain heterogeneity in river morphology. Hence, there is a loss of habitat and biodiversity, as well as a reduction of feeding coastal ecosystems by nutrient-laden water and sediments.

Dams and weirs were also blamed to produce rapid changes in river stage (HA7). In the Ter, such changes are mainly by manoeuvres of dams and weirs to maximise the hydroelectric production. This can be dangerous for river users and wash-out and strand aquatic species. Barriers also lower flow velocity of water upstream (HA8) and capture sediment moving downstream (HA9), which completely modify the riparian habitat in both sides of the barriers.

As it is illustrated in Fig. 21, up to 30 connections relate the hydrological alterations with certain provided benefits. However, most of the impacts produced by HA indirectly occur by damaging the components of nature that are necessary to get those benefits (e.g., riparian forest for timber extraction, biodiversity for bird watching). From the complete list of linkages, 32 are between HA and components of nature, 22 between only components of nature, and 37 between components of nature and benefits (see **Appendix B**).

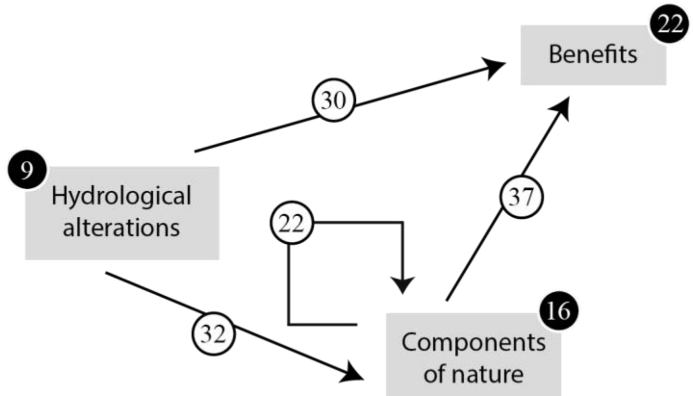


Fig. 21. Scheme of the network about the impact of hydrological alterations on benefits from the Ter River. Note: In black circles there is the number of objects found; in white, the number of links between them.

5.3.3 A cause-effect network to visualise potential tradeoffs and synergies

A cause-effect network was built from all relationships found in the previous section between hydrological alterations, components of nature and provided benefits. Tradeoffs appear when the achievement of a given benefit drives a HA, which in turn has a negative effect in the generation of another benefit. A synergy appears when this effect is positive.

Table 10. Tradeoffs between river benefits regarding the instream flows management

	Consumptive withdrawals (drinking water supply, intensive farming, industry, irrigation, preservation of historical canals and wetlands, inter-basin water transfer) HA1, HA2, HA8	Non-consumptive withdrawals (hydropower, industry) HA1, HA5, HA7, HA8	Dam management (hydropower, irrigation, security against floods, inter-basin water transfer) HA1, HA2, HA3, HA4, HA5, HA6, HA7, HA8, HA9
Fishing	–	–	–
Appreciation of nature	–	–	–
Boating	–	–	–
Drinking water supply	+	–	–
Dumping debris	–	–	–
Game	–	–	–
Grazing	0	–	–
Hydropower	–	+	+
Industry water supply	+	+	–
Intensive farming	+	–	–
Inter-basin water transfer	+	0	+
Irrigation	+	–	+
Preserv. coastal ecosystems	–	0	–
Preserv. historical canals	+	–	–
Preserv. wetlands	+	–	–
Relaxing sound	–	–	–
Riverbank activities	–	–	–
Security against floods	–	–	+
Swimming	–	–	–
Timber extraction	–	–	–
Walking, jogging, cycling	–	–	–
Washing clothes	0	–	–

Note: Columns inform about three drivers of alteration caused by the consumption of certain benefits (in brackets) and the consequent hydrological alterations; rows, about the benefits that suffer the impact of those alterations. HA1: decrease of magnitude of the current flow; HA2: decrease of magnitude of the annual flow; HA3: increase of magnitude of the summer flows; HA4: flow stabilisation; HA5: prolonged low flows; HA6: reduction of magnitude and frequency of high flows; HA7: rapid changes in river stage; HA8: lowering the flow velocity; and HA9: capture of sediment moving downstream. In the results area: + means positive effect and – negative effect of the drivers of those hydrological alterations to the variety of benefits. 0 means that no effect is perceived, and ± that both types of effect are found.

Table 10 shows potential tradeoffs and synergies in the Ter basin. The results are grouped in three categories of drivers that produce HA: 1) consumptive withdrawals, that divert water without returning it into the river (e.g., domestic uses); 2) non-consumptive withdrawals, for hydropower or industrial refrigeration, which return the same amount of diverted water; and 3) dams, which store water in reservoirs – and unintentionally, sediments –, and divert or release it according to seasonal management priorities (reportedly, those indicated by the watershed authority). These priorities include protection against floods, the water transfer to other basins, drinking water supply, irrigation, and preservation of a minimum instream flow (not an e-flow regime).

The results show that all benefits can be damaged by at least one HA. Those benefits more closely related to a good quality of the ecosystem (e.g., fishing, appreciation of the natural environment and riverbank activities) are the most damaged. Hence, the clearest tradeoffs appear between these benefits and the major driver of alteration, the dam management that prioritises inter-basin transfers, irrigation and flood prevention. Synergies are not as obvious to identify, as positive effects of alterations are basically driven by the same uses that generate them. Indirectly, to prevent floods, dams can stabilise released instream flows and empty the reservoirs before the autumn, which is actually beneficial for hydropower producers and irrigators, respectively. Besides, synergies and tradeoffs can also appear simultaneously to the same benefit through different HA. For instance, water diversions in the Baix Ter Plain benefit irrigation and the historical canals, but in summer, the increase of water within the canals can be damaging for their ecosystem.

5.4 DISCUSSION

5.4.1 Characterisation of ecosystem services to inform about water conflicts

Since the phase of interviews, it was clear that the ES approach was an effective tool to facilitate the communication and dialog with water managers, members of the scientific community and other local stakeholders. When asked for listing provided benefits, the stakeholders put forward multiple ways of benefiting from the Ter River together with the description of who is benefiting and where the ecosystem service is produced and consumed. The systematic identification of these relationships was carried out, paying particular attention to diverging views between stakeholders.

On the basis of these results, we can argue that the bottom-up exercises in the benefit characterisation has been useful in three respects:

First, many of the identified benefits go beyond the items in checklists from the literature. The participation of varied stakeholders is found to be crucial to detect less conspicuous river benefits highly valued by the local actors (e.g., relaxing sound of the flowing stream; romantic settings in unaltered riverbank; inspiration to generate artwork as the statue '*Les Llúdrigues*, i.e. 'The otters'), new fashions (e.g., sports as jogging or kayaking), past uses that are being recuperated (e.g., swimming or playing in the riverbank), or even ancient ones, probably lost forever (e.g., washing clothes). Hence, working from the ground-up helps to complement global assessments, such as MA or TEEB, showing the whole potential of the river as a provider of goods and services.

Therefore, any assessment of ES that aims at being comprehensive and supporting management should study and get the intellectual support of the people being benefited from rivers. Of course different stakeholders, such as the river authority or a given economic actor, operate and get benefits at different scales (Hein et al., 2006; Scholes et al., 2013), and then the relevance of the benefits identified above may differ according to the scale of analysis.

Second, the use of a fund-service definition of ES, based on the ecological functions concept, is helpful to understand the multiple biophysical underpinnings of certain benefits. For instance, the suitability of a river for swimming is clearly a benefit for the interviewed children. This benefit requires the maintenance of morphologically diverse stretches with beaches, pools and waterfalls, combined with certain water conditions in depth, velocity, temperature and physicochemical quality, and the conservation of aesthetically pleasant settings. These structures and processes derive into ecosystem functions according to our working definition.

Depending on the working definition of ES, the classification system can be more or less confusing. While it is clear that swimming – as a benefit – is a cultural benefit, from the fund-service side it would be hard to categorise swimming as cultural, since it is an activity that also benefits from the ecosystem functions related to the supporting and regulation of the ecosystem. This problem was found commonly along the characterisation step. For this reason, our results point out the suitability of giving more room for a fund-service definition to complement the benefit-based definition of ES – such as the one in MA –, whenever stakeholders' involvement is going to be a relevant part of the research and there is an interest to explain benefit provision based on the biophysical conditions of the ecosystems.

In addition, the distinctive physical characteristics that an ES must have according to the fund-service definition are found to be important to avoid oversimplification. For instance, water supply in different ways can become separate ES, as the requirements for the refrigeration of industrial processes, irrigation or drinking are so different.

Third, different stakeholders can have dissimilar – even totally opposed – perceptions on the same material process. For instance, flood irrigation of rice fields and the historical canals are believed to waste water by some environmentalists and water managers. Other environmentalists and farmers argue that it rather contributes to the recharge of aquifers and the preservation of traditional green landscapes. Acknowledging divergences helps to comprehend stakeholders' opiniona and to anticipate their position before a conflict breaks out. Most common divergences arise from traditional *versus* new environmentalist approaches, feelings toward wilderness *versus* what is exotic, private *versus* public use of the river, and monetary *versus* non-monetary values. In addition, divergences sometimes occur when there are knowledge gaps (e.g., the belief in different villages of the Pyrenees that otters/grey herons/great cormorants/mallards are depleting trout populations).

Similarly, distributional issues also illustrate the geographical scales of potential conflict (e.g., cities *versus* countryside, upstream *versus* downstream, water donor *versus* receptor catchment, etc.). Hence, gathering that information from this variety of local views, and acknowledging that some benefits are generated because somewhere else the river ecosystem is providing ES, avoids the oversimplification of likely tradeoffs (Hirsch et al., 2011).

5.4.2 Hydrological alterations

The classification of HA allowed to obtain a wide understanding of sources of potential conflict in this basin. Two findings were of particular relevance: there is not only one use generating impacts, but several, and each use can generate different impacts, as it is shown above. This complexity is acknowledged by the locals' view. For them, environmental flows should not only be a minimum flow requirement, as often understood in water planning, but a variable flow regime that incorporates natural drought and flood episodes.

This vast amount of collected information demonstrates the great expertise of stakeholders. As one of the premises in this chapter is to control the quality of their knowledge, we wonder whether the processes described above are essentially different from descriptions in the scientific literature on HA. Several references were employed for crosscheck the hydrology-ecosystem links (see **Appendix B**). The most relevant references are Poff et al. (1997) and Whiting (2002) for the variety of features of an instream flow regime; Kondolf (1997) specifically for the role of sediment on river ecosystems; Kondolf and Wilcock (1996) for high flows and Lake (2003) for low flows; and Cushman (1985) for rapid variations of flow below hydropower facilities. After that, we observed that the literature confirm practically all propositions from the local perceptions.

Moreover, stakeholders add a precise identification of the relevant processes at local level, specifically those that explain the provisioning of the benefit. The academia and activists from the civil society are particularly aware about the river ecosystem, and environmental managers from the public administration about the instream flows management for promoting river uses. The information gathered from the private sector is found to be less encompassing for establishing relationships, but very valuable in terms of detailing the activities they perform.

According to the results here presented, it is possible to state that people in the Ter have a well-informed perspective of their own environmental context. Moreover, stakeholders recognise not only the complexity to fulfil ecological requirements, but also the complexity of all interactions from river flows to benefits. Here we mean stakeholders in the aggregate. Some have very different perceptions from others. Management based on bottom-up stakeholders' view would demand therefore a democratic process that does not simplify complexity by imposing some particular views over others.

5.4.3 Potential tradeoffs and synergies among ecosystem services

Broadly speaking, in the case of the Ter River, water flows diverted by private or semi-private actors (hydropower producers and water supply distributers) seem to impair freely accessible benefits (recreation, aesthetics, cultural traditions) or benefits enjoyed by the less powerful actors of the river basin (farmers). There is also a tension between consumptive and non-consumptive users. These ways to simplify the explanation of the conflicts in the river basin might, however, be misleading.

Besides the results shown in **Section 5.3**, similar to an extent to the conventions in the scientific literature, the network analysis employed here to disclose potential tradeoffs unveiled unexpected relations. This confirms that conflicts over river flows can be far more complex. Specifically, three findings need to be explained.

First, the same use can damage or be damaged by certain water management depending on the priorities of the administration and the abundance of the resource. For instance, hydropower production can prolong low flows in the Upper Ter, although is not as preferential as drinking water supply in a very dry season. For instance, during the drought of 2007-2008, the supply of the metropolitan Barcelona and a minimum instream flow prevailed above the hydropower production in the Lower Ter.

Second, the same HA can be both beneficial and damaging for the same use, through different mechanisms. Therefore the knowledge of the river system is highly valuable to discern such mechanisms and perform the most sustainable management. For instance, security against floods clearly depends negatively on flood flows, especially when the floodplain is urbanised. But, moderate high flows can also prevent dangerous floods. This happens because regular high flows maintain a clean river channel from excesses of plants and sediments, avoiding an increase of the flood level. Even the preservation of the riparian forest makes the flood slower. Likewise, prolonged low flows can be harmful for native fishes, but it is more damaging for the invasion of exotic species, which is an even more harmful hazard.

Third, potential tradeoffs do not mean actual tradeoffs. On one hand, many tensions with different levels of importance were identified in the Lower Ter because of the demand for irrigation and the RMB supply. The amount of water extracted for the Ter transfer is so great that makes the competition between the rest of river uses high. On the other hand, all the benefits found in e.g., Camprodon Valley seem to be compatible with each other according to the interviewees. This is eventually dependent on the interplay between the available water flows and the existing global demands, which changes over time somehow linked to precipitation, water transport efficiency and the market value of some goods and services dependent on water provision (e.g., crops).

Moreover, even actual tradeoffs may not generate conflict. This may be due to several reasons. First, tradeoffs can be actually recognised by the potentially impacted actor. For example, some hydropower producers have strong positive feelings toward the river ecosystem, so they agree on the need of environmental flows despite the ensuing loss in energy production. Second, the general public may ignore, for instance, that the decrease of the aquifer level is due to riverbed incision caused in the Lower Ter by the storage of sediments behind the dams. Third, there may be resignation as when the licences for consumptive uses are for long (e.g., for hydropower plants, they are for around 65-75 years). And finally, people may better appreciate what they have closer. In Girona, as a populated city with several tributaries closer to the city centre, many people is not as aware for the state of the Ter River, a bit farther away. **Chapter 7** deeply explores the causalities behind the conflicts in the Ter basin from a historical perspective.

The methodology adopted based on stakeholders' involvement and network analysis does not identify current conflicts, which are figured out by interviewing key stakeholders and analysing the media. What we are illustrating here are those potential tradeoffs that can evolve into conflicts. Currently, the environmentalists in the Upper Ter are confronted with most hydropower producers, who in fact monopolise the water management in that sub-basin. The conflicts in the Lower Ter are much more complex, involving a broader range of sectors. Although most users could be rival in managing the resource – especially between environmentalists and irrigators –, all agree that the water transfer to Barcelona is the major problem. However, should predictions on climate change (ACA, 2009b) are met or the current water management is changed, conflicts in the area may intensify in the near future.

Chapter 6

Tradeoffs and synergies under different water management and climate scenarios

6.1 INTRODUCTION

Models allow the simulation of scenarios over time and space. In order to incorporate alternative water management and climate scenarios in the assessment of the ES provided by the Ter River, this chapter engages with the modelling literature to test the potential of the ES concept in cases of potential conflict related to alternative management visions. For this, the idea of tradeoffs and synergies will be explored in depth.

Approximately 6,280 articles appear in ScienceDirect combining the keywords 'ecosystem services' and 'modelling' for the period 2010-2014[8], which demonstrates the interest in using models in integrated assessments. Modelling tools are found useful for quantifying the provision of river ES (e.g., Liu et al., 2008), helping to better understand changes over time and space (Burkhard et al., 2013; Koch et al., 2009; Nelson et al., 2009), hence making water resource decisions more effective, efficient and defensible (Bennett et al., 2009; Volk, 2013). However, very few studies on modelling socio-economic benefits provided by instream flows at a watershed level have been published so far (e.g., Fanaian et al., 2015; Johnson and Adams, 1988; King et al., 2003; Korsgaard et al., 2008). While their contributions are clearly insightful, they usually lack comprehensiveness in terms of the scope of ES included in the analysis, and stakeholder engagement is usually missing. Additionally, none of these studies specifically aims at explaining conflicts or discussing their results in the light of distributional issues. The understanding of the dynamics of appropriation of water flow-dependent ES and their relation to social conflicts thus remains an area to be addressed.

In this respect, our specific objectives are: 1) to offer an innovative methodology, based on modelling exercises with stakeholder engagement, for assessing ES provided by water flows; 2) to explore the potential of this methodology for understanding inter-stakeholder

[8] As of the date of February 15, 2015.

conflicts, in the particular case of the Ter River (Catalonia, Spain); and 3) to analyse different alternatives proposed by the water authorities and the civil society.

This chapter only analyses the ES provided in the Lower Ter. We considered to exclude the Upper Ter from an ES provision model due to the following reasons:

1. The unique important water withdrawal that generates conflict is the chain of SHPP, whose effects on instream flows are already accounted by the ACA (Bardina et al., 2016).
2. Most of ES cannot be correlated with instream flow levels (e.g., relaxing sound, swimming, inspiration, calm-water kayaking, grazing). Fishing and the preservation of the river ecosystem are the most correlated, but their requirements are also well known by the watershed authority (ACA, 2005).
3. The effects of the operation of the SHPP on the ecosystem are highly related to the discharge of the instream flows, but also to the lack of river continuity and the loss of aquatic habitat due to the barrier effect of weirs.

Therefore, in this chapter, we use the Lower Ter sub-basin to illustrate the operationalisation of the modelling approach here proposed. **Section 6.2** broadly explains the methods employed, in particular those referring to the involvement of stakeholders.

Then, a water management model using WEAP software recreates water flows in all watercourses either the river channel or diversion canals and demand sites. Four different management scenarios are simulated: the business as usual, a new management proposed by the ACA and two environmental alternatives that consider a different implementation of the PSCM. They are based on available management plans as discussed with the corresponding authorities and on stakeholders' positions. These steps are described in **Section 6.3**.

Based on the results of the water allocation model, service suitability curves – designed by taken into account the local stakeholders' perceptions – allow a modelling of the provision of each ES under each scenario (**Section 6.4**). The results are aggregated to analyse spatial/temporal patterns (e.g., seasonal variation, water-year types) and ES performance, as shown in **Section 6.5**. For both models (water allocation and ES provision), we introduce some specific questions in our case study in order to explore the potential usefulness of the models for solving problems related to water planning, taking into account multiple stakeholders' preferences. Finally, **Section 6.6** discusses such usefulness and the potential of modelling ES from water flows for understanding environmental conflicts.

6.2 METHODS

The proposed methodology is in fact constituted by two different models integrated in the same process. First, a 'water allocation model' provides the distribution of water flows through all watercourses (river and diversion canals) and demand sites. This is done by introducing different scenarios of water allocation and including water demands and priorities of usage. The second is an 'ES provision model'. It indicates the level of ES provision in relation to the water flows obtained from the water allocation modelling.

The details of the entire model building process and the outcomes from both models are represented in Fig. 22 and described in the subsections below.

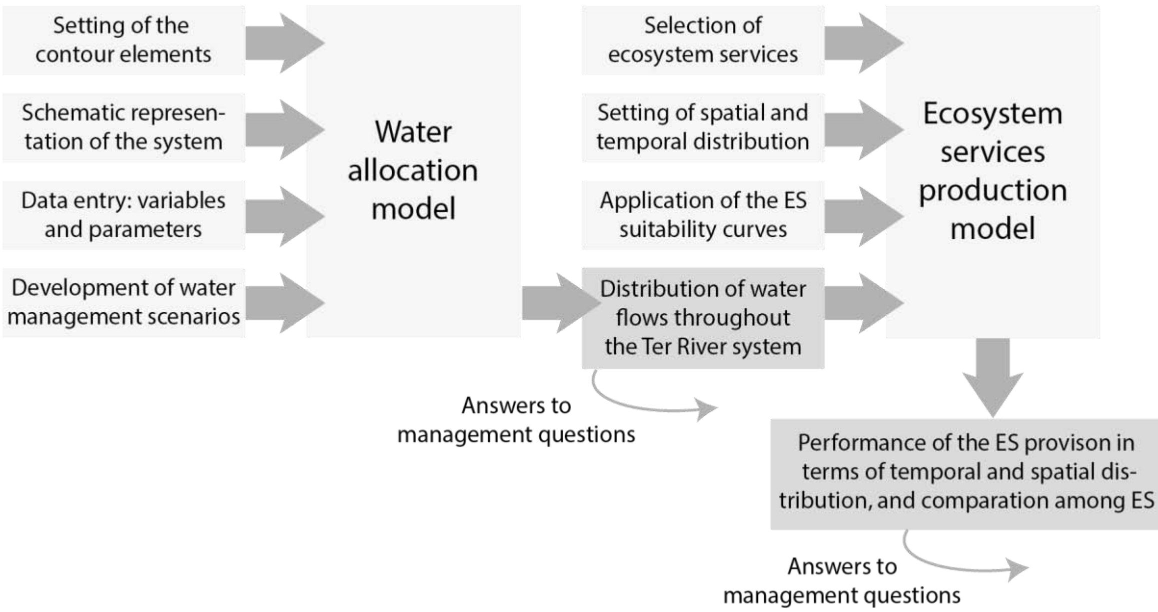


Fig. 22. Diagram of the model building processes

Researchers, upon noting the lack of the inclusion of people's values and needs in ES assessments (Menzel and Teng, 2009), have increasingly engaged stakeholders in the assessment process as a way to obtain results that subsequently society can accept. This includes using several participatory modelling approaches (Voinov and Bousquet, 2010). For instance, Videira et al. (2009) based their framework on Group Model Building and Mediated Modelling for scoping the problems, pressures and impacts perceived by stakeholders in a Portuguese river basin. Nelson et al. (2009) engaged stakeholders in defining land use change scenarios for their InVEST modelling tool. Hobbs et al. (2002) and Haines-Young (2011) employed Fuzzy Cognitive Mapping and Bayesian Belief Networks, respectively, for exploring the effects of management changes on ecosystem components and valued ecosystem services.

In our case, we build a stakeholder-based modelling framework to capture local views on water management and on preferences about ES provision. In particular, three different methods were used to engage stakeholders and extract data to feed our models:

- **Interviews of key informants**. The twenty interviews performed in **Chapter 5** determined the scope of the *problematique* and allowed the selection of those ES to be incorporated in the models.
- **Workshops with stakeholders**. We also organised two workshops with a total of twenty well-informed participants – representing the variety of ES studied. They

took place in in two different towns of the Lower Ter sub-basin (Salt and Torroella de Montgrí). In both workshops, three exercises were performed: first, the mapping of the ES provision; second, a brainstorming of limitations that obstruct this ES provision; and third, the attribution of the amount of instream/out-of-stream flow that the provision of different levels of service require.

- **A survey**. 10 of our key informants and 11 organisations that work for the improvement of the water management in Catalonia responded a survey designed to prioritise different sites for water allocation and, in relation to this, develop the water management scenarios.

With the results obtained, we undertook an extra workshop in Girona in order to disseminate the findings of this work as well as to validate the methodology and the results provided by the model. Twelve people assisted. They were experts in some of the ecosystem services modelled and different from the assistants in other workshops. The validation consisted in four exercises were the participants had to:

1. describe the level of agreement on the results of ES provision obtained for different time periods (summer, autumn, dry years, rainy years, etc.);
2. amend the suitability curves used for the ES provision model by using their own knowledge and interest;
3. mark the stretches of the river where the participants profit from the river and write the conditionings that avoid to make profit of it;
4. and list specific events that have conditioned the provision of the different ES for the recent years for the purposes of developing the management scenarios and for better understanding the inter-stakeholder tensions.

Appendix A give further details regarding the stakeholder engagement methods employed.

6.3 A WATER ALLOCATION MODEL

The software used to design and run this model is Water Evaluation And Planning (WEAP), developed by the Stockholm Environment Institute (SEI) (www.weap21.org). It is an scenario-driven decision support system model, operating on the principle of water balance accounting. WEAP offers integration between biophysical hydrological processes and governance on the allocation of water resources (e.g., Vogel et al., 2007; Yates et al., 2005).

The aim of this model is to generate estimates of water flows, being either diverted water (e.g., for irrigation, hydropower, domestic supply) or instream flows (e.g., for kayaking, fishing, maintaining the ecosystem). To this end, first, the contour elements of the model (spatial and temporal scale and accuracy need to be set up as contour elements of the model. Second, all links between watercourses and demand sites have to be schematised. Third, the data related to parameters and variables according to the current management must be input. Finally, alternative scenarios have to be proposed and variables have to be modified accordingly. Then the model is ready to be run.

6.3.1 Setting of contour elements

We employed monthly series of water flows in order to consider the seasonal variability within a year, as they are more regularly available than daily data and offer higher reliability, according to the watershed authority. Therefore, all daily series obtained were transformed into monthly series. The median was used instead of the average so as to avoid bias generated by extreme events.

The model was designed using hydrological series comprising the period between October 1980 and September 2008. Our 28-years period includes 7 dry years, 14 normal years and 7 wet years[9] and therefore captures different hydrological situations likely to occur in future.

6.3.2 Schematic representation of the system

The elements illustrated in the scheme of the Lower Ter system (see Fig. 23) consist of:

- the Ter River and eight tributaries of the Lower Ter,
- the five most relevant sewage treatment plants (STP) – those with a higher outflow than 0,2 Hm^3/year,
- three dams regulating the flow regime (Sau, Susqueda and Pasteral) plus twelve weirs,
- three main urban consumption demand sites (i.e., the RMB, Girona city and its outskirts and the urbanised tourist developments of the Costa Brava), including domestic and industrial uses,
- the nine irrigation communities (IC) that consume the most water,
- fourteen run-of-the-river small hydropower plants (SHPP),
- one spot requiring diverted water for health and aesthetic uses (the Onyar River in Girona),
- three historical canals with specific hydrologic requirements for biodiversity protection,
- and three wetland areas nearby these historical canals.

Appendix C details the elements described above.

[9] Dry years represent those with an annual contribution below the 25th percentile; normal years are those between the 25th and 75th percentiles; and wet years, above the 75th percentile.

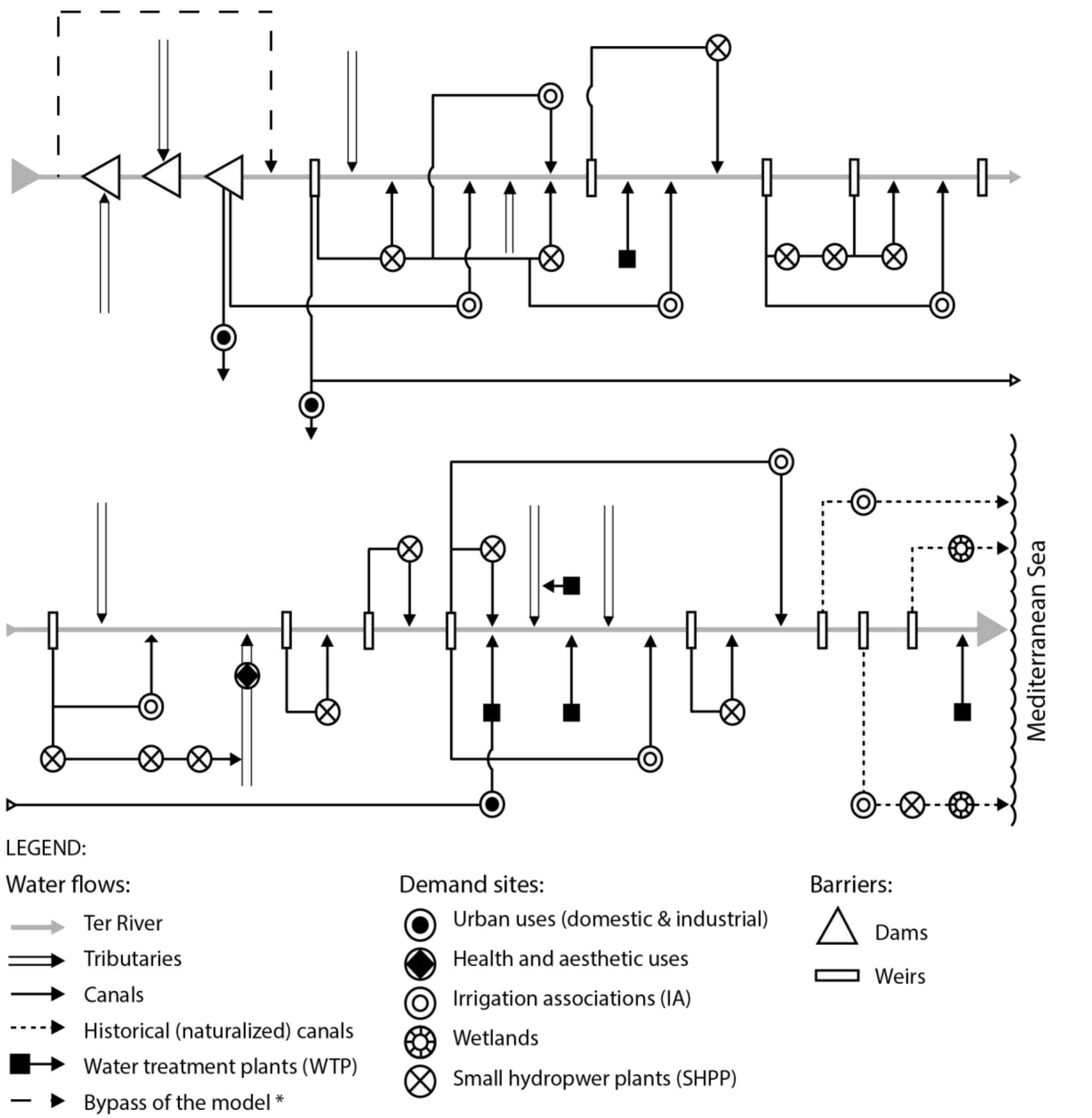


Fig. 23. Scheme of the Lower Ter River system. * This bypass represents the actual management manoeuvres that prevent the total emptying of the reservoirs when there are natural extremely low water flows.

6.3.3 Data entry and validation process

There are three entry variables that provide water inflows into the Lower Ter system: the Upper Ter flowing into the reservoirs, the tributaries of the Lower Ter sub-basin and the discharge of the STP that are fed by water sources outside the Ter system (e.g., surface waters from other river basins, groundwater).

Additionally, there is a variety of parameters required by the model, and these in turn are related to the elements mentioned in **Section 3.1.2**. They include monthly demands, flow returns in percentages, the capacity of the reservoirs, e-flow requirements, etc. An important parameter to highlight is the priority level for water allocation – attributable to all demand sites, e-flow requirements and the storage of water. The WEAP model distributes the water flow available in a given month, supplying the most preferential demand sites first, then supplying the second most preferential demand sites, and so on until there is no available water to deliver in that month.

We combine data from multiple sources to define all variables and parameters. These sources are basically hydrological planning regulations (BOE, 2008a, 1959; DOGC, 2007); water management plans made by the watershed authority (ACA, 2010, 2009a, 2005); regulations for applying environmental measures to construction (BOE, 2008b, 2007); and some studies from the National Weather Service (2002) and the Chair of Mediterranean Coastal Ecosystems (Quintana, 2010). The identification of pertinent sources for these data (**Appendix C**) is itself part of the participatory process before the construction of the model. That is, among the available references on regulations and literature, these were validated through the interview process. Still, as indicated below, opening the modelling process to the participation of stakeholders revealed discrepancies between the parameters proposed by these references and the ones proposed by other stakeholders at the local level.

In order to validate the model, we employed the monthly series of the observed water level – convertible to volume stored – in Sau and Susqueda reservoirs and compared them with the changes in water volume obtained from the model. The validation period selected was January 2003-December 2008, since all the data required were available for those years. That period included two important drought episodes that generated social conflict: the 2005 and the 2007-2008 droughts. The correlation between the observed and the simulated data resulted to be excellent (R= 0.929), hence the model was considered acceptable.

6.3.4 Development of water management scenarios

We generated scenarios that represent plausible options for water management and water flow allocation in particular. This subsection summarises the water management scenarios designed and the process through which they have been developed.

The information for the scenario development process comes from: 1) direct observation of the current situation from field research; 2) interviews with technicians of the ACA; 3) a review of laws and plans regarding the management of the Ter River that the Catalan government is enforcing or is willing to enforce; and 4) a survey among activists (10) and non-profit organisations (11) who demand an environmentally enhanced water management.

Business as usual (BAU)

Thus, we proposed four management scenarios: the current situation and three plausible developed alternatives, suggested by multiple stakeholders from the Ter River basin. The 'business-as-usual (BAU) scenario' represents the current management situation, consistent with prevalent hydrological planning and its actual implementation by the ACA. To summarise, BAU gives priority to all consumptive uses above the preservation of the ecosystem, and to the water transfer above intra-basin irrigation uses. Table 11 gives the priority list according to this scenario and to the alternative ones. According to BAU:

- The drinking water supply is the first of importance, especially the supply of Girona and the Costa Brava. This priority comes from national and regional laws.
- The water transfer to the RMB decreased during the last years down to 165 Hm^3/s approximately, which corresponds to the 75th percentile of the water diverted during the rainy period 2009-2012. 166 Hm^3/s is also the maximum withdrawal currently established in the contract.
- Industrial uses have, in practice, the same priority as domestic uses, since the pipes are physically the same.
- Girona lives off of tourism and attempts to maintain the water level of the Onyar River, which is fed by water from the Ter, as a preferential use. Besides the waterscape of the Onyar is the most famous image of the city, the water flow contributes to the removal of odors and litter.

Table 11. Priority of the demand sites to run the model for the three management scenarios

	Scenarios			
Demand site	BAU	NEW	COM	ECO
Minimum instream flow for tributaries	5	5	5	5
Water treatment plants	10	10	10	10
Minimum instream flow for the Ter	10	10	10	10
Irrigation in tributaries	15	15	15	15
The e-flows from the PZBT for the Ter in Pasteral and Girona	55	-	20	20
The e-flows from the PZBT for the Ter in the rest of sites	70	-	20	20
An extra e-flow (up to 80 % of the inflow to the reservoirs)	-	-	-	30
E-flow for the tributaries	70	10	10	10
An intermediate e-flow level	-	20	-	-
Filling of the canals when the summer flow is too high	85	85	90	85
Maintenance of the historical canals (a minimum flow)	-	-	45	-
Maintenance of the historical canals (the optimal flow)	80	80	85	45
Irrigation	40	40	40	55
Domestic uses in Girona	20	30	30	35
Industrial uses in Girona	20	35	30	60
Domestic uses in the Costa Brava	20	30	30	35
Industrial uses in the Costa Brava	20	35	30	60
Domestic uses in the Metropolitan Region of Barcelona	30	30	50	60
Industrial uses in the Metropolitan Region of Barcelona	30	35	50	70
Aesthetic and health uses of the Onyar River in Girona	35	70	55	60
Reservoirs capacity to save water	40	40	60	60
Conventional hydroelectricity production	60	60	75	80
Run-of-the-river hydroelectricity production	65	65	80	60

Note: The lowest number, the most preferential demand site. The darkness of the background also shows the priority. Written in grey, all the demands equal for all scenarios, explained in detail in **Appendix C**.

- The irrigation communities participate in the Ter-Llobregat Discharge Commission and ensure that the water is discharged during the summer, when is more demanded.
- According to the Law of the Ter (BOE, 1959), there is the attempt to enforce 3 m^3/s passing by Girona. There is a controversy between the ACA and some environmental organisations about the measurement point in Girona. The ACA states that the amount is shared between the river and the Monar Canal.
- The Zonal Plan for the Lower (ACA, 2009a) is not approved so e-flows are not compulsory for existing uses.
- Hydropower producers can divert the water they need (always under their contract), only discharging a minimal instream flow to preserve the river.
- There is certain neglect of the historical canals hence the wetlands that they feed. Since some stretches were piped, neither the farmers nor the public administration seem to take care of these ancient waterways.

Compatibility of uses (COM)

The 'compatibility-of-uses (COM)' scenario is based on the goals of the ACA concerning plans and studies that is enforcing or willing to enforce, but not yet implemented. This scenario reflects full respect for commitments of the Catalan government and the ACA with the civil society and administrations of Girona province to make the variety of water uses compatible. It maintains the same order of priorities as in BAU, except for the e-flows and other environmental uses. The assumptions that we consider for this scenario are:

- The e-flows not considered a use itself, but a previous restriction to any use. This is defined in national and regional water laws. Therefore, each barrier, dam or weir, has to discharge that amount of water established in the PZBT (ACA, 2009a), following the assigned monthly variability.
- The Law of the Ter is reinterpreted. Before diverting any water to the RMB, 1 m^3/s must be assured for Girona and Costa Brava urban supply, the needs for the irrigation (estimated then in 150 Hm^3/year, which is more than what is usually consumed) must be satisfied, and 3 m^3/s of instream flow have to pass by Girona.
- To compensate the implementation of e-flows, the desalination capacity for supplying the RMB increases, actually foreseen for 2015 (ACA, 2010). This would facilitate the water transfer to decrease down to 134 Hm^3/year. However, this reduction would not be undertaken in dry years, when the dependence on the Ter River is higher.
- Industrial uses also have the same priority as domestic uses, as in BAU.
- The PZBT also calculates the water requirements for irrigation: a total amount of 55.7 Hm^3/year for the most significant communities. This scenario considers these water demands, instead of the current withdrawals.

- The Environmental Impact Statements for the piping of the historical canals (BOE, 2008b, 2007) have to be enforced. This means that at least 0.3 and 0.2 m^3/s of water have to pass by the Sentmenat and Molí de Pals canals, respectively.
- As run-of-the-river hydropower plants are damaged by the implementation of e-flows, the PZBT proposes an increase of the maximum flow they can divert.

Ecosystem priority (ECO)

From the results from the surveys among individual activists and non-profit organisations, we were able to perform a cluster analysis and to separate the surveyees in two groups (see in Fig. 24 a representation of this results). The priorities from one group resulted very similar to those considered for the COM scenario, while those from the other group were employed to build a new scenario named as 'ecosystem-priority (ECO) scenario'. The ECO scenario is the preferred by those environmental organisations that call for a natural flow regime. They are not only naturalist organisations, but also scientists and environmental technicians of the town councils. They have the most opposite views to the current management, giving the maximum priority to the ecosystems and the minimum to the Ter water transfer, industry and hydropower production.

For this scenario, we consider the following factors:

- The reservoirs have to discharge at least the 80 % of their inflow, except for high flows. This is the appropriate amount considered by some environmentalists. In order to avoid floods, the discharge is limited to 74.3 m^3/s, established in the PSCM as the necessary flow to maintain the channel features.

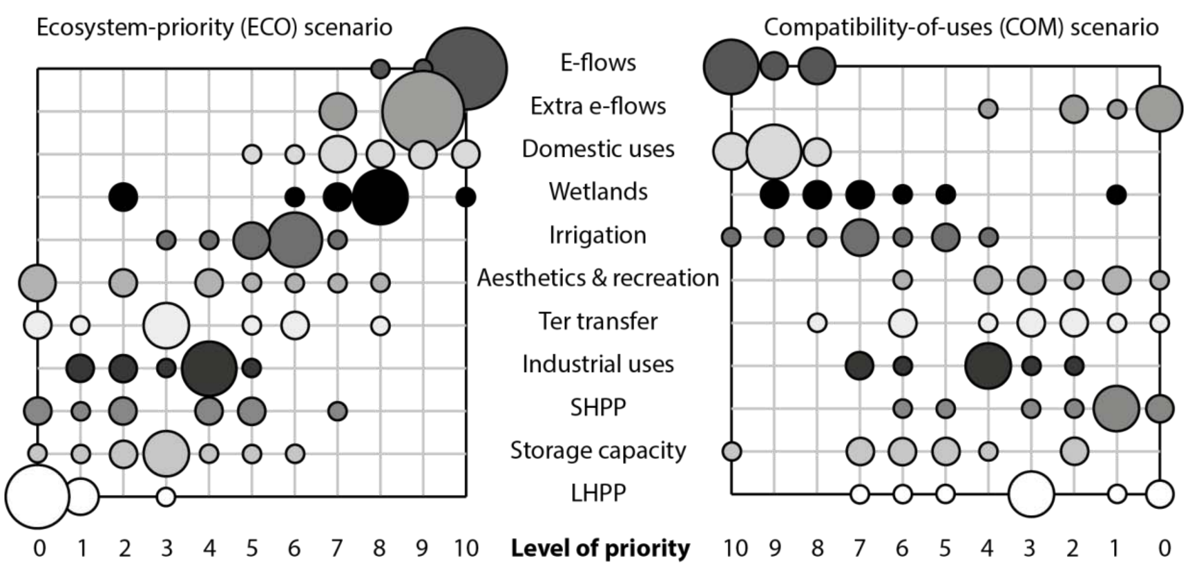


Fig. 24. Results from the surveys among environmental organisations. The x-axis shows the level of priority (10 is the maximum level, while 0 the minimum), the y-axis the different demand sites, and the size of the bubble the number of answers.

- Each barrier discharges the flow established in the PZBT. However, differently from the COM scenario, the authorised diverted flow is not increased to compensate the hydropower producers[10].
- A more in-depth reduction of the water transfer is reached down to 115 Hm^3/year. According to the Management Plan, this could be undertaken thanks to an increase of the desalination capacity and other measures not foreseen in a short term.
- Industrial uses are forced to be much less preferential than domestic uses, irrigation, e-flows and environmental uses.
- This scenario also assumes the irrigation demands indicated in the PZBT.
- There is a strong effort to preserve the historical canals and wetlands by delivering the water flows estimated by Quintana (2010).

Table 12 summarises the three mentioned management scenarios in terms of demand sites and environmental requirements for a practical comparison.

Table 12. Description of the water demands for the three management scenarios

	Management scenarios		
Demand site	BAU	COM	ECO
E-flows within the Ter River channel	They are not compulsory for current and valid concessions	In all cases, they are compulsory	Compulsory. Besides, 80% of the reservoirs' inflow is always discharged
Historical canals and wetland preservation	Certain neglect of the historical canals	A minimum flow to feed the historical canals (BOE, 2008b, 2007)	An e-flow regime (Quintana, 2010)
Irrigation	The current consumption	Demands corresponding to the needs calculated in ACA (2009a).	Demands corresponding to the needs calculated in ACA (2009a).
Drinking water supply to Girona and Costa Brava	Of prime importance	The most important after the enforcement of the e-flow	The most important after the enforcement of the e-flow
Drinking water supply to the RMB	165 Hm^3/year (the maximum by concession)	134 Hm^3/year in wet and normal years. 166 Hm^3/year in dry years	115 Hm^3/year. Less preferential than intra-basin uses
Industrial uses	Industry has the same priority as domestic use	Industry has the same priority as domestic use	The least preferential
Aesthetic and health uses in Girona city	Intermediate level of priority	Intermediate level of priority	Intermediate level of priority
Hydroelectricity production	What is established in their concession, without any requirement of discharging an e-flow	Increase of flow capacity to compensate the e-flow enforcement	Forced to discharge the e-flow

[10] The legality of this measure is controversial, but some interviewees affirm that it is feasible.

New management plan (NEW)

From the participatory methods already explained above, only the last three management scenarios were developed. However, during the writing of this thesis, the ACA elaborated the new Water Management Plan for the period 2016-2021 (ACA, 2015), which is neither revised nor approved yet. Then, we decided to develop a 'new-management-plan (NEW) scenario'. NEW appears as a slight modification of BAU in transition to the COM scenario. The few differences between NEW and BAU are detailed as follows:

- E-flows are considered a previous restriction to any use, as in COM and ECO. However, each barrier has to discharge the flows established in the plan, which corresponds approximately to the 60% of those agreed in the PSCM (ACA, 2005).
- The hydropower production of run-of-the-river plants can be damaged by the implementation of e-flows. For compensating that, we establish an increase of the maximum flow they can divert (foreseen in the Management Plan 2016-2021) based on the proposal in the PZBT.
- The priority level of the aesthetic and health uses of the Onyar River in Girona is very low, as the *other uses* category in the Management Plan.

Climate scenarios

Besides the water management scenarios, we deemed it suitable to consider a climate change scenario. As there are multiple studies stating that the instream flows in the Mediterranean basin will decrease for the next decades, we found necessary to add an extra scenario taking into account the climate change. Thus, we have eight scenarios to be run in the model, as a result of the combination of the water management and climate scenarios (Table 13).

Table 13. Scenarios to run the model

		Climate scenarios	
		No climate change (-)	Climate change (+)
Water management scenarios	Business as usual	BAU	BAU+
	Compatibility of uses	COM	COM+
	Ecosystem priority	ECO	ECO+
	New management plan	NEW	NEW+

"Water and climate change. Diagnosis of the impacts foreseen in Catalonia" (ACA, 2009b) is the most relevant work compiling all the studies on climate change and hydrologic systems that can be applied in Catalonia. The lack of knowledge regarding this issue is mentioned several times, especially for snow-and-rain-fed rivers as the Ter. However, they give some general conclusions, from which we can extract useful insights:

- A study of the Cardener mountain River (ACA, 2002) shows that the average of the annual contribution could suffer a reduction of the 3 % if the temperature varies +1ºC, or the 11 % if, in addition, there is a decrease of 5 % of the precipitation.

- A more general study interpolating national climate models to the annual contribution in small and medium catchments (Iglesias et al., 2005; MMA, 2006) attributes a decrease of 15 % of the instream flows due to a lowering of the precipitation (-5%) and the increase of the temperature (+1 ºC).
- In Pyrenean headwaters, Rasilla (2006) foresees the melting period for one month earlier, hence also the maximum annual flows.
- "At the end of the 21st century, the Mediterranean basin will face to an increase of the density, length and extension of the droughts due to the migration of the polar fronts to the North (Llasat et al., 2008)" (ACA, 2009b, p. 157).
- Regarding the seasonal evolution of the instream flows, in summer times they could double their lowering, while this reduction would be moderate in winter, when the precipitation could even increase.

For that climate scenario, we do not need an accurate forecast of the natural flows. Instead, we aim at seeing what ecosystem services are exposed to a greater threat of climate change. Therefore, based on the literature mentioned, we draw a likely trend that reduces an 11 % of the annual inflows to the reservoirs, and a 15 % of the inflows from the tributaries and the runoff. This reduction is differently expressed depending on the season. So the summer is the most affected period unlike the winter, whose reduction is halved. Besides, the melting period is simulated to start one month earlier. Table 14 shows month by month the corresponding equation that represents the mentioned trend.

Table 14. Calculation of the monthly flows from the natural regime series for the scenario under the climate change effects.

Months	Ter River inflow	Lateral runoff and tributaries
October	$= m_{oct} - 0.11 \cdot m_{oct}$	$= m_{oct} - 0.15 \cdot m_{oct}$
November	$= m_{nov} - 0.11 \cdot m_{nov}$	$= m_{nov} - 0.15 \cdot m_{nov}$
December	$= m_{dec} - 0.11 \cdot m_{dec}$	$= m_{dec} - 0.15 \cdot m_{dec}$
January	$= m_{jan} - 0.055 \cdot m_{jan}$	$= m_{jan} - 0.075 \cdot m_{jan}$
February	$= m_{feb} - 0.055 \cdot m_{feb}$	$= m_{feb} - 0.075 \cdot m_{feb}$
March	$= m_{mar} - 0.055 \cdot m_{mar}$	$= m_{mar} - 0.075 \cdot m_{mar}$
April	$= (m_{abr} + 0.17 \cdot m_{jun}) - 0.11 \cdot (m_{abr} + 0.17 \cdot m_{jun})$	$= m_{abr} - 0.15 \cdot m_{abr}$
May	$= (m_{may} + 0.17 \cdot m_{jun}) - 0.11 \cdot (m_{may} + 0.17 \cdot m_{jun})$	$= m_{may} - 0.15 \cdot m_{may}$
June	$= (0.66 \cdot m_{jun}) - 0.11 \cdot (0.66 \cdot m_{jun})$	$= m_{jun} - 0.15 \cdot m_{jun}$
July	$= m_{jul} - 0.22 \cdot m_{jul}$	$= m_{jul} - 0.30 \cdot m_{jul}$
August	$= m_{aug} - 0.22 \cdot m_{aug}$	$= m_{aug} - 0.30 \cdot m_{aug}$
September	$= m_{sep} - 0.22 \cdot m_{sep}$	$= m_{sep} - 0.30 \cdot m_{sep}$

m is the monthly median of daily flows used to calculate the series of the natural regime from 1980 to 2008.

6.4 AN ECOSYSTEM SERVICES PROVISION MODEL

Despite the useful information that can be obtained from water allocation modelling, the outcomes do not specify the concrete benefits that locals would have. In order to predict future tensions among groups of interest, it is necessary to know what those water flows mean in terms of ES and to analyse where and when they can be threatened.

To this end, we developed the ES provision model by using Microsoft Excel spreadsheets. First, we selected those most important and water flow-dependent ES. Second, with the help of the stakeholders that participated in the workshops and interviews, we defined the spatial and temporal distribution of the ES provisioning. Third, based on the stakeholders' preferences, we built the suitability curves of ES production (Korsgaard et al., 2008). Finally, we applied those suitability curves to transform the monthly hydrologic data obtained from the water allocation model into ES provision levels.

6.4.1 Selection of ecosystem services

In **Chapter 5**, we identified twenty-eight forms of benefitting from the Ter River. Information from twenty interviews was used to link water flows, components of the river ecosystem and benefits, in order to define and characterise the whole service of the Ter. From that list, we have selected those ES (see Table 15) based on:

- the importance for the locals (the number of times occurring in the interviews),
- the dependence on the water flows,
- and the quantifiable relationship with these water flows.

Thus, the ES that were first considered such as the snow production for skiing, the recreational capacity of riverbanks, and the space for swimming, were excluded from the list. Others were divided in two separate ES according to their differences regarding flow requirements (e.g., fly-fishing and elver fishing, in Pics. 10 and 11).

Pic. 10. Fly-fishing.
It is an angling method in which an artificial *fly* is used to catch fish. In the Ter River, it is basically employed for catching brown trout. Due to the habitat requirements of this specie, fly-fishing is practiced in whitewaters.

Pic. 11. Elver fishing.
This art of fishing is only practiced in the calm waters of the Ter estuary. It uses eel bucks to trap elvers moving upstream.
Source: Juli, from *Angula del Ter*.

Table 15. Ecosystem services being modelled and their flow requirements

Instream flow-dependent ecosystem services

- Maintenance of the river ecosystem: instream flow regime, monthly modulated, required for the conservation of the river structure and biodiversity.
- Protection from saltwater intrusion: a minimum flow that prevents seawater intrusion, thus preserving the coastal ecosystems and the wells that provide drinking water.
- Elver fishing: a minimum flow in the river mouth that guides the elver to the river. The elver is only allowed to be fished between October and March.
- Fly-fishing: instream flows that provide a suitable habitat for brown trout and avoid the colonisation by exotic species. Possible only in a stretch of a few kilometres downstream from the Pasteral Reservoir.
- Whitewater kayaking: any instream flow – but the more the better – that allows a spot to be practiced. Especially performed between the Pasteral Reservoir and Girona.
- Calm-water kayaking: instream flows that maintain a certain water level without producing white water, especially desirable in summer. In spring it is prohibited in some stretches where waterfowl are breeding.

Diverted flow-dependent ecosystem services

- Domestic uses in Girona and the Costa Brava: drinking water for intra-basin uses (Girona) or uses within the same province (the Costa Brava), actually considered as the same water management area.
- Domestic uses in the RMB: drinking water being transferred from the Pasteral Reservoir for domestic uses.
- Industrial uses in Girona and the Costa Brava: a small amount part of the drinking water for industrial use (most of it comes from wells).
- Industrial uses in the RMB: drinking water being transferred from the Pasteral Reservoir for industrial purposes. It represents a small part, since most of the water supply comes from wells.
- Hydropower production: water flow diverted directly from the river to produce electricity from run-of-the-river SHPP. It requires as much water as possible, but all water diverted is then returned.
- Irrigation: water required from April to September to maintain agriculture: mainly rice, poplar and fruit tree plantations.
- Preservation of the historical canals: water flows, diverted from the Ter to irrigate the Baix Ter Plain, transported by very old canals that have been naturalised over time, housing now endemic species and protected habitats.
- Preservation of wetlands: water flowing through the historical canals then feeds some wetlands included in a Natural Park, belonging to the Natura 2000 Network.
- Onyar River in Girona: water diverted for irrigation and hydroelectric purposes that flows into the Onyar River, creating a valuable waterscape within the historical and tourist city of Girona. This water is also used to dilute wastewater and eliminate bad smells.

6.4.2 Setting of spatial and temporal distribution

The delimitation of areas and seasons where and when the ES are actually produced is essential to avoid false outcomes during irrelevant time periods (e.g., autumn and winter for the irrigation) or in irrelevant stretches of the river (e.g., the river mouth for fly-fishing). Table 15 informs about these temporal and spatial restrictions.

This information allows for a more accurate calculation of ES production, since the water flow requirements may vary along the river and over the year. These requirements are defined using ecosystem services suitability curves.

6.4.3 Application of the service suitability curves

The suitability curves have been thoroughly used to study the preferential hydraulic conditions for river fish (Bovee, 1986; Raleigh et al., 1986). Korsgaard et al. (2008) developed the idea and an application for using similar curves to quantify the production of ecosystem services, using the Service Provision Index (SPI). Very few studies have used them (Fanaian et al., 2015; Korsgaard et al., 2008) and they focussed on monetary valuations of a few relevant water flow-dependent ES. Here we elaborate on the use of suitability curves for a comprehensive variety of ES with the participation of stakeholders, with the aim of analysing environmental conflicts.

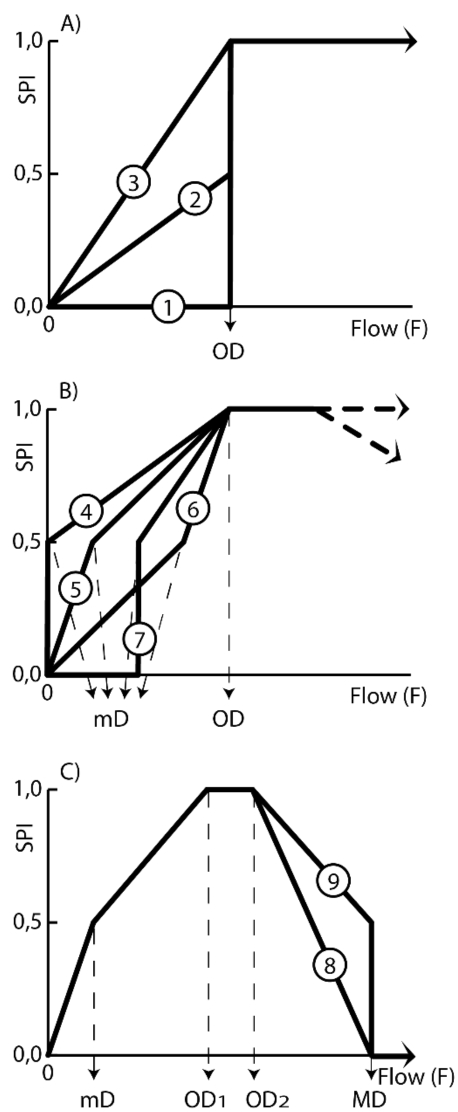


Fig. 25. Service suitability curves relating ES production (represented by SPI) to water flows. *mD*: flow demand for a minimally acceptable ES production (0,5). *OD*: flow for an optimal level of ES production (1). *MD*: maximum flow for providing any benefit (0). **4A.** Only OD was specified by stakeholders. Function 1 represents the water required for the wetland maintenance; 2, the protection from saltwater intrusion; and 3, the withdrawn water for industrial production. **4B.** Stakeholders specified OD and mD. Function 4 represents the whitewater kayaking, without a minimum flow requirement; and 5, the preservation of historical canals, the aesthetics of the Onyar River in Girona and the suitability of the mouth for elver fishing. Function 6 corresponds to fly-fishing, irrigation and domestic water supply; and 7, to hydropower production. **4C.** Stakeholders specified OD, mD and MD. Function 8 represents the preservation of the river as an ecosystem itself; and function 9, the calm-water kayaking. See **Appendix D** for more details regarding uncertainties and technical restraints related to each curve.

The suitability curves presented here were discussed in the workshops previously mentioned. Participants provided biophysical indicators of water flows, representing different levels of ES production: i.e. ‘nil’ (SPI = 0), ‘minimally acceptable’ (SPI = 0.5) and most preferred or 'optimum' values (SPI = 1). The shape of the curve for a given ES changes slightly according to the season. For instance, farmers actually need less water for irrigation during rainy months.

The answers vary from specific amounts of flow to citations of studies with some recommendations (ACA, 2010, 2009a, 2005; BOE, 2008b, 2007; Montaner, 2010; Quintana, 2010) or the use of indicators (e.g., the abundant presence of algae along the watercourse). These values were then amended or corroborated using the literature or interviewing specific stakeholders.

The curves representing the relationship between instream/diverted flows and ES production can be grouped into three types (Fig. 25). First, there are curves designed only with an optimal demand of flow, which brings ES production to a maximum level. Second, most of the curves also present a demand of flow required to achieve a minimally acceptable level of ES production. Finally, there is a group of curves with a water flow, which stops providing any benefit if exceeded. For detailed information about them, their sources and the underlying equations, see **Appendix D**.

6.4.4 Distribution of water flows throughout the Ter River system

Scenario by scenario, ES by ES, month by month and stretch by stretch, each suitability curve is applied to a watercourse in order to obtain 27-year series of ES provision in terms of SPI.

6.5 RESULTS

6.5.1 Outcomes in views on the conflicts over water flows

Tenty-five Catalan non-for-profit organisations that aim a better water management answered to the questionnaire about the case of the Ter River. Only eleven are related to the Ter basin, so their preferences were selected to develop the scenarios. Although the sampling is not enough for a statistical analysis, the set of the 25 responses show different views on the water flow management, thus allow a better understanding of ensuing tensions.

In sum, 80% of the surveyees think that the management of the Ter should belong to the citizens of the Ter basin, who should participate in and control over the water flows (84%). In order to guarantee a sustainable water management, most of the respondents call for the conservation of river ecosystems (92%), the enhancement of local and traditional models of management that promote and preserve good practices (84%) and the inclusion of technological measures that increase the efficiency in the transport and use of water (80%). Moreover, 76% of the respondents want the Ter transfer to be subject to the e-flows and the intra-basin uses, while 24% would stop the transfer. Likewise, most of the respondents want to implement an e-flow regime without any economic compensation for the hydropower producers (71%), whose licenses should not be respected (67%).

Finally, some controversies appear when the organisations are asked about the cultural heritage that represents the hydraulic infrastructure (e.g., weirs, canals) and its removal, about the idea of returning to a pristine river or to a river managed with traditional knowledge, about the option of delegating the water management to scientists and technicians, and about the limitation of the RMB's growth and the disconnection of its industries from the Ter in order to decrease the water transfer.

Appendix A shows all the answers from the survey.

6.5.2 Outcomes in water flows

The outcomes of the water allocation model facilitate responses to specific questions related to water uses, demands and final water distribution, under the variety of scenarios mentioned. Table 16 synthesises the resulting 27-year[11] series of the water allocation model, which provide information that allows answering questions such as: what is the most demanding use of water? What management scenario is more sensitive to the ecosystem? How will climate change disturb the dynamics of water flows?

Table 16. Minimum and maximum annual flow contribution resulting from the WEAP model (Hm^3)

	Water management and climate change scenarios					
	BAU	BAU+	COM	COM+	ECO	ECO+
Inflows into the Ter River-system						
Into the reservoirs[1]	172-923	149-824	172-923	150-824	172-923	150-824
From the tributaries[2]	26-309	22-264	32-310	28-267	32-310	28-267
From lateral runoff	35-363	30-311	42-365	36-314	42-365	36-314
Total water inflows[3]	266-1391	231-1252	276-1396	241-1257	276-1396	241-1257
Resultant instream flows						
Discharged from the dams	98-784	88-682	137-820	138-711	218-869	203-763
In Girona above Onyar	47-846	40-757	90-856	89-765	136-935	127-850
In Girona below Onyar	124-1016	106-921	174-1057	167-955	247-1123	226-1030
Reaching the sea	92-1085	88-976	138-1128	131-1015	197-1191	178-1079
Resultant diversion flows						
Transfer to the RMB	165-165	165-165	130-165	91-165	26-104	17-100
Intra-basin urban supply	18-18	18-18	18-18	18-18	17-18	16-17
Irrigation	55-104	42-101	45-68	39-68	45-68	44-68
Hydropower (average)	60-114	55-113	60-150	56-146	86-120	88-120
Hydropower (largest SHPP)[4]	65-231	54-217	77-240	66-226	138-259	127-256
Historical canals, wetlands	47-107	34-102	62-103	53-102	87-108	83-108

[1]These include the Upper Ter plus the tributaries that directly flow into the reservoirs. [2]These include the WTP outflows that run into the tributaries. [3]This sum also includes those WTP outflows (3.83 Hm^3) whose water source is not the Ter River (e.g. water from wells). [4]This represents the average of the SHPP that uses the greatest water flow.

[11] The first year of the complete 28-year series is common to all scenarios.

Our results demonstrate the amount of water transferred to the RMB, especially in dry years when the amount of water diverted from the reservoirs is close to their inflows. Another noteworthy result is how essential the tributaries and the lateral runoff are for helping the river to recover the instream flow levels. The extreme differences between maximum and minimum levels of instream flow are logical, and it is especially interesting to see the fierce competition among demand sites when the levels are minimal. COM and especially ECO give some priority to the ecosystem, which allows for a much higher minimum flow than in BAU. Differences between scenarios are not that noticeable when water abounds. In addition, it is also significant that the production of hydroelectricity may potentially use the most water, although this is subsequently returned. ECO curiously gives more water to hydropower than other scenarios do, presumably due to its preference for intra-basin uses. Climate change would slightly have an effect on the Lower Ter system. In all cases, the least preferential use is the most damaged.

6.5.3 Outcomes in ecosystem service performance

This stage of the methodology is related to stakeholders' values and preferences. Such results enable an analysis of possible clashes between water users. Thus, the outputs of the model will explain ES production under the conditions of each scenario, with the combination of three other variables:

- Spatial distribution of ES provision related to the multiple stretches of the river and demand sites (e.g., SHPP, IC)
- Temporal organisation of ES provision: monthly, seasonally, annually or by water-year type (dry, normal or wet).
- Comparison among the performance of the different ES, identifying tradeoffs and synergies.

The methodology can be applied for informing to a number of possible management questions. In order to illustrate the potential of this approach, Fig. 26 shows six diagrams representing how the outcomes of the model can help to answer six possible management-related questions in the case of the Ter. For instance, we observe stretch by stretch the ES performance by analysing the outputs of the model using geographic information systems (GIS). In the Lower Ter, the most damaged riverine communities would be those located upstream of Girona city due to the lack of instream flows caused by the concentration of hydropower production (Fig. 26A and Fig. 26B). Fig. 26B shows the SPI related to each SHPP for the 'hydropower' ES, demonstrating that the ECO scenario tends to increase the benefits of these plants, particularly for those located downstream.

By exploring the results month by month, we can aggregate them by season or by water-year type to generate valuable information. So much so that the results show an interesting variation of the SPI for ecosystem preservation between months. This happens particularly for the BAU scenario, in which the flow regime in dry years is seasonally reversed, generating only good conditions in summer and the worst ones in spring (Fig. 26C).

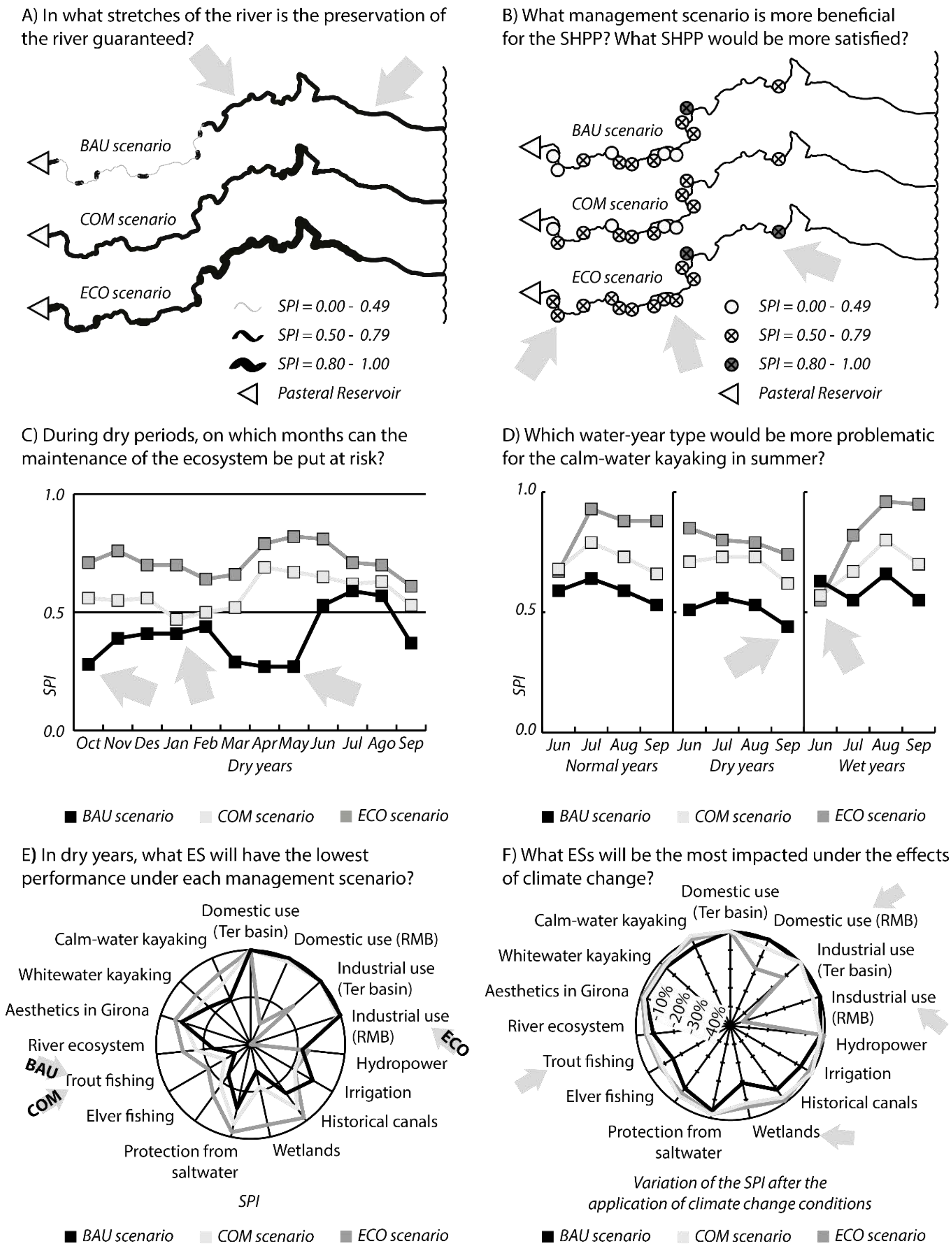


Fig. 26. Outcomes of the ecosystem services model answering specific questions. **A** and **B** show the Service Provision Index (SPI) of particular ES along the river course. **C** and **D** illustrate the SPI over time, in different months and water-year types. **E** and **F** explain tradeoffs among the ES performance in relation to the water management and climate change scenarios. Grey arrows point to the answers of the questions laid out.

Regarding the comparison between water-year types, remarkable enough is that dry years have an impact on calm-water kayaking under the current situation. However, under COM and ECO, the wet years generate an excessive flow that can impair such recreational activity in June (see Fig. 26D) due to high water velocities and the presence of tree branches close to the water level.

Table 17. Service Provision Index obtained from the ES provision model

The impact of climate change is not considered

	Dry years				Normal years				Wet years			
	BAU	NEW	COM	ECO	BAU	NEW	COM	ECO	BAU	NEW	COM	ECO
Domestic uses in Girona	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Domestic uses in the RMB	1.00	1.00	0.96	0.24	1.00	1.00	0.50	0.25	1.00	1.00	0.50	0.39
Industrial uses in Girona	1.00	1.00	1.00	0.61	1.00	1.00	1.00	0.74	1.00	1.00	1.00	0.96
Industrial uses in the RMB	1.00	1.00	0.97	0.00	1.00	1.00	0.81	0.01	1.00	1.00	0.81	0.26
Hydropower production	0.55	0.56	0.56	0.62	0.58	0.61	0.59	0.62	0.62	0.68	0.67	0.64
Irrigation	0.76	0.69	0.54	0.54	0.97	0.96	0.58	0.58	1.00	1.00	0.64	0.64
Preservation of hist. canals	0.64	0.84	0.84	0.96	0.78	0.90	0.88	0.98	0.90	0.96	0.96	1.00
Preservation of wetlands	0.29	0.50	0.46	0.87	0.62	0.73	0.66	0.91	0.84	0.91	0.86	1.00
Protection against salt int.	0.69	0.69	0.86	0.95	0.77	0.75	0.94	0.97	0.86	0.87	0.99	1.00
Elver fishing	0.40	0.42	0.54	0.67	0.56	0.56	0.66	0.78	0.76	0.76	0.83	0.94
Fly fishing	0.19	0.22	0.32	0.52	0.37	0.36	0.43	0.65	0.70	0.69	0.73	0.89
Preservation of the river	0.40	0.44	0.58	0.72	0.53	0.54	0.64	0.78	0.74	0.74	0.80	0.87
Aesthetics of the Onyar	0.77	0.74	0.74	0.84	0.80	0.82	0.79	0.83	0.83	0.94	0.92	0.84
Whitewater kayaking	0.59	0.62	0.68	0.78	0.69	0.69	0.74	0.84	0.85	0.85	0.88	0.95
Calm-water kayaking	0.53	0.59	0.71	0.82	0.57	0.63	0.69	0.73	0.39	0.42	0.44	0.51

Consideration of the impact of climate change

	Dry years				Normal years				Wet years			
	BAU	NEW	COM	ECO	BAU	NEW	COM	ECO	BAU	NEW	COM	ECO
Domestic uses in Girona	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Domestic uses in the RMB	1.00	1.00	0.87	0.19	1.00	1.00	0.48	0.21	1.00	1.00	0.50	0.36
Industrial uses in Girona	1.00	1.00	1.00	0.50	1.00	1.00	1.00	0.65	1.00	1.00	1.00	0.92
Industrial uses in the RMB	1.00	1.00	0.89	0.00	1.00	1.00	0.79	0.00	1.00	1.00	0.81	0.13
Hydropower production	0.54	0.53	0.55	0.61	0.56	0.58	0.57	0.62	0.61	0.68	0.67	0.64
Irrigation	0.66	0.64	0.53	0.52	0.90	0.84	0.58	0.56	1.00	1.00	0.64	0.64
Preservation of hist. canals	0.59	0.81	0.80	0.95	0.69	0.87	0.86	0.97	0.88	0.96	0.93	1.00
Preservation of wetlands	0.21	0.41	0.44	0.75	0.46	0.63	0.60	0.88	0.79	0.88	0.79	0.97
Protection against salt int.	0.68	0.68	0.83	0.89	0.73	0.74	0.92	0.95	0.82	0.84	0.97	1.00
Elver fishing	0.37	0.40	0.51	0.62	0.50	0.52	0.62	0.73	0.71	0.72	0.79	0.90
Fly fishing	0.15	0.21	0.31	0.46	0.29	0.29	0.39	0.60	0.66	0.64	0.67	0.85
Preservation of the river	0.36	0.41	0.55	0.68	0.46	0.48	0.60	0.74	0.70	0.70	0.75	0.84
Aesthetics of the Onyar	0.75	0.69	0.72	0.82	0.78	0.77	0.76	0.83	0.83	0.94	0.92	0.84
Whitewater kayaking	0.57	0.61	0.68	0.75	0.64	0.66	0.72	0.81	0.84	0.83	0.85	0.94
Calm-water kayaking	0.48	0.55	0.68	0.79	0.54	0.62	0.71	0.74	0.39	0.44	0.46	0.53

Finally, comparing the performance among different ES, we identified tradeoffs and synergies. Fig. 26E shows a total synchronisation among those instream flow-dependent ES such as the preservation of the river ecosystem, the protection from saltwater intrusion and both types of fishing. Meanwhile, there are clear tradeoffs between other ES (e.g., the water transfer and the protection of wetlands). In any case, fly-fishing appears as the most damaged ES under the BAU and the COM scenarios, and the industrial use from the water transfer under the ECO scenario. Moreover, climate change particularly affects those ecosystem services less prioritised by each management scenario already mentioned (Fig. 26F). Curiously, the ES provision in COM is barely affected by climate change.

Table 17 shows the complete set of results for dry, normal and wet year types and for all management and climate scenarios. It is possible to observe that the NEW scenario hardly contributes to a more egalitarian management with respect to BAU. Another interesting outcome is that the management of the river is a factor of the SPI more important than the climate change.

6.5.4 Validation of the results

The results of the validation process provide valuable information for improving the model as well as for considering other conditionings affecting the ES provisioning besides the distribution of water flows that the model informs.

As Table 18 shows, participants in the workshop identified basically divergent opinions on the suitability curves elaborated in the previous workshops and on the results that the model obtained.

6.6 DISCUSSION: HOW IS THE MODEL HELPFUL FOR DEALING WITH WATER CONFLICTS?

6.6.1 The model and conflicts in the Lower Ter

Water management decisions have historically emphasised the production of ecosystem services that depend on regulated flows hence on the construction of extensive infrastructure. Such decisions have typically imposed tradeoffs that reduce benefits from “free-flowing services” (Auerbach et al., 2014). To understand how tradeoffs among ES can evolve into social conflicts, we address some questions here. What is the magnitude of such tradeoffs? To what extent are the multiple stakeholder types satisfied with a specific level of ES provision?

As seen in the previous sections, assessing the ES performance helps to answer these questions. Doing so by using modelling helps to focus on specific time periods and stretches of the river, as well as on multiple hypothetical water management or climatic scenarios. We contrasted the outcomes from our ES provision model with tensions between water users observed during the fieldwork throughout the Lower Ter sub-basin.

Table 18. Type of emendations made during the validation workshop

Emendations	Examples
The participants do not agree with the results because…	
The restrictions of supply were not considered	▪ Water supply for domestic, industrial and irrigation suffer restrictions when there is a drought, not considered in the model. ▪ There were also legal constraints for producing hydroelectricity during the droughts of 2005/2006 and 2007/2008.
There are other factors beyond those considered for the modelling exercise	▪ Wetlands and historical canals depend especially on the irrigation management rather than the availability of water in a certain month. The presence of walls along the river also avoids the wetlands to receive water from floods and the piping of the canals also stopped irrigators from taking care about the historical ones. ▪ The stop of the saltwater intrusion is highly dependent of the groundwater extraction, rather than the instream flow of the Ter. ▪ Calm-water kayaking could be done downstream from Girona. But, as the most of the instream flow comes from the STP, the water quality is not suitable.
Participants have a different view on what a *dry year* means	▪ Participants usually put a very low value for dry years because they consider them as drought periods, what is not always like this.
The model does not consider illegalities	▪ Hydropower facilities usually take more water than what is allowed, so kayakers usually perceived that the conditions of the river are worse than what the model expects.
The participants do not agree with the suitability curves because…	
Each beneficiary see their curve in a different way	▪ A current citizen and a businessman of a water distribution company would draw differently the suitability curve for domestic uses.
There are subtypes of ES with different requirements	▪ The free-style kayaking requires much less water than the rafting.
The shape of the curve does not fit their thoughts	▪ For domestic water supply, the curve should be exponential instead of linear. This is because. ▪ The shape is hardly correct, but difficult to imagine another way to calculate the provision of water for the wetlands maintenance too.
They were more demanding than what we considered	▪ According to the irrigators, those flows established in the zonal plan are lower than those that provide a minimum benefit, since to be implemented they should spend in new infrastructure. ▪ For the historical canals, the flows provided by the study of Quintana (2010) offers the minimum level of benefit instead of the optimal level, which should be the historical flow according to the participants. ▪ There was also a discussion on the maintenance flows proposed in the PSCM. Some of the participants think that the instream flow level in that plan is below than the minimum level of service provisioning.

Both expected and unexpected results appeared around three core elements concerning ES provision: spatial distribution, temporal distribution and tradeoffs/synergies.

Spatial distribution of ES provision. Ecological distribution conflicts about dams and water policy pit some regions against others (Selby and Hoffmann, 2011; World Commission on Dams, 2000), and different interests and values are brought into play (Martinez-Alier et al., 2010). Through the model, we observe that water withdrawals for domestic, industrial and irrigation purposes alter the flow regime along the whole length of the Lower Ter, while continuous diversions for hydropower are placed only in the upper stretches. This is similar to what happens in Himachal Pradesh (India), where the tensions around hydropower are consequence of the cumulative effects of multiple projects rather than a response to a particular one (Baker, 2014). Consequently, there are real difficulties for accomplishing goals of socially accepted e-flows, especially where there is this cumulative water extraction.

The stretch where the Ter flows through Girona city is where the uses compete the most. Besides hydropower and irrigated land, the river is so frequented by anglers and other recreational users (particularly runners and cyclers), who actually benefit from the preservation of the waterscape. Despite this rivalry, some stakeholders are suggesting that the resolution of the challenges in this stretch could be applied for responsible management and then be exported to the whole river basin.

Temporal organisation of ES provision. Regarding the seasonal distribution of inter-stakeholder tensions, some not-so-obvious facts occur due to inter- and intra-annual variation of ES production, and even due to a combination of both. An excessive water flow in wet springs can be damaging, e.g., for the calm-water kayaking. However, in dry years, when the share of the resource is low – as it happened in 2008 (Martin-Ortega et al., 2012) –, the instream uses are more impaired, precisely in spring, when the instream flows are low – because of efforts to save water for the summer – and ecological requirements are high. In summer, irrigation demands force the dams to discharge a high amount of water, subsequently reversing the flow regime. This has a synergistic impact on kayaking, but negative effects on the preservation of the ecosystem.

Temporal distribution of outcomes also contributes to a better management. Since there is an excess of water in the summer, and a lack of it in the spring, an increase of water extraction by SHPP in summer, linked to a reduction in spring, could be a solution, as the watershed administrator proposes in the COM scenario.

Tradeoffs and synergies among ES performances do not always occur as expected. From our model, whitewater kayaking may seem to be particularly synergistic with the ecosystem preservation and fishing practices because of their similarity regarding instream flow requirements (riffles and rapids). However, the spatial coincidence of both activities makes them rival for the use of the same areas (i.e. while boats may scare fish when they pass, kayakers sometimes complain about the litter abandoned by anglers).

Regarding consumptive uses, the bulk of water from the Ter is diverted to satisfy water needs in the RMB, creating a major impact on the provision of all the other ES. But it should be also recognised that the flow used to produce hydroelectricity is by no means negligible. However, in two management scenarios (COM and ECO) the prioritisation of intra-basin uses compensates for the obligation of discharging an e-flow. Therefore, hydropower producers should not fear the requirement of e-flows when accompanied by the reduction of the water transfer to the RMB. An exception would be a scenario under the climate predictions of Bangash et al. (2013), which entails a decrease of between 5 and 43% of the total hydropower production.

In any case, comparing different ES among them does not mean that they have the same level of importance: we suppose that drinking water supply will be always more preferential than fishing. Measuring this level of importance is not our objective here and can be easily analysed by other techniques, e.g., a sociocultural valuation (Maestre-Andrés et al., 2015).

6.6.2 Strengths and weaknesses

Modelling the biophysical underpinning of ES provision

Modelling exercises are said to effectively represent complex interactions and adapt to new situations (Jakeman and Letcher, 2003; Volk, 2013), as our model attempts with new management or climate scenarios. Then, we can easily readjusted our model if, for instance, new parameters of e-flows are included in the regulatory framework for the basin. In turn, GIS applied to the modelling outcomes (i.e. ES provision) is found to be indispensable for visualising their spatial distribution in relation to the variety of physical and social contexts, as seen in Sherrouse et al. (2011) and in Villamagna et al. (2014). Additionally, models may provide a neutral atmosphere for discussing political disputes due to water scarcity, growing consumption and non-equitable distribution of resources (Gaddis et al., 2010; Homer-Dixon, 1994).

Our approach, based on the notion of 'ecosystem services', seeks the intersection point between the biophysical functioning of the Ter River and the well-being of the population that benefits from it. By modelling, we put numbers on these interactions. Thus, it is possible to visualise the mechanism through which some management policies can deliver an unequal distribution of benefits. This helps to understand social tensions that arise from water management decisions as much as they do from the competition for the water flows – for providing different ES.

Moreover, the use of suitability curves that links water flows and ES provision basing on stakeholders' preferences makes the evaluation process more straightforward – because the curves are easily constructed – hence enables including multiple ES for a broader assessment. Suitability curves are particularly useful for those ES whose production do not continuously increase in relation to the water flow.

However, several limitation of the methodology must be acknowledged. Modelling is a simplification process. Thus, the exercise for this case has inevitably reduced the multiple hydrological alterations and ES identified by in **Chapter 5**. Here only monthly variations are considered and a reduced number of ES has been evaluated. Alterations occurring on a smaller scale are invisible to the model (e.g., rapid increases of the river stage to empty the reservoirs and prevent floods that may put recreationists in danger; exceptional days with zero flow that drastically alter fish populations). Some of them, such as exceptional floods, might damage infrastructure and impede the benefit production in a medium term.

Besides, dams and weirs generate other impacts on river ecosystems as well as on the ES provided by free-flowing rivers. Dams are weirs are barriers for fish migration (Larinier, 2001); they impede the sediment moving downstream, hence cause riverbed incision and the decrease of the aquifer level (Kondolf, 1997); and they change the habitat upstream where the water is dammed, so the lotic and exotic species take over from the lentic and native ones (Aparicio et al., 2000; Moyle and Mount, 2007).

The consideration of all these factors can imply a very complex and time-consuming exercise. It is even sometimes the lack of data what produces this lack of completeness (e.g., the impossibility of creating a suitability curve for the aesthetic view of the Ter River). Then, the outcome of this model has to be taken as a helpful insight for a broader analysis rather than a solution itself. In the same way, further assessments should determine the specific application of any ES provision model instead of seeking for a broad but ambiguous goal.

Participatory framework for ES provision modelling

The contribution of stakeholders is so central to this assessment in order to consider the dynamics of social factors at the same level of importance as the technical ones (Gaddis et al., 2010). This leads us to emphasise that environmental and economic sustainability are not the only factors essential for water management. The question of what social sustainability means for communities living off of rivers should also be addressed (Andre, 2012).

As already disclosed by Hirsch et al. (2011) and Whitfield and Reed (2012), gathering relevant information from the variety of local views, and acknowledging that some benefits are generated because somewhere else the river is providing ES, avoids the oversimplification of likely tradeoffs and can create potential for cooperative management decisions, giving room for socially accepted policies. Therefore, modelling studies should incorporate stakeholders not only for participating in the validation of outputs but for being a part of an adaptive feedback together with researchers (Jakeman and Letcher, 2003).

In particular, this study contributes to the state-of-the-art of stakeholder-based modelling of water ecosystem services in four ways. First, interviews with locals from different policy cultures (academy, administration, companies and the general public) for identifying and selecting ES helped to determine the socio-cultural factors behind conflicts that, as Robbins (2012) warned, escalate when certain actors are ignored or marginalised. This is the case of those environmentalists defending the preservation of the historical canals. Second, calculating the SPI as a representation of the satisfaction level of different stakeholders – instead of accounting for 'objective' KWh or m^3/s – homogenises the resulting value and puts all ES beneficiaries on the same level for an equal comparison to identify unequal distribution of the resource.Third, the participatory mapping identified conditions other than water flows (e.g., biophysical, infrastructural, legal) that delimit the spatial distribution of the ES performance (Videira et al., 2009). Some examples would be: 1) infrastructural elements, such as river walls along the paths, which can become distressing for those people who enjoy the ES from the riverbanks; 2) legal factors, such as the prohibition of kayaking when and where the waterfowl are breeding; and 3) mismanagement, such as the negligence of the river, since events like the dumping of debris may damage the turbines if there are high flows dragging it downstream. Finally, as Swetnam et al. (2011) and van Delden et al. (2007) indicate, the inclusion of stakeholders in the scenario-building processes made the spatial models helpful for providing policy relevant information.

These four ways of contribution provide novel elements that, however, may generate their own complexities and uncertainties. For instance, the results of the participatory process can be related to representativeness issues, that is, an excessive trust on the expertise of selected participants, although the selection process was as thorough as possible. This is a limitation of our methodology that requires transparency and social validation in order to obtain applicable outcomes.

6.6.3 Beyond modelling ecosystem services

At a different level of discussion, the political forces related to water management need to be considered beyond the biophysical contribution to the ES provisioning. Environmental activists in the Ter River basin do not only demand concrete management manoeuvres in specific river stretches, they also fight to avoid the privatisation of the public company that transfers water from the Pasteral reservoir to the RMB, and to make the hydropower producers pay taxes in accordance with the damage they cause to the river. As Andre (2012) and Sorg et al. (2014) indicate, institutional solutions are often recommended for addressing social stability beyond technical measures for environmental and economic purposes.

In the Ter basin, there are divergent political profiles among the people struggling for better water management. They all scrupulously share a defence of the implementation of e-flows and the reduction of the water transfer to the RMB. However, two opposite views compete for leadership of the opposition to the BAU scenario. On the one hand, some groups are totally against any water transfer, hence they struggle to remove them, recognising that an extra effort should be made in order to reduce the industrial consumption of water in the RMB and to improve its own water quality. On the other hand, other actors would be content with the enforcement of the PSCM (ACA, 2005) – and therefore with a certain level of water transfer to the RMB – but they support the idea of shared pressure among all the river basins. Hence, they would not object to a network of inter-basin water connections – also known as 'water bank'. Facing such different views regarding water management, it is unavoidable that tensions appear; and an ES provision model cannot help here.

Chapter 7

Power and the access to water flows through the history of the Ter management (1950-2015)

7.1 INTRODUCTION

The hydro-social cycle[12] of the Ter River basin was independent from the hydro-social cycle of Barcelona until 1966 (March, 2015), when the water transfer started its operation. Since then, the dependence of the city metabolism on the Ter's waters is total, but also the dependence of the intra-basin uses on the water demand in the metropolitan Barcelona. Struggles against the over-exploitation of the river has become recurrent, particularly during drought events (Ruhí, 2012). This has subsequently led to a major conflict related to the water transfer. But other tensions among local stakeholders have also appeared in competition for the leftovers, as we will see in the second part of this chapter.

Alternatives for a reduction of the water transfer and the implementation of the e-flows, as the compatibility-of-uses (COM) and ecosystem-priority (ECO) scenarios mentioned in **Chapter 6**, have been promoted by some groups of actors. Any alternative eventually requires measures to redirect the water guarantee of the RMB supply to other sources. In face of this, opposite views on the strategy and on other objectives (e.g., the public management of the Ter transfer) emerge and clash with one another. This is what the results from the survey performed among non-for-profit organisations also show (**in Appendix A**).

Water conflicts usually appear as a clash of interests (Martínez-Alier, 2002) and under the approach adopted in this dissertation we connect such interests to water flow-related ES. As argued in previous chapters, tradeoffs alone cannot explain the actual occurrence of conflict, so political forces related to water management need to be considered.

Then, which are these political forces and how are they related to ES? Are there social power relationships in water management decisions hiding interests beyond water management? Some studies on the political ecology of water conflicts in Catalonia point in

[12] Linton and Budds (2014) define the hydrological cycle as "the socio-natural process by which water and society make and remake each other over space and time".

that direction. For instance, March (2015) explains how some forecasting studies presented a dreadful water future for urban Barcelona, thus legitimising the Ebro transfer. Otero et al. (2011) shows that the water management policy in a small rural village was employed as a smokescreen for urban speculation.

Any environmental conflict uncovers ecological inequity and social injustice (Armiero, 2008). In the Ter River basin, an exploration of the conflicts over water flow management could unveil unbalanced access to water flows for the provisioning of some services at the expense of others. Following Ribot and Peluso (2003), access is understood in this context as the bundles and webs of power that enable different intra-basin and extra-basin actors to benefit from the water flows of the Ter River. Understanding access to water flows and the ensuing ecosystem services help to identify water conflicts.

While the interviews in **Chapter 5** has proven helpful to identify socio-economic benefits and the modelling approach in **Chapter 6** to analyse their distribution, now the purpose is to understand how and why society-nature relations have changed over time and space. This type of critical historical approach strengthens a political ecology analysis by enquiring how power relations, and their representation, application, and the ways these have spread, changed and been internalised under global capitalism (Davis, 2015, 2009). Note that the role of environmental knowledge production itself in this process is also interrogated, and here the role of ES-based approaches also come under scrutiny.

With this in mind, the specific objective of this chapter is to study the political ecology of the water flows in the Ter River since the year when the water transfer to Barcelona was seriously proposed (1950). We use a critical historical perspective for understanding: 1) which water flow-dependent ES have been promoted and which ones have been ignored or even suppressed; 2) what actors, and through which actions for either implementing policies or for resisting them, have defended certain ES over others; and 3) through which mechanisms has the power been exerted in order to gain, control and maintain access to water flows.

Thus, this chapter conducts a critical historical research that, by combining quantitative and qualitative data, bridges the social and ecological aspects necessarily involved in a political ecology analysis (Walker, 2005; Zimmerer and Basset, 2003). This is done by tracking over time and space those natural and social events that help to understand where, how and in what manner environmental conflict articulates (Guha and Martínez-Alier, 2013). On the basis of a chronology of the major water flow-related conflicts in the area, we scrutinise the ES provision through the different actors and institutions, and we try to understand how they use power for gaining, controlling and maintain access to the water flows.

7.2 METHODS

Our methodology encompasses three steps. First, we build an overview of the Ter *problematique* regarding the conflicts over management of water flows from secondary sources of information (e.g., books, news, etc.). Second, we gather some primary data, a combination of qualitative and quantitative data that enhances the integrity of findings by providing numbers and arguments (Bryman, 2008, p. 609), which also help to reconnect social and biophysical sciences. Third, we analyse the available information in a way that the qualitative data helps to discover sources of conflict (related to ES, actors and power actions) and the quantitative data allows to confirm the hypotheses settled down.

7.2.1 Overview of conflicts

In order to gain the overview, the types of sources consulted were both books (Aigües de Barcelona, 1991; Ballestar Dot, 2012; Gaya, 2014; Sanmartín et al., 2003) and scientific journal papers (Bardina et al., 2016; March and Saurí, 2013; March, 2015; Pavón, 2007).

These sources were useful to identify important events that, as turning points, determined either the way of managing water flows and/or the dominant discourses regarding water policy (Fig. 27 shows the political context of these events). Such events facilitated the demarcation of different time periods that, along this chapter, are used to place the conflicts and conflictive episodes in. These turning point events are:

- 1950: The *Confederación Hidrográfica del Pirineo Oriental* (Hydrographic Confederation of the Oriental Pyrenees, CHPO) requests a draft for the water supply to the metropolitan area of Barcelona with water from the Ter River.
- 1966: The water transfer from the Ter River to Barcelona becomes operational.
- 1985: The Water Law in Spain is approved and the authority and responsibility on water is transferred to the Catalan government.
- 1998: The Catalan Water Agency is created soon after the formal approval of the Water Framework Directive (2000).
- 2008: There is a severe drought that affects the supply of Barcelona. Likewise, the global economic crisis starts in Spain.

The Spanish transition to democracy (1975-1978) was also a milestone. In terms of water management it did not mean a great change. However, the institutions in charge of the water administration became elected democratically since then, and the recognition of the freedom of assembly, association and expression allowed to generate public discussion on water flow management. Because of the radical change between the dictatorship and the democratic times, we selected different sources (see **Section 7.2.2**) that were particularly appropriate for each specific period. For instance, in order to obtain data from the dictatorial period, we preferred the archives, while newspapers are more reliable sources of data during the democracy.

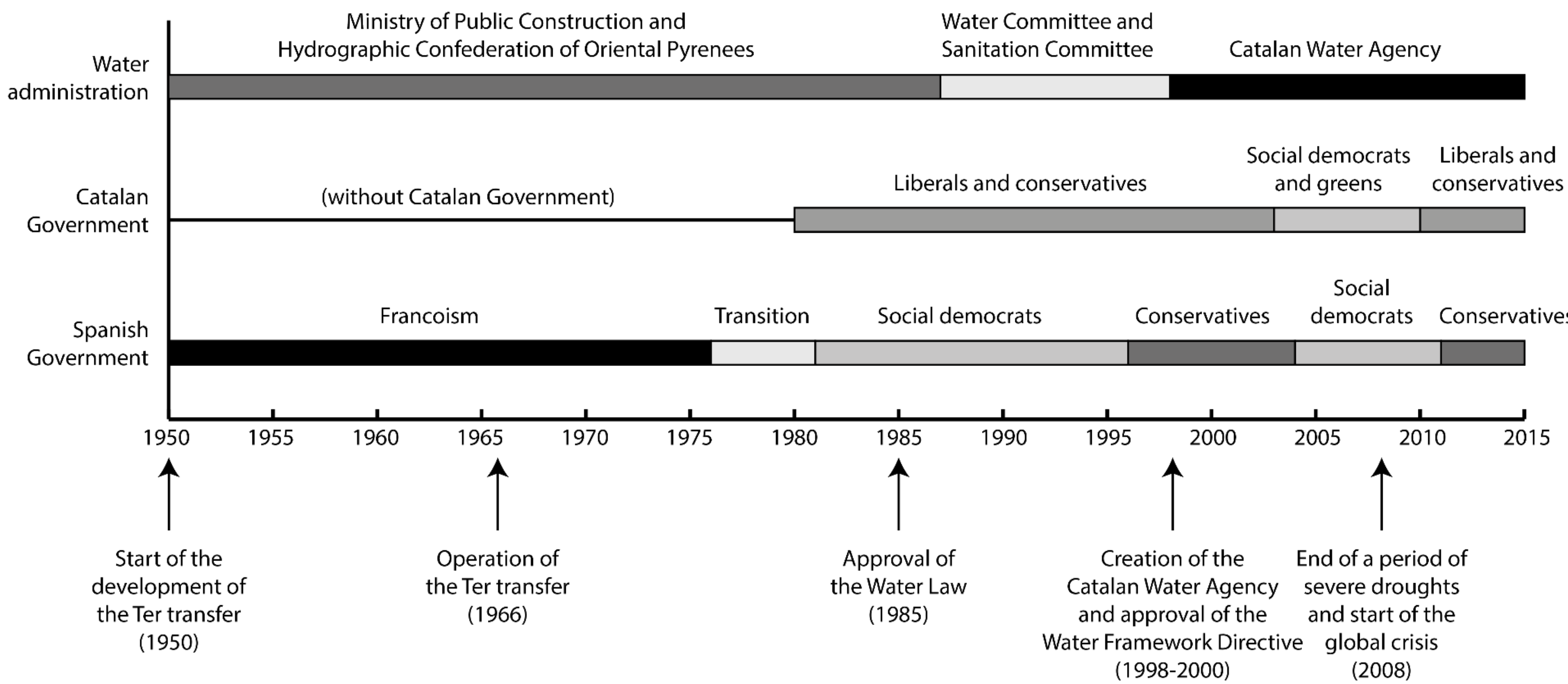


Fig. 27. Time periods selected for this study in relation to political periods

7.2.2 Data sources and organisation

Qualitative data

On the basis of the overview, we scrutinised primary sources for gathering the qualitative data. As Watts alerts (2013; in Davis, 2015), a wholesale dependence on archival sources may distort results. For this reason, we supplemented our sources with oral history, especially for those actors that hardly had voice in some periods under analysis. As a result of this process, the list of consulted sources is as follows:

- **Official gazettes:** *Boletín Oficial del Estado* (of the Spanish Parliament, BOE) and *Diari Oficial de la Generalitat de Catalunya* (of the Catalan Parliament, DOGC), to obtain legal documents of that regulation that has influenced the water flow management.
- **Historical archives:** *Arxiu Històric de Girona* (Historical Archive of Girona, AHG) and *Arxiu Comarcal d'Osona* (Archive of Osona County, ACOS), to look for projects, newspaper cuttings, official letters, etc.
- **Newspaper libraries:** a news compilation from the ACA and the library of La Vanguardia, the most read newspaper in both Francoist and democratic regimes in Catalonia[13].
- **Analogical and digital archives from non-profit organisations and audio files from the interviews with:** *Grup de Defensa del Ter* (Advocacy Group for the Ter, GDT), *Aigua és Vida* (Water is Life, AeV), *Associació de Naturalistes de Girona* (Naturalists Association of Girona, ANG), *Gent del Ter* (People from the Ter), *Associació per a l'Estudi i la Millora dels Salmònics-Rius amb Vida* (Association for the Study and the Improvement of the Salmonidae-Rivers with Life, AEMS) and the *Federació Catalana de Pesca Esportiva i Càsting* (Catalan Casting and Sport Fishing Federation, FCPEC).

We introduced each document gathered (i.e. text files, pictures, audio, etc.) in Atlas.ti software. We reread all documents, selected relevant quotations for the research and coded them according to the type of information they provide. We also grouped codes and documents into families and these in super-families (See Table 19).

Atlas.ti is a special workbench for qualitative analysis that helps to articulate concepts and give responses to some specific questions. This can be done by searching specific quotations that relate different codes (only if they have been codified using more than one code). For instance, news of a demonstration can be coded with the following codes: '*Plataforma del Ter*' (Ter Platform), 'lack of flow', 'reduction of the Ter transfer', 'demonstration', 'irrigators' and 'environmentalists'. Thus, we can use Boolean operators

[13]La Vanguardia is a newspaper edited in Barcelona, with a daily circulation of above 230,000 copies and ca daily 800,000 readers. Among the paid-for newspapers, it is usually the most read in Catalonia and the third most read in Spain. http://www.grupogodo.net/institucional/historia/index.html

(AND, OR and NOT) to find specific quotations that help to answer different questions. For example, for the question “is there any report against hydropower companies for having left the river completely drained?” we could make a search of: (REPORT OR FINE OR RESOLUTION) AND (WEIR OR HYDROPOWER) AND NO_WATER. Furthermore, we can filter the search by type of documents: e.g., by news, by documents from the dictatorship period or by documents provided by the GDT. In short, Atlas.ti does not respond to any research question, but it arranges the information in order to facilitate the search of answers.

Along the description of the results (**Sections 7.3 and 7.4**), all cited historical references are numbered in brackets and described in **Appendix E**.

Quantitative data

The historic record of water flows provided by the ACA and the supplier consortiums of Girona and the Costa Brava was collected. In particular, the types of water-flow data include instream flows, water withdrawals, and reservoirs inflows and outflows (see Table 20).

Table 19. Families of documents and codes used for organising the qualitative data.

Codification of documents	
Source	BOE; DOGC; AHG; ACOS; GDT; AeV; ANG; AEMS and FCPEC.
Type of document	Agreement; minutes; allegations; announcement; op-ed articles; letter; communicate; decree; interview; study; project; parliamentary working document; law; book; instructional materials; news; order; plan; royal decree; publicity; report; resolution; vignette.
Author	Institutions (ACA; Campdevànol Council; *Consorci Alba-Ter*; Provincial Council of Girona; Catalan government); political parties (ICV-EUiA; PSC); non-for-profit organisations (*Assamblea d'Entitats Ecologistes de Catalunya*; AeV; ANG; *Agrupació de Societats de Pescadors d'Osona*; *Ecologistes en Acció;* POT; *Projecte Rius*; FCPEC; GDT); companies and their organisations (*Aguas Potables San Feliu;* COCIG; *Consorci Costa Brava*; SGAB-Agbar); unions; and newspapers (*Ausona*; *Diari de Girona*; *Diario de Barcelona*; *El 9 Nou*; *El Alcázar*; *El Correo Catalán*; *El Economista*; *El País*; *El Periódico*; *El Punt Avui*; *La Marxa*; *La Vanguardia*; *Los Sitios*; *Revista Electricidade*; *Setmanari de l'Alt Empordà*; *Solidaridad Nacional*; *TeleXprés*).
Monthly dates of publication	Specific months with available data from “March 1950” to “October 2015”.
Codification of quotations	
River course	Ter; Rhône; Ebro; Llobregat; Besòs; Fluvià; and Muga.
State of the flow	Ecological flow; excess of flow; flow damming; flow diversion; flow recuperation; flow variability; insufficient flow; no flow; sanitary flow; sudden changes in water flow; water flow approved by contract.
Ecosystem services	Aquiculture; protection from saltwater intrusion; sanitary flows; kayaking; water purification; environmental education; bottling; skiing; aesthetics and landscape; golf; farming; conservation of the river ecosystem; of the riparian forest and of the beaches; boating; Onyar river in Girona; architectonic heritage; fishing; hydropower production; sea production; historical canals; aquifers recuperation; irrigation; domestic supply to the RMB; Barcelona city; Girona city; Costa Brava and to other town; tourism.

River management	
Infrastructure	Canalisations and derivations; Ter-Llobregat network; desalination plans; dams and reservoirs; gauging station; sewage treatment plant; weir; Ter transfer.
Planning	*Aigua per Unir*; alternative; increase of the demand; self-sufficiency; water bank; infiltration ponds; water consumption; dam removal; decontamination of aquifers; water saving; drought management; obsolete infrastructure; interconnection of networks; improvement of the canals; water demand; new water culture; new sources of water; expansion of irrigated land; comprehensive plan for Catalonia; zonal plans for the implementation of e-flows; recuperation of aquifers; recuperation of water flows; redistribution of water; pipe reparation; water restrictions; return to donor basins; water reuse; sovereignty; sustainability; water transfers; tanker vessels; protected areas.
Regulations and programmes	*Aigües* Vives; *Compromís del Ter*; drought decrees; Water Framework Directive; Water Law; Fishing Law; Management Plan; PSCM.
Economy	Water banks; economic benefit; economic compensation; cost of water management; economic cost; energetic cost; social cost; crisis; de-growth; economic development; European funding; commons; employment; water price; private use; tax.
Actors	
Public institutions	ACA; authority agents; Barcelona Council; Girona Council; other councils from municipalities and provinces of the Ter River basin; Metropolitan Area of Barcelona; ATLL; CHPO; Department of the Environment; Catalan government; Spanish government; *Junta d'Aigües*; *Ministerio de Obras Públicas*; Catalan Parliament; European Parliament; European Commission.
Public and private consortiums and committees	*Aigües de Girona*; *Salt i Sarrià de Ter*; *Consorci d'Aigües de Tarragona*; *Ter-Llobregat Discharge Commission*; *Consorci Costa Brava*; *Consell per a l'Ús Sostenible de l'Aigua*; *Junta Administrativa del Nuevo Abastecimiento de Barcelona*.
Companies and their organisations	Acciona; *Asociación de Productores de Energías Renovables*; *Associació de Productors i Usuaris d'Energia Elèctrica*; *Associació d'Empresaris de l'Estartit i Illes Medes*; *Cambra Agraria de Girona*; *Junta Central d'Usuaris d'Aigües Superficials i Subterrànies del Baix Ter*; COCIG; *Cercle d'Economia*; bottling industry; irrigation communities; other industries; banks; Endesa; hydropower producers; *Hidroeléctrica de Cataluña; S.A.*; SGAB-Agbar; tourism sector; and unions.
Non-for-profit organisations	AEMS; AeV; ANG; AEEC; Ateneu; *Confederació de Federacions d'Associacions de Catalunya*; *Ecologistes en Acció*; FCPEC; GDT; GEDENA; *Gent del Ter*; Greenpeace; *Plataforma del Ter*; POT; *Xarxa per una Nova Cultura de l'Aigua*; fishermen.
Political parties	CiU; PSC; ERC; PP; ICV-EUiA.
Power	
Exercises of power	Abuse; bribe to activists; data control; to rush; to remove expression forms; expropriation; expulsion; lack of information; lack of representation; lack of transparency; contempt; review of projects in the summer break; injustice; irregularity; lobbying; preferences of use; privatisation; advertisement; sanction; judgement; administrative silence; shady political interests; use of emergencies; use of certain vocabulary.
Forms of resistance	Ludic-claiming action; allegation; conference; report; dissemination in the street; literary writing; technical study or project; manifesto; demonstration; motion; graffiti; op-ed article; legislative proposal; verbal violence; signature campaign.
State and action of actors	Agreeing; alarming; being happy; threatening; arguing; accepting; committing; checking; trusting; criticising; declaring; stating; demanding; reporting; illustrating; imposing; improvising; unfulfilling; informing; opining; alerting; proposing; giving up; calming down; chatting.

Note: Codes in italics are in Catalan or Spanish. All acronyms are in the Acronyms and abbreviations Section.

Quantitative data is then associated to qualitative data using dates as connecting links. So different events occurred in a certain month (e.g., the approval of laws, a water restrictions period, a demonstration, an opinion article in the newspaper, etc.) are linked to data of water flows. This allows us to see the influence of water flows on certain political events, and vice versa.

Table 20. List of the quantitative data gathered.

Type of data	Available moths
Flows through the gauging station in Sant Joan	October 1974 – September 2015 (3 missing)
Flows through the gauging station in Ripoll	January 1950 – September 2015 (17 missing)
Flows through the gauging station in Roda de Ter	October 1950 – April 201 (36 missing)
Flows through the gauging station in Pasteral	July 2002 – September 2015 (33 missing)
Flows through the gauging station in Girona	October 1985 – September 2015 (48 missing)
Flows through the gauging station in Torroella	January 2006 – September 2015 (0 missing)
Inflows and outflows of Sau and Susqueda	January 2003 – December 2014 (0 missing)
Water withdrawal to Girona and Costa Brava	July 2001 – December 2014 (0 missing)
Water withdrawal to Barcelona and surroundings	February 1996 – December 2014 (0 missing)
Water withdrawal to the main irrigation communities	January 2006 – December 2014 (0 missing)

Note: all data is obtained monthly. Source: ACA.

7.2.3 Analytic procedures

We start the analysis by developing a chronological description of those conflicts related to water flows throughout the Ter River basin. This helps us to tell the history of the Ter River through the five periods defined above (**Section 7.3**).

Similarly as was done in Environmental Justice Organisations, Liabilities and Trade (EJOLT) Project (EJAtlas, 2016), we characterise the top five conflicts for illustrating the different patterns of social tensions. Thus, we described the project that originated the conflict, its promoters and the resistances represented in order to focus our data search in primary sources later on.

Then, we analyse the forms of access to water flows by which different actors benefit through the ensuing ecosystem services (**Section 7.4**). This is done in three steps. First, we interpret the provision of the ES from a historical perspective. Second, we analyse actors and institutions and map them in an interest-influence matrix (Reed et al., 2009). Third, we scrutinise different paths of power that actors have employed for either gaining, controlling or maintaining a particular model of water management that give them access to different ecosystem services (Ribot and Peluso, 2003).

In relation to the second step, the development of an interest-influence matrix, the procedure involved two different assessments. On the one hand, we evaluated the level of encompassing interest (sensu Olson, 1982)[14] by summing different scores per category of ES (see an example in Table 21) for each actor (either a public institution, a company or a

[14] According to Olson (Olson, 1982), "*encompassing organisations have some incentive to make the society in which they operate more prosperous, and an incentive to redistribute income to their members with as little excess burden as possible, and to cease such redistribution unless the amount redistributed is substantial in relation to the social cost of the redistribution*".

for-non-profit organisation). For instance, hydropower producers are highly interested in just provisioning services, and fishermen are interested in both provisioning and cultural services. Meanwhile, the ACA is quite interested in several ES. On the other hand, the influence of the actors was assessed in relation to their opportunities to use right-based sources of access, i.e. legal or illegal, and different mechanisms of access listed by Ribot and Peluso (2003), i.e. technology, capital, markets, labour, knowledge, authority, identities and social relations. The rating from 0 to 3 was done based on the size of the organisation and on the ability of using these mechanisms perceived from the qualitative data.

The sum of the rating per instrument and source makes the total influence per actor; and the maximum among actors of the same type provides the total influence per sector (e.g., environmentalists, water distributors). The levels of interest and influence change between the dictatorial and the democratic periods.

Finally, we plotted the values obtained for both types of assessments, distinguishing four different sectors. The original distinction made by Reed et al. (2009) of ‘crowd’, ‘subjects’, ‘context setters’ and ‘key players’ has been here modified to ‘gang’, ‘well-intended crowd’, ‘flow shapers’ and ‘great benefactors’. This classification and the analysis of power mechanisms introduced in **Section 7.4** is the base for the chapter discussion presented in **Section 7.5**.

Table 21. Example for the calculation of interest and influence for the matrix.

	Example of calculation		
	Actor 1	Actor 2	Total sector
Ecosystem services as interests			
Regulation	3	2	3
Supporting	2	1	2
Provisioning	2	3	3
Cultural	1	1	1
TOTAL			9
Access as influence			
Rights-based access			
Legal	2	2	
Illegal	1	1	
Structural and relational access mechanisms			
Technology	3	2	
Capital	2	1	
Markets	0	0	
Labour	2	2	
Knowledge	2	3	
Authority	3	3	
Identities	0	1	
Social relations	3	2	
TOTAL	18	17	18

The score is 0-3 depending on the degree of interest an actor shows toward different types of ecosystem services and on the degree of influence they have for legally or illegally accessing to the management of water flows and for using certain mechanisms of power.

7.3 CHRONOLOGICAL DESCRIPTION OF MULTIPLE CONFLICTS

Historically, the management of rivers has triggered multiple fights for the control of water flows and the access to their associated benefits, also in the Ter River basin (Buxeda, 2011). However, 1950 marked a hinge in the history of the hydro-social cycle of the Ter River through a new dimension of conflict: the tensions between intra- and inter- basin uses. Since the 19th century, several attempts had already been made to bring the Ter's waters to Barcelona. In 1896, for instance, the capital of Catalonia issued a public tender in order to assess different options. One of the proposals was to build four little reservoirs in the Ter River basin (Duran, 1897).

Regardless of the manoeuvres for taking water from the Ter, the construction of the Sau reservoir was projected since the Second Spanish Republic (Cruañas, n.d.). In 1949 the works for placing a new dam in the core of the Guilleries massif started with no signs of opposition (Boadas et al., 1987; Pladevall and Viñolas, 2009). According to some voices from the territory, one of the most beautiful landscapes in Catalonia was destroyed, but, as a result, Sau "*avoided a waste of a lot of cubic hectometres of water* […] *to favour the country's progress*" [1].

Nevertheless, the public opinion of the inhabitants of the Lower Ter dramatically changed in 1950, as the purposes of constructing the Sau dam also changed. The agreement for initiating the development of the preliminary project of the Ter transfer, which also included the construction of an extra dam (i.e. Susqueda), would represent for some opinion-generating actors an unacceptable decision, a swindle and an injustice [2,3].

1950-1966. Mistrust during the planning and construction of the Ter transfer

In November 1958, the Ministry of Public Construction (*Ministerio de Obras Públicas*, MOP) approves by decree the final project for transferring water from the Ter River to Barcelona city and its area of influence [4] (see Fig. 28 for a graphical timeline). In 1959, the Francoist Cortes confirmed the decree with the force of law through the called Ter Law. It explicitly prioritised intra-provincial uses (3 m^3/s for instream uses, basically for hydropower and sanitary flows [5], 1 m^3/s for the supply of Girona city and the Costa Brava, and the amount of flow required to fulfil the irrigation needs), above a maximum of 8 m^3/s to supply the RMB. However, the process to achieve the approved proposal was not easy and the opposition to the project was almost unanimous in the province.

After the initiative for studying the Ter transfer in 1950 [6], the *Cámara Oficial de Comercio e Industria de Girona* (Official Chamber of Commerce and Industry of Girona, COCIG) became the staunchest actor against the project [7]. Their main argument was that there was not water surplus in Girona province. All water from the Ter was necessary for the economic development of the province. Thus, the water transfer would bring the outmigration of the local industry, would have a severe effect on the irrigated agriculture, and would be an obstacle for the tourism development of the Costa Brava.

Besides the document of opposition written by the COCIG, more than 350 written complaints were sent by the town councils, farmer unions, among others (Pavón, 2007). The most elaborated one was the assessment made by the Provincial Council of Girona. Their position was that the Ter transfer would impede to irrigate 62.950 ha of the irrigable land estimated in Girona. Moreover, the Provincial Council argued that the transfer would hinder the contracts of the small hydropower producers. Thus, as a solution for the supply of Barcelona, they proposed to further exploit the Llobregat River (in those days the main source) and, in case of further necessity, to transfer the Ebro River's waters.

That proposal was not as far off the claims of different institutions from Barcelona that also opposed to the MOP project. The *Sociedad General de Aguas de Barcelona* (General Society of Water for Barcelona, SGAB), the water distribution company of Barcelona since 1882, preferred an inter-basin transfer from the Ter River to the Llobregat headwaters, since they owned the Llobregat extraction sites (Gaya, 2014). The Barcelona Council, which aspired to a growth of the city, saw the Ter transfer as a provisional solution that should become final only after the Ebro transfer [8]. However, these two institutions ended up agreeing with the MOP's proposal [9,10,11], while the COCIG kept the struggle up.

By the end of 1966, right after the tests of the Ter transfer started, the COCIG presented an alarming report, not only about the transfer itself, but especially about the danger of the construction of the Susqueda dam, deemed as controversial as Sau [12]. As in many other cases of dam construction, there had already been tensions when the locals had to leave their homes before the filling of the reservoir (Bach, 1999; Pladevall and Viñolas, 2009). Some lost their job after the flooding of their factory (Sanmartín et al., 2003). Thirty-three workers even died during the construction process (Boadas et al., 1987), which was silenced.

Yet the most controversial fact was the type of dam chosen by the MOP and the company *Hidroeléctrica de Cataluña, S.A.* for Susqueda (an arch dam), and the seismically active terrain where this dam was going to be placed [13]. Only a few years before, the village of Fréjus (France) was flooded after the Malpasset arch dam broke (Boadas et al., 1987; Pladevall and Viñolas, 2009), causing 423 deaths[15]. Many alarming op-ed articles [2] and reports [12] appeared in local and regional media, and generated concern about the 135 m wall. Even a vignette appeared where a technician from the MOP in front of the dam said: "I don't know why you are panicking. I think that you, those from Girona, don't care about one more or one fewer flood" [14] (Fig. 29). Actually, *Hidroeléctrica de Cataluña* argued that such dam was necessary for avoiding floods in future, besides benefiting the irrigators by controlling the flow regime and helping the aim of supplying the RMB.

[15] http://ecolo.org/documents/documents_in_french/malpasset/malpasset.htm

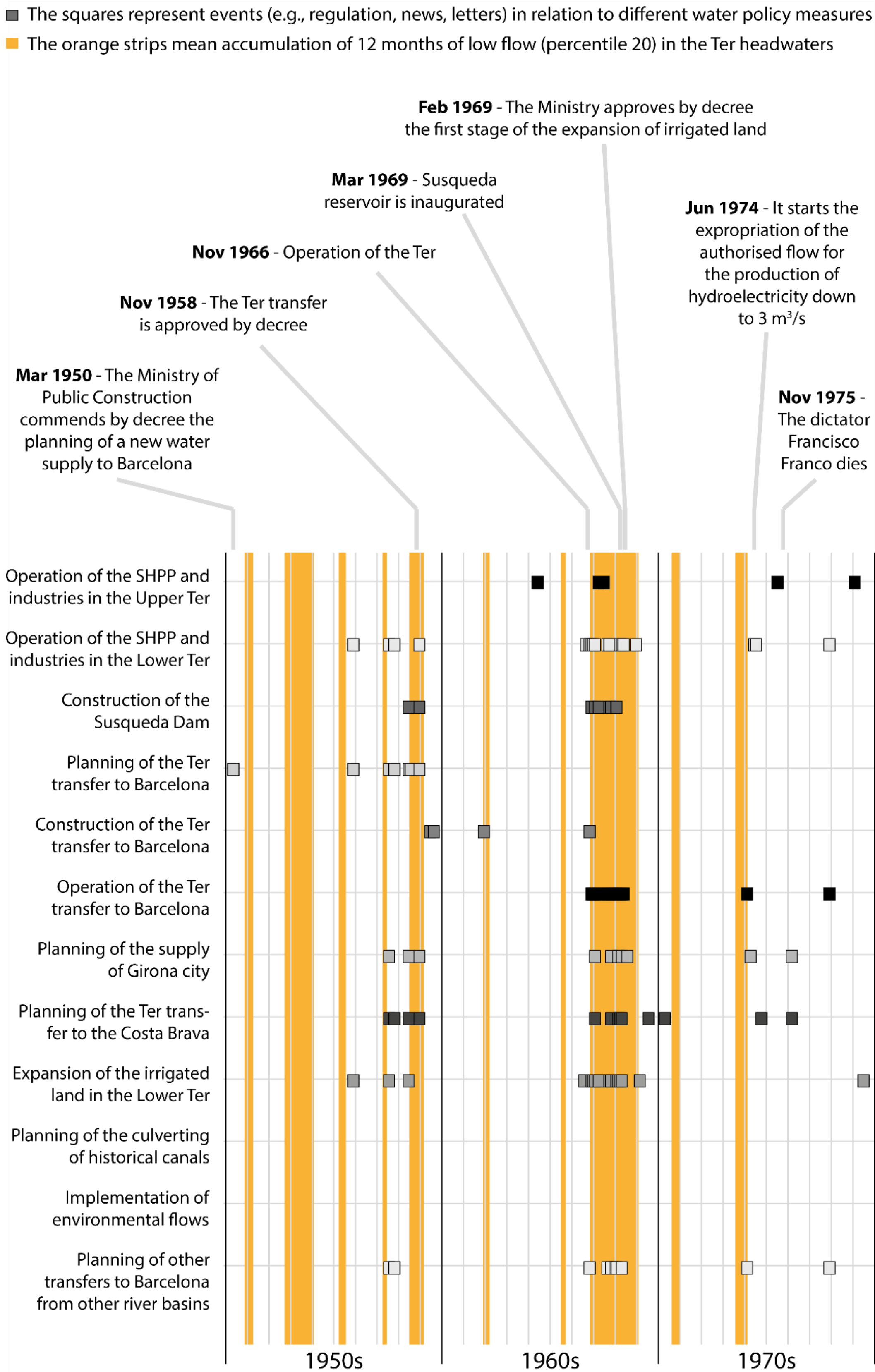
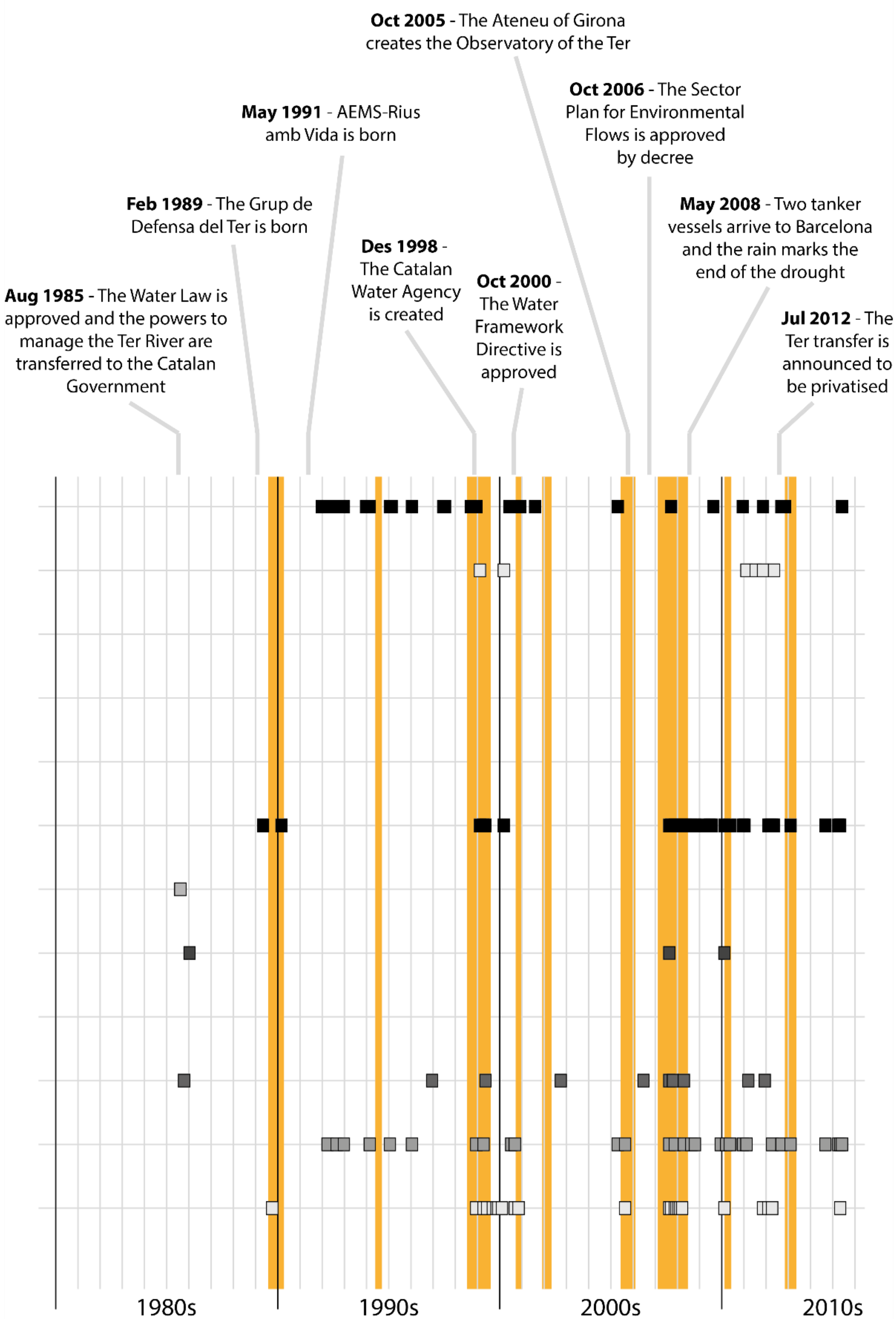


Fig. 28. Timeline of the management of the Ter River


Oct 2005 - The Ateneu of Girona creates the Observatory of the Ter
May 1991 - AEMS-Rius amb Vida is born
Oct 2006 - The Sector Plan for Environmental Flows is approved by decree
Feb 1989 - The Grup de Defensa del Ter is born
Des 1998 - The Catalan Water Agency is created
May 2008 - Two tanker vessels arrive to Barcelona and the rain marks the end of the drought
Oct 2000 - The Water Framework Directive is approved
Aug 1985 - The Water Law is approved and the powers to manage the Ter River are transferred to the Catalan Government
Jul 2012 - The Ter transfer is announced to be privatised
1980s
1990s
2000s
2010s

The governor of Girona province sent letters to the Minister repeatedly asking for detailed technical information that could calm down the inhabitants of Girona [15]. After some meetings that took place in Madrid [16] and Girona [17], the governor was convinced of the benefits of the dam [18]. Since the its inauguration in 1969 [19], there were no further complaints.

An exception is the bizarre story in April 1983, when two presenters of the local radio started to read a piece of Miquel Fañanàs' book "*Susqueda i altres narracions*", which simulates a breakdown of Susqueda dam[16]. Although they clarified that this was part of a science-fiction, the quality of their interpretation and the special effects they added made many people believe that there was a real danger, spreading the terror throughout the riverbank towns. People packing their luggage, phone calls to the police and the firefighters… The drama became indignation when they discovered the truth. Nowadays, the general public do not show concerns on the safety of the dams although some people still do not feel calm in thinking about the lifespan of the dam[17].

1966-1985. Unfulfilment of the commitments for Girona province

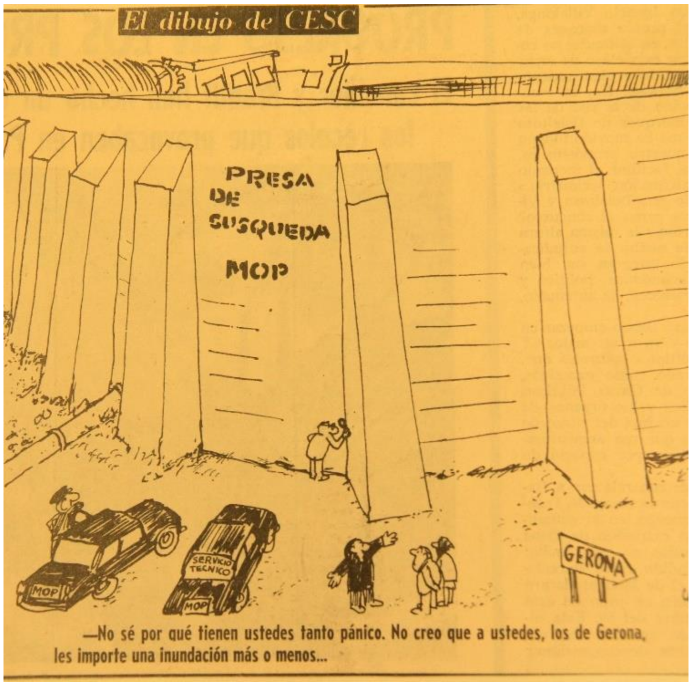
In November 1966, 1 m^3/s from the Ter began to be allocated to the supply of the RMB. During that year the instream flows of the Ter had been meager and a drought started then that lasted until the beginning of 1969. In parallel to the social concern about the risks of the Susqueda dam, the local society considered that the water transfer had been a poor bargain. In fact, while Barcelona had enough water for the summer of 1968, even for sharing it with the surrounding municipalities [20], Girona – at that moment only supplied from groundwater sources – was expecting water restrictions. Looking for new sources of water, Girona was pondering the digging of new wells or a diversion from the Llémena Stream, a tributary of the Ter River [21]. However, Porcioles, the influential Mayor of Barcelona during the Francoist economic development period after 1959 insisted upon the undeniable preference given to Girona province for the use of the Ter's waters [10].

Again, the COCIG and the Provincial Council of Girona led the protests through their newsletter [22] and through political pressure to the MOP [23,24], respectively. And again, the Ebro transfer was being proposed as the best solution [21,25,26,27,28], amid the jokes of political cartoonists [29] (Fig. 29). The main issue was the distrust of the Girona society on the MOP. Neither the project to expand the irrigated land nor the supply of Girona and the Costa Brava had started yet, although the MOP had committed to develop such projects at the same time than the water transfer [23,30].

[16] El Punt. "L'escenificació, per ràdio, d'una rebentada de Susqueda, va sembrar l'alarma" (April 22, 1983).

[17] One of the interviewees in the **Chapter 5** expressed his concern about the lifespan of the Susqueda dam.

A



B

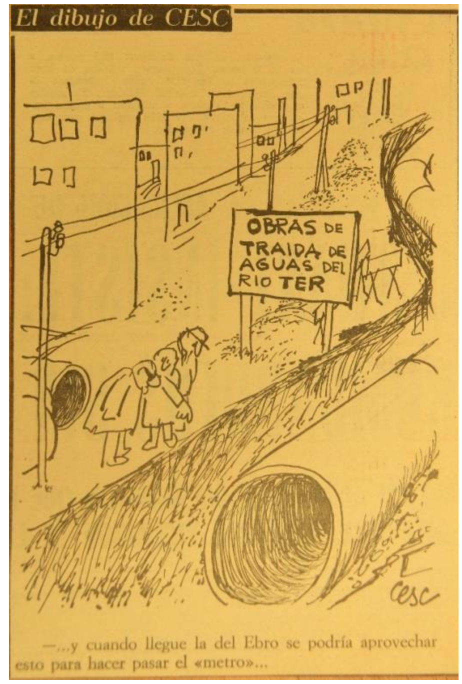


Fig. 29. Vignettes in 1968 representing different conflicts in the Ter bsin. Notes: Translation of the vignettes in English. **A.** "*Susqueda dam. MOP*" "*I don't know why you are panicking. I don't think that one more or one less flood matters to you, those from Girona*". **B.** "*Works of the water transfer from the Ter River*" "*... and when the Ebro ones arrive, that could be used for making the subway pass through it*".

The final project of the Ter transfer considered 48,000 ha of irrigated land in Girona province. This proposal was presented to the inhabitants of Girona as a compensation [5]. Due to the extraction of water from the Ter, the irrigation throughout the Lower Ter was supposed to be supplied with water from the Fluvià River, although the dams and canals for this purpose were never built. In 1968, the Minister answered a tough letter of the governor of Girona, who had criticised the slowness of the irrigation project. The Minister promised to having the first phase of the *Plan General de Colonización* (General Plan of Colonisation) ready by 1970 [31]. In fact, he approved it by decree in 1969 [32].

Table 22. Hectares of irrigation planned and hectares and percentage finally executed.

Irrigation communities	Committed by the Minister in 1968 (ha)	Operational at present (ha, %)	
Bescanó-Salt	1,000 ha	384 ha	38.4 %
Cervià-Sant Jordi-Colomers	1,235 ha	534 ha	43.2 %
Dreta del Baix Ter	7,015 ha	2,390 ha	34.1 %
Esquerra del Baix Ter	4,890 ha	3,980 ha	81.4 %

Sources: AHG [31] and ACA (2009a).

Nevertheless, the Ministry backed out on this promise in 1976. Seemingly, it considered that the expansion of the irrigation was not going to be necessary, since the province was turning into urban and tourist (Boadas et al., 1987). Nowadays, the irrigated land in the Lower Ter only takes up about 8,000 ha (see Table 22).

Bringing water from the Ter to Girona city and the Costa Brava (the latter, outside the Ter basin) was even more difficult. Although the Governor of Girona announced – and the Minister confirmed – that Girona would be able to be supplied from the Ter by the summer 1969 [33], the supply became operational only in 1973[18]. The municipalities of the Costa Brava would wait until 1993 to receive water from the Ter, despite the studies since the 1970s alerting about the increasing demand in the area, and the requests for water transfer by the water distribution company in this area [34,35,36].

COCIG's complaints also referred to the industrial facilities, in particular to the SHPP. Due to the decree of the Ter transfer that established a minimum discharge that allowed 3 m^3/s of instream flows passing by Girona [4], all contracts were expropriated in order to restrict the legal capacity of the hydropower plants to such amount– down from a concession of 8, 10 or 12 m^3/s [37]. One of the fiercest fighters against the construction of the Susqueda dam was actually an engineer owner of an affected hydropower facility [30,38].

After the long drought of 1966-1969, there are few reports of social tensions in the Ter basin, probably because water consumption in the RMB came to a standstill in 1973 (Aigües de Barcelona, 1991). However, in the RMB, tensions between the SGAB and the Barcelona Council made it apparent the desire to control water management. In order to promote collaboration between these organisations an advisory committee was created in January 1967 (ABC, 1969).

One particular session of this committee in 1970 sheds light into the difficulties of such collaboration, by highlighting the progressive divergence of interests, the introduction of service fees, and the different approaches taken about water sources. On the one hand, the SGAB insisted upon a comprehensive regulation – with an improvement of the water quality – of the Llobregat River in order increase its control over the hydro-social cycle of the RMB. They requested a new reservoir and a new treatment plant whose extraction point was upstream of the polluted stretches. Meanwhile, the Council pushed for taking advantage of the Ter instead, since its water supposed much lower energy costs, because of the elevation of the extraction point, and much better water quality. Such tensions became even more evident following mutual accusations of outstanding payments (Gaya, 2014).

Finally, the SGAB received an authorisation from the MOP to regulate the Llobregat River and a concession with 6.7 m^3/s extra, which would be added to the 5.3 m^3/s in force. The underlying problem of the quality of water had become a priority. So the SGAB also pushed in order to have the control of increasing problems, not only related to the industrial saline pollution coming from potash mining, but also dozens of other pollutants coming from a growing industrial sector (Gorostiza et al., 2015).

Actually, the wealthiest neighbourhoods of Barcelona were receiving the worst water quality (from the Llobregat) and causing unease, which surfaced to the newspapers headlines. This generated public pressure for river regulation.Meanwhile the Council

[18] http://www.aiguesdegirona.cat/html/adg/index1_girona.html

attempted to interconnect the Ter and Llobregat systems, also for expanding the area supplied by the Ter. The Barcelona Council eventually accepted the MOP decision for a comprehensive solution of the Llobregat. Nevertheless, the rivalry remained, then expressed in relation to the service fees (Gaya, 2014).

Despite the regulation of Llobregat's waters, some predictions indicated an exponential growth of water demand in the metropolitan Barcelona that would require a new source of water in the 1980s [32]. Once more the Ebro transfer was brought on the table [39]. For the Ter, that would represent the hope for a gradual recovery of the instream flows. However, the stop exploitation of the was postponed.

Just after the death of the dictator Franco (1975), water management policies remained unchanged. However, the democratic shift was spectacular in terms of social rights. This had an impact on the views on water management rather than on the management *per se*. In the Second Spanish Republic (1931-1939), there had already been civil movements for a better water management, especially in relation to the water quality (Gorostiza et al., 2015). But all of them were repressed during the dictatorship, when the environmental advocacy was reduced to scout groups, hiking associations and geographer societies (Mora, 2012). They were naturalists rather than activists, as happened in the case of the first environmental organisations in the Ter basin (ANG and GEDENA) created in 1981. Water activism would raise one decade later, together with the maturity of the democracy.

1985-1998. Abuse of hydropower facilities

The 1980s saw the most significant changes in relation to water management. The Water Law that determined the priority among water uses was approved in 1985. This Law also transferred all responsibility and authority related to the water management of the internal basins of Catalonia to the Catalan government. The internal basins of Catalonia are those flowing exclusively within the Catalan borders, in opposition to rivers that cross also other regions, like the Ebro, which are managed by the Spanish government.

With the transfer of responsibilities, the Catalan government created the *Junta d'Aigües* (Water Committee) and the *Junta de Sanejament* (Sanitation Committee) to regulate the extraction, distribution and treatment of the water in Catalonia. It also created a public company *Aigües Ter-Llobregat* (Waters of Ter-Llobregat, ATLL) with the aim of managing the water extraction from the Ter and Llobregat basins, treating that water and transporting it to the municipal water tanks of the RMB.

The1980s were a bustling decade in terms of droughts. Barcelona suffered water scarcity in 1983, in 1985-1987 and in 1988-1990. The 1985-1987 drought led to the preparation of a plan for water restrictions that eventually would not be applied. This drought also accelerated the construction of the Ter-Llobregat interconnection, finished in March 1987.

The 1988-1990 was more dramatic, particularly in the Ter basin. The levels of Sau and Susqueda reservoirs were at their lowest point in 20 years. The technical design of the reservoir made that water was taken from the bottom, where the quality remained lower due to the lack of oxygen [40,41]. Thus, the transfer to the RMB was limited by decree to 5.5 m^3/s [42], while the SGAB got a reduction of the water consumption after an effective awareness campaign on water saving, and impeded the implementation of water restrictions (Aigües de Barcelona, 1991). This decree also reduced the discharge from the reservoirs up to 2 m^3/s – with an extra 0.5 m^3/s in summer to satisfy the demands of the irrigators from the Lower Ter [42].

The lack of instream flows in the Ter River during this period meant an increase of the concentration of pollutants. After an episode of fish mortality in the Sau reservoir in 1989 the GDT was created (Ballestar Dot, 2012). Besides the GDT, other important environmental organisations in the area appeared during that period, such as the *Ateneu Juvenil, Cultural i Naturalista de Girona* (henceforth, Ateneu) and AEMS in 1991.

The number of complaints against hydropower facilities increased after the creation of the GDT and AEMS. Since the 1990s, these associations, together with local fishing associations and some town councils of Ripollès County, have been organising multiple leisure-claiming actions [43,44,45], wall painting [46], statements and manifestos [47,48,49], op-ed articles [50], and even legislative proposals [51,52,53]. One of their main criticisms along with polluting spills was that the small hydropower plants may divert so much water that the river sometimes becomes dry, hence damaging the river ecosystem [50] and fishing activities [54]. This was – and still is – often done in accordance to the law, since the concessions often allow the extraction of a high water amounts (e.g., in Orís municipality, a hydropower can take 10.5 m^3/s [55], almost the average of the natural flow regime), and for decades [56]. Therefore, these environmental organisations propose to first modify the hydropower authorisations on the basis of the environmental flows; after that to adapt the current authorisations so as to make them compatible with the life in the river; and finally to remove those weirs that severely alter the life conditions of the river [48].

At the institutional level, the socialist and the left-green parties – in the opposition during this period– launched some initiatives [51,52]. They called on the Catalan government to first report the situation in force of the Catalan rivers regarding the e-flows; to second present a programme of measures for implementing a minimum flow; and to third set a rigorous control for enforcing the law.

The governmental party *Convergència i Unió* (CiU), a coalition of liberals and conservatives, voted against the proposal in the Parliament arguing that the schedule presented was too tight. They promised to study such *problematique* during the following months, in the context of the preparation of the Water Plan for Catalonia [57]. Four years later, after seeing that the problem remained, the socialist party presented another proposal [53], calling for expropriating those hydropower facilities, which lacked social interest.

1998-2008. Attempts for implementing environmental flows

The first attempt to implement a minimum flow that could preserve the wildlife (particularly fish) of the Ter River was the *Aigües Vives* (Living Waters) programme. The origin of this programme was the drought of 1998-2002. Representatives of the Catalan government brought together municipalities of the Ter basin, irrigation communities, fishermen, hydropower producers and environmental organisations to work on an agreement for maintaining and watching instream flows and fish populations during 1999 [58,59]. That agreement also drove an awareness campaign.

Aigües Vives did not specified any amount of minimum flow, and it received some criticism due to this reason. In fact, the GDT avoided collaborating with the programme, arguing it did not correspond to a strategy of conservation, and considering it as an improvised measure [60,61]. The GDT also complained about cases of fish mortality and about the fact that river rangers appeared only when the flow was being recovered so was not necessary [62,63].

In 2003 a coalition of three left parties, socialists, republicans and left-greens (the *Tripartit*) entered the Catalan government. The *Agència Catalana de l'Aigua* (ACA) had been recently created in order to unify all powers related to water. The arrival of the *Tripartit* in office seem to coincide with an increased effort by the ACA to study and permanently implement e-flow regimes in all internal basins. Another relevant milestone of that year was the legal transposition of the WFD to the Spanish regulations. The directive had been approved in 2000, changed the paradigm of water resources management. The requirement of the maintenance of the good ecological status of water bodies became a fundamental boundary for water exploitation.

In 2005 the ACA published the *Pla Sectorial de Cabals de Manteniment* (Sector Plan for Maintenance Flows, PSCM) – with the agreement with environmental organisations –, which was approved by decree (DOGC, 2006). However, once e-flows had been defined, the Plan's implementation was hindered by significant administrative, economic and social challenges (Bardina et al., 2016). Historical users that had already obtained water rights from the river were criticised by environmentalists, which still see the concessions as an unfair appropriation of a public good.

The Water Management Plan for the period 2009-2015 only obligated to discharge an e-flow to new authorised facilities, while an implementation with the old owners required a negotiation process. In practice, that encompassed most of the concessions. Thus, after a tense and long participatory process where conflicting views often clashed, zonal plans for specific watersheds were elaborated on the basis of the PSCM for implementing e-flow regimes.

The one of the Upper Ter was the first to be requested because of the high density of hydropower plants and associated complaints. The Lower Ter, instead, had had the hydropower concessions expropriated down to 3 m^3/s so their effect was actually less harmful and the implementation less urgent. The ACA employed different strategies for harmonising water uses and e-flows, such as temporary changes in water use, but maintaining the same annual energy production. Another strategy was negotiating the extension of water rights beyond the expiration date. But the ACA also planned a reduction of environmental requirements to minimise impact on existing licenses where implementation impact costs were significant (Bardina et al., 2016). Despite the effort to prepare this zonal plan, its approval got delayed until the last-minute and could not be approved. The later return of CiU to the Catalan government in 2010 accelerated the removal of the e-flows from the ACA priorities so their implementation in Catalonia is still a under discussion.

Beyond the struggles for implementing an e-flow regime, this was a tumultuous period. In ten years, three deep droughts occurred: in 1998-2002, in 2004-2005 and in 2007-2008. During the whole period, five drought decrees by the Catalan government plus some extensions were enforced. Not unexpectedly, they foresaw restrictions for the instream flows and the local users such as farmers (see Table 23), who mobilised again against the over-exploitation of the Ter River to feed the demand of the RMB perceived as always-increasing [64,65].

Actually, during the drought of 2005, the Ateneu created the Observatory of the Ter, an entity in charge of keeping record and analysing the amount of water flow diverted to Barcelona. Since then, naturalists from the Ateneu made dissemination about the issue of the Ter instream flows [66]. Thus, when the next drought appeared, the level of awareness had increased so a broad platform was organised and put together mayors, environmentalists, industrialists and farmers and fought for more water within the basin itself. The called *Plataforma del Ter* (Ter Platform) organised a demonstration in Girona [65] and legally sued the ACA for failing to fulfil the Ter Law [67].

These mobilisations had their own outcomes. First, the water transfer was significantly reduced after the drought, passing from an average of 195.59 Hm^3 in 2001-2007 to 156.24 Hm^3 in 2008-2014; and second, the *Tripartit* Government committed to annually reduce the Ter water transfer even more, down to 130 Hm^3 in 2012 and to 115 Hm^3 in 2015, by signing the *Compromís de Celrà* (Celrà Commitment, February 2008).

Table 23. Distribution of water flows during the validity of each drought decree in the 1998-2008 period.

Water uses	Apr 1999	May 2000	Jan 2002	May 2005	Apr 2007
Water to the RMB[A]	5.5 (6.5) m^3/s	6 (7) m^3/s	6 (7) m^3/s	-	-
Water to be discharged[B]	3-4 m^3/s	3 + I m^3/s	1.5-3 m^3/s	-	-
Hydropower[C]	1-2 m^3/s	1-2 m^3/s	-	H	H
Irrigation[D]	1 m^3/s	I	45 Hm^3	50-60 Hm^3	50-60 Hm^3
Instream flow in Girona[E]	2 m^3/s	1.5-2 m^3/s	1.5 m^3/s	1 m^3/s	0.46 m^3/s
Instream flow in Torroella[F]	-	0.5 m^3/s	0.3 m^3/s	0.3-2 - H m^3/s	-

A. Average flow of the Ter transfer; the maximum instant flow in brackets. **B.** That flow depends on the season and on the irrigation needs (I). **C.** It is compulsory to discharge a minimum flow. H, flow permitted by contract. **D.** Usually from June 15 to September 15. I, undefined irrigation needs. **E.** The mandatory instream flow passing by Girona downstream of the inflow of the Girona STP. **F.** The mandatory instream flow. Sources: DOGC (2007, 2005, 2002, 2000, 1999)

Notwithstanding, a better supply of the RMB was and is still key for reducing the Ter transfer. Actually, new forms of bringing water to the city, including other inter-basin water transfers, were proposed during the whole period. However, the proposal changed depending on who were their supporters and who opposed them. Thus, during the 1998-2002 drought, ATLL proposed to study a water transfer from the Rhône River. Transferring water from the Rhône has been a long discussed engineering project promoted since the 1990s that is usually discarded because of the high costs involved. However, it is a recurrent argument in the water management debate in Catalonia.

After ATLL proposal regarding this option, the GDT rapidly responded against by accusing ATLL of just being driven by economic and political interests, and being based on an obsolete water management philosophy of the 20th century, ignoring, among other cautions, the radioactive pollution that affects the Rhône [68]. At that time, a 'new water culture' expanded throughout the academic and activist spheres. The influential works of Martínez Gil (1996) and Arrojo and Naredo (1998) contributed to this expansion.

Multiple environmental NGOs organised themselves in order to defend the new water culture in public conferences [69,70] or manifestos [71,72]. The mobilisation took place specifically in Girona around the *Plataforma d'Oposició als Transvasaments* (Platform of Opposition to Water Transfers, POT) [73], which also included some left-wing political parties and unions. Meanwhile, the Spanish Ministry of Agriculture was planning a massive water transfer to bring water from the Ebro River to South-East Spain and to Barcelona – always with the complicity of the CiU Government in Catalonia. Plenty of protests flourished in the Ebro basin. They received the support of some environmental organisations from the Ter (e.g., the GDT and the ANG), which went to the demonstration in Barcelona with the slogan "*Ni el Ter ni l'Ebre*" (Neither the Ter nor the Ebro) (Ballestar Dot, 2012). The arrival of the left parties in both the Catalan government (2003) and the Spanish government (2004) put a stop to the water transfer projects. The water management discourse quickly aligned with the principles of the New Water Culture.

During the 2004-2005 drought, some voices demanded again a water transfer from the Rhône (e.g., the foundation *Cercle d'Economia*) or the Ebro rivers (e.g., Agbar) [74]. The *Tripartit* reaffirmed its positon against new water transfers and increased the diversity of the sources of supply such as desalination plants, recharge pools, decontamination of aquifers or reuse of wastewater [74,75,76] (ACA, 2010), also for reducing the Ter transfer [77].

However, the 2007-2008 drought, soon after the previous one, was extreme and the planned infrastructure (most notably, one of the desalination plants) was not ready. The economic and social costs resulting from the drought were high, encompassing: 1) production losses in the agricultural (201.5 M€, including direct and indirect costs, for the period between April 2007 and January 2009), commercial (163.8 M€), industrial (221.2 M€) and hydropower sectors (71.0 M€); 2) the expenses for structural and alleviation measures (81.6 M€); and 3) non-market welfare losses owing to water restrictions (691.4 M€) and environmental damage (50.9 M€) (Martin-Ortega et al., 2012). Much has been commented upon the costly transportation of water from the Rhône River in two tanker vessels, which was foreseen as a last-resort emergency measure [78].

However, the most controversial planned measures involved enabling water transfers; first, from the Segre River (tributary of the Ebro) [79], and finally, from the Ebro itself [80,81]. Both Catalan and Spanish governments were determined to build the water-transfer infrastructure in order to put an end to that emergency situation. The so-called "Ebro mini-transfer" was argued to be the result of an urgent need. The Catalan government and the metropolitan authority made a call for territorial solidarity in the context of a reduction of water consumption per person about 100 L/day in the metropolitan area of Barcelona (EMA, 2008). The economic relevance of the city was also commonly mentioned to justify this measure.

None of these reasons was convincing enough to the people from the Ebro, who showed rising discontent, and organised another big demonstration – this time without politicians – with banners where the Catalan government were called "betrayers" [82]. In the moment of the maximum tension, at the end of the summer of 2008, heavy rain showers calmed the situation. A particularly rainy second half of 2008 made the works for the water-transfer infrastructure unnecessary. Either this or the first signs of the global crisis in Spain, with ensuing cuts in public expenditure, contributed to the suspension of these works.

2008-2015. Perpetuation of the problems in the Ter basin

Although droughts were not a compelling issue after 2008, the economic crisis had a direct effect on the water management measures proposed by the *Tripartit*. Once built, the desalination plant remained inoperative because of the high costs of desalination processes. The use of the water from the Ter was a cheaper option, so the promised reductions in transferred flows only occurred for a few years (between 2009 and 2011) [83,84] (see Fig. 30). Nevertheless, the Ter Law was complied with, as the highly debated 3 m^3/s were actually passing by Girona [85]. Even the higher flows of the PSCM were passing by Girona in those stretches where the river is not diverted by any SHPP. Absence of droughts indeed helped to the observance of the Law.

After the events of 2007-2008, many organisations from Girona such as the Ateneu, the COCIG, the *Plataforma del Ter* and the *Consorci Alba-Ter* – which is a consortium that groups multiple riverside towns – took a positive stance towards the Ebro mini-transfer [76,87]. Several elements contributed to this.

First, the organisations recognised the domestic use as preferential above the rest. Second, they admitted that Barcelona, as the capital of Catalonia and a dense urban area, requires a lot of water to satisfy its needs. Third, the organisations noted that there is already a water transfer, the one from the Ter one. In a way, this entailed a veiled criticism to anti-transfer movements, which historically had barely referred to the Ter situation.

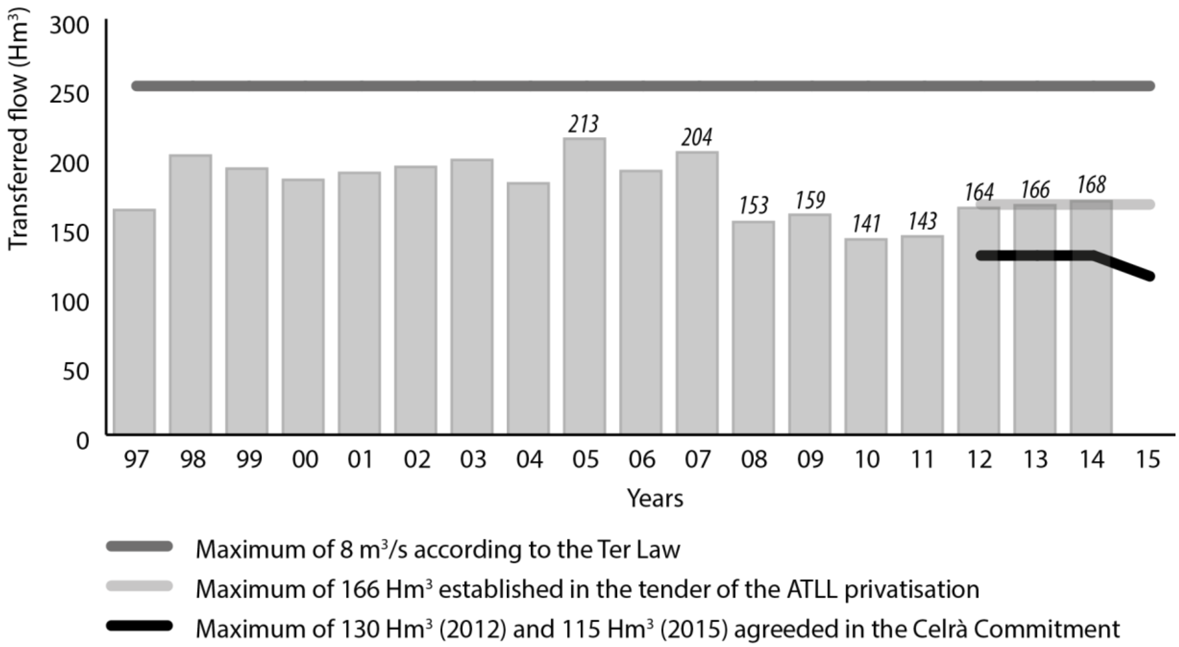


Fig. 30. Amount of water transferred each year to the RMB for the 1997-2015 period. Sources: ACA [82,86].

Therefore, they proposed that all main watersheds in Catalonia (including the Ebro) should collaborate with the supply of Barcelona in order to reduce the pressure on the Ter River. Building on that idea, some proposals appeared in the media to tackle the problem without raising the opposition of the Ebro defenders. Some op-ed articles in Diari de Girona and in La Vanguardia defended the option of returning the treated water to its original watershed [88,89]. Another idea, with more social support, came from the Segre basin: *Aigua per Unir* (Water to Unite) (Aldomà, 2012). Since most consumption in Catalonia is related to irrigation in the Segre basin, the idea was that the Catalan government invested in making irrigation more efficient. Then the water savings could be redirected to supply Barcelona and thus reduce the Ter transfer. According to the defenders of *Aigua per Unir*, a win-win solution.

This idea convinced mayors of the Ter basin, the governor of Lleida province (where the Segre basin is) and the *Plataforma del Ter* among others [90,91]. They organised public conferences and published op-ed articles [92]. However, it did not convince either the Catalan government or the majority of environmental organisations. The Catalan government does not want to get in trouble with the people from the Ebro basin and rather bets on the Rhône transfer [92]. While the environmental organisations, more varied among them, hardly see a compatibility between a new water transfer, the new water culture and a public water management.

In fact, some of the environmental organisations, together with some unions and neighbourhood associations, formed in 2011 the *Aigua és Vida* platform (Water is Life, AeV). AeV advocates for a public water management in its entire cycle, and appeared as a consequence of the decision of the Catalan government to privatise the public company

ATLL. The Government actually recognised to be selling “the goose that lays the golden eggs” because of the need of enforcing financial austerity. The privatisation was planned to last 50 years and the contract also established the authorisation of taking up to 166 Hm^3/year from the Ter [90,86], what would fail to carry out the *Compromís de Celrà* [93]. AeV and the *Consorci Alba-Ter* actually competed for being the opposition to such unfulfilled promises.

AeV presented a motion to all municipalities of the Ter basin, for guaranteeing an e-flow regime for the lower Ter and against the privatisation of ATLL. Following the action-reaction principle, the *Consorci Alba-Ter* presented some days later another motion with some noticeable differences. Regardless of the status of ATLL – whether it becomes private or stay public –, they asked for: 1) avoiding a reduction of the instream flows; 2) updating the Ter Law of 1959; 3) enforcing the *Compromís de Celrà*; and 4) considering the *Aigua per Unir* idea [91].

At the time of writing this thesis, the contract with Acciona, the company that won the tender, was cancelled by the Catalan High Court because of certain irregularities. Acciona still manages the Ter transfer, since the Catalan government is appealing against this decision and does not have enough cash to reimburse Acciona. Moreover, the Catalan government is in process of approving the new Water Management Plan (for the 2016-2021 period), which will enforce the implementation of e-flows to all hydropower facilities, although such e-flows only represent about 60% of the flow calculated for the PSCM. The ACA argues this is part of a progressive implementation. Academics and environmentalists have already raised an outcry for setting back progress achieved in previous years [94,95].

The neglect of the historical canals

Besides the evident tensions about water transfers, the lack of instream flows and the abuse of hydropower facilities, the conflict over the neglect of the historical canals is essential to understand the divergent views on the alternatives about river management. As it is already explained, since the Ter Law, the farmers had been fighting for an expansion of the irrigated agriculture that had not been fulfilled. The main obstacles had been the renunciation to the Fluvià transfer, so that expansion would hardly come with an increase of the water supply.

Once the Catalan Government had the control of the water management, the idea for expanding the irrigated agriculture returned along with the modernisation of the irrigation system. Thus, the government decided to construct new pipes, which would transport the flows in a more efficient manner. *Gent del Ter* fought against that project because considered that the flows within the canals would drastically decrease, so all their associated socio-cultural and ecological benefits were in danger [96]. Moreover, various organisations presented formal allegations [97]. Finally, the pipes were constructed and the environmental organisations got an e-flow from the statement of environmental impact

[98], which has not strictly been implemented. Currently, there is a mismanagement of the historical canals, and the water remains stagnant, eutrophicated and smelly [96].

The divergence between farmers and ecologists also took place within the *Plataforma del Ter,* in which *Gent del Ter* unwillingly decided not to be included because of the coolness of the platform regarding the Ebro and Rhône transfers. Gent del Ter actually calls for a new water culture to avoid that a possible reduction of the Ter transfers serves for the growth of golf camps and hotels in the Costa Brava. A member of *Gent del Ter* complained: "*They are depleting the water from rivers, the natural distributor, in order to distribute it by themselves* [referring to water distribution companies]" [96].

7.4 OUTCOMES FROM HISTORY: CHANGES IN ECOSYSTEM SERVICES, ACTORS AND POWER RELATIONS

After the chronological account of how the conflictive management of the water flows has taken place over the different periods, in this section we analyse the specific conflicts in connection to the ES at stake, the actors involved and how they have exercised power. First, we present the main conflicts over water flows in relation to the ecosystem services involved (**Section 7.4.1**). Second, we map the variety of actors and the interests they have had in the ES provision and their influence for accessing to water flows (**Section 7.4.2**). Finally, we describe the mechanisms of power by which actors gain, control and maintains access to water flows (**Section 7.4.3**).

7.4.1 Broadening the perception of ecosystem services provision and conflicts

From the previous section, it is easy to realise that several conflicts have developed in the Ter River basin regarding the appropriation of some water flow-related ES. Using water flows to generate a particular benefit has often been done at the expense of other water benefits, usually those dependent on instream flows. Rather than sparse and disconnected struggles in the river basin, the historical analysis allows to identify a list of five conflicts that have recurrently articulated stakeholders' demands in relation to water flows. They are the construction of undesirable dams, particularly Susqueda, the prioritisation of inter-basin against intra-basin supply, the lack of instream flows in either Upper or Lower Ter and the neglect of the historical canals of the Baix Ter Plain (Fig. 31).

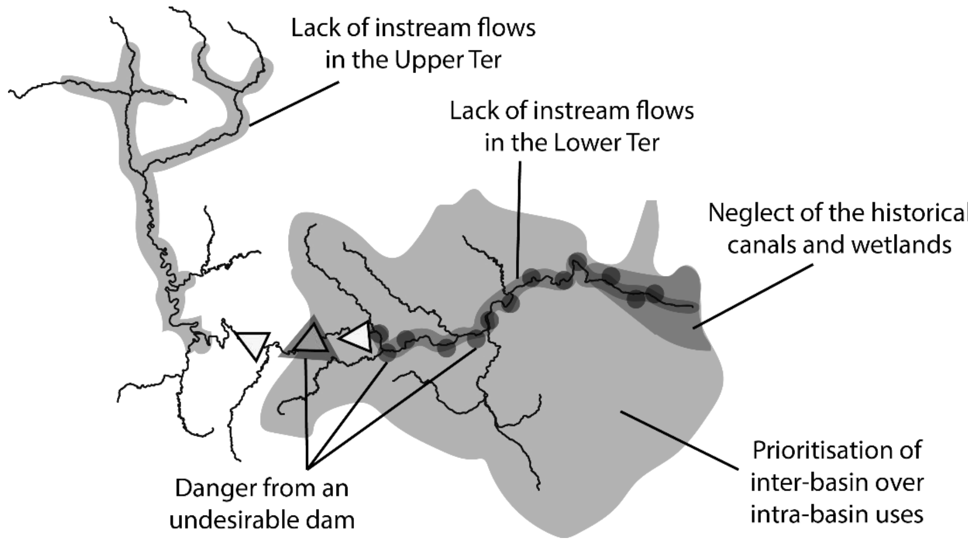


Fig. 31. Main areas affected by conflicts over water flows in the Ter basin. The grey intensity represents the number of conflicts overlapped.

Of course other water conflicts could be mentioned. For instance, the Ter basin is the main source of bottled drinking water in Spain, with water extractions above 1 Hm^3/year that often are taken outside the region (Espejo, 2001). This situation is regularly denounced by the environmentalists [99] (Ballestar Dot, 2012). Another relevant example is the impact of intensive pig farming, a very important economic activity for some municipalities (DAAM, 2006). The management of pig slurry causes groundwater pollution and has forced several municipalities to switch from wells to surface water uptakes as the source for domestic water supply [43]. While being relevant, the impact of these conflicts over water flow management is relatively minor and therefore they are not part of the analysis.

In this section we focus rather on the five conflicts mentioned above. From an spatial point of view, some of these conflicts connect areas that that gain access to some ES and areas that loose in terms of ES provision. Fig. 31 maps the ‘loser’ areas within the Ter basin. Some of these areas overlap and, in this way, spatial analysis is helpful to identify possible hotspots of distributive injustice regarding water flows. Although practically nobody is concerned anymore about a the collapse of the Susqueda dam, the rest of the conflicts remain as open disputes in relation to how the benefits of water flows are distributed and who is benefited by the related ES.

For a more systematic interpretation we characterise the conflicts based on the data of the historical research, highlighting the ES at stake, how they are promoted and defended and by whom (see Table 24). Although the commodity under discussion is the amount of water flow and how it is allocated, the issues involved are diverse, including the extension of infrastructures, water grabbing and water privatisation. They are all clearly related to each other. The conflict often confronts the promoters of specific projects that mean an important change in the way how water flows are managed and the actors opposing those projects.

Table 24. Characterisation of the top five conflicts in the Ter River basin

Conflict	Period	Causes	Discussion topics	Actors: Decision-makers	*vs.*	Resistance
Danger from an undesirable dam	1958-1969	Resistance against the flood of Susqueda village and the fear that the dam breaks hence destructively floods the towns downstream	Infrastructural needs	MOP, CHPO, *Hydroeléctrica de Cataluña, S.A.*	*vs.*	Civil society in Girona province, including the COCIG, the agrarian chamber, town councils and local media
Prioritisation of inter-basin over intra-basin uses	1950-	Lack of proportion between the water flows for the RMB and the Ter basin and unfulfilment of commitments with the Girona society, such as the expansion of irrigated land or the 3 m^3/s of instream flows	Water grabbing	MOP, CHPO, Barcelona City Council, the Catalan and Spanish governments, *Hydroeléctrica de Cataluña, S.A.*, Endesa, Acciona, ATLL	*vs.*	Civil society in Girona province, including the COCIG, the agrarian chamber, town councils, environmentalists (Ateneu, ANG, *Gent del Ter*), farmers, and citizen platforms
Lack of instream flows in the Lower Ter	1966-	The addition of water withdrawals (the Ter transfer, domestic and industrial uses, irrigation) causes severe hydrological alterations that affect the normal functioning of the river ecosystem	Privatisation of water flows Marginalisation of non-marketed ES	The Catalan government, hydropower producers,	*vs.*	Environmentalists (ANG, Ateneu, GDT, *Gent del Ter*), town councils and citizen platforms
Lack of instream flows in the Upper Ter	1991-	The hydropower producers usually legally take great amounts of water. They sometimes cause illegal HA	Privatisation of water flows Marginalisation of non-marketed ES	Hydropower producers,	*vs.*	Environmentalists (GDT, GEDENA), town councils and fishermen associations (AEMS)
Neglect of the historical canals and wetlands of the Baix Ter Plain	2000-	After piping the historical canals,	Privatisation of water flows Marginalisation of non-marketed ES	The Catalan government, irrigators	*vs.*	Environmentalists (ANG, *Gent del Ter*)

Affected area	Ecosystem services: Promoted	Ecosystem services: Defended	Mobilising forms	End of the conflict
Riverbank towns of the Lower Ter	Water supply for domestic and industrial uses, hydroelectricity production	Preservation against floods	Media, political pressure, reports	The Susqueda dam was finally constructed as a round double curvature dam and it has been working without any danger. However, some distrust remain
The Lower Ter sub-basin	Inter-basin water supply for domestic and industrial uses	Intra-basin water supply for domestic and industrial uses, hydropower and irrigation	Media, political pressure, reports, demonstrations, allegations,	The water transfer was reduced in 2008 from 6 to 5 m^3/s, but several commitments remain without being accomplished and the privatisation of ATLL perpetuates the conflict
The entire Lower Ter	Inter-basin water supply for domestic and industrial uses, hydropower and irrigation	The preservation of the river ecosystem, the maintenance of the aquifers, fishing, kayaking, sanitary uses, aesthetics	Festive protests, media, reports, demonstrations	An e-flow regime is not implemented yet and there is not an effective control of the water extractions either
Those stretches of the river affected by hydropower facilities	Hydropower production mainly, but also irrigation and industrial uses	The preservation of the river ecosystem, fishing, kayaking, aesthetics	Festive protests, media	An e-flow regime is not implemented yet and there is not an effective control of the water extractions either
The Baix Ter Plain	Irrigation	The preservation of the historical canals and wetlands, the maintenance of the aquifers	Reports, allegations,	Neither the ACA, nor the owners nor the irrigators take responsibility for the management of the historical canals

The promoters usually integrate the water authorities, and water companies or energy companies, while the opponents are the environmental organisations or a broad group of local institutions, organisations and companies. Still, the setting is complex and, in the case of the battle for the implementation of e-flows, the water authority (ACA) have entered in direct confrontation with the hydropower producers, and in alliance with the members of the civil society.

Looking at the provision of ES, it seems to have barely changed in the last 65 years. However, the awareness on the variety of ways people benefit from ecosystems has increased over time. A proof of this is the evolution of the research on social benefits of river restoration, already mentioned in **Section 3.3.3**. The historical perspective of this chapter is also part of this trend. Generally speaking, the actors related to water flows have moved from a production-oriented focus towards a broader view of the benefits from instream flows.

Thus, after the proposal for constructing the water transfer in 1950, the water supply for domestic uses was the dominant ES. Actually, provisioning services were by far the main concern between 1950 and 1985: domestic uses, irrigation, hydropower and other industrial uses –; although there are also a few references to the unpleasant aesthetics of a dried up river [1,22] and to the sanitary benefits that instream flows provide [5,7].

Tensions due to competition among consumptive uses within the basin existed, but were uncommon. Rather, they were generated among regions and among institutions. Thus, a variety of actors from Girona – through sometimes surprising alliances [64] – have not ceased in their claims, especially against the excessive water flows diverted to Barcelona. Neither the Spanish government nor the Barcelona Council showed themselves really involved in such conflict. Indeed, the government was who called the shots.

As the consumptive uses are rival among them, the great water extraction to the RMB has also caused competition for the leftovers among the locals, especially during drought events. Confrontation has sporadically appeared between farmers and hoteliers [100], between environmentalists and farmers [101], and environmentalists and hoteliers [62,63]. The latter, focused on the water supply for tourist facilities.

Actually, many different ES relate to recreational activities and tourism. Among them, the most water-consuming activities (e.g., ski resorts [99,102,103], campsites [104] and golf camps [63]) are defended by big companies and by the Catalan administration due to their role in the development of rural counties. Oppositely, environmental organisations and small companies, such as nature guides, see them as an obstacle for the conservation of the environment. Non-consumptive uses, such as kayaking (Ballestar Dot, 2012), fishing, environmental education [71] and cultural heritage [98] are seen as generating a better fit between economic development and conservation. Actually, the preservation of the ecosystem is a valuable attribute increasingly appreciated by tourists.

Of all documents analysed, the first use of ecological values as an argument of the mobilised actors appears in 1992 [105,57], already in the democratic era and just after the creation of the GDT and AEMS. It appeared closely connected to trout provisioning for fishing; and against the abuse of hydropower facilities. Sensitive local politicians, fishing and environmentalists talk about the life in rivers that has to be preserved and complain: "*the attitude of the authorities allows the owners of the canals to be owners of the waters. Neither fish nor fishermen nor landscape nor ecosystem nor anything else*" [50]. So, in part, there is a notion of development different than the one of a direct exploitation of the water flows.

A well-preserved river ecosystem was also acknowledged as a way to maintain multiple regulating services. Regulating services appear less frequently in stakeholders' calls than other ES, although there is evidence that there were tensions related to them. For instance, a few months after the inauguration of the Susqueda dam, a phreatic-level drop annoyed farmers [24]. The water transfer was even blamed for local weather change [66]. The dilution capacity of instream flows under drought episodes or fish mortality caused by the malpractice of a hydropower plant [63,106] are also changes in regulating services that do not go unnoticed.

Even the water flowing into the sea start to be acknowledged as a source of benefits. In recent decades, and against the paradigm that the non-diverted water is wasted, scientists and environmentalists have defended the contribution of instream flows for keeping the salt wedge away [95], to beach regeneration [101] and to sea fish production [107].

The increasing recognition of all these ES has fostered the agreement around the need to preserve river ecosystems. Despite this, an e-flow regime is not being implemented in the Ter River, as AEMS frequently reports [108,109,110] and the ACA recognises with regret [111,112].

7.4.2 Actors and mobilisation forms

The ES provided throughout the Ter basin are linked to the interests of different stakeholders in accessing to water flows. The ability to gain, control and maintain such access is represented by bundles and webs of powers that each actor exercises in different forms and levels (Ribot and Peluso, 2003). Who is who within this entanglement of power and interests? From the results from above, we elaborate an interest-influence matrix (based on Reed et al., 2009). The parameters evaluated in that matrix are the level of encompassing interest (Olson, 1982) represented by the variety of ES defended and the influential level of accessing to water flows represented by the use of different mechanisms of power (see Fig. 32 for the interest influence-matrix and **Section 7.2.3** for a description of the method). Note that the chart is used to facilitate the interpretation of stakeholders' positions and their changes rather than as a strict quantitative appraisal of interest and influence.

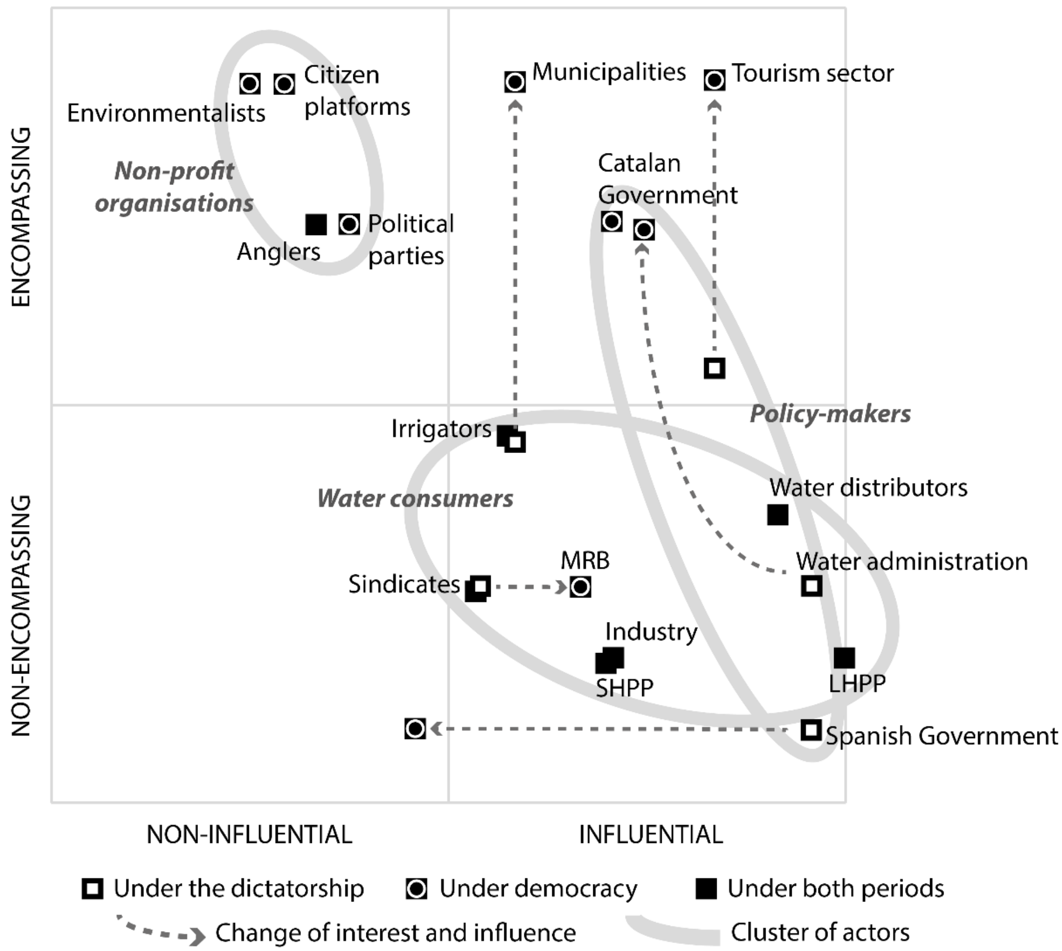


Fig. 32. Interest-influence matrix of the stakeholders present in the Ter water conflicts, considering ecosystem services as interest and access to water flows as influence. Note: Scientists are not being represented, since each individual has different interest and influence, not as a collective. Municipalities also include supra-municipal public bodies.

The position of each actor in the interest-influence matrix is derived from data from the previous sections. In interpreting the outcome, we do not only observe the implications of each actor's location in the matrix but also how location has changed during the period of analysis. Encompassing actors can be influential (called 'great benefactors') or non-influential ('well-intended crowd'); and there are also non-encompassing influential actors ('flow shapers'). Only the Spanish government in democracy is a studied non-encompassing and non-influential actor, categorised as 'gang', since it does not represent a relevant actor in the Ter River anymore. Rather than examining the situation of each actor, a motivation for this analysis was also to look at the performance of three groups of actors that regularly interact in the conflicts: policy-makers, water consumers and non-profit organisations.

Policy-makers

The democratisation of Spain actually meant a change of the position of policy-makers. The Spanish government via MOP and CHPO had been the major decision-maker in relation to water management. However, it lost its influence as a 'flow shaper' at the expenses of the Catalan government, which appeared as a newcomer. Actually, the Catalan government, via *Junta d'Aigües* and ACA, is a 'great benefactor', since it is an encompassing actor in charge to administer both water withdrawals and river ecosystems, while the CHPO was narrowly focussed only on the water supply. All these institutions manage the water flows through laws, plans and fines; but of course they have been acting differently depending on whether they have existed under dictatorial or democratic values, and whether they have been right or left wing.

Water consumers

This group is basically composed by distributors, irrigators, hydropower producers. Of course, some of them may be interested in regulating services, such as the maintenance of the aquifer level or the water purification. However, they are clearly non-encompassing actors, whose key requirement is the direct use of certain amounts of water. During the dictatorship, they led the opposition to governmental projects, especially via business associations such as the COCIG or the agrarian chamber.

Although they are not policy-makers, water consumers have a great control over the water flows thanks to their wealth (in terms of money or property) and the fact that they operate dams and weirs. They are actually the 'flow shapers' of the Ter. In addition, they can sponsor reports in newspapers [113] or publish their opinions [30], elaborate their own magazines [12,22,7] or books (Aigües de Barcelona, 1991), and even make studies that favour their standpoints [34,35]. When it is necessary, they can present allegations. That was the case of the ones presented by the hydropower plant owners against the expropriation of their concession [114], or those presented by Agbar when they lost the tend for privatising ATLL [65]. These mobilisation forms are usually formal.

Water consumers have always been influential, and with their interests always fixed in their specific goals. The political coalitions from the past start failing because their former allies either lose influence (Spanish government) or broaden the scope of their interests (Catalan government and municipalities). Still, these connections are strong enough to mobilise their positions in face of unwanted normative developments, such as the water management plans of the ACA. While the interest of the water users do not collide with each other, they can cooperate (e.g., Endesa[19] with ATLL).

Farmers are yet a special sector within the water consumers group. They are less wealthy but well organised. They have actively participated in broader organisations, such as the *Plataforma del Ter* [65] and have threatened several times to demonstrate against unwanted

[19] Endesa, *Empresa Nacional de Electricidad, S.A.*, is the hydropower company currently in charge of Sau and Susqueda.

developments [64]. Farmers also have a broader interest in water flow management than other water consumers, since they have less options in face of the negative effect of salt intrusion or a possible decrease of the aquifer level.

Within the group of water consumers, the tourism sector and the municipalities are actors that have become encompassing in democracy and have a level of influence as a great benefactor. In fact, they appreciate the highest variety of water flow-dependent ES. This makes the tourism sector having similar interest in the use of the water for provisioning (for the supply of hotels, swimming pools and golf camps), regulating (for the maintenance of beaches, aquifers and the salt wedge) and cultural services (for the aesthetics of the waterscape and the provision of a space for recreation).

Finally, municipal and supra-municipal public bodies are water consumers that hold power over the water distribution but cannot directly make regulatory decisions over the Ter water flows. Actually, they sometimes own a specific share of the water distributors. Because of the narrow relationship with the decision makers, they usually attempt to influence them by straightforward means such as legislative proposals (e.g., for revising the SHPP contracts) [115,51], motions (e.g., for the reduction of the Ter transfer) [116] or allegations (e.g., for the preservation of the historical canals) [98].

Non-profit organisations

Non-profit organisations only became relevant under the democratic period, when the expression of dissent was granted under a fully recognised right to free speech. We categorise them as ‘well-intended crowd’, since it is a group without a strong influence but with a wide variety of interest do defend. They clearly encompass supporting and regulating services in order to preserve the river ecosystem.

Fishermen societies are well-organised associations. However, they have not been as influential in relation to water flows as they have been to stewardship of riparian zones and related conservation policies. In the past, they mobilised to preserve the e-flows [117,103,118]. Nowadays their engagement into politics is indirect, and related to the more or less influential role that the anglers umbrella organisations had with policy makers. It is also noteworthy that cyprinid (e.g. carp) angling, the typology with the highest number of angling licences in Catalonia, is not much related to the instream flow level (see **Chapter 5**). Instead, the fly-fishermen from AEMS-*Rius amb vida*, are a very active group and consider themselves as environmentalists.

Environmental organisations are newcomers to the matrix, as they were prohibited under the Francoist regime. They have usually driven citizen platforms to broaden the support to their claims, together with the civil society and other organisations such as political parties, irrigation communities, neighbourhood associations, etc. Thus, the citizen platforms have broadened the scope of environmentalists (e.g., AeV also reports the privatisation processes and water restrictions to households that cannot afford the supply [66]) and have increased their ability to organise demonstrations [65] (Ballestar Dot, 2012). But the intensity of their activity is very irregular, with temporary peaks of mobilisations after specific threats. As an illustration, the *Plataforma del Ter* practically ceased its activity after the 2007-2008 drought.

7.4.3 The exercise of power for accessing to water flows

The distribution of power and interest among different actors is clearly unequal. In a context where maintaining the broadness of ES provision from river flows constraints some specific interests, it is to expect that actors with power will exert it.

The next management plan (ACA, 2015) could illustrate this. It schedules the implementation of only the 60% of what is recommended in the PSCM (see the NEW scenario in **Section 6.3.4**). Although it considers the e-flow regime as a target for achieving a good ecological status, many exceptions are allowed (e.g., infrastructure for energy production, road infrastructure, and even infrastructure justified for a sustainable development!) [119]. Is this a way of maintaining the power of water distribution and hydropower companies over the water flows? How have the changes happened when the previous plan had a more strict set of measures? Which structural and relational access mechanisms are activated and by whom? In this section we will examine the different ways in which power has been exercised by different actors for gaining, controlling and maintaining access (*sensu* Ribot and Peluso, 2003) to certain water flows.

Forms of gaining, controlling and maintaining access

In the case of the Ter River, the main wind of change in the exercise of power is indisputably the political regime in Spain. This leads us to examine the situation during the dictatorship and the democratic period separately.

Under dictatorship

The lack of political parties and political representatives elected by universal suffrage made decrees and laws the most frequent form of the Spanish government for exercising power, as there was no need to persuade the opponents. The decree of 1958 that established the water transfer to Barcelona [4] was approved despite the entire Girona province being against the water transfer and without much right to reply.

In fact, the mobilising forms were also very limited during the dictatorship; and this is the reason why it is very relevant that in the 1950s and 1960s the municipalities in Girona, the industrial and agrarian chambers and the local media were able to raise their voice. This was usually done by formal means, such as letters, as the ones exchanged between the Girona governor and the ministry of public construction [15,120], op-ed articles in the local media [30] and reports in their own publications [7,12,22]. They sometimes illustrate different forms of exercising power. For instance, the COCIG criticised that the public presentation of the draft of the Ter transfer project and that the review and comment period took place during the summer break, in August 1957 (BOPG, 1957).

In case of stronger opposition, of course force was always a way of imposing the MOP's priorities. Gallussa, the last inhabitant of the Susqueda village, flooded nowadays, had to leave her home by boat!, against her will, once the filling of the reservoir started (Pladevall and Viñolas, 2009). The Francoist regime was also interested in avoiding opposing voices, especially from the local institutions (e.g., the governor of Girona province or the mayor of Girona city); and compensations were the main measure to persuade them. However, big promises – such as the expansion of the irrigation network simultaneously to the water transfer [17,23] or the maintenance of 3 m^3/s in Girona [3] for instream uses – ended up with no implementation.

Throughout the research process we found insufficient evidence to analyse the forms of power to control the water management in the Upper Ter. This lack of information can indicate either a lack of inter-stakeholder tensions – although the Buxeda's book (2011) shows that this is unlikely – or a more intensive control over the local media of those more rural areas. Oral history seems a particularly required approach for future studies in this region.

Under democracy

In the democratic era, the Ter transfer to Barcelona has been working at full strength. The exploitation of the Ter did not evolve much, but the social rights of the opponents did. They actually gained influence on water management issues due to the recognition of the rights of assembly and association. Thus, environmental organisations defending well-preserved river ecosystems increased the influence of opposing views regarding water management. These organisations, usually together with political parties and sector organisations (e.g., fishermen or farmers), have mobilised to resist unwanted developments, such as a new transfer, and to gain power for an implementation of the e-flows. They employed multiple forms of mobilisation, both formal and informal. Some examples are allegations [97,119], signature campaigns [66,69], reports [121], public talks [66,122], dissemination in the street [69], literary works [101], wall painting [46,66] and many ludic-claiming actions against the over-exploitation of the river (e.g., a football match within the riverbed [46], a competition of 'dry angling' [45] and a descent by kayak with the motto "we want a river to live in" (Ballestar Dot, 2012)).

Despite some appearent achievements, e.g., when the PSCM or the *Compromís de Celrà* were signed, again big promises were actually betrayed [123,93,86] and the business-as-usual scenario resisted. Water distributors and hydropower companies have benefited from those situations mainly thanks to three elements. First, the water concessions authorised under dictatorship have been maintained in democracy and have long-term expiry date. Some examples of long contracts are found on the water extraction for hydroelectricity production (65 years, 75 or even in perpetuity) [56,124,125], for industrial companies (65-99 years) [126,127], for irrigated agriculture (99 years) [128] and for domestic uses (99 years or in perpetuity) [129,130]. Even the privatisation of ATLL was for a long period (50 years) [90]. Such concessions, together with the lack of human and technological means for assessing the discharge and diverted flows, make the public control of their activity difficult.

The second element is this lack of mechanisms for controlling the data. In front of that situation, the opposition can hardly prove their arguments. This is why there was a discussion about the control of the water extraction for hydroelectricity production [52]; about the publication of gauged instream flow data [119]; or about where to install the gauging station in Girona, whether upstream or downstream of the Onyar confluence [131]. The latter point was recently made by the Ateneu and the ANG, which painted in a bridge pillar a mark of the 3 m^3/s that should pass by Girona [132].

Finally, there is a lack of representatives of intra-basin [133,134,4,66], non-consumptive [135] and non-profitable [119] uses in the different committees, councils and commissions that the ACA has constituted in order to advice or make decisions on water management. Representatives of big companies are usually favoured (see Table 25). This also happened during Franco times, since the governor of Girona complained that the Provincial Council could not be represented in the Discharge Commission [135].

Table 25. Representation of different organisms within current councils and commissions.

Actors	Advisor Council for the Sustainable Use of Water	Administrative Council of the Catalan Water Agency	Discharge Commission of the Ter-Llobregat system
Policy-makers	1	12	7
Catalan government	0	8	2
Water administration	1	4	5
Water consumers	15	9	20
Municipalities	4	3	5
Water distributors	2	0	5
Business and industry	2	3	0
LHPP	0	0	1
SHPP	0	0	1
Irrigation	1	0	6
Tourism sector	1	0	0
Unions	5	3	2
Non-profit organisations	8	2	2
Environmentalists	2	0	1
Citizen platforms	1	0	0
Fishermen	0	0	0
Recreationists	1	0	1
Scientists	3	0	0
Other organisations	1	2	0
TOTAL	24	23	29

Note: in this table there are only presented those actors with voice and vote. Source: ACA.

(Unchanged) forms of legitimising power exercises

The need for winning over the general public is essential in democracy for reducing the opposition and maintaining the status quo, represented by a specific manner of managing water. Despite the drastic political transformation occurred in Spain after the death of Franco, the forms of legitimising power exercises have not substantially changed.

The legitimacy of actions is determined in combination of two phases. First, little by little, by incorporating a seductive language able to persuade and convince. Second, to act suddenly – but not hastily –, under the pressure of a crisis situation such as floods or droughts, which requires emergency responses that, in other circumstances, would have been contested. Predominant discourses in relation to drought events are actually well studied in political ecology (Kallis, 2008).

Different strategies are accompanied of different discourses. These discourses aim to promote some ES at the expense of others in order to facilitate or damage the implementation of certain water policies. For example, rather old-fashioned discourses about water flows being wasted when draining into the sea [41,1] generate contempt for the implementation of e-flows. The less profitable activities are sometimes despised too. Thus, the mayor of Molló, a village that owned a hydropower plant, said: "*We need to prioritise people instead of trout*" to protect its facility against fishermen's pressure for removal [136]. In the same line, during the drought of 1998-2002, the manager of the hotel sector in central Costa Brava claimed a preferential use of the water above irrigation by defending: "*We believe that it is first the people, the tourism, and then the crop fields*" [100].

Opposition against water transfers is also attempted to be dissuaded through discourses related to the water availability in different watersheds or time periods and to a 'claim' of solidarity between river basins [17,74,137,138] (Aigües de Barcelona, 1991). This increases the social acceptance of water transfers. The media has even changed the vocabulary employed, e.g., by using 'mini-transfer' [81], 'interconnection of networks' [139] or even 'purchase' [80] instead of 'transfer'. Even the pipes that bring water to the Costa Brava are never considered as a water transfer, although these coastal municipalities do not belong to the Ter basin either. In addition, other terms are used for greenwashing. These are the cases of 'sustainable development', as an argument for restricting the achievement of a good ecological status [123], 'green energy', for promoting the expansion of SHPPs [113], or 'ecological flows', to mean 3 m^3/s in Girona, what is required by the Ter Law but far from the e-flows established in the PSCM [85,140].

In relation to critical episodes used as arguments to approve or accelerate controversial laws, contested measures and conflictive infrastructure, droughts and economic crisis have been the most effective. Fig. 28 shows a high number of decisions made during dry periods. Some examples are the decree of approval of the Ter transfer in 1958 [4] (the instream flow registered in Ripoll for that year is the minimum for the whole period); the supply of the Maresme County from the Ter (Sanmartín et al., 2003) (during the 1966-1969 drought); the works for buring the historical canals and using pipes instead [141,101,96], and the Ebro *mini-transfer* [81] (during the 2007-2008 drought); or the announcement of the privatisation of ATLL [90] (in the July 2012, only 3.49 m^3/s were entering to the Sau reservoir). During the development of the Ter transfer project (1950-1966), the water consumption per capita in Barcelona increased by 139% – from 204.1 to the mammoth amount of 488.6 L/inhab/day (Ostos and Tello, 2014). Who knows whether the reason was to build a solid argument for legitimise the contested transfer?

Besides droughts, economic crises are a typical argument too. In this way, in the Ter basin these crises have been employed to slow down the Plan for expanding the irrigated land [30], to avoid using the expensive desalination plants for reducing the Ter transfer, or to privatise ATLL [93].

7.5 DISCUSSION

Based on the aforementioned results, we present next the arguments for a discussion on ecosystem services, power and actors. First, we describe the current situation of ES delivery in the Ter River basin and examine the exercise of political power, arguing that water management has barely changed since the days of Franco, as Swyngedouw (2015) also shows. Second, we reflect on the usefulness of combining historical and ES-based approaches for a political ecology analysis of water conflicts.

7.5.1 The persistence of the business as usual despite the political changes in Catalonia

The pressure to extract water flows from the Ter River to benefit the users from other basins has been high since the 1950s. This was said to be alleviated by a transfer from the Fluvià River, first, and indirectly by the Ebro or the Rhône rivers to Barcelona, later on, but none of these ideas was ever executed. The lack of water sources for the supply of Barcelona has been the main reason argued by the Spanish and Catalan governments to explain why the Ter transfer has not been reduced as promised. When the desalination plants started to be operational, the economic crisis became the most repeated reason to justify the lack of a reduction of the water transfer. Once (if ever) the crisis is over, the argument will likely be that the contract of the privatisation of ATLL prevents reducing the Ter transfer. Aware of the political and social changes in Catalonia in relation to water management, the question is why the as usual persists. A similar question could be made in relation to the implementation of e-flows.

The 1950s unequivocally represented the major turning point for the water management in the Ter basin. The Sau dam was being built with the purpose of avoiding floods downstream and saving water for irrigation in summer. The happiness of the inhabitants of Girona province did not last. The MOP proposed a transfer of initially 12 m^3/s – then reduced to 8 m^3/s – to Barcelona that would be approved in 1958.

Such proposal was executed together with the launch of a series of commitments addressed to the Girona province for the reinforcement of the water security, the expansion of the irrigated land and a maintenance of a minimum instream flow for sanitary and industrial purposes. Such proposals were going to be achieved with water from the Muga and Fluvià rivers. In addition, a reduction of the Ter transfer once the Ebro's waters would start to be transferred was also promised. However, the Franco's government unfulfilled almost all such commitments with various arguments. They involved the need of focusing the economy of the Girona province on tourism rather than agriculture, the development of the regulation in the Llobregat River – which favoured the interests of the SGAB –, and the lack of serious water crises after the 1966-1969 drought.

The end of the dictatorship represented great changes in Spain in terms of rights and freedoms. As described in **Section 7.4.1**, the social recognition of the ES of rivers was broadened growing on arguments mainly provided by environmentalists. In contrast to the COCIG, whose claims were basically focused on water provision for Girona province, the environmentalists' argumentation was also developed from the defence of what we call supporting and regulating services, and even to the cultural amenities obtained from a healthy river. Little by little, this comprehensive view of the river was embraced by tiny entrepreneurs (e.g., kayak instructors) and some town councils (e.g., those grouped in the Consorci Alba-Ter).

At the institutional level, the new water culture carved a niche after the demonstrations against the Ebro transfer, the approval of the WFD and the arrival of the *Tripartit* in the Catalan government. The new water culture defends: 1) the water use in accordance with the respect of the e-flows; 2) the diversification of sources of water extraction for minimising the impacts; and 3) the self-sufficiency at a watershed level through the control of water demand (Estevan and Prat, 2006). Environmentalists, together with some town councils and fishermen, had been struggling since the 1990s for an e-flow that preserved the ecosystem and its diversity of goods and services. They finally had some institutions listening to their claims and encouraged to make relevant changes in water management. Actually, the approval of the PSCM was celebrated as a historical achievement. Notwithstanding, since 2006 when the plan was passed by decree, there has been little in the implementation process.

An ex-president of the GDT actually felt certain disappointment and apathy after years of fights when he was asked about the current situation in the Upper Ter. Environmentalists from the Lower Ter express similar feelings in relation to the reduction of the Ter transfer. The results in previous sections demonstrate two complementary reasons. On the one hand, the absolute power that the Franco's government had under the dictatorship, in democracy this is shared among different actors. However, these actors are those already benefited by the inertia of power leading to a BAU scenario. On the other hand, those actors with an alternative view have not been able to construct one discourse powerful enough to convince the political parties and institutions to make the changes that would be preferable for them.

The residents of the Ter basin cannot decide over the Ter River, mainly because the river is subordinatd to the RMB's demands. The ACA undertook participatory processes where local actors are informed about the management plans and other programmes and participate in the consultation with their opinion and ideas. However, the decisions are made outside the watershed. A clear example is the Discharge Commission, in which few members are from the Ter basin. Most of the members are actually for-profit entities that benefit from water withdrawals, ignoring the multiple services provided by instream flows. Moreover, these for-profit users have traditionally got concessions for hydroelectricity production or irrigated agriculture through an authorisation for 50 years upwards.

These obstacles currently impede a democratic management of the Ter River and make it difficult to apply any environmental measure against the interests of the BAU supporters (e.g., the construction of a fish pass or the implementation of e-flows). An option would be to expropriate hydropower facilities, a measure in fact implemented during the Franco's government, which is however an expensive solution. A current unfavourable government for such expropriation and the economic crisis do not help either.

The other reason why there is not an implementation of e-flows that ensures a more equitable distribution of benefits is the lack of a strong alternative about the water management. The management of the 2007-2008 drought discredited the *Tripartit* government, which hoisted the flag of the new water culture but lost its cool in the last month of the drought bringing tanker vessels from Marseille, planning the Ebro and Segre transfers and praying to the *Moreneta*[20]. The short period of time for implementing the measures programmed and the fierce attacks that government received from the conservative media (March and Saurí, 2013) impeded the setting of the new water culture in Catalonia, since the Ebro and the Rhône transfers are still in an ongoing debate.

Moreover, there is not a united alternative from the activism due to different dimensions of the conflict that are prioritised. Broadly speaking, while the *Plataforma del Ter,* the Ateneu, which recently broke up, the *Consorci Alba-Ter* and the COCIG have emphasised the intra- *versus* inter-basin uses discussion, those purely environmental activists (i.e. GDT, ANG and *Gent del Ter*, among others) have rather prioritised the instream *versus* the diverted flows discussion. Despite common ground on the management of the Ter basin, the unavoidable debates on the management at the Catalan level (e.g., regarding the Ebro transfer) and on the public *versus* private management accentuate the disagreement.

The fact that the Ebro River has never been transferred and that the Ter transfer has been reduced to 166 Hm^3/s are little victories of activists, considering that there has not been an important drought since 2008 and the Barcelona's desalination plant remain practically unused.However, the economic crisis after 2008, the demographic reversal in Catalonia (with increased outmigration and slowly declining population) make the exaggeration of future water demand less and less plausible.

[20] The familiar Catalan name for the Virgin of Montserrat, the Patron Saint of Catalonia.

7.5.2 A critical historical approach of the ecosystem services

During the 2007-2008 drought, there were changes in socio-political relations and water use that revealed some hidden inequalities (e.g., between intra- and inter-basin water users, between instream and diverted flow-dependent users, etc.) that remain unnoticed by modelling tradeoff exercises as in the previous chapter. The historical analysis of the Ter River has proved to be helpful in order to understand these inequalities, also expressed in environmental development programs (e.g., the PSCM) (Davis, 2015). Such inequalities derive from social, spatial and temporal patterns of access to the ecosystem services provided by the environment (Martinez-Alier, 2003).

In particular, a critical historical approach contributes to the political ecology of the case of the Ter River in four different ways. First, a characterisation of the case is necessary to question when the conflict began, when it was identified, when it will disappear; and this characterisation can be linked with the geography of that conflict (Martinez-Alier, 2003). Second, it contextualises all events in a way that we can discern between significant and trivial information, between causes and consequences, etc. Third, it facilitates the observation of discourses, as hidden power exercises through language, assessments, maps or forecasts, that become meaningful when are analysed as a whole (Armiero, 2008; Kallis, 2008). Finally, it has helped to bridge qualitative data (e.g., approval of a decree, a demonstration) with quantitative data (e.g., instream flows, water discharges and withdrawals) in a way that the latter can confirm hypothesis that the former pinpoints about some use of power (Bryman, 2008).

Thus, we observed that the conflict related to the Ter transfer is not only a water distribution conflict among different stakeholders generated during the last droughts. Rather, it is the outcome of 65 years of unfulfilled promises and attempts to decide from the Ter basin the management of the Ter River. The conflict comes from the earlier 1950s, when the demographic growth of Catalonia required an increase of the water supply (Saurí, 2003). Then, the Sau reservoir was already under construction and was going to facilitate such an increase.

The conflict is then expressed as a fear of the breakdown of the Susqueda dam, the lack of instream flows in the Lower Ter and the recent works for piping (i.e. bury underground) the historical canals. That is because they are either related to the technical requirements for transferring the water, or to the noticeable consequences of the transfer, or to the arguments for later reducing it. At the same time, these interrelations among conflicts are expressed at different scales in a way that an original inter-basin conflict is subsequently replicated in multiple conflicts at a local scale (see Fig. 32 in **Section 7.4.2**). In other terms, an ES-based approach to conflicts in the Ter River basin cannot be confined to the basin itself; it scales up and "out" at least to the Catalan level.

By knowing the role of the dictatorial power in Spain until 1976, we calibrated the magnitude of the tensions in each period. For instance, the number of publications in local journals against the Ter transfer was outstanding, although such number would have passed totally unnoticed in democracy, let alone the thorough reports elaborated by the COCIG. The role of the media was then acknowledged.

Likewise, there are often advertisements of Endesa or Agbar in the Catalan newspapers. So the interviews with environmental activists become necessary to compensate the preveiling mutual understanding between big companies and the media. The period and the location of activist are also important to contextualise. For instance, the GDT, which emerged from a fish mortality period, has become a reference among the environmental organisations even though it comes from Manlleu, a small town of 20,000 inhabitants.

After all, activists are not so capable to make their discourses penetrate in the public opinion. Rather, they are the for-profit companies through the media that have been showing hydropower as 'green energy', as if they did not threaten the river ecosystem, or 'inter-basin connexions' as something totally different to inter-basin transfers. The 'water that lacks in some regions but exceeds in others' is a well-known discourse in political ecology, which actually made the option of the Rhône transfer visible albeit it is a 'hydrodinosaur' doubtfully sustainable (Barraqué, 2000).

The Ebro transfer has also been contested in multiple studies in both ecological and economic terms (Arrojo, 2006; Naredo, 2006; Prat and Ibanez, 1995), but its construction was proposed at Spanish level both by socialists and conservatives governments. This happened during the most severe droughts. Droughts are argued to be profitable for powerful interests given how institutions distribute costs and benefits (Kallis, 2008). Thus, in 2007-2008, the priorities for the Catalan government were clear for many farmers when they had to stop irrigating while the CocaCola factory did not have to stop operations.

Many decisions were hastly made during extreme events. The *Aigües Vives* programme was an improvised plan that, according to the GDT, attempted to gain a discourse on environmentalism over the environmental organisations. The signature of new concessions (e.g., for a golf club) wold allow an increase of the water demand and the legitimation of future transfers. Finally, the construction of the Ebro transfer discredited the new water culture.

In addition, there is also an ongoing discussion on whether droughts are politically produced and discursively-mediated crises (Bakker, 2000). For example, Kaika (2003) attributes the 1990 exhaustion of Athens's reserves not so much to a meteorological drought but to urban growth and increasing consumption. In our case, it is important to highlight the great growth of the 2nd ring of the metropolitan Barcelona in the early 2000s, with more gardening and swimming pools than in Barcelona city (March, 2015; Saurí, 2003). Then, we could affirm that water conflicts in the case of the Ter River somehow uncover problems of urban speculation, although the efficiency has strongly increased in Barcelona in the last decades (Masjuan et al., 2008; Ostos and Tello, 2014; Otero et al., 2011; Saurí, 2003).

In conclusion, as Linton and Budds (2014) and Swyngedouw (2009) argue, water flows to multiple stakeholders in different places and in a conflict-ridden process. Each techno-social system for organising the water flows (through dams, canals, pipes and the like) shows how social power is distributed in a given society. Our results show two techno-social systems, in two separate sub-basins in a single river. Each of them present their own conflicts and a different distribution of power in their societies.

On the one hand, the Upper Ter is an isolated basin with multiple individual tensions on specific weirs, disconnected from drought periods and more related to the differences of power between small hydropower producers and the ACA, which is pressing for the accomplishment of the e-flows where they are compulsory. On the other hand, the Lower Ter is necessarily connected to the hydro-social cycle of the metropolitan Barcelona, which creates multiple interrelated conflicts at different scales. Conflicts there necessarily go with drought periods and, apparently, with the subordination of the Catalan government to the big companies (e.g., Endesa). In the Lower Ter, the issue of e-flows has obtained a higher media impact, probably because of the involvement of several spheres of the Girona society. However, the Upper Ter is actually the sub-basin that has drawn the major attention of the ACA.

Of course, the role of companies such as Endesa or ATLL is significant, but also the resistance of the Ebro people that impedes the Ebro transfer, perhaps at the expense of the Lower Ter.

After this historical analysis of the Ter River, we have realised about the necessity of a historiography that examine how historians have studied river flows. Hydrologists study the history of climatic events, such as floods (Llasat et al., 2005). Environmental historians study, for instance, how humans have shaped the environment through the development of hydraulic works (Pavón, 2007). Political ecologists analyse discourses and practices involved in the implementation of e-flows (Fernandez, 2014) or in the privatisation of water flows (Barca, 2007). A historiography of river flows would include different theoretical frameworks, different methods for gathering, organising and analysing data, and different case studies to review.

Chapter 8

Conclusions

The central objective of this thesis was to apply the notion of ecosystem services to the understanding of ecological distribution conflicts related to water flows management. This started from a thorough review of the literature related to ES and to socio-economic assessments of instream flows restoration/preservation projects. Insights from the literature informed the development of a conceptual framework for the use of the ecosystem service concept and an analytical framework for its application to the case of the Ter River. Subsequently, three specific applications of an ES-based approach allowed analysing inter-stakeholder conflicts in the Ter River basin.

First, we unravelled the relationships between water flows management, the components of nature and the delivery of ES through a qualitative analysis accounting for key stakeholders' views. Second, we used a stakeholder-based model in order to assess the ES provision over time and space in the Ter River basin and hence find tradeoffs and synergies according to four different management scenarios. Finally, we went back to the 1950s, when the Spanish government initially projected the Ter water transfer to Barcelona in order to study the exercise of power behind the historic appropriation of water flows and the corresponding ES.

This chapter concludes the thesis by summarising the main findings obtained and describing the arguments why an ES-approach may be useful to understand water conflicts (**Section 8.1**). **Section 8.2** discusses briefly ecological economics, political ecology and ecosystem services-based approaches, and the contribution of this work to these fields, as well as some limitations to have in mind in further research studies. In this respect, we bring some ideas for forthcoming investigation for the case of the Ter River and for other water conflicts in **Section 8.3** and implications for water policy and activism in **Section 8.4**.

8.1 CONCLUSIONS: HOW HAS AN ES ASSESSMENT HELPED TO UNDERSTAND SOCIAL CONFLICT OVER WATER FLOW MANAGEMENT IN THE TER RIVER BASIN?

Decisions on water allocation have historically emphasized the production of ecosystem services – such as hydropower and irrigation – that depend on the construction of infrastructure, usually at the expense of altering the hydrologic dynamics of the river. Such decisions have typically imposed tradeoffs that reduce benefits from free-flowing services (Auerbach et al., 2014). The growing competition over water resources has triggered political disputes among stakeholders hence it has raised academic interest on conflict resolution (e.g., Mianabadi et al., 2014) and, in general, on tools for informing water management in the context of conflict.

Acknowledging the advantages of the ES concept for approaching social and biophysical areas of research and for engaging with stakeholders pointed out by previous literature, we developed a novel framework to analyse ecological distribution conflicts in relation to water flows. Such framework accommodated three innovative applications of ES that study the conflicts of the Ter River from multiple points of view (see Table 26), presented in **Chapters 5, 6 and 7**. Our work confirmed the original expectations on the benefits of using the ES concept in several ways. These are outlined in the Sections 8.1.1-8.1.5 below, which refer to:

1. stakeholders' engagement;
2. recognition of the plurality of benefits provided by water flows in river ecosystem;
3. the link between river ecosystems and human well-being at different temporal and spatial scales;
4. tradeoffs among stakeholders' interests in relation to different management and climate scenarios; and
5. power relationships between actors.

Table 26. ES applications for the Ter case with different approaches and methods employed.

	Methodology	Temporal approach	Dimension of the conflict
Chapter 5	Qualitative analysis based on the opinion of key stakeholders to identify ES and find ecological incompatibilities and socio-cultural divergences in their provisioning.	Current situation	Socio-cultural and ecological
Chapter 6	Integrative modelling for distinguishing tradeoffs over time and space and among ES under various water management and climate scenarios.	Possible future scenarios	Biophysical
Chapter 7	Historical analysis of the water management through a 65-years period to characterise the interest and influence of different stakeholders for the appropriation of ES.	Past performance	Political

8.1.1 Engaging with stakeholders

In any riverside town in the Ter basin, when one enters in a bar, orders a coffee and asks about the river, most often the response is a long list of complaints about its management. The dams are discharging a ridiculous instream flow… This generates eutrophication and fish mortality… As a result, the river stinks… The ACA does not allow the locals to take water as they always did… People has to go through tedious bureaucratic processes after any request to the water administration... Definitely, the river matters for locals.

Still, when directly interviewed, they sometimes express the idea that their views will contribute little to research on water flow management or governance. The language used in that type of research so far may have focused on concepts and terms that are far from the people's experience. Using an ES-based approach in interviews or workshops made most of them feel comfortable, since it was easy for people to relate ES to their interests on the river.

Fifty-one people participated in our interviews or workshops as information providers. Some of them were key stakeholders with a central position in our snowball-sampling network. Some others did not have a prominent role in the network but were highly specialised in some ES. There were even some unexpected stakeholders, such as the fifth grade students from Fermí's class, whose explanations have greatly benefited this dissertation.

For the participants, the ES-based approach is usually seen as an increasingly influential concept that helps to accumulate arguments for defending a certain form of managing rivers. Stakeholders also admit that the application of this approach is limited. For example, the participants usually prefer simpler messages, such as the monetary valuation of benefits from the ecosystems because they think that will be easier to include in policy-making.

8.1.2 Recognition of the diversity of benefits

Many features of freshwater ecosystems are relevant for people who daily live with rivers. The lack of recognition may entail the absence of public participation. Without recognition, one cannot fight for an egalitarian distribution of water resources (Guha and Martínez-Alier, 2013). It is like a union, which cannot legally strike, cannot bargain, if it is not recognised. Even disregarding distributional issues, lack of recognition becomes as a major dimension of environmental injustice (Schlosberg, 2007).

There are plenty of ways people use, enjoy or feel the Ter River. Some ES that were absent from the reviewed literature are the relaxing sound of the current water, the mystic atmosphere of the riverbank, the feelings inspired by emblematic species, and the appreciation of historical canals as natural and cultural heritage. In fact, the historical canals sometimes look abandoned because neither the ACA nor the Natural Park managers nor the landowners (the irrigation communities) are taking responsibility for their management. Other cases of disregarding stakeholders' values occur in relation to the Discharge Commission of the Ter-Llobregat system and the Advisor Council for the Sustainable Use of Water, where most of the members represent for-profit interests.

This lack of recognition also brings knowledge gaps, misunderstandings and divergences. During one workshop, some participants directly accused an elver fishermen of depleting eel populations, when fishermen are actually part of a European repopulation program. Likewise, other complaints exist regarding the surface irrigation because many people ignore that maintains the waterfowl habitat and the aquifer level, and prevents from seawater intrusion.

Nevertheless, not all disagreement comes from knowledge gaps. An ES characterisation also helps to see other common divergences arisen from traditional versus new environmental approaches, feelings toward wilderness versus what is exotic, private versus public use of the river, and monetary versus non-monetary values. Even, when the water flows management is perceived as just at one level may cause an injustice at another level (Patrick et al., 2014).

8.1.3 Hydrological alterations and ecosystem services

Besides the characterisation of people's views, **Chapter 5** also points out the need of giving more room for exploring the biophysical support of ES production. On the one hand, a benefit may need plenty of river attributes to be successfully provided. For swimming, children may use a riverside tree to jump in a pool, need the water to be clean and enjoy the river by playing with rocks and refreshing themselves under a waterfall. On the other hand, the same element of the ecosystem may provide a wide range of services depending on its features. Thus, irrigation and kayaking need water flows particularly in summer, while a sediment-laden flow in spring is what is required for the preservation of the riparian vegetation.

The alteration of the hydrological features of rivers has an impact on this biophysical functioning, as already analysed for Mediterranean rivers (Belmar et al., 2013). However, some activities have become adapted to the existing conditions of the river, either altered or natural. Freestyle kayaking and fly-fishing are practiced in stretches dominated by riffles and rapids, while calm-water kayaking and carp fishing require dammed stretches. However, although one could find alliances between freestyle kayakers and fly-fishermen to preserve the natural flow regime, they also compete for the same space and this creates tensions. While boats may scare fishes as they pass through the angling zones, kayakers sometimes complain about the litter abandoned by anglers in what they expect to be a 'natural' waterscape.

Spatial and temporal localisation of ES production allows to pinpoint these hotspots of concentration of activities in particular stretches and seasons. In Girona, the bulk of the water is extracted for hydropower and irrigation. However, runners and cyclers would rather prioritize the preservation of the waterscape. Despite the challenges imposed by such competition among users, some stakeholders claimed this to be an opportunity for agreeing on a responsible management scheme to be exported to the whole basin. The observations during the mapping process as well as the results obtained illustrate the geographical distribution of tensions. For instance, water donor basins (the Ter River) *versus* receptor catchments (in the RMB). But also the distribution of synergies. E.g., water demand for irrigation improves the flow conditions for kayaking in summer, when this activity is mostly frequented.

8.1.4 Tradeoffs under the alternative scenarios

The previous characterisation and localisation contributed to the identification of incompatibilities between ES linked to diverging hydrologic conditions or to the use of the same space in the same season. Yet, we question the magnitude of those tradeoffs and to what extent multiple stakeholder are satisfied with a specific level of ES provision. Quantifying and valuing the ES production help to answer these questions. Performing this by modelling not only permits that, but also focuses on specific time periods and stretches of the river, as well as contrasts the results with multiple hypothetical water management or climatic scenarios.

For the case of the Ter River, we simulated four different water management scenarios through a water allocation-ES provision model (see **Chapter 6**). These scenarios are: BAU, which represents the current situation; COM, which considers different plans and programmes that the Catalan Water Agency prepared but have not enforced yet; NEW, which corresponds to the new management plan, with lower expectations than in COM; and ECO, which gives a minimal preference to the transfer to Barcelona.

As expected, the results of the model show that most of the water flow is transferred to the RMB in BAU; and the disconnection of the transfer would mean an almost perfect harmony among intra-basin uses, as ECO illustrates. However, the supply of the RMB would be in question after the water resources from the Llobregat River decrease up to 49%, as it may happen under climate change conditions (Bangash et al., 2013).

Bangash et al. (2013) also predicts a possible decrease as much as 43% of the total hydropower production, the second withdrawal in terms of flow amount. Therefore, the already damaged instream uses will be seriously threatened if there is no effort to change the current situation, especially in dry years. The NEW scenario does not represent a significant change with respect to BAU; hence, COM and ECO appear as alternatives claimed by the civil society of Girona province and partially shared by some technicians from the public administration. The main difference between these two alternatives is the level of reduction of the water transfer to the MRB. The more reduced the water transfer is (the maximum in ECO), the more improved the instream uses are expected to be.

In any scenario, the harvest may be jeopardised in dry years, as it happened in 2008 (Martin-Ortega et al., 2012), unless farmers irrigate more efficiently. The industry would be somehow affected if the management changes according to the COM or ECO scenarios, but the conditions of the natural park (including the wetlands and historical canals) and associated services such as tourism would improve. Interesting enough, results also show that hydropower producers do not have to fear an implementation of the environmental flows in case this measure is accompanied by the reduction of the water transfer.

Finally, the validation workshop has been essential to realise about the limitations of modelling (further explained in **Section 8.1.6**). The disparity of results show, for instance, that the historical canals are not harmed because of the lack of water in the Ter basin (what can be evaluated by using our model), but because of the mismanagement, as explained above.

8.1.5 The history of access to ecosystem services from water flows

To date, the COM and ECO scenarios represent the two different alternatives to the business as usual that defend the implementation of e-flows and the reduction of the Ter transfer. By modelling, these two alternatives seem to represent two different degrees of closeness to a naturally variable flow regime. However, by analysing these scenarios from a historical perspective, we can see strong social and political differences that makes difficult an agreement among the respective defenders.

Thus, COM represents a great spectrum of the Girona civil society. It has been held by the *Plataforma del Ter*, the Ateneu, which the *Consorci Alba-Ter* and the irrigation communities; and *Aigua per Unir* is the specific idea on board, already explained in **Section 7.3**. This does not put into question the current profit-driven rationalities that leads the water policy in Catalonia, focus the arguments on one dimension, i.e. the accounts of water flows, and feels comfortable in the intra- *versus* inter-basin conflict. Its solution, based on the sharing the supply of Barcelona among different donor basins in Catalonia, do not fit in other territories outside Catalonia. The main weakness is the difficulty that any government would dare build an Ebro or Segre transfer.

Instead, ECO is defended by the purely environmental activists (i.e. GDT, ANG and *Gent del Ter*, among others). They move into the instream *versus* diverted flows front. They are completely against any new water transfer, what supposes an inconsistency regarding the already existing Ter transfer. Their proposal is long-termed, is deeply involved in the new water culture and links the water management with other inevitable political dimensions such as those related to the territory and the economic growth.

As we have seen in **Chapter 7**, a critical historical perspective of the ecosystem services provision allow us to see different interests from different actors. However, the power that these actors hold in order to decide on the management of the Ter River is not related to such interests. Rather, it is related to several influence factors such as the capacity to pay advertisements or to write op-ed articles in the newspapers and make their discourses penetrate, the capacity to be organised and demonstrate and fight, the capacity to directly contact with the decision-makers.

8.3.1 Limitations of the ES applications

This thesis specifically accounts for the ecosystem services that depend on the level of water flows in order to evaluate the allocation policies of the Ter's waters. Such specificity unavoidably implies some limitations that should be overcome in further research (see **Section 8.3**). As follows, we scrutinise the main limitations of each application of our ES-based approach to water conflicts.

Chapter 5 analyses ES provision form the ecological and social perspectives by means of twenty interviews with local stakeholders. Although twenty was considered a reasonable number because the amount of cited services was high, it would have been desirable to interview senior in influential companies such as Agbar, Endesa or ATLL. At the beginning, we exclude those stakeholders because they were difficult to contact and their view was not specific for the Ter River basin.

Furthermore, the interviews only showed the signal of the effects among hydrological alternations, components of the river and ES, but not the magnitude of such links. The addition of a questionnaire that had quantified such relationships would have allowed the development of a Bayesian Believe Network as an ecological-economic model (e.g., Mcvittie et al., 2014).

In the model of **Chapter 6**, there are several constraints because of the need of gathering very detailed data, since the software does not accept inaccurate data. However, we do not consider uncertainty issues in the model process but in the interpretation of the results. Thus, the results under any scenario have to be interpreted as trends that mark differences from the BAU scenario, rather than strict values of ES provision.

Again, the number of participants has been a limitation. Although twenty participants in the two workshops of the Lower Ter is a good number for working efficiently, during the validation workshop, we found divergent views with respect to the suitability curves developed before. In fact, the suitability curves tool resulted not useful for particular services hardly to relate to water flows such as the beauty of a river spot – despite evidences demonstrated by Pflüger et al. (2010). This is actually the reason why the characterisation of services in **Chapter 5** is a good complement for the model. In particular, it accounts those ES difficult to model and the different views on the same ES. During the validation workshop, for instance, some participants noticed that the suitability curves should be differently designed by the company that benefits from the ES provisioning process (e.g., a water distributor) than by the final beneficiary of such ES. In the model, the lack of considering factors others than water flows for the ES provisioning is actually the main cause of disparity between the outcomes of the model and the opinion of the stakeholders. For instance, a kayak instructor valued the provisioning of calm-water kayaking much lower partially because of the discharge of high flows in the late summer to avoid an excessive filling of the reservoirs. Such high flows that occur in a few days become diluted in a monthly average so the model does not reflect them very well.

Finally, in relation to the historical approach of the political ecology of the Ter River management (**Chapter 7**), the broadness of the analysis is one of the strengths of the methodology employed, but it also presents some limitations. Thus, this chapter is an overview of serveral conflicts rather than an in-depth analysis of one specific conflict. So many questions have arisen during the works that we would have liked to answer but we did not. Is it possible to imagine a Catalonia (or Spain, or Europe) with all the watersheds interconnected? Is it possible, on the contrary, to imagine a Ter River without Sau and

Susqueda once these dams become obsolete? Towards which scenario would we move in a more participatory era where the power became more balanced?

8.2 CONTRIBUTIONS TO THE THEORETICAL AND METHODOLOGICAL FRAMEWORKS

8.2.1 Contribution to the notion of ecosystem services

This application of an ES-based approach to an ecological distribution conflict is *per se* a contribution to the ecosystem services research, since not many publications have employed such approach for conflict analysis, and absolutely none for analysing tensions in relation to water flows[21]. Besides the novelty of methods employed, already emphasised in the previous section, we index here the four main advancements of this thesis in the notion of ES:

- Purpose-driven and case-specific ES applications need to go beyond the usual classifications of ES.
- Rivers as networks provide ES beyond their temporal and spatial boundaries.
- Non-monetary valuation techniques and mapping representation allow to assess weakly comparable ES without the need of aggregating their values.
- ES is not only a pedagogical, technical and policy notion, but also political.

In the same way species are classified according to genus, family or order, but also divided in sub-species, ecosystem services can also be grouped and divided in multiple ways. This actually entailed multiple discussions (de Groot et al., 2002; Fisher and Turner, 2008; Potschin and Haines-Young, 2015; Wallace, 2007). This dissertation has demonstrated the diversity of ways people use, enjoy and feel the ecosystems of their surroundings, but we doubt the utility of current classification systems.

The MA and later assessments and classification systems (e.g., TEEB, CICES) classify ES in regulating, provisioning, cultural and sometimes supporting services. This classification is seen as being useful to engage with stakeholders, although we found some ES difficult to attribute to one specific group. Does fly-fishing go into either the provisioning or the cultural services group? As water distributes ecosystem services at different temporal and spatial scales, the category of supporting services is useful to represent the effects that water flows have on ecosystem services provided by ecosystems other than rivers (e.g., wetlands, beaches, historical canals).

Notwithstanding, are the MA and CICES classification systems the best possible for analysing water conflicts? We have seen other ways of classifying services. These do not

[21] In a search to ScienceDirect, only four publications not related to this thesis use the keywords "conflict" and "ecosystem services" in the title at the date of June 2016. Three are related to biodiversity and protected areas (Bullock et al., 2011; Kovács et al., 2015; Niedziałkowski et al., 2014) and one to bathing waters (Quilliam et al., 2015).

only categorise the sources of benefit, but also the type of beneficiaries that can access to those services and the impact on the environment related to their provision. Thus, there are people benefitting from intra- or inter-basin uses, and from instream and out-stream uses. At the same time, some of these out-of-stream uses consume water, while others return it entirely to the river channel, such as the hydropower production. Some services are clearly marketed and have an economic significance, and others are more associated to social and cultural values (Brauman et al., 2007). Even some ES like rice agriculture can be associated to different types of values at the same time, since provides economic welfare to farmers, traditional landscape considered heritage and habitat for waterfowl. Services can also be characterised along a continuum from rival to non-rival and from excludable to non-excludable (Fisher et al., 2009). In addition, the ES provided by a free-flowing river are also very different from those related to a humanised landscape, with weirs and canals (Auerbach et al., 2014). Interesting enough, this was the argument given by an old lady from Sant Quirze that preferred the water flowing within the canals, hence through the town: "I feel like living in Venice!" Such classifications of ES illustrate different dimensions in which inequalities in relation to recognition, representation and distribution may take place and inevitably turn into social tensions. This happens because some services are actually contradictory to one another, particularly if they are maximised (Kull et al., 2015).

An ES is not uniformly provided either. It varies along the river, since the fish species and the riparian vegetation are not the same in all stretches, nor the landscape nor the society, which also have changed through history. The significance of the river as a spot for fishing and as a mean of transport has decreased over time, but other recreational activities such as kayaking or jogging are flourishing now. The scale of the services also matter and affect conclusions about ES provision (Hein et al., 2006; Kull et al., 2015). The waterscape of the Ter is enjoyed *in situ*, while the Ter's waters are distributed throughout a great portion of Catalonia. Temporal and spatial patterns of ES provision are mainly defined by water flow conditions (i.e. different degrees of alteration in terms of frequency or magnitude), but also by other constraints that can be biophysical (e.g., a dense stripe of riparian forest that impede the access to the water table), legal (e.g., a stretch used for catch and release fishing), infrastructural (e.g., an abandoned weir) or related to management (e.g., the entrance of the historical canals). There are even social constraints. In contrast to the rest of citizens of Manlleu, children and immigrants are not really fussy when they go to swim, as they never saw the river in its extremely polluted condition two decades ago.

On the basis of the complexity that an ES assessment supposes in considering all these multiple dimensions of socio-ecological relationships, our ES application is consistent with Kallis et al.'s (2013) proposal to avoid monetary valuation when certain conditions are not fulfilled. Although Bardina et al. (2016) undertook a benefit transfer exercise for the Upper Ter with positive outcomes for the preservation of the river ecosystem, such results could be not so clear for the Lower Ter. Can the WTP for a restored river overtake the economic value of the water flow that supplies the industry in the RMB? We might doubt that. In fact, a monetary valuation of the Ter transfer reinforces the inequalities of power and income among the different stakeholders, it is not conducive to improve the ecological status of the river and does not recognise other languages of valuation. Thus, instead of an aggregation of monetary outcomes, in front of a conflict scenario, we found that networks, radial graphs, maps and chronologies become better tools for assessment (e.g., Burkhard et al., 2012; Dearing et al., 2012; Haines-Young, 2011; Plieninger et al., 2013; Sanon et al., 2012).

Ecosystem services can then be useful in multiple approaches. However, Norgaard (2010) alerts us not to be blind the complexities of the challenges we are facing, in our case, the understanding of conflicts related to water flows. As a response to some controversies exposed by Barnaud and Antona (2014) and others (e.g. the conflicts of interests, power plays, scales issues associated with the management of ES), the ES is a powerful concept that needs to be engaged with. The ES as a political notion "*facilitates certain types of interventions and discussions that reflect particular discourses, power relations, and political-economic structures, even if, at times, it is somewhat undermined*" (Kull et al., 2015, p. 132). However, there are just a few case studies where the ES concept has been seen as a political notion (e.g., Depietri et al., 2016; Horcea-Milcu et al., 2015) and too many assessments take an apolitical view of ES. This can actually drive results that represent the opposite to what was expected according to the objectives (Corbera et al., 2007). An example of the political meaning given to ES in this dissertation is the use of the ES as political interest in the interest-influence graph (see Fig. 32, **Section 7.4.2**) to analyse the stakeholders' position along the history of the Ter.

8.2.2 Contribution to the ecological economics and political ecology debates

As the notion of ecosystem services has become more commonplace – both in academic and popular discourses – ecological economists and political ecologists have expressed scepticism about its application to resource management. Barnaud and Antona (2014) show that the concept of ecosystem services is beset with uncertainties and controversies at several levels (e.g. conceptualisation, economic valuation, and implementation); Arsel and Büscher (2012) place ecosystem services as a tool of a neoliberal conservation; and Corbera et al. (2007) assert that it can reinforce unequal power relationships. However, ES-based approaches also feature virtues that give room for the integration of ES in the political ecology sphere. They include, for instance, the enhancement of the awareness of socio-environmental linkages, the identification of distributional issues related to service loss and the evaluation of tradeoffs (Rodríguez-Labajos, 2016).

The case of the Ter River, through the lens of ecosystem services, shows then those and other qualities that an ES-based approach provide to ongoing debates on ecological economics and political ecology. In this subsection, we particularly evaluate the contribution of our work to four topics of discussion in relation to water conflicts:

1. co-evolution of nature-society;
2. plurality of values;
3. varieties of environmentalism; and
4. power instruments to gain, control or maintain access to water flows.

While political ecologists usually see the economy and society as smaller circles within an independent, external circle called ‘nature’ or ‘ecosystem’, from a political ecological perspective, ecosystems are entangled in social and political process, so ecosystem services are socially produced (Depietri et al., 2016; Ernstson, 2013). The position of those boundaries between nature and society can entail water injustices, particularly when droughts are solely attribute to climatic causes (Ioris, 2012; Zwarteveen and Boelens, 2014). The lack of rain during the 2007 was dramatic, but the extreme dependence of Barcelona on the Ter’s waters had a critical role on the costly water restrictions suffered by irrigators and hydropower producers[22]. As claimed by Armiero (2008), we found the social in nature and the nature in society. In Salt town, for instance, the architecture and street art is linked to the river and its fauna, while the ‘natural’ floodplain wetlands need to be artificially irrigated because the dams caused a disconnection with the phreatic level.

With the appropriate engagement of local stakeholders, we identified ES that go beyond a profit-driven perspective of water availability and we have used and embraced other forms of usage, enjoyment or feeling river ecosystems. Similarly to the work done by Molina-Camacho (2012), we have also identified conflicting rationalities (divergences on profitable *versus* non-profitable management, public *versus* private, exotic and beautiful *versus* native and unpleasant, etc.) and languages of valuation (e.g., some people appeal to personal experiences that others have not lived). The historical canals, although they divert water from the river, are a vital element for the Baix Ter Plain landscape; and those that defend their protection actually struggle against those that accuse them of being inefficient. The historical canals are also another example of co-evolution. Endemic species live in those human-made canals, which in turn trace ancient branches of the river mouth.

Those different rationalities on ES provision and nature-society relationships have also generated different varieties of environmentalisms (Guha and Martínez-Alier, 2013; Martinez-Alier, 2003). The ‘defence of rivers’, against the water transfer and for the preservation of the instream flows and the associated biodiversity. The ‘ecosystem people’, living in accordance with the natural functioning of the river (environmental educators, white-water kayakers, small irrigators, etc.), against the always-growing city of Barcelona and the ‘ecological invaders’ that allow this growth. The ‘urban straggles’ for having a clean river with recreational space. Finally, although not many people is currently directly living off of the Ter River, the ‘environmentalism of the poor’, the environmentalism of those that had free access to water, fish, river rocks or wicker, but that do not have it now and complain about all the licences they must request at the ACA. Those

[22] Irrigators lost 249.4 M€ during the April 2007-January 2009 period, and the hydropower producers 114.1 M€ (Martin-Ortega et al., 2012).

environmentalisms also claim either a natural flow regime or a managed e-flow regime. In fact, we could attribute to COM and ECO scenario these two perspectives of flow regime.

Who takes advantage and controls access to water resources and who loses that access to specific benefits constitute ecological distribution conflicts (Ribot and Peluso, 2003; Rodríguez-Labajos and Martínez-Alier, 2015b). We have analysed those perceptions that COM and ECO represent through an integrative modelling approach. Our model simulates the share of the water flows by different stakeholder groups under both alternative scenarios besides the business as usual. Spatial and temporal patters of distributional issues have been found useful to associate conflicts with different areas or stretches of the river and with different seasons or periods. Besides, this ES modelling also puts numbers on ecological distribution conflicts and helps to perform an argumentation based on the materialities (i.e., the benefits) behind the power exercise for gaining or maintaining the control of water management. ES modelling also helps to overcome the error of a political ecology without ecology (Rodríguez-Labajos and Martínez-Alier, 2015b; Walker, 2005). Thus, quantification of either water flows or service provision are helpful to identify the water conflicts studied in ecological economics and political ecology.

8.3 PROPOSALS FOR FURTHER RESEARCH

This thesis provides plenty of insights that can be employed for further research on river management, on political ecology of water conflicts or on ES applications.

From the beginning, the scope of this thesis has been to study the whole river basin. However, we have mainly focussed on the conflicts in the Lower Ter because the Ter transfer has been much more contested than the SHPP, as became apparent through interviews and documents found in the archives. Notwithstanding, some conclusions from the Upper Ter are very interesting and could become the seed for new research.

First, the chain of SHPP not only alters the instream flows throughout the sub-basin, but also the aquatic habitat, by creating new dammed stretches, and the river continuity, as weirs are barriers to fish migration. These three types of hydromorphological alteration, together with the fact that the chain consists of dozens of weirs instead of a unique dam, make a comprehensive river restoration challenging. For instance, to make the river suitable for whitewater kayaking, at least some consecutive weirs should be permeable to the traffic of boats, in addition to discharging a suitable flow. Instead of the assessment presented in **Chapter 6**, for the Upper Ter it would be interesting to develop a multi-criterial methodology to assess the socio-economic benefits of a stretch of the river by applying different restoration measures (from a better management of the sluices to the construction of fish passes or dam removal) to multiple weirs. Then, the results could suggest different factors affecting the value of restoration measures on weirs (e.g. distance to the next weir, distance to the town, architectonic heritage). Furthermore, further research could ponder upon what weirs and with what measures the watershed administration should act for a restoration.

Second, the hydraulic infrastructure in the Upper Ter was constructed decades ago. Many elements of such infrastructure have become part of the architectonic heritage and new forms of *nature* have appeared, as well as new forms of enjoying the river. For instance, the dammed water has constituted new habitat for carps and for the riparian forest; and recreationists looking for a *natural* spot have colonised these areas too (for swimming, fishing, appreciating the beauty, etc.), as we explain in **Chapter 5**. However, those *new* environments are subject to the WFD and, if they impede achieving a good ecological status, restoration measures should be undertaken. In the Molló village, in the Camprodon Valley, the court of law decided in favour removing a dam that was discharging a ridiculously small flow. AEMS reported the owners to the administration, who had made repeated calls to them to discharge a minimum flow. Although one would think that this decision had been correct, since there was no water flowing downstream so one would suppose that the people would enjoy again seeing a living river, the results were not as expected. During some fieldwork performed with the M.Sc. student Mathias Brummer about this case, some locals recognised the fact that the river was being over-exploited but also agreed on their opposition to the dam's removal. The reasons given were several. First, the stretch of the stream affected by the withdrawal (the Ritort, a tributary of the Ter) is not accessible for visitors, so it barely provides recreational and aesthetic ecosystem services. Second, the little reservoir created was actually visited, especially by young people, for swimming. Third, the tribunal had to decide between two extreme solutions, neither of them considered beneficial for the village. Fourth, the decision of closing the hydropower plant removed the unique source of renewable electricity in the village, forcing the village to depend on external and polluting sources. Finally, the decision was seen as an extra instrument of the ACA to centralise the control of access to water resources by the villagers. Therefore, an interesting new research project could be an in-depth analysis of those factors (e.g., access to ES, governance of hydraulic infrastructure) that influence the opinion of those people who do not make profit directly from hydropower, but rather assume that there is an over-exploitation of the river.

A final idea for further research would include the combination of qualitative and quantitative data and the exploration of GIS for the analysis of conflicts. Multiple initiatives have been using maps to illustrate river conflicts at a local scale, e.g., a spatial description of the impact of oil companies (Orta-Martínez, 2010), and even at a global scale, e.g., a classification and characterisation of multiple conflicts around the world (EJAtlas, 2016). Thus, similarly to what is done in **Chapter 7**, the addition of biophysical spatial data (e.g., freshwater availability, historical occurrence of droughts or floods, river ecosystem functions that can potentially provide ES) to those databases on conflicts, would improve the understanding of distributional causes of such conflicts.

8.4 POLITICAL IMPLICATIONS FOR WATER POLICY AND ACTIVISM

This thesis does not provide a monetary value that would be a desirable outcome for the water administration in order to prove the socio-economic benefits of instream flows and negotiate the implementation of the e-flows, especially in the Upper Ter. However, monetary valuation would undermine a complex reality of societal-ecological interactions. Instead, we characterised those instream flow-dependent ES and the varied perspectives about their management, as well as potential synergies and tradeoffs that may appear between such ES. These insights can inform the water administration – and private users – about the offsetting of new projects such as new water withdrawal or the implementation of e-flows.

Actually, interesting projects are currently going on in the Ter basin. The Consorci Alba-Ter is developing a plan of uses of the Ter River, whose aim is to organise the recreational activities with respect to the ecosystem and the existent uses. Thus, by acknowledging the constraints for the provision of associated services and the tradeoffs between new and existent uses, this work facilitates a better design and implementation of the plan. Likewise, water consumers of the Lower Ter – mainly irrigators but also town councils and the tourist and industrial sectors – have already constituted the *Junta Central d'Usuaris d'Aigües Superficials i Subterrànies del Baix Ter*. This committee aims to unify strategies to have a higher influence on decisions to be made about dam management. Although the Water Law only allows to the creation of committees of water consumers, this thesis demonstrates the need for the new Junta to count on less visible stakeholders for important political decisions that could affect the instream flow-dependent ES.

Finally, from this thesis, we can highlight commonalities among activists, although it seems that the opposition to water transfers and *Aigua per Unir* are incompatible.

- A defence of the implementation of an e-flow regime should be an unwavering position, since all activists claim an improvement of those instream flow-dependent ES.
- Any watershed that provides water, as the Ter basin does, should be compensated economically so that money could be invested in, for example, a river restoration project or an improvement of the irrigation efficiency.
- Besides the necessary compensation, another key for an agreement would be the decentralisation of the water management. This would allow the water provider to control the ‘tap’ for the transfer. However, this would create a fierce opposition in the metropolitan Barcelona and likely in the Catalan government.

A personal opinion is that, in the long term, the control of the transfers by the donor basin and the economic compensations could make possible a future Ebro transfer (I am not saying it is necessary) to reduce the Ter transfer. However, in order to get the acceptance of anti-transfer movements, this would require a public, democratic and decentralised management of water, which would include all beneficiaries from instream flows poorly recognised now. Anyway, this could not be a finally sustainable solution since supply-oriented policies have proven to increase water demand and fail in the long term. As water policies are in accordance with urban policies (Masjuan et al., 2008; Otero et al., 2011; Saurí, 2003), questions that should be asked are: 1) whether Catalonia still needs to concentrate its population and industrial activity in the metropolitan area of Barcelona; and 2) whether the second ring of the Barcelona conurbation, far from consisting of compact towns as it used, cannot make an effort to reduce water consumption.

Nevertheless, considering the multiple crisis – political, economic, social – that Catalonia is facing, it is difficult to think in the long term and to put the water issues on the table. Who knows whether we will have to wait until the next drought in order to change the water policies?

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Appendixes

APPENDIX A. STAKEHOLDER ENGAGEMENT PROCESSES

A.1 Interviews with key stakeholders

We interviewed twenty stakeholders, key in the conflicts about the Ter River, in order to identify the ES provided by the Ter River and their relation to the water flow management. In **Chapter 5**, we inform about the methodology employed to select those key informants and we expose later the results obtained from the analysis of the interviews. **Appendix B** lists in minute detail all relationships established between water flows and ES.

The interviews were semi-structured and the script was the following:

Introduction to the interviewee

- Name and surname of the interviewee.
- Some questions to break the ice, e.g., "Today I've seen many people cycling along the river. I hadn't been in this town in so long."
- Asking for switching on the tape recorder.
- Explanation on the purpose and the outline of the interview.

The interviewee's life in relation to the river

- Where they live and where have lived; where they work and where have worked.
- Reason for which their life is linked to the Ter River or some of its tributaries.
- For how long the interviewee enjoys from a life linked to the Ter.

The ecosystem services

- Definition of the ecosystem services concept.
- Explanation on our understanding of the Ter River as an ecosystem that includes, not only water, but also its associated aquatic fauna, the floodplains, the phreatic level, etc.
- The services provided by the Ter and consumed by the interviewees.
- Other services provided by the Ter that are consumed by other people.
- The influence that ecosystem services have on the riverside towns.
- The services the interviewee would like the Ter provided, but for some reason it does not.
- Evolution of the service provision over time.

Problems of the Ter River.

- Reasons for which the river does not provide those services that, according to the interviewee, it should. Reasons for which they have decreased or disappeared.
- Possible solutions for the recuperation of ecosystem services.
- Evolution of the services previously mention in relation to the implementation of e-flows.
- Compatibility among different ecosystem services (e.g., whether there is no water the irrigation due to an excess of water consumption for domestic purposes) and priority levels.

The propriety of the river

- The propriety of the variety of natural o human-made elements of the river (e.g., the water, the flora and the fauna, the weirs and canals).
- Access to the water flows and to the ecosystem services.
- Agreement or disagreement degree of the interviewee on the current management of the river and the water flows.

A.2 Survey among environmental organisations and citizen platforms

By using SurveyMonkey®, we sent a questionnaire in May 2014 to the representatives of different non-for-profit organisations that work for a better management in Catalonia. Twenty-five organisations responded. They included environmental organisations, unions, citizen platforms and an association of civil engineers. Table A1 shows the script of the questionnaire with all the questions and some of the answers.

We selected 11 of the 25 organisations to develop the management scenarios (see **Section 6.3.4**), since they were the only organisations working in the Ter River basin. For that task, we also added 10 individual key informants. The information obtained from these 10 individuals come from another survey made to a large number of people of the Ter basin. Due to the lack of representativeness of the sample, we only selected those respondents from our snowball sampling (see **Section 5.2.1**).

Table A1. Questionnaire performed among twenty-five associations that struggle for a better water flow management.

Introduction
Presentation of the project This questionnaire is part of doctoral thesis conducted by Dídac Jordà Capdevila at the Institut de Ciència i Tecnologia Ambientals (ICTA) of the Universitat Autònoma de Barcelona (UAB). The object of this study is the ecosystem services that the Ter River provides for the human well-being and the effects of the water flow management to the supply of those services.

Objectives of the questionnaire

The objectives of the present questionnaire are to know:

- different models of water management that different environmental organisations propose;
- the position of the organisations on the water supply management: the case of Barcelona;
- the position of the organisations on the river management: the case of the Ter;
- the nature of different environmental organisations in Catalonia and their line in relation to the management of rivers and water flows.

Introduction questions

- Name and surname of the respondent.
- Name of the organisation, which the respondent belongs to.
- Position of the respondent in the organisation.
- Date of today.

Water management models in Catalonia

Write 1-3 keywords that explain the objectives of your organisation.

The human right to water is expressed by means of:	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ the water management, which should be a public, owned by the State	*4.0%*	*0.0%*	*32.0%*	*12.0%*	*44.0%*	*8.0%*
▪ the water management, which should be common and belong to the citizens of the Ter basin	*0.0%*	*0.0%*	*16.0%*	*28.0%*	*52.0%*	*4.0%*
▪ a minimum supply of 50-100 L/person/day free of charge	*0.0%*	*24.0%*	*24.0%*	*24.0%*	*20.0%*	*8.0%*
▪ the water management, which should be controlled and participated by the general public	*0.0%*	*0.8%*	*4.0%*	*28.0%*	*56.0%*	*4.0%*
In general, to guarantee a sustainable water management, we need:	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ the enhancement of local and traditional models of management that promote and preserve good practices	*0.0%*	*0.0%*	*8.0%*	*44.0%*	*40.0%*	*8.0%*
▪ the conservation of river ecosystems, since they are the main source of water	*0.0%*	*0.0%*	*4.0%*	*4.0%*	*88.0%*	*4.0%*
▪ the inclusion of technological and management measures that increase the efficiency in the distribution and use of water	*0.0%*	*4.0%*	*12.0%*	*24.0%*	*56.0%*	*4.0%*
▪ the centralisation of the water management, with the appropriate knowledge on water availability and territorial demands for a fearer distribution	*4.0%*	*8.0%*	*28.0%*	*20.0%*	*32.0%*	*8.0%*
▪ the cost recovery in the water price of all types of use (e.g., irrigation, domestic, industrial)	*0.0%*	*12.0%*	*20.0%*	*36.0%*	*24.0%*	*8.0%*

Water management in the metropolitan Barcelona

What is the main challenge about the water supply of the RMB?

The current situation of the supply of the RMB is:	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ The region is well supplied	*4.2%*	*20.8%*	*16.7%*	*33.3%*	*4.2%*	*20.8%*
▪ The region consume too much water considering its population and industry	*0.0%*	*25.0%*	*33.3%*	*4.2%*	*12.5%*	*25%*
▪ There are too many people and industry considering the sources of available water	*0.0%*	*4.2%*	*20.8%*	*33.3%*	*25.0%*	*16.7%*
The best measures for solving the supply issues in the RMB are those that:	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ disconnect the industries that consume the most water of the Ter-Llobregat network	*0.0%*	*33.3%*	*25.0%*	*8.3%*	*8.3%*	*25.0%*
▪ restraint the growth of the city according to the availability of water	*0.0%*	*4.2%*	*16.7%*	*33.3%*	*33.3%*	*12.5%*

▪ improve the quality of own water sources (e.g., aquifers, Llobregat River)	*0.0%*	*0.0%*	*0.0%*	*25.0%*	*66.7%*	*8.3%*
▪ develop a new infrastructure with an enough capacity to definitively solve all problems related to the water supply of Barcelona (e.g., the Rhône transfer)	*66.7%*	*20.8%*	*4.2%*	*0.0%*	*0.0%*	*8.3%*
▪ increase the diversity of own water sources (e.g., reuse of wastewater, operation of desalination plants)	*0.0%*	*8.3%*	*20.8%*	*25.0%*	*37.5%*	*8.3%*
▪ create a water blank, small connections between watersheds to increase the diversity of water sources and provide higher water security	*20.8%*	*37.5%*	*12.5%*	*12.5%*	*4.2%*	*12.5%*

Water management in the Ter basin

A suitable management of the Ter transfer implies:	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ to maintain the current situation, but also to increase the diversity of the water sources in case of droughts	*9.5%*	*52.4%*	*4.8%*	*19.0%*	*9.5%*	*4.8%*
▪ to subject the Ter transfer to the implementation of e-flows and to the intra-basin uses	*0.0%*	*4.8%*	*14.3%*	*23.8%*	*52.4%*	*4.8%*
▪ to stop the transfer and to supply the RMB from its own sources	*0.0%*	*23.8%*	*42.9%*	*14.3%*	*14.3%*	*4.8%*
▪ to discharge water according to a naturally variable flow regime, without the interference of other uses (e.g., kayaking, irrigation)	*0.0%*	*19.0%*	*23.8%*	*38.1%*	*14.3%*	*4.8%*
In respect to the hydropower plants:	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ weirs should be removed in order to maximise nature in the river	*0.0%*	*14.3%*	*42.9%*	*28.6%*	*9.5%*	*4.8%*
▪ the owners should discharge e-flows established in the PSCM without receiving any compensation	*4.8%*	*9.5%*	*0.0%*	*14.3%*	*57.1%*	*14.3%*
▪ the water management should respect the current concessions	*23.8%*	*42.9%*	*28.6%*	*4.8%*	*0.0%*	*0.0%*
▪ weirs and canals represent a cultural heritage that need to be preserved, since they have aesthetical and cultural values	*19.0%*	*4.8%*	*57.1%*	*14.3%*	*4.8%*	*0.0%*

Arrange the following uses of the Ter's waters from more to less important:
Industry (including pig farming), historical canals, wetlands and other contiguous ecosystems, capacity of dam storage, a minimum flow that avoids to have a dry river, inter-basin water supply, irrigation, large hydropower plants, an e-flow as the one established in the PSCM, intra-basin water supply, aesthetic and recreational uses, small hydropower plants, and an e-flow regime higher than what is established in the PSCM. (*results are shown in Fig. 24, **Section 6.3.4***)

Do you have, from your organisation, any proposal in relation to some of these uses?

Do you identify of any type of injustice in relation to the water flow management in the Lower Ter?	Yes	No	I do not know
	85.7%	*0.0%*	*14.3%*

What is the main origin of such injustice?

▪ Sociocultural: the lack of awareness on one particular group of actors	50.0%
▪ Economic: the unequal distribution of the wealth (in a broad sense) generated by the river	83.3%
▪ Political: the lack of participation in the decision making of some actors linked to the river	72.2%

Do you identify of any type of injustice in relation to the water flow management in the Upper Ter?	Yes	No	I do not know
	76.2%	*4.8%*	*19.0%*

What is the main origin of such injustice?

▪ Sociocultural: the lack of awareness on one particular group of actors	*44.4%*
▪ Economic: the unequal distribution of the wealth (in a broad sense) generated by the river	*61.1%*

- Political: the lack of participation in the decision making of some actors linked to the river *61.1%*

The organisations and their opinion line

What is the position of the organisation in relation to the following affirmations?	I totally disagree	I disagree	I partly agree	I agree	I totally agree	I do not know
▪ We need to come back to a consume and management models based on the traditional knowledge of the river	*0.0%*	*28.6%*	*42.9%*	*14.3%*	*9.5%*	*4.8%*
▪ The river has to be 100% pristine and natural	*0.0%*	*23.8%*	*42.9%*	*28.6%*	*4.8%*	*0.0%*
▪ The water management has to be in the scientists and technicians' hands.	*4.8%*	*19.0%*	*42.9%*	*28.6%*	*4.8%*	*0.0%*
▪ We need to aspire to a maximum level of efficiency in the use and transport of water	*0.0%*	*0.0%*	*4.8%*	*47.6%*	*47.6%*	*0.0%*
▪ Humans are the main enemy of rivers	*4.8%*	*19.0%*	*19.0%*	*19.0%*	*28.6%*	*9.5%*
▪ The deterioration of rivers starts with the expansion of industry	*0.0%*	*9.5%*	*47.6%*	*23.8%*	*14.3%*	*4.8%*
What type of organisation do you represent? What is its origin?						
With which other organisations do you work in relation to the water management? In which say?						
What is the geographical scope of your organisation?						

Notes. Results are written in italics. They represent the percentage of those who answered, between 21 and 25, depending on the question.

A.3 Participatory workshops and complementary interviews

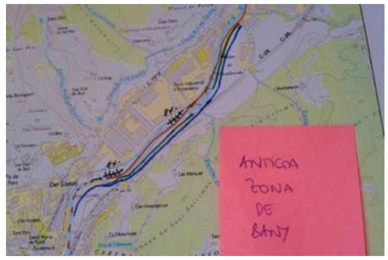
We organised four workshops in the four study areas: in Llanars (Camprodon Valley), Manlleu (Vic Plain), Salt (Girona) and Torroella de Montgrí (Baix Ter Plain) (see Pics. A1, A2 and A3). The main objective of those workshops was to gather some data for the stakeholders-based ES provision model (see **Section 6.4**). In those workshops, we grouped the participants according to three types of expertise: in water supply (for either domestic, industrial or irrigation uses), in culture and recreation (e.g., environmental educators, kayakers, fishermen) and in the river and contiguous ecosystems (mainly environmentalists and scientists). For each group, we arranged the following exercises:

1. Mapping of those stretches of the river where different ES are currently provided.
2. Description of those biophysical, legal, infrastructural and management constraints for ES provisioning.
3. Draw of a suitability curve for each ES, including those water flow levels that satisfy a minimum level and an optimum level of ES provision.

After the workshops, in April 2014, we performed six interviews in order to complement the information gathered.

For the reasons detailed in **Section 6.1**, we excluded the Upper Ter from the modelling exercise. In fact, some issues occurred during the workshops in the Camprodon Valley and in the Vic Plain. In the former, we surprisingly had to leave the room one hour before the workshop finished. In the latter, only three people attended. Anyway, the performance of these two workshops was very useful as pilot workshops for those in the Lower Ter. Results of the workshops in Girona and in the Baix Ter Plain are in **Appendix D**.

Pic. A1. Beatriz explaining the instructions of an exercise during the workshop in Torroella.



Pic. A2. Different ecosystem services marked along the river course.

Pic. A3. Participants marking the map in the workshop in Llanars.

A.4 Validation workshop

We organised one validation workshop in February 2016 in Girona (see Pics. A4, A5 and A6) with two main objectives: first, to present in public the results of the thesis for any person that could be interested; and second, to know the level of agreement of a variety of stakeholders –different from those that participated in previous workshops – on the information obtained from the other workshops and from the model developed in **Chapter 6**. The workshop was structured in four specific exercises with the following purposes:

1. To agree or disagree on the results obtained from the model for each ecosystem services and considering different seasons (autumn, winter, spring and summer) and water-year types (normal, dry and wet).
2. To emend the maps of ES provision and inform about the biophysical, legal, infrastructural and management constraints.
3. To emend the suitability curves.
4. To enumerate those historical events that meant a significant turning point for the provision of specific ES.

Results of this workshop are presented in **Section 6.5.4**.

Pic. A4. Presentation of the results of the thesis.

Pic. A5. Materials to validate.

Pic. A6. The recreationists group validating the results for calm-water and whitewater kayaking.

APPENDIX B. LIST OF LINKS BETWEEN HYDROLOGICAL ALTERATIONS, COMPONENTS OF THE ECOSYSTEM AND ECOSYSTEM SERVICES

In the following tables, we list all relationships that different interviewees (identified with an 'I' in Fig. 17 and Table 8, in **Section 5.2.1**) highlighted among hydrological alterations (HA), components of the river ecosystem and socio-economic benefits. We also crosschecked those relationships not directly related to ES with scientific literature. We employed such relationships in **Chapter 5**.

Table B1. List of effects of hydrological alterations on components of nature

HA	Effect	Components of the ecosystem	Interviewees that identified such link	References used for crosschecking
HA1	-	Status of native fishes	I-03, I-09, I-13	(Benejam et al., 2010; Jowett and Richardson, 1995; Næsje et al., 1995; Whiting, 2002)
	-	Status of native eels	I-20	(Jowett and Richardson, 1995)
	-	Water quality	I-09, I-14, I-20, I-17	(Poff et al., 1997)
	-	Aesthetics of the landscape	I-13, I-14, I-16, I-01, I-02	(Brown and Daniel, 1991; Pflüger et al., 2010)
HA2	-	Biodiversity in terms of species and habitats	I-14	(Whiting, 2002)
	-	Structure and quality of riparian vegetation	I-03	(Johnson et al., 1976; Richardson et al., 2007; Whiting, 2002)
	+	Sea water invasion	I-20	(Glover, 1959)
	-	Aquifer level	I-12	(Glover, 1959; Whiting, 2002)
HA3	-	Structure and quality of riparian vegetation	I-11	(Poff et al., 1997; Richardson et al., 2007)
	-	Status of native fishes	I-13	(Næsje et al., 1995; Whiting, 2002)
	+	Spread of exotic species	I-11, I-13	(Aparicio et al., 2000)
HA4	-	Structure and quality of riparian vegetation	I-13	(Poff et al., 1997; Richardson et al., 2007)
	-	Status of native fishes	I-11, I-03	(Bunn and Arthington, 2002; Næsje et al., 1995; Whiting, 2002)
	+	Spread of exotic species	I-09, I-11, I-13, I-03	(Aparicio et al., 2000; Boix et al., 2010; Lake, 2003; Prats et al., 2009)
	-	Water quality	I-13	(Poff et al., 1997)
HA5	-	Structure and quality of riparian vegetation	I-02	(Busch and Smith, 1995; Poff et al., 1997; Richardson et al., 2007)
	-	Status of native terrestrial fauna	I-02, I-01	(Ballinger and Lake, 2006)
	-	Status of native aquatic birds	I-01	(Cushman, 1985; Poff et al., 1997)
	-	Status of native fishes	I-11, I-10, I-03	(Benejam et al., 2010; Boix et al., 2010; Cushman, 1985; Lake, 2003; Næsje et al., 1995; Poff et al., 1997; Whiting, 2002)
	-	Spread of exotic species	I-11, I-03	(Boix et al., 2010; Closs and Lake, 1996; Scott and Helfman, 2001)
	-	Aquifer level	I-12	(Glover, 1959; Lake, 2003)
	+ / -	Biodiversity in terms of species and habitats	I-10, I-04, I-01	(Boix et al., 2010; Closs and Lake, 1996; Scott and Helfman, 2001)

	-	Aesthetics of the landscape	I-13, I-02	(Pflüger et al., 2010)
HA6	-	Diversity of river morphology	I-11, I-13	(Jackson and Beschta, 1992; Kondolf and Wilcock, 1996; Ligon et al., 1995; Whiting, 2002)
	-	Structure and quality of riparian vegetation	I-13	(Kondolf and Wilcock, 1996; McBride and Strahan, 1984; Poff et al., 1997; Richardson et al., 2007; Whiting, 2002)
	-	Aquifer level	I-12, I-04	(Glover, 1959; Whiting, 2002)
	-	Biodiversity in terms of species and habitats	I-13	(Bunn and Arthington, 2002; Kingsford and Thomas, 1995; Kondolf and Wilcock, 1996)
HA8	-	Status of native fishes	I-03	(Jowett and Richardson, 1995)
	+	Spread of exotic species	I-14, I-15, I-03	(Boix et al., 2010; Geiger et al., 2005; Janes et al., 1996)
	-	Water quality	I-15, I-03	(Friedl and Wüest, 2002)
	-	Aesthetics of the landscape	I-06	(Pflüger et al., 2010)
HA9	-	Diversity of river morphology	I-11, I-08, I-12	(Kondolf, 1997; Ligon et al., 1995; Poff et al., 1997)

Table B2. List of effects of hydrological alterations on ecosystem services

HA	Effect	Ecosystem services	Interviewees that identified such link*
HA1	-	Preservation of historical canals	I-16, I-19, I-15
	-	Hydropower	I-09, I-07
HA2	-	Preservation of wetlands	I-14
	-	Preservation of coastal ecosystems	I-17, I-11, I-16
	-	Drinking water supply	I-10
	-	Irrigation	I-19
	-	Inter-basin water transfer	I-13, I-15
HA3	+	Irrigation	I-11, I-15
HA4	+	Hydropower	I-11
HA5	+	Preservation of historical canals	I-16, I-19, I-15
	-	Swimming	I-01
	-	Grazing	I-04, I-01
	-	Hydropower	I-07
	-	Industry water supply	I-05
	-	Intensive farming	I-08
	-	Irrigation	I-16, I-15
HA6	-	Preservation of wetlands	I-17, I-11, I-12
	-	Preservation of coastal ecosystems	I-17
	+	Hydropower	I-11, I-07
	+	Security against floods	I-13, I-02, I-05
HA7	-	Riverbank activities	I-13
	-	Swimming	I-13
	-	Washing clothes	I-13
	-	Fishing	I-13
	-	Boating	I-13
	-	Hydropower	I-09
HA8	-	Boating	I-11
	-	Relaxing sound of the flowing stream	I-06, I-07
	-	Dumping debris	I-06
HA9	-	Preservation of coastal ecosystems	I-11, I-16, I-12

*As we rely on the stakeholders' opinion on how the ecosystem generates benefits for the human well-being, we did not need to crosscheck with the literature.

Table B3. List of effects of some components of the ecosystem on other components

Components of the ecosystem causing impact	Effect	Affected components of the ecosystem	Interviewees that identified such link	References used for crosschecking
Aquifer level	+	Structure and quality of riparian vegetation	I-11	(Johnson et al., 1976; Richardson et al., 2007; Whiting, 2002)
	-	Sea water invasion	I-12, I-04	(Glover, 1959)
	+	Water quality of aquifers	I-12	(Glover, 1959)
Biodiversity in terms of species and habitats	+	Aesthetics of the landscape	I-01	(Montgomery, 2002)
Diversity of river morphology	+	Biodiversity in terms of species and habitats	I-13	(Aparicio et al., 2000)
	+	Structure and quality of riparian vegetation	I-13	(Richardson et al., 2007)
	+	Status of native fishes	I-09	(Aparicio et al., 2000; Bunn and Arthington, 2002; Meffe and Sheldon, 1988; Pusey et al., 1993)
	+	Aquifer level	I-11, I-08, I-12	(Kondolf, 1997)
Spread of exotic species	-	Water quality	I-14	(Roberts et al., 1995)
	-	Biodiversity in terms of species and habitats	I-13	(Aparicio et al., 2000; Bunn and Arthington, 2002; Poff et al., 1997; Stanford et al., 1996)
Status of native amphibians	+	Status of native aquatic birds	I-02	*
Status of native fishes	+	Status of native otters	I-01	(Ruiz-Olmo et al., 2001)
	+	Status of native aquatic birds	I-02	(Lake, 2003)
Structure and quality of riparian vegetation	+	Biodiversity in terms of species and habitats	I-13, I-03	(Whiting, 2002)
	+	Status of native terrestrial fauna	I-02	(Ballinger and Lake, 2006)
	+	Status of native fishes	I-03	(Baltz and Moyle, 1984; Whiting, 2002)
	+	Water quality	I-08, I-03	(Baltz and Moyle, 1984; Knight and Bottorff, 1984; Richardson et al., 2007; Whiting, 2002)
	+	Aesthetics of the landscape	I-13, I-01, I-02	(Pflüger et al., 2010)
Water quality	+	Status of native fishes	I-09, I-13, I-10, I-18, I-20, I-15	(Aparicio et al., 2000)
	+	Status of native crayfish	I-06	*
	-	Spread of exotic species	I-09	*
	+	Aesthetics of the landscape	I-13, I-14, I-01	(Pflüger et al., 2010)

* Too specific relationship to find suitable references for crosschecking

Table B4. Relationship between components of nature and benefits for the human well-being

Components of ecosystems	Effect	Affected benefits	Interviewees that identified such link*
Aesthetics of the landscape	+	Appreciation of the natural environment	I-10, I-08
	+	Riverbank activities	I-11, I-10
	+	Fishing	I-03
	+	Walking, jogging and cycling	I-09, I-10, I-16, I-01
Aquifer level	+	Preservation of wetlands	I-11, I-12
	+	Intensive farming	I-10
	+	Drinking water supply	I-10, I-12
	+	Irrigation	I-11
Biodiversity in terms of species and habitats	+	Appreciation of the natural environment	I-08
Diversity of river morphology	+	Swimming	I-01
	+	Security against floods	I-08
Sea water invasion	-	Irrigation	I-12
	-	Preservation of wetlands	I-20
	-	Drinking water supply	I-20, I-12
Spread of exotic species	-	Preservation of historical canals	I-13
	-	Swimming	I-09
	+ / -	Fishing	I-09, I-17, I-10, I-16
	+ / -	Appreciation of the natural environment	I-13, I-20
Status of native amphibians	+	Appreciation of the natural environment	I-02
Status of native aquatic birds	+	Appreciation of the natural environment	I-09, I-13, I-02
Status of native crayfish	+	Appreciation of the natural environment	I-02
Status of native eels	+	Fishing	I-09
Status of native fishes	+	Fishing	I-10, I-03, I-01
	+	Appreciation of the natural environment	I-13
Status of native otters	+	Appreciation of the natural environment	I-01
	+	Game	I-11, I-01
Status of native terrestrial fauna	+	Appreciation of the natural environment	I-02
Structure and quality of riparian vegetation	+ / -	Appreciation of the natural environment	I-02
	+	Riverbank activities	I-10
	+	Swimming	I-10
	+	Fishing	I-03
	+	Walking, jogging and cycling	I-13, I-16
	+	Timber extraction	I-11, I-10, I-08
	+	Security against floods	I-08
Water quality	+	Swimming	I-09, I-10, I-20, I-01, I-07
	+	Drinking water supply	I-10, I-20
Water quality of aquifers	+	Drinking water supply	I-10

*As we rely on the stakeholders' opinion on how the ecosystem generates benefits for the human well-being, we did not need to crosscheck with the literature.

APPENDIX C. DATA FOR THE WATER ALLOCATION MODEL

The objective of this appendix is to clarify some methodological aspects of the development of the water allocation model in **Chapter 6**, for those readers who want more detail on modelling applications. In the context of the general research of ecosystem service assessment, we have created a model for the water allocation in the Lower Ter sub-basin to know how much water would be diverted or discharged to provide a variety of benefits – according to different plausible scenarios.

First, Table C1 lists all elements taken into account for the modelling process, as well as all particularities considered during the schematisation of the Lower Ter system with the WEAP software. Second, the input data regarding variables and parameters is described in Table C2 for water inflows and Table C3 for other parameters. The data that describes such inflows and parameters and the sources of information are also presented.

Table C1. Elements of the Lower Ter system.

Rivers		
the Ter River		
Only the lower course of the river: from the reservoirs system to the Mediterranean Sea.		
Tributaries		
the Major Stream	the Osor Stream	the Terri River
the Rupit Stream	the Llémena Stream	the Farga Stream
the Brugent River	the Onyar River	
These are the main tributaries in the Lower Ter, of which the ACA has natural instream flows data, from the Sacramento model[23]. Each tributary includes an estimation of all their water consumption.		
Main water treatment plants (WTP) flowing into the river system		
Anglès WTP	Banyoles WTP	Torroella de Montgrí WTP
Girona WTP	Celrà WTP	
These are all the WTP that treat more than 0.2 Hm^3/year of water. Except Girona WTP, the rest treat water from urban uses supplied by underground water sources.		
Dams		
Sau	Susqueda	Pasteral I
They form three separated reservoirs. Yet, the model does not consider an independent management for each dam, since the focus of research is on the water uses below the Pasteral I (the last and smallest reservoir). Besides storing and diverting water, the reservoirs also produce hydroelectricity, which is not considered in this study.		
Urban demand sites		
the Metropolitan Region of Barcelona	Girona and its outskirts	Costa Brava
Those are the most important demand sites for urban water supply (mainly domestic and industrial uses). Girona is the only urban site completely bound by the limits of the Ter River basin and that returns the water used to the Ter again. The Costa Brava Consortium supplies municipalities included within the catchment and municipalities out of it. In any case, this demand site is considered an intra-basin water supply. The MRB and Costa Brava also take water from other sources (aquifers and other rivers), so we assumed that the temporal fluctuations regarding their water availability are equal to those happening in the Ter River.		
Irrigation communities as demand sites		
La Pardina IC	Sèquia Monar IC	Sèquia Vinyals IC
Anglès i comarca IC	Sant Julià de Ramis-Cervià de	La Presa de Colomers IC
Sant Julià de Llor IC	Ter-Sant Jordi Desvalls-	Molí de Pals IC

[23] Sacramento is a model used by the ACA to calculate the instream flows that Catalan rivers would have had if no water diversions had taken place (National Weather Service, 2002).

Salt- Bescano i Vilablareix IC	Colomers i Jafre IC	

They are the main irrigation communities and those of which the ACA havs information of diverted flows for the last years. They take water from specific weirs, but the non-consumed water is diffusedly returned to the Ter, what complicates the design of the scheme of the model. To tackle this issue, we agreed to locate the water returns in the most distant fields from the diversion points. This slightly underestimates the instream flows, but does not affect the bulk of the model.

Small (run-of-the-river) hydropower plants (SHPP) as demand sites

Pasteral II SHPP	Grober SHPP	Mitjans SHPP
Anglès SHPP	Salt 1 Gassol SHPP	Torres Hostench SHPP
Bonmatí SHPP	Salt 2 El Molí SHPP	Flaçà SHPP
Vilanna SHPP	Montfullà SHPP	Molí de Pals SHPP
Bescanó SHPP	Aurora SHPP	

These are all the active run-of-the-river hydropower plants. All of them are placed in specific canals nearby the river course, except the Molí de Pals SHPP, which is placed in an irrigation canal.

Historical canals

Sentmenat Canal	Molí de Pals Canal	Vell Canal

These canals are some centuries old so they are claimed to be preserved for architectural heritage protection. Moreover, they harbor endemic species and are partially included in a Natural Park, belonging to the Natura 2000 Network.. The historical canals have their own instream flow requirements, which have been incorporated to the model.

Wetlands

Multiple wetlands close by the historical canals

They include diverse lagoons, marshes and rice crops, very demanded by waterfowl. These lands are fed by freshwater from the Ter passing through the historical canals, and are also included in the Natural Park.

Table C2. Water inflows input data.

Water inflows	Data used to describe inflows	Data source
Inflow to the reservoirs system from the Upper Ter	Monthly flow entering the Sau reservoir by means of estimations taken from the level of the reservoir. The data corresponds to series from October 1980 to September 2008	Daily register of the reservoirs state (ACA)
Inflow to the Lower Ter system from its tributaries	Daily instream flow of 8 tributaries at each confluence point with the Ter as if there were not any diversion (from October 1980 to September 2008), estimated by hydrological modelling	Sacramento model (ACA)
Inflow to the Lower Ter system from lateral runoff	Daily lateral runoff flowing into the Ter River as a differential of daily instream flows between gauging stations along the Ter River (from October 1980 to September 2008)	Sacramento model (ACA)
Inflow to the Lower Ter system from water treatment plants	Annual treatment flow for those WTP that exceed 0.2 Hm^3 and treat water coming from other sources (e.g. other catchments, groundwater)	Treatment plants exploitation report (ACA, 2012)

Table C3. Parameters input data.

Parameters	Data used to describe parameters	Data source
Environmental flow requirements		
Environmental flow regimes	Monthly instream flows for each gauging station along the river	PSCM (ACA, 2005)
	Monthly instream flows for each infrastructure	PZBT (ACA, 2009a)
	A discharge from the reservoirs representing the 80% of their inflows from the Upper Ter	Some environmental organisations and scientists
Minimum flows	Estimation of a 25% of the flow established in the PSCM in august	Interviewees from ACA

Diverted flow to wetlands and historical canals	Estimation of monthly diverted flows, specific for each canal, which in turn supplies its irrigation fields and wetlands	Quintana (2010) and other interviewees
	Estimation of 0.3 m^3/s for the Sentmenat canal	BOE (2007)
	Estimation of 0.2 m^3/s for the Molí de Pals canal	BOE (2008b)
Demands for health and aesthetic purposes		
Diverted flow for health and aesthetic uses in Girona city	Estimation of 0.5 m^3/s	Other interviewees
Demands for urban uses		
Water demand for urban (domestic and industrial) uses	Monthly percentile of 75% of diverted flows during rainy years with water abundance (2009-20012)	Monthly register of the main water withdrawals from the Ter from 2002 to 2012 (ACA)
	Monthly series of diverted flows, specific for the supply of the MRB (between 2003 and 2008)*	
	134 and 115 Hm^3/year for the water transfer to Barcelona, corresponding to a plausible reduction thanks to the implementation of desalination plants and other measures	Management Plan (ACA, 2010)
	Percentages of usage in relation to domestic and industrial uses. The losses and other – e.g., municipal – uses are attributed to both uses in same proportion	Mailings to water distribution companies
Consumption	Estimated in 20%	BOE (2008a)
Demands for irrigation		
Water demand for agriculture from the Ter River	Monthly percentile of 75% of diverted flows during rainy years with water abundance (2009-20012)	Monthly register of the main water withdrawals from the Ter from 2002 to 2012 (ACA)
	For Sèquia Monar IC and its SHPP, an actual series of diverted flows between 2003 and 2008, as it was too variable to use the percentile of 75% for the validation process.	
	Estimation of monthly water requirements per each IC considering the current irrigation infrastructure	PZBT (ACA, 2009a)
	+20% of the annual demand for dry years / -20% of the annual demand for wet years	Interviewees and the Catalan Weather Service
Water demand for agriculture form the Rupit and the Major tributaries	Estimated annual demand (2% of the annual instream flow for the Rupit Stream and 4% for the Major Stream) with a monthly distribution taken from the average of the Ter IC demands	Interviewees with staff from the ACA
Water demand for agriculture from the rest of tributaries	Annual demand estimated from the data of municipal irrigation needs, with a monthly distribution taken from the average of the Ter IC demands	Diputació de Girona (study of the theoretical irrigation demands at municipal level, 2007)
Consumption	Estimated in 80-95%, depending on the water supplied per hectare	BOE (2008a)
Demand for run-of-the-river hydroelectricity		
Authorised diverted flow	Between 3 and 10.2 m^3/s	PZBT (ACA, 2009a)
Minimum turbines capacity	Between 0.7 and 1.8 m^3/s	PZBT (ACA, 2009a)
Gross head	Between 2.3 and 14.6 m	PZBT (ACA, 2009a)
Net head	Between 1.5 and 13.8 m	PZBT (ACA, 2009a)
Efficiency	Between 75 and 90%	PZBT (ACA, 2009a)

Demand for large-dams hydroelectricity		
Maximum turbine flow	Authorised flow Sau: 70 m^3/s, Susqueda: 50 m^3/s, Pasteral: 30 m^3/s	PZBT (ACA, 2009a)
Tailwater elevation	Sau: 97 m, Susqueda: 166 m, Pasteral: 26 m	PZBT (ACA, 2009a)
Reservoirs functioning		
Storage capacity	Sau: 150 Hm^3, Susqueda: 233 Hm^3; Pasteral I: 2 Hm^3	ACA webpage
Initial storage	Average of the storage on October 1980 Average of the storage on January 2003*	Daily register of the reservoirs state (ACA)
Volume elevation curve	Volume elevation curve	Interviewees with staff from the ACA
Maximum hydraulic outflow	It is not considered that there is a maximum	Interviewees with staff from the ACA
Net evaporation	Monthly estimated gains and losses by precipitation, evaporation and infiltration	Interviewees with staff from the ACA
Daily observed volume*	Register of the daily volume of both reservoirs (between 2003 and 2008) estimated by the reservoir elevation measurements	Daily register of the reservoirs state (ACA)
Top of conservation	Maximum storage volume to prevent flooding (331 Hm^3)	Interviewees with staff from the ACA
Top of buffer	Monthly threshold volume below which the discharge of water from the reservoir is constrained	DOGC (2007)
Top of inactive	There is no volume considered not available for allocation	Interviewees with staff from the ACA
Buffer coefficient	0.14, as the value that fits better the model and the reality together	Adjusted during the calibration process

* Information used only for the validation of the model.

Besides the parameters that describe all the elements mentioned, each demand site, as well as the environmental flow requirements and the reservoir capacity to save water, has a parameter representing the priority of such elements for water allocation. The most preferential demand sites are those that describe the availability of water for the Lower Ter system: demands in tributaries and uses that supply the WTP. These are excluded from the variables to play with for the construction of management scenarios because they are not affected by changes in the Ter River management.

APPENDIX D. CHARACTERISATION OF ECOSYSTEM SERVICES

This Appendix consists of a set of sheets that include different outcomes from the interviews, workshops and modelling process for each ecosystem service. Thus, for a particular ES, the appendix describes the ecosystem functions that support it, the social perception, its distribution over time and space, the correspondent suitability curve based on the stakeholders' perceptions and the results for the BAU and the alternative scenarios: COM and ECO. It also illustrates the service with a picture.

Domestic uses in Girona Province

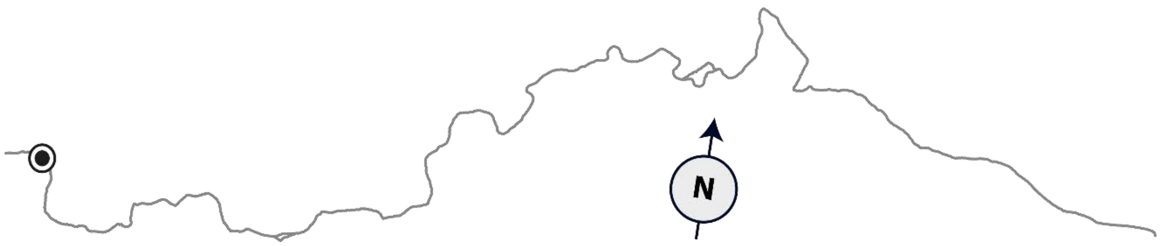
Definition: drinking water supply for intra-basin uses (Girona) or uses within the same province (the Costa Brava).

Identification rate: 30% of the interviewees.

Social perception: the most important use. For some people, the supply of the Costa Brava (in Girona province) is considered as intra-basin, while for others it constitutes an inter-basin water transfer.

Spatial and temporal location: especially in the Costa Brava, the water demand increases a lot in summer.

Source: *Patronat de Turisme Costa Brava Pirineu de Girona*

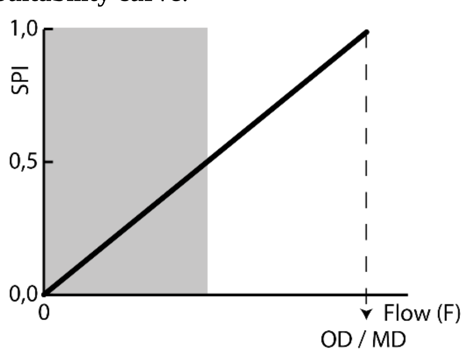


Biophysical constraints: decrease of the runoff due to climate change and afforestation.

Legal constraints: the WFD is difficult to apply in countries with dry summers with high demands.

Management constraints: the increase silting of reservoirs.

Suitability curve:

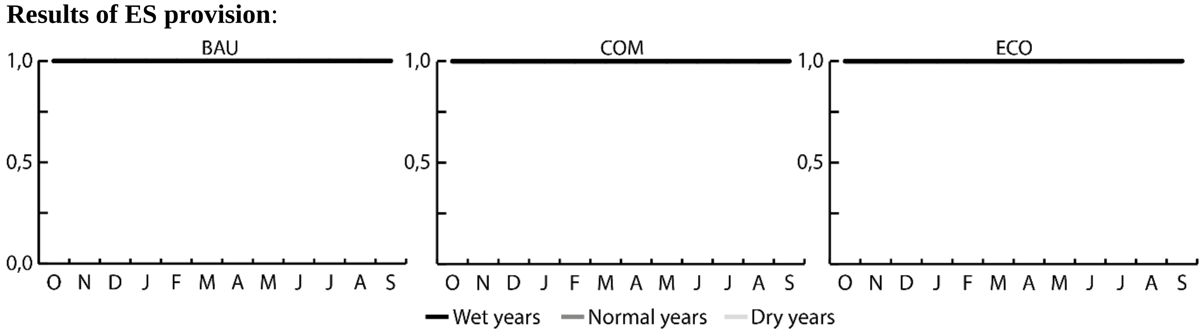


$$SPI(F)\ \left\{ OD > \boldsymbol{F} \rightarrow \frac{F}{OD} \right.$$

F: diverted water from the Pasteral II weir flowing to Girona and the Costa Brava for domestic purposes.

OD / **MD**: 11.0 Hm^3/year (Girona) and 4.9 Hm^3/year (Costa Brava), corresponding to 94.1% and 83.0% of the 75th percentile of water flows diverted from the Ter to supply these areas (see also Appendix C) (sources: interviews and e-mails to water companies). These amounts correspond to maximum values that the model allows to supply.

Results of ES provision:



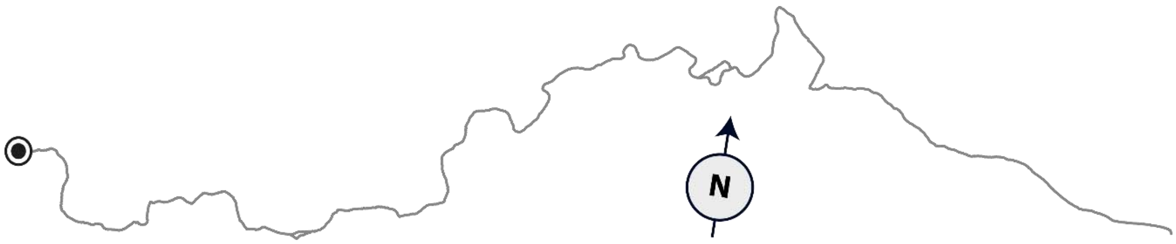
Domestic uses in the RMB

Definition: drinking water flows from the Ter transfer for domestic uses in the metropolitan region of Barcelona.

Identification rate: 80% of the interviewees (together with industrial uses in the RMB).

Social perception: most of people think the amount of water extracted for domestic uses in the RMB is excessive.

Spatial and temporal location: homogeneous consumption over time and space.

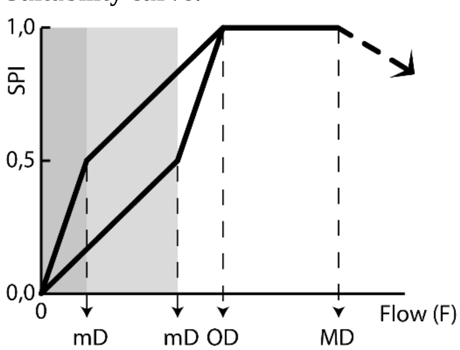


Biophysical constraints: decrease of the runoff due to climate change and afforestation.

Infrastructure constraints: the metropolitan region of Barcelona depends too much on the Ter.

Management constraints: the increase silting of reservoirs.

Suitability curve:



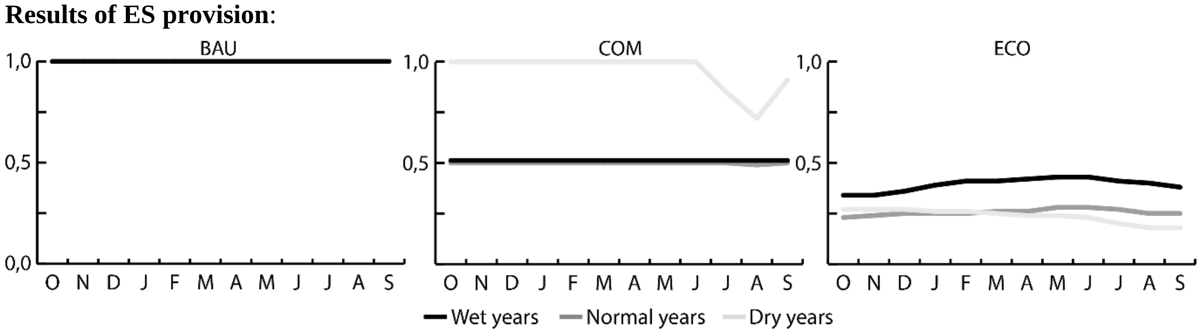
$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F} - \mathrm{mD}}{\mathrm{OD} - \mathrm{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

F: diverted water from the Pasteral reservoir flowing to the MRB for domestic purposes.

mD: 102.1 Hm^3/year, corresponding to 76.2% of 134 Hm^3/year, amount that considers the launch of the desalination plants and a consume of water per inhabitant of 100 L/day (ACA, 2010).

OD / **MD**: 125.5 Hm^3/year, corresponding to 76.2% of 164.7 Hm^3/year, the 75th percentile of water flowing from the Ter to supply the MRB (see also Appendix C) (sources: interviews and e-mails to water companies). These amounts correspond to maximum values that the model allows to divert.

Results of ES provision:



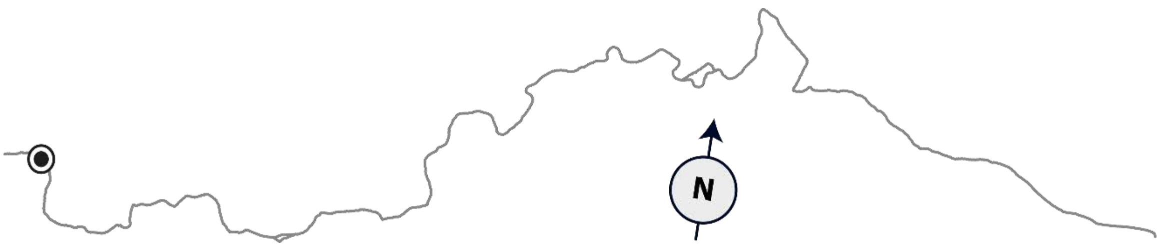
Industrial uses in Girona Province

Definition: drinking water flows to supply industries in the Girona conurbation or and the Costa Brava. It represents a small part of the water demand as most of it is supplied by wells.

Identification rate: 40% of the interviewees.

Social perception: for some people, the supply of the Costa Brava (in Girona province) is considered as intra-basin, while for others it constitutes an inter-basin water transfer.

Spatial and temporal location: homogeneous consumption over time and space.

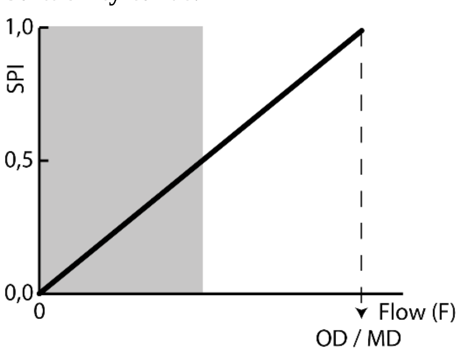


Biophysical constraints: decrease of the runoff due to climate change and afforestation.

Legal constraints: the WFD is difficult to apply in countries with dry summers with high demands.

Management constraints: the increase silting of reservoirs.

Suitability curve:

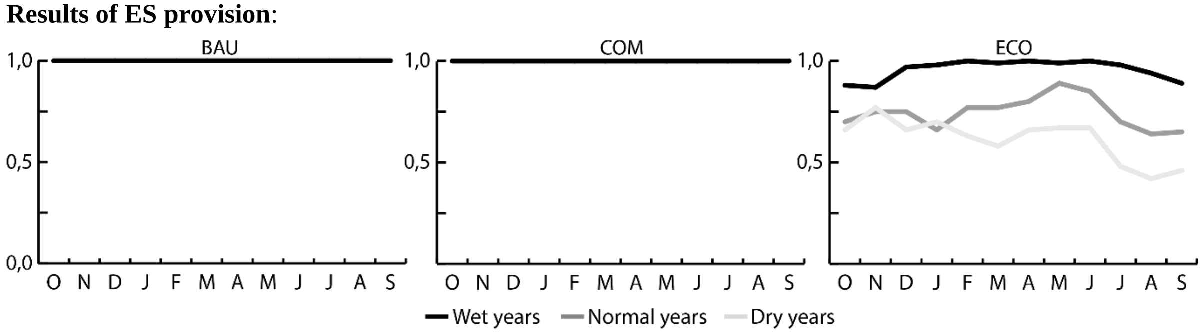


$$SPI(F)\ \left\{ OD > \boldsymbol{F} \rightarrow \frac{F}{OD} \right.$$

F: diverted water from the Pasteral II weir flowing to Girona and the Costa Brava for industrial purposes.

OD / **MD**: 0.7 Hm^3/year (Girona), 1.0 Hm^3/year (Costa Brava), corresponding to 5.9% and17.0% of the total of urban uses (sources: interviews and e-mails to water companies). These amounts correspond to maximum values that the model allows to supply.

Results of ES provision:



Industrial uses in the RMB

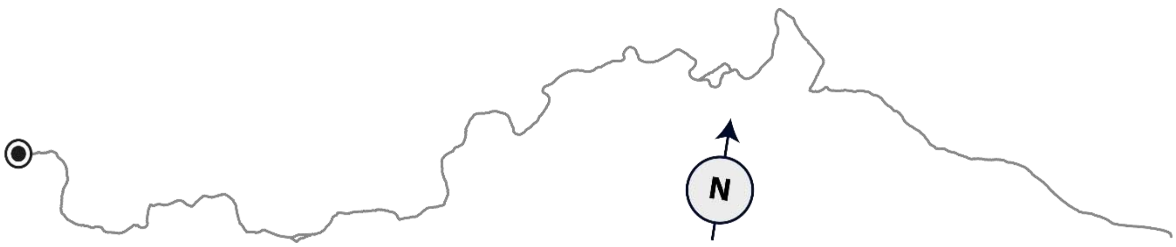
Definition: drinking water flows from the Ter transfer to supply industries in the RMB. It represents a small part of the water demand as most of it is supplied by wells.

Identification rate: 80% of the interviewees (together with domestic uses in the RMB).

Social perception: the main complain is that, during the 2007-2008, the CocaCola factory was in operation when the irrigators had to reduce the water consumption.

Spatial and temporal location: homogeneous consumption over time and space.

Source: Angèlica Millán

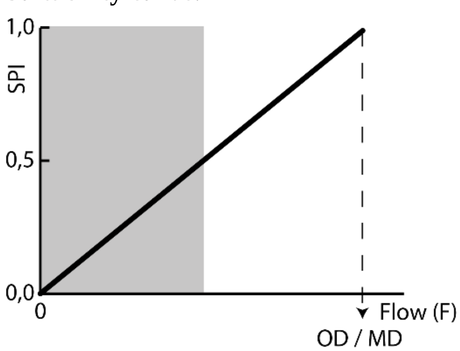


Biophysical constraints: decrease of the runoff due to climate change and afforestation.

Infrastructure constraints: the metropolitan region of Barcelona depends too much on the Ter.

Management constraints: the increase silting of reservoirs.

Suitability curve:

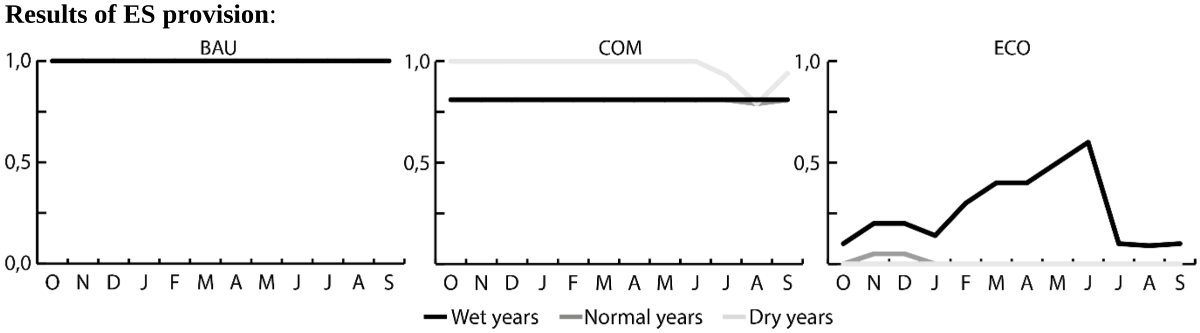


$$SPI(F)\ \left\{ OD > \boldsymbol{F} \rightarrow \frac{F}{OD} \right.$$

F: diverted water from the Pasteral reservoir flowing to the MRB for industrial purposes.

OD / **MD**: 39.2 Hm^3/year (MRB), corresponding to 23.8% of the total of urban uses (sources: interviews and e-mails to water companies). These amounts correspond to maximum values that the model allows to supply.

Results of ES provision:



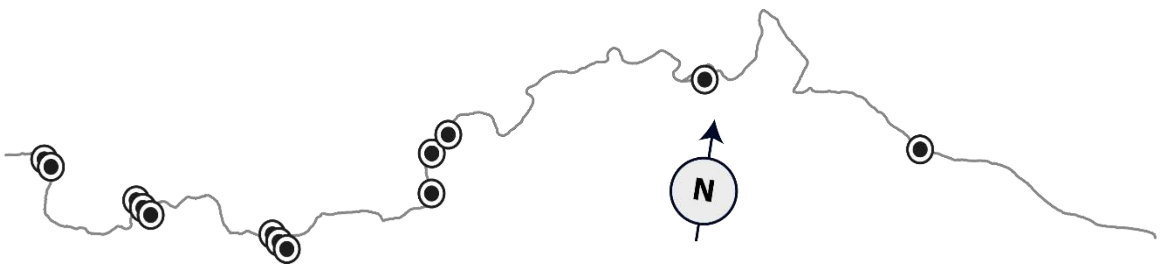
Hydropower production

Definition: water flow diverted directly from the river to produce electricity from run-of-the-river SHPP. It requires as much water as possible, but all water diverted is then returned.

Identification rate: 10% of the interviewees in the Lower Ter (in the Upper Ter the rate was 100%).

Social perception: they are the cause that the Ter is becoming a dried up river, but the hydropower producers and many locals defend this renewable energy.

Spatial and temporal location: SHPP are concentrated in the Upper Ter.



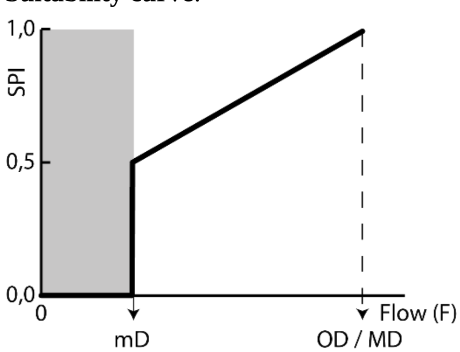
Biophysical constraints: irregular flow.

Infrastructure constraints: big infrastructure to maintain.

Legal constraints: lack of flexibility by the ACA.

Management constraints: debris in the river channel.

Suitability curve:



$$SPI(F)\begin{cases}\sum OD \geq \sum \boldsymbol{F} \geq \sum mD \rightarrow 0.5 + 0.5\dfrac{\sum \mathrm{F} - \sum \mathrm{mD}}{\sum \mathrm{OD} - \sum \mathrm{mD}} \\ \sum mD \geq \sum \boldsymbol{F} \rightarrow 0\end{cases}$$

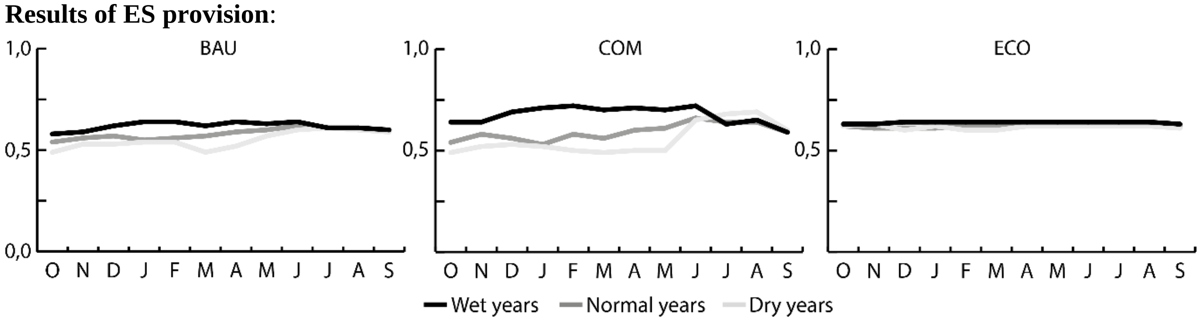
F: diverted flow from the Ter River to SHPP.

mD: minimum water flow to make the turbines working (ACA, 2009a).

OD / **MD**: maximum capacity of the canals that divert water for hydropower (ACA, 2009a).

Σ: sum of the SPI obtained from all SHPP.

Results of ES provision:



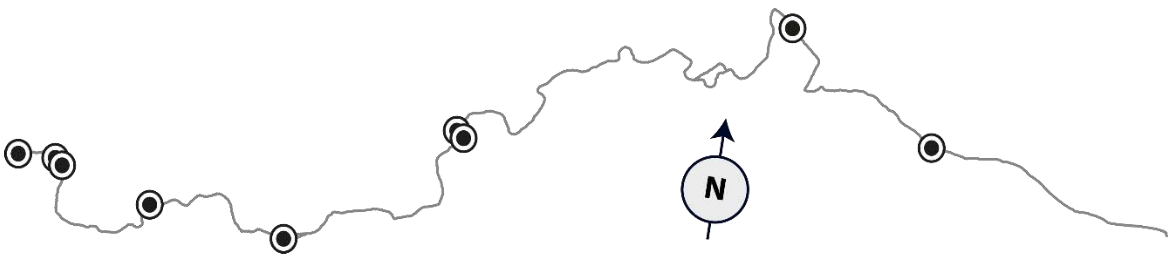
Irrigation

Definition: supply and store of non-polluted water to maintain agriculture: mainly rice, poplar and fruit tree plantations.

Identification rate: 90% of the interviewees.

Social perception: for some people, irrigators are the main originators of the lack of instream flow, especially those that grow rice and fruit trees.

Spatial and temporal location: this activity is especially located in the Lower Ter. The most water consumption takes place between April and October.

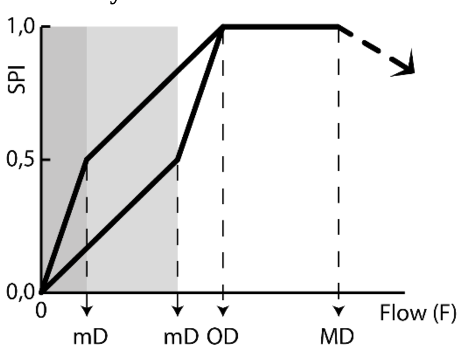


Biophysical constraints: the climate change that affects the water availability.

Infrastructure constraints: loses in old canals, the disuse of the Colomers dam.

Management constraints: the increase silting of reservoirs.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F} - \mathrm{mD}}{\mathrm{OD} - \mathrm{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

F: diverted flow from the Ter River to irrigated land.

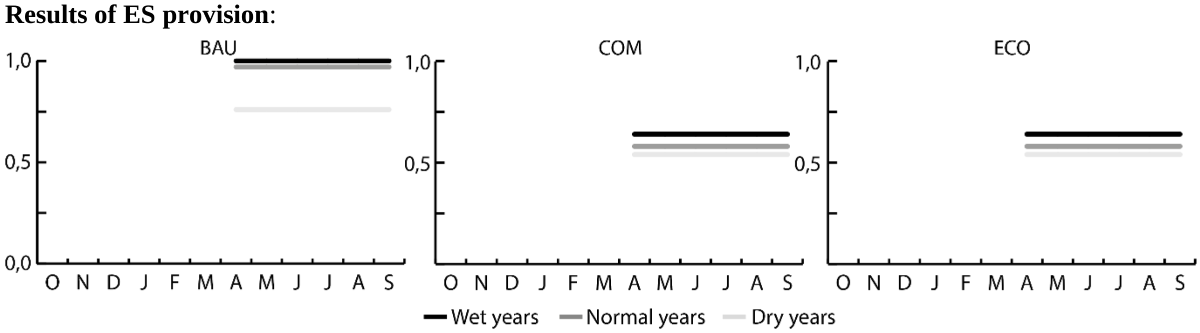
mD: those requirements established in the Zonal Plan for the Lower Ter (ACA, 2009a) (55 Hm^3/year +/- 25% for dry/wet years) (sources: interviews).

OD: water demand that irrigators ask for (65 Hm^3/year +/- 25% for dry/wet years) (sources: workshops and interviews).

MD: maximum capacity of the irrigation canals.

The SPI obtained for all fields were averaged by assigning to them different weights in relation to their area.

Results of ES provision:



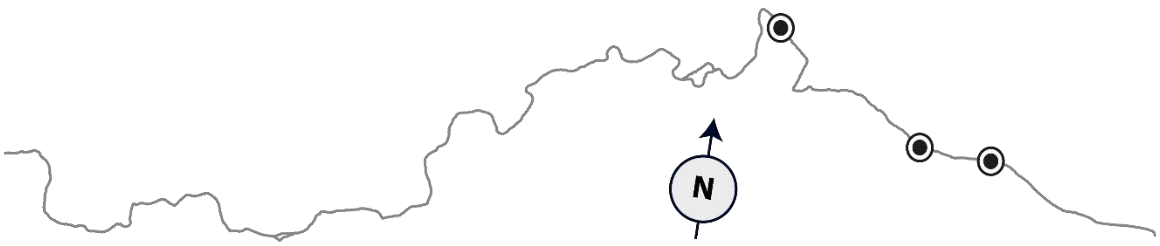
Preservation of historical canals

Definition: water flows, diverted from the Ter to irrigate the Baix Ter Plain, transported by very old canals that have been naturalised over time, housing now endemic species and protected habitats.

Identification rate: 60% of the interviewees.

Social perception: they are either natural and cultural heritage or an inefficient way of transporting water.

Spatial and temporal location: located in the Baix Ter Plain, especially transport water in April-October, when farmers irrigate.



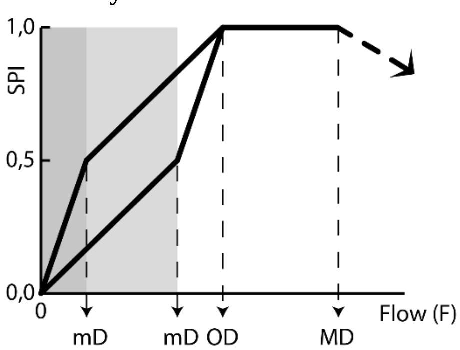
Biophysical constraints: presence of exotic species.

Infrastructure constraints: there are barriers for the fish.

Legal constraints: lack of a budget to enforce the law.

Management constraints: wastewater flowing into the canals.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \geq \text{mD} \rightarrow 0.5 + 0.5\dfrac{\text{F} - \text{mD}}{\text{OD} - \text{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

F: diverted flow from the Ter River to irrigation fields and wetlands in the Lower Ter Plain through the historical canals.

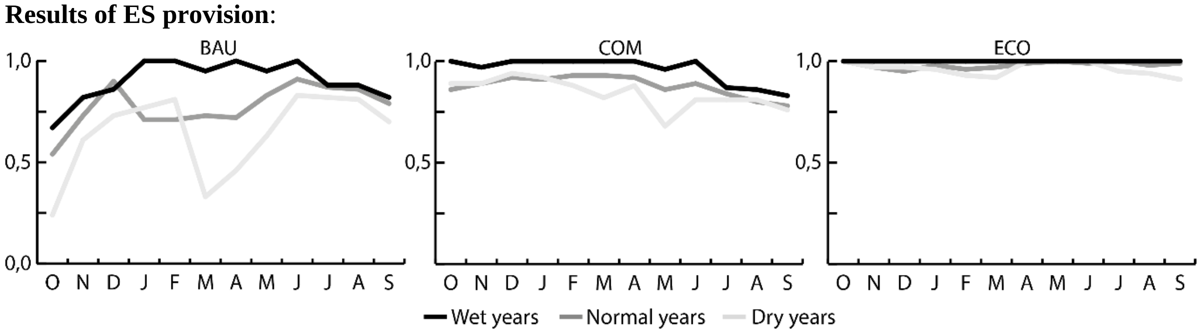
mD: the e-flows proposed by the Ministry of the Environment (BOE, 2008b, 2007).

OD: the e-flows proposed in a study about the hydrological functioning of the Lower Ter Plain (Quintana, 2010).

MD: maximum capacity of the irrigation canals.

The SPI obtained for all historical canals were averaged by assigning different weights in relation to the length.

Results of ES provision:



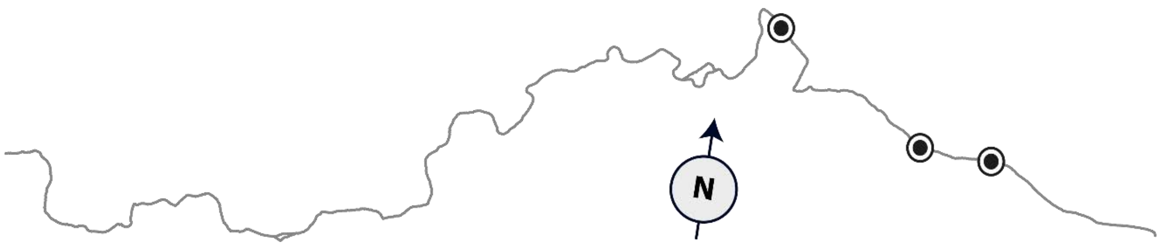
Preservation of wetlands

Definition: water flowing through the historical canals then feeds some wetlands included in a Natural Park, belonging to the Natura 2000 Network. They are also fed by groundwater and rain.

Identification rate: 90% of the interviewees.

Social perception: not so appreciated, although it is for the naturalists.

Spatial and temporal location: located in the Baix Ter Plain.



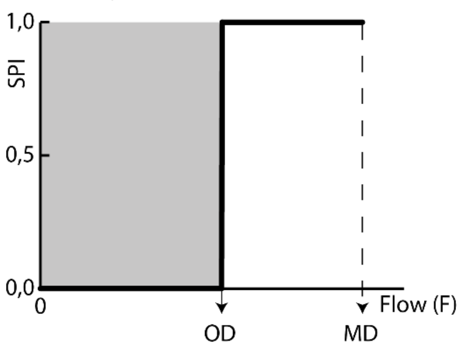
Biophysical constraints: presence of exotic species.

Infrastructure constraints: walls along the river channel.

Legal constraints: lack of a budget to enforce the law, the current law of exotic species.

Management constraints: mismanagement, aggregate extraction.

Suitability curve:



$$SPI(F)\begin{cases} MD \geq \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \rightarrow 0 \end{cases}$$

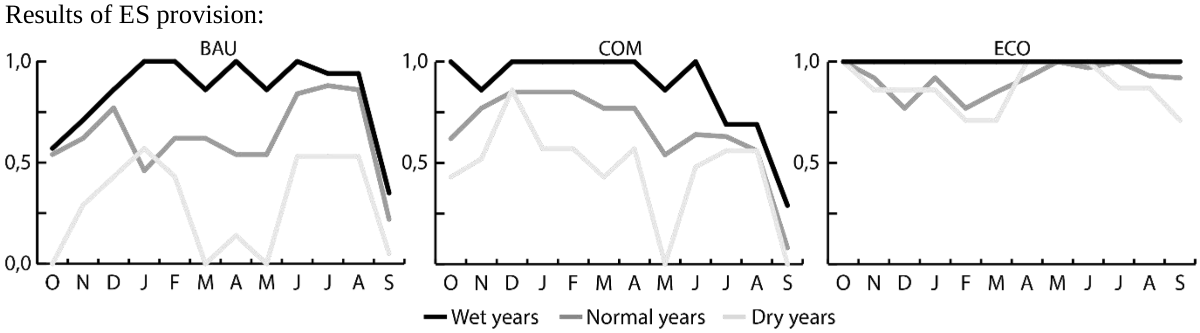
F: diverted flow from the Ter River to wetlands through the historical canals.

OD: the environmental flow proposed in a study about the hydrological functioning of the Lower Ter Plain (Quintana, 2010).

MD: an undefined maximum flow unknown or not worrying for the beneficiaries.

The SPI obtained for all wetlands were averaged by assigning to them different weights in relation to their area.

Results of ES provision:

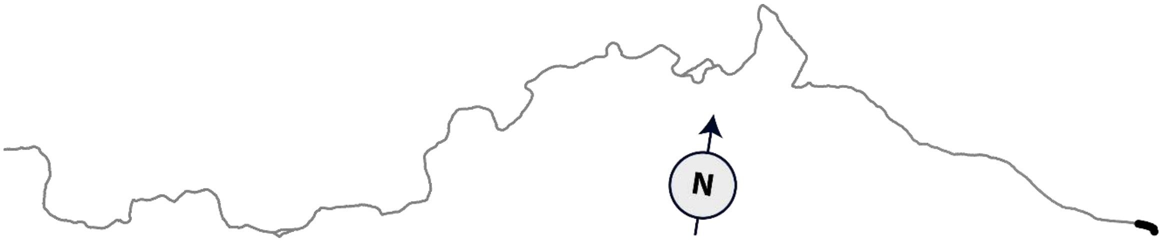


Protection against saltwater intrusion

Definition: a minimum flow that prevents seawater intrusion, thus preserving the coastal ecosystems and the wells that provide drinking water.

Identification rate: 50% of the interviewees (together with the preservation of coastal ecosystems).

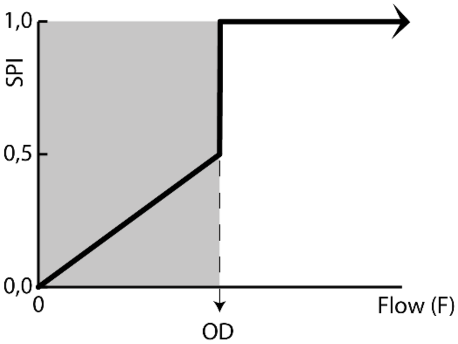
Spatial and temporal location: the water flow is required in the mouth of the river. The flow through the historical canals and the irrigation also contribute to the fight against saltwater intrusion.



Infrastructure constraints: the lack of flows in the historical canals.

Management constraints: the shift towards rainfed agriculture.

Suitability curve:

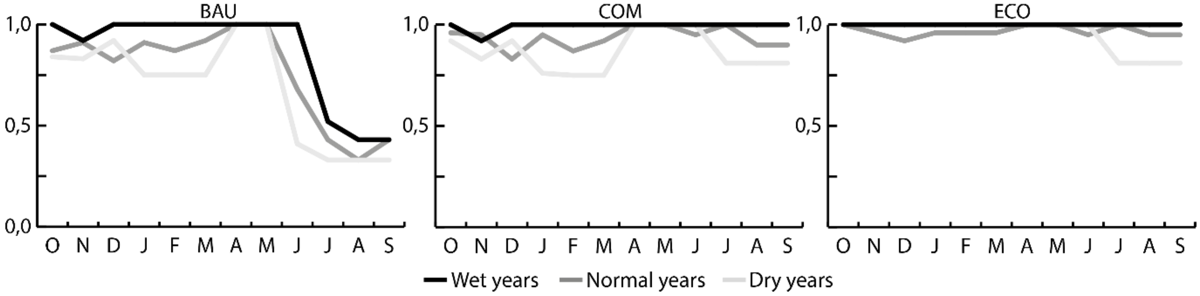


$$SPI(F)\begin{cases} \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{OD} \end{cases}$$

F: instream flow ending up in the Mediterranean Sea.

OD: 3.4 m^3/s proposed in a study about the hydrological fluxes throughout the Lower Ter Plain (Montaner, 2010).

Results of ES provision:



Elver fishing

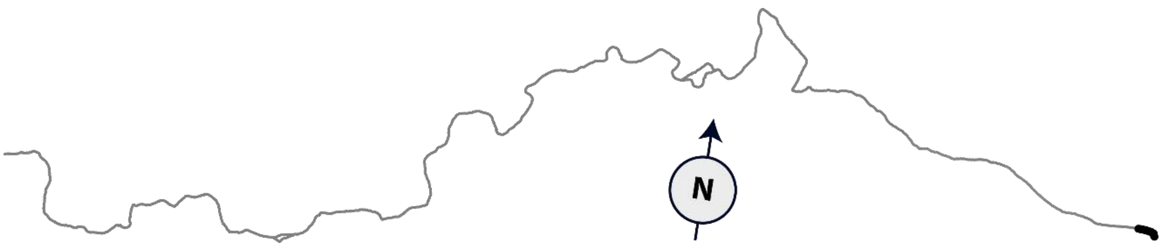
Definition: a minimum flow in the river mouth that guides the elver to the river. The elver is only allowed to be fished between October and March.

Identification rate: 90% of the interviewees (together with other types of fishing).

Social perception: there is a controversy about whether they damage or help to the recuperation of eel populations in the Ter.

Spatial and temporal location: it only takes place between October and March in the mouth of the river.

Source: Juli, from *Angula del Ter*.



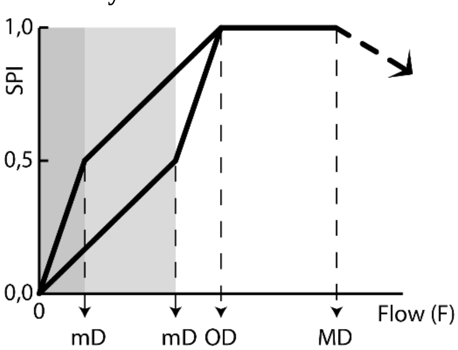
Biophysical constraints: trees within the river channel and algal blooms.

Infrastructure constraints: weirs and dams.

Legal constraints: many requirements. Allowed in October-March.

Management constraints: lack of cleaning the channel.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \ \rightarrow 1 \\ OD > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F} - \mathrm{mD}}{\mathrm{OD} - \mathrm{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

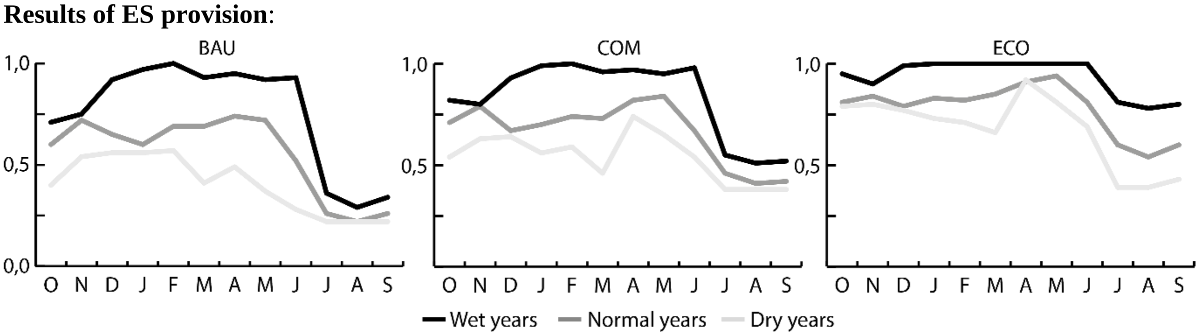
F: instream flow ending up in the Mediterranean Sea.

mD: 5 m^3/s, corresponding to that flow below which 90% of the days with algae and fish accumulation are found (sources: workshops and Meteoestartit database).

OD: 12 m^3/s (sources: workshops).

MD: an undefined maximum flow unknown or not worrying, from which an increase of the flow can be dangerous for the beneficiaries.

Results of ES provision:

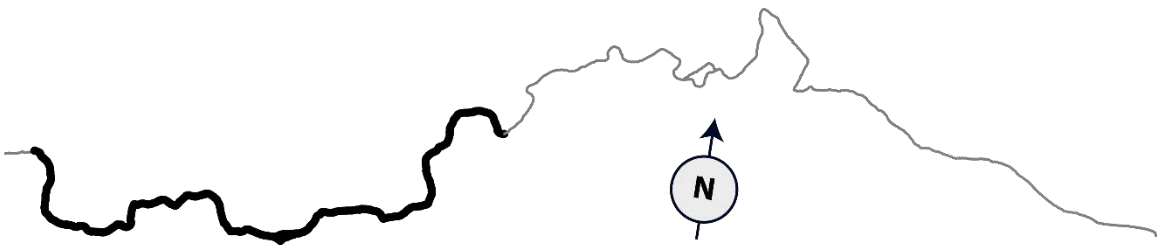


Fly fishing

Definition: instream flows that provide a suitable habitat for brown trout and avoid the colonisation by exotic species. Possible only in a stretch of a few kilometres downstream from the Pasteral Reservoir.

Identification rate: 90% of the interviewees (together with other types of fishing).

Spatial and temporal location: mainly in the stretches between the Susqueda dam and Girona, during the whole year.



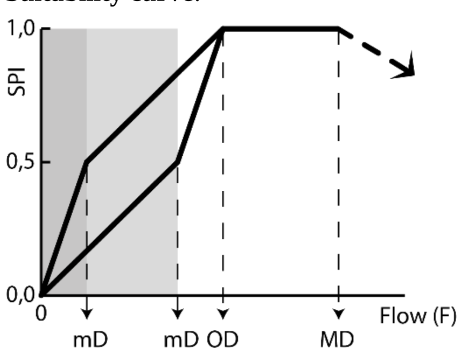
Biophysical constraints: predators (e.g., otters or exotic bird species).

Infrastructure constraints: dams, weirs and the lack of fish passes.

Legal constraints: the licences.

Management constraints: sudden discharges of flow.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F} - \mathrm{mD}}{\mathrm{OD} - \mathrm{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

F: instream flow in the Ter River between the Pasteral II weir and the returns of Bescanó irrigation fields.

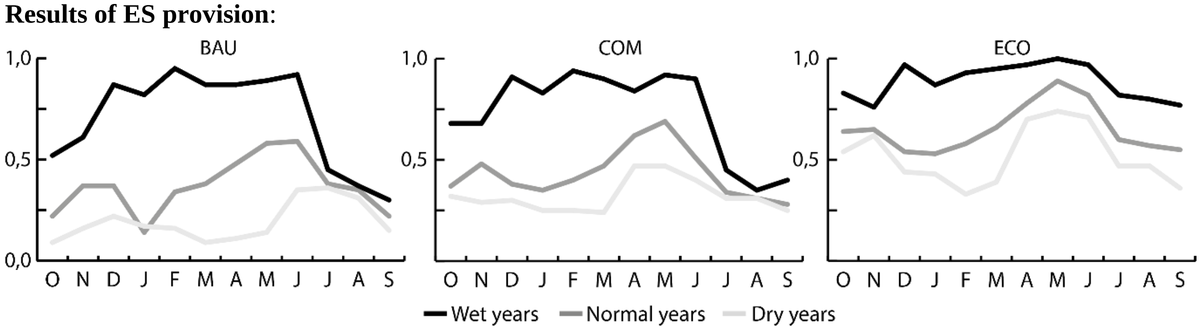
mD: 6-8 m^3/s (sources: interviews).

OD: 8-11 m^3/s (sources: interviews).

MD: an undefined maximum flow unknown or not worrying, from which an increase of the flow can be dangerous for the beneficiaries.

The SPI obtained for all stretches were averaged by assigning different weights in relation to their length.

Results of ES provision:



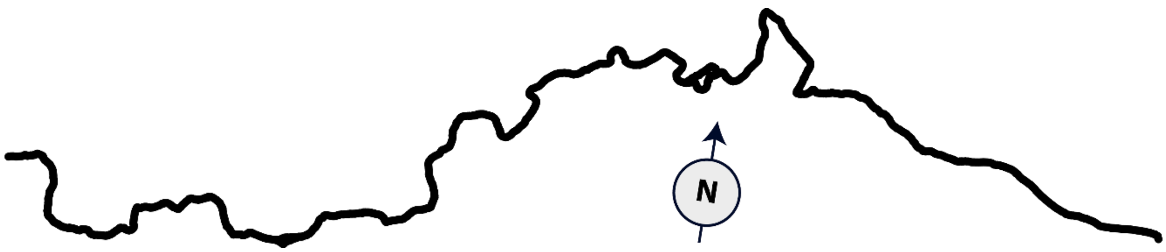
Preservation of the river ecosystem

Definition: instream flow regime, monthly modulated, required for the conservation of the river structure and biodiversity.

Identification rate: 60% of the interviewees.

Social perception: sometimes a highly anthropic landscape is more appreciated than a well-preserved ecosystem.

Spatial and temporal location: the whole length of the river and the whole year.



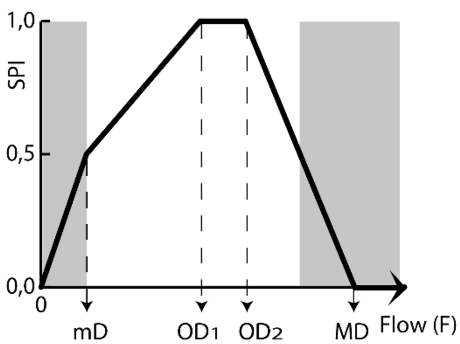
Biophysical constraints: exotic species.

Infrastructure constraints: weirs, dams, canalisation, urban areas, croplands, roads.

Legal constraints: lack of inclusion in the 2000 Natura network, the demarcation of the river

Management constraints: wastewater from the STP, the cleaning of the riparian vegetation

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} \geq MD \rightarrow 0 \\ MD > \boldsymbol{F} \geq OD_2 \rightarrow 1 - \dfrac{F - OD_2}{MD - OD_2} \\ OD_2 > \boldsymbol{F} \geq OD_1 \rightarrow 1 \\ OD_1 > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F} - \mathrm{mD}}{OD_1 - \mathrm{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

F: instream flow all along the Lower Ter River

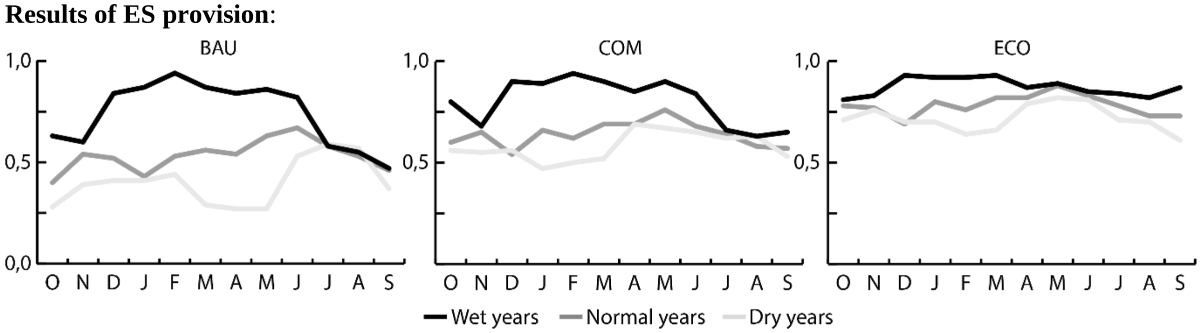
mD: the e-flow proposed in the PSCM (ACA, 2005)

OD1 - OD2: 80-100 % of the natural flow (sources: workshops)

MD: 200 % of the natural flow (sources: workshops)

The SPI obtained for all stretches of the river were averaged by assigning to them different weights in relation to their length.

Results of ES provision:



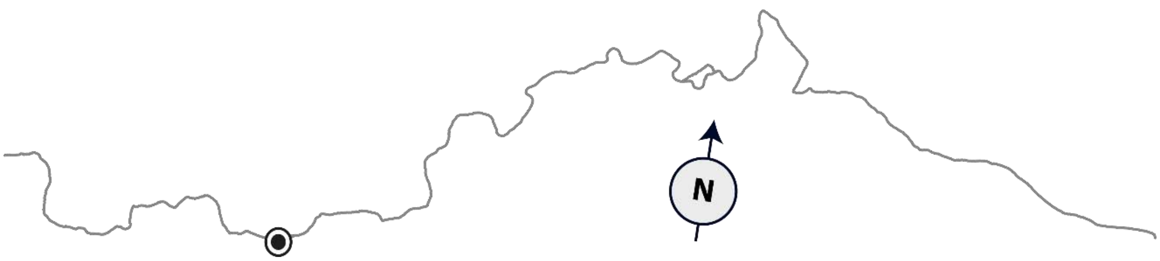
Aesthetic view of the Onyar in Girona

Definition: water diverted for irrigation and hydroelectric purposes that flows into the Onyar River, creating a valuable waterscape within the historical and tourist city of Girona. This water is also used to dilute wastewater and eliminate bad smells.

Identification rate: unknown. The identification was together with tourism, the aesthetics of a river and the capacity of removing debris.

Social perception: the water through the Onyar creates a beautiful landscape and an icon in Girona. Few people knows that it comes from the Ter.

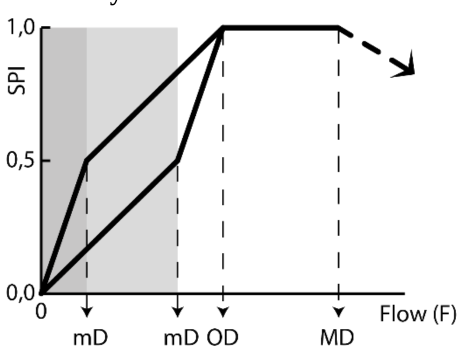
Spatial and temporal location: Girona. The whole year.



Biophysical constraints: algal blooms.

Management constraints: the operation of the Monar canal.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \ \rightarrow 1 \\ OD > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F - mD}}{\mathrm{OD - mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

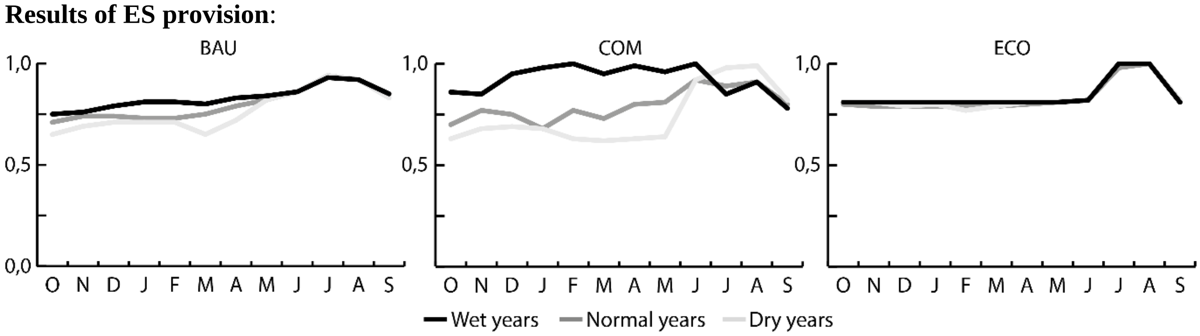
F: diverted flow from the Sèquia Monar to the Onyar River.

mD: 0.5 m^3/s (sources: workshops).

OD: 4.5 m^3/s, as it is the maximum capacity of the canal (sources: workshops).

MD: maximum capacity of the Monar canal, which flows into the Onyar River.

Results of ES provision:



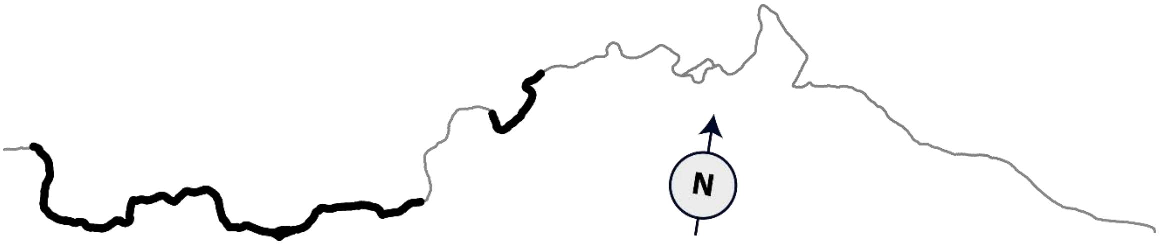
Whitewater kayaking

Definition: any instream flow – but the more the better – that allows a spot to be practiced. Especially performed between the Pasteral Reservoir and Girona.

Identification rate: 50% of the interviewees (together with calm-water kayaking).

Social perception: it brings the people close to the river. They may scare the fauna.

Spatial and temporal location: especially in the whitewhater park (Bescanó-Salt), but in the entire stretch between the Pasteral dam and Girona. During the whole year, mainly in spring and summer.

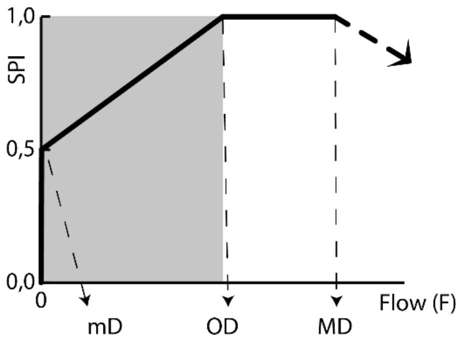


Infrastructure constraints: weirs and the lack of fish passes adapted to kayaks.

Legal constraints: insurance, licence, authorisation, prohibition in spring in some areas.

Management constraints: discharges from Susqueda.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} > MD \rightarrow ? \\ MD \geq \boldsymbol{F} \geq OD \rightarrow 1 \\ OD > \boldsymbol{F} \rightarrow 0.5 + 0.5\dfrac{F}{OD} \end{cases}$$

F: instream flow between the Sèquia Monar (canal) outflow and inflow.

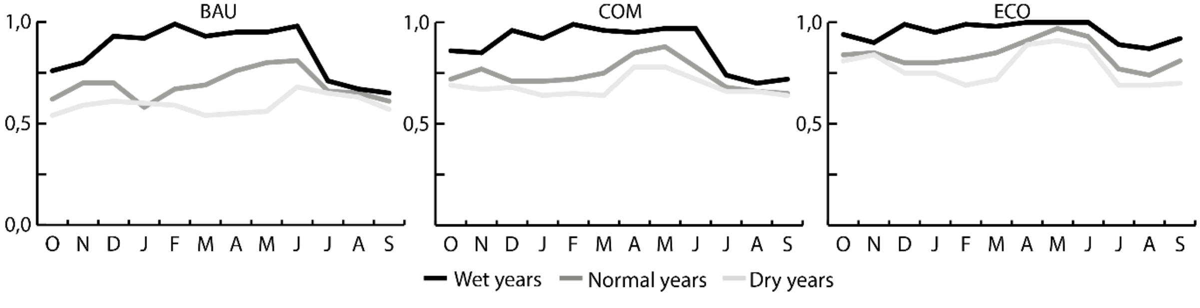
mD: no minimum flow required (sources: workshops and interviews).

OD: 10-12 m^3/s (sources: interviews).

MD: an undefined maximum flow unknown or not worrying for the beneficiaries.

The SPI obtained for all stretches of the river are averaged by assigning to them different weights related to the length.

Results of ES provision:



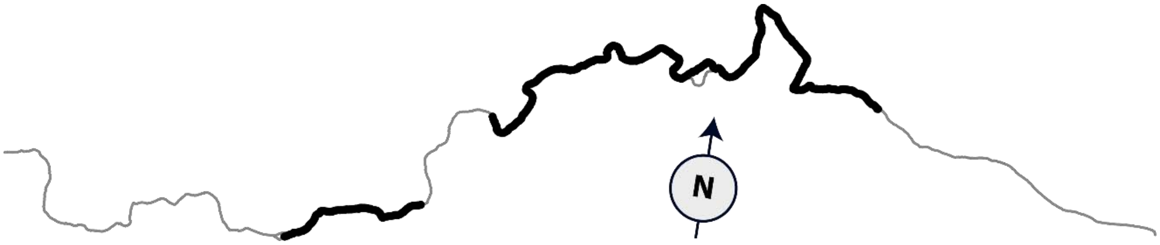
Calm-water kayaking

Definition: instream flows that maintain a certain water level without producing white water, combined with a beautiful scenery.

Identification rate: 50% of the interviewees.

Social perspectives: Bring people closer to the river, but requires artificial instream flows and may be a source of exotic species.

Spatial and temporal location: In spring, it is prohibited in some stretches where waterfowl are breeding. Most visitors come in summer.



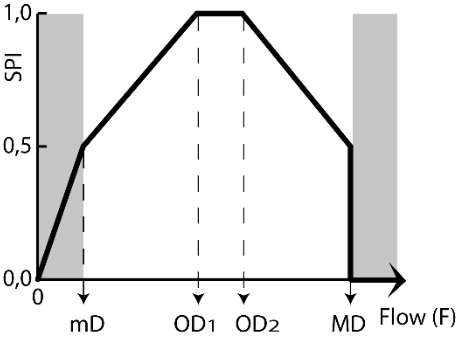
Biophysical constraints: lack of flow, big trees and others.

Infrastructure constraints: the presence of weirs.

Legal constraints: insurance, licence, authorisation, prohibition in spring in some areas.

Management constraints: sudden high flows that make cancel the activity.

Suitability curve:



$$SPI(F)\begin{cases} \boldsymbol{F} \geq MD \rightarrow 0 \\ MD > \boldsymbol{F} \geq OD_2 \rightarrow 1 - 0.5\dfrac{F - OD_2}{MD - OD_2} \\ OD_2 > \boldsymbol{F} \geq OD_1 \rightarrow 1 \\ OD_1 > \boldsymbol{F} \geq \mathrm{mD} \rightarrow 0.5 + 0.5\dfrac{\mathrm{F} - \mathrm{mD}}{OD_1 - \mathrm{mD}} \\ mD > \boldsymbol{F} \rightarrow 0.5\dfrac{F}{mD} \end{cases}$$

F: instream flow between the towns of Sant Julià de Ramis and Verges

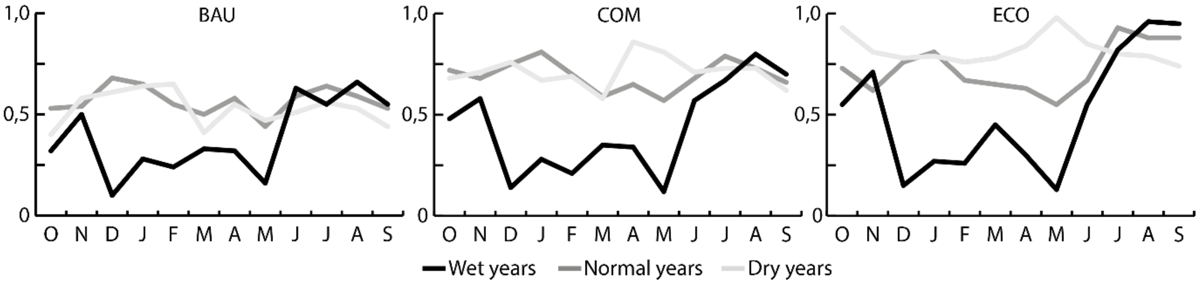
mD: 5 - 7 m^3/s (sources: interviews)

OD1 - **OD2**: 10 - 12 m^3/s (sources: interviews)

MD: 25 m^3/s (sources: interviews)

The SPI obtained for all stretches are averaged by assigning to them different weights related to the length.

Results of ES provision:



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