Linking social perception and risk analysis to assess vulnerability of coastal socio-ecological systems to climate change in Atlantic South America

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Abstract

Nowadays no other region on earth is more threatened by natural hazards than coastal areas. However the increasing risk in this area is not just a climate extreme events' result. Coasts are the places with highest concentration of people and values, thus impacts continue to increase as the values of coastal infrastructures continue to grow. Climate change aggravates chronic social vulnerabilities since social groups may be affected differently both by climate change as well as by risk management actions. Relationships between these groups are often characterized by inequality, with different perceptions, response or adaptation modes to climate hazards. Misperception of these differences often leads to policies that deepen inequities and increase the vulnerability of the weakest groups. Population affected by climatic extreme events increases dramatically resulting in urgent adaptation intervention. We address the interdependence of risk perception and vulnerability of coastal communities, and the relevance of ecosystem services for adaptation. We developed a methodology where risk analysis, and communities' risk perception are linked through key actions at strategic points of risk assessment: i) initial interviews with qualified local informants to complete an inventory of ecosystem services, ii) a social valuation of ecosystem services by local people, iii) assessment of stakeholders' social vulnerability. This approach allows a truly socially-weighted risk assessment to be validated in three sites: Valle de Itajai (Brazil), Estuary of Lagoa dos Patos (Brazil), and Laguna de Rocha (Uruguay). In this novel approach, risk assessment is forced by social perceptions, thus risk treatment can better contribute to realistic adaptation arrangements to cope with climate forces. Public policies could be improved, recognizing healthy functioning ecosystems as key factor for coastal resilience and wellbeing.

Key Words: ecosystem services, risk assessment, social perception, extreme climatic events, coastal areas

1. INTRODUCTION

In the next decades, the global population affected by coastal flooding and other extreme climatic events will increase dramatically, resulting in a growing need for adaptive interventions (Adger et al. 2005). The increasing impact of Climate Change is exacerbated because the speed of change is uncertain. The implementation of appropriate actions by the various levels of government is difficult because of the uncertainty of timing and magnitude of Climate Change, and also because of the small window of time of the administrative mandate of governments compared to the time required for the Climate Change to be perceived. There is a need to implement actions to assist in the development of robust and adaptive management to address uncertain future conditions (IPCC 2007).

Studies have shown that socio-ecological systems do not generally respond to changes, such as those induced by Climate Change, in a linear manner. Tipping points, described as the achievement of critical thresholds in the system, manifest themselves only after cumulative effects are reached, thereby producing dramatic fast changes (Westley et al. 2011). The capacity of socio-ecological systems to adapt to external disturbances (e.g. flooding) without shifting to different states is known as resilience (i.e. less vulnerable to external forces), and depends on factors such as biological, institutional and knowledge diversity.

Biodiversity and ecosystem services, especially those associated with wetlands (Boyd & Banzhaf 2007) are natural benefits that people obtain from natural processes (e.g. availability of food and freshwater, protection from erosion, disease regulation, and landscape values), and can be classified as provisional, regulation, support, and cultural services. Ecosystem services are tied to human health, well-being and ecosystem health and integrity (WHO 2010). The recognition of the key role played by ecosystem services in reducing the effects of Climate Change is growing worldwide (MEA 2005), although the interdependence is complex and sometimes hidden.

Risk analysis framework is accepted to assist decision-making systematically in doing recommendations as a response to risks and prioritize issues where to focus management efforts (Fig. 1) to address human and natural topics with potential impact (Gimpel et al. 2013), like climate change. The risk analysis approach allows to define links between hazards and ecosystem services (i.e. depicting a pathway effects), which can be used to take the best decision during risk management and risk communication (Lozoya et al. 2011). Enormous discrepancies are commonly observed in risk definitions, perceptions and evaluations, mainly between public opinion and scientific perspectives (Figueiredo 2009).

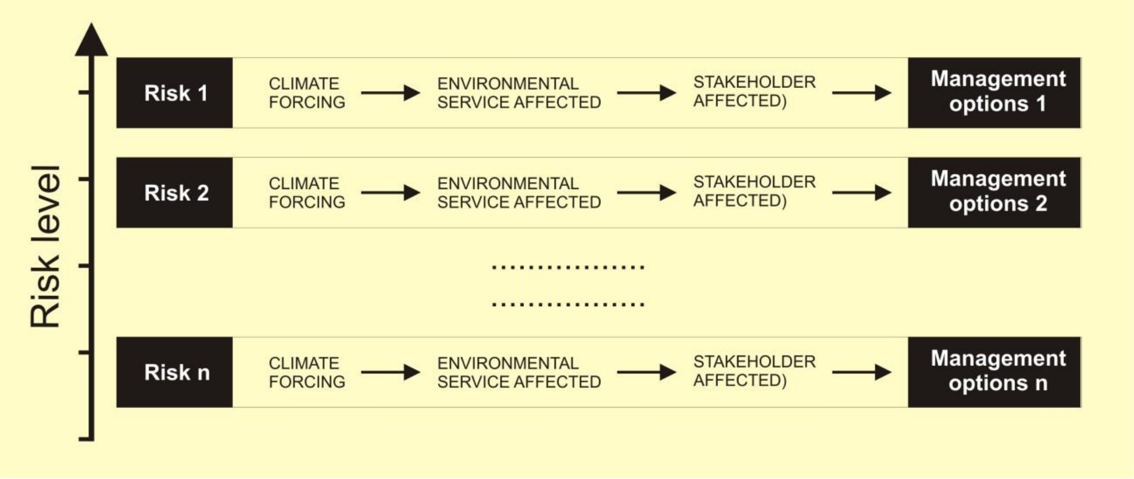


Figure 1. The role of risk assessment in assisting decision-making to prioritize issues and define management options to cope with climate change. Without a quantitative rank of the risks the decision where to focus management efforts is unfounded.

Understanding social perceptions of climate change risks is critical to motivate public support to promote adequate policies. According to Mastrandrea et al. (2006), climate-related risks are commonly perceived by the public as remote, deniable or manageable, and these misunderstandings must be overcome to motivate support for policy actions (Franck 2009). Risk perception is important because individuals and institutions must be aware and understand climate change as a present threat in order to develop planned adaptation (Burton et al. 2002).

2. AN INTERDISCIPLINARY APPROACH TO RISK ASSESSMENT

2.1. Coastal areas within the Anthropocene

The implications of a changing climate are more significant for coastal areas than anywhere else. No other region is more threatened by natural hazards, including winds, storms surges, large waves, hurricanes, and tsunamis (Kron 2013). However, it is not the natural hazard as such that accounts for the consequences of an extreme event. These hazards are natural processes that have always affected the coastal zone. Natural hazards become disasters only if people are killed or injured and/or their possessions damaged or destroyed. Thus, “catastrophes are not only products of chance but also the outcome of the interaction between political, financial, social, technical and natural circumstances”. Coasts are not just subject to more intense and more frequent natural events, but they are also the places with the highest concentration of people and values. The impacts and associated costs of these natural hazards to humans continue to increase as the amount and values of coastal infrastructures continue to grow.

Few years ago ca. 3,000 million peoples lived within 200 miles of the sea, which is to say that almost half of our species lives in the coastal zone (i.e. the 10% of land), bearing densities 2.5 times greater (UNEP 2004 in Tett et al. 2011). This large concentration of population and activities in coastal areas, with its associated effects on the environment, would be part of what a growing number of scientists call a new geological epoch: the Anthropocene (Crutzen and Stoermer 2000). Over the past decades there has been a significant economic growth worldwide. Although uneven and mainly benefiting developed countries, this growth allowed people to access more resources (including natural resources) and thus have more services. While this has contributed to satisfying more needs, current models of growth and development also generated environmental degradation.

This upward trend enhancing general vulnerability makes coastal regions ever riskier. Certainly, the number of natural catastrophes in these areas has been increasing in recent decades (Kron 2013). In this scenario, to achieve a sustainable development (natural, socio-economic and cultural) in coastal areas is even more significant. Integrated Coastal Zone Management (ICZM) arises as a strategy that promotes this kind of development, especially after the World Summit on Sustainable Development in 2002, when it incorporates the principles of the Ecosystem Approach.

2.2. Integrated Coastal Zone Management and risk

ICZM strive for achieving a balance between social, environmental and economic interest in coastal areas, through an approach based on ecosystem-based management, stakeholders' involvement and the development of operational tools (Conde et al. 2012). During the last decade, countless countries, governments and organizations have adopted ICZM as the most suitable policy to effectively address issues and problems in the complex coastal domain. It is seen as the superior course of action to integrate technical, political and communities' interests and considers the participation by local stakeholder as an elementary component for a successful management (Christie et al. 2005).

As an important component of ICZM planning, the interest in coastal risks analysis and assessment has been growing in the last decade. Risk analysis is internationally recognized as an approach to assist decision-making. It is a systematic way of gathering, evaluating, and disseminating information leading to recommendations in response to an identified risk. It is a tool intended to provide decision-makers with an objective, repeatable and documented assessment of the risks posed by a particular action.

Yet risk fields are characterized by a certain lack of clarity on many concepts and principles. Risk analysis has been broadly defined as including risk assessment, risk characterization, risk communication, risk management, and policy relating to risk (e.g. Society of Risk Analysis). However, to many (e.g. ISO, FLOODsite, UNISDR), risk analysis is part of risk assessment and is defined as "a methodology to determine the risk by combining probabilities and consequences". In turn, risk assessment implies to understand, evaluate, and interpret the perception of risk and societal tolerance, to inform decisions and actions in the risk management process (see Fig. 2).

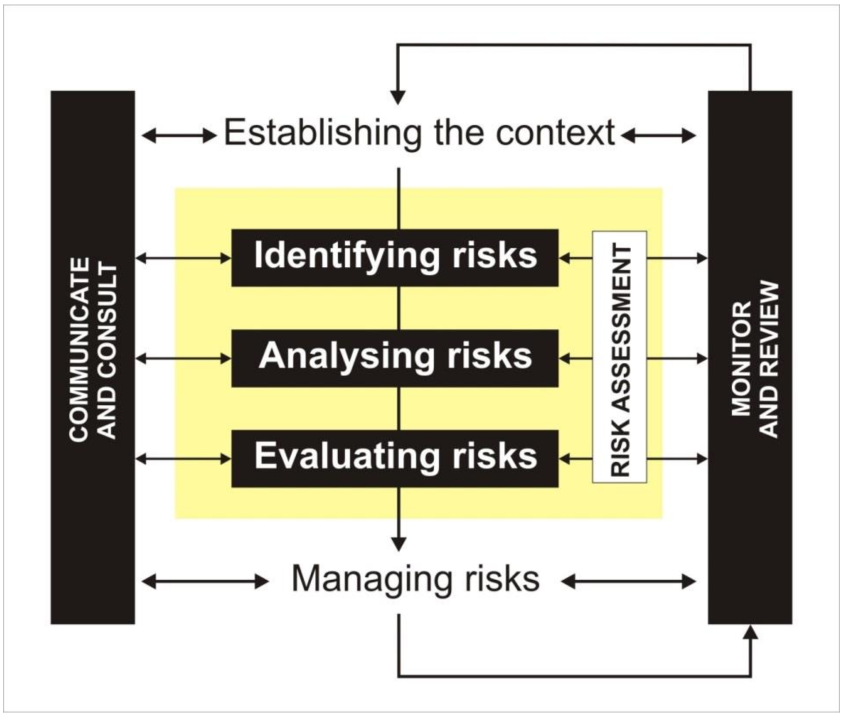


Figure 2. Key components of the Risk Management Process (modified from Australian/New Zealand Risk Management Standard).

Given this lack of clarity on many concepts and principles it is essential, when seeking to carry forward researches on these topics, to establish *a priori* certain terms and common language in order to be sure of being all talking about the same concepts. This lack of clarity may be even more troubling considering that interdisciplinary cooperation between physicists, ecologists, economists and social scientists is essential in risk management processes. Even the use of English is not already a guarantee, since several terms may be interpreted differently in different countries (FLOODsite project 2005). Following previous experiences (e.g. FLOODsite project 2005, UNISDR 2009, DEFRA 2011) we agreed on a set of key definitions to be used in our project and in this chapter that are presented in the glossary in Table 1.

The set of terms defined in Table 1 present its own particular relationships, which are tentatively depicted in figure 3. Key components of the risk assessment method, both addressing the risk on ecosystems and stakeholders derived from climate change hazards, are shown as the central mechanism of an integral risk management process. Ecosystem services are presented as the vital connecting component between end users and ecosystems, and human adaptation and ecosystem conservation as the strategies to cope with natural and anthropic hazards.

Table 1. Glossary developed from previous risk management projects (FLOODsite 2005, UNISDR 2009, DEFRA 2011), establishing main key definitions used in this chapter.

CONCEPT	DEFINITION
Acceptable risk	The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions.
Adaptation	Adjustments in socio-ecological systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities
Consequence	An impact such as economic, social or environmental damage/improvement. May be expressed descriptively, by category (e.g. High, Medium, Low) or quantitatively (e.g. monetary value).
Disaster	Serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.
Ecosystem services	The benefits that people and communities obtain from ecosystems.
Ecosystem service value	Public's net willingness to pay for an ecosystem service (economic definition); relative value given by stakeholders to ecosystem services in relation to their wellbeing (social definition).
Engagement	Where the public and/or stakeholders are asked to directly and actively take part in decision processes, but a public agency/authority is still responsible for the decision.
Exposure	Quantification of the receptors that may be influenced by a hazard (e.g. number of people and their demographics, number and type of properties etc.).
Hazard	A physical event, phenomenon or human activity that may lead to harm or cause adverse effects. A hazard does not necessarily lead to harm. Can be natural o human induced.
Impact	The effect that a risk would have if it happens.
Inherent risk	Risk arising from a specific hazard before any management action has been taken.
Qualitative risk assessment	Describes the probability of an outcome in terms that are by their very nature subjective as the assessment typically assigns relative values to assets, risks, controls and effects.
Quantitative risk assessment	A methodology used to organize and analyze scientific information to estimate the likelihood and severity of an outcome. Objective numerical values are calculated for each component gathered during risk analysis.
Residual risk	The exposure arising from a specific risk after action has been taken to manage it (making the assumption that the action is effective).
Resilience	Ability of a system, community or society exposed to hazards to resist, accommodate, absorb to and recover from the effects of a hazard in a timely and efficient manner, including the preservation of its essential structures and functions.
Response	Provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health

	impacts, ensure public safety and meet the basic needs of the people affected.
Risk	The consequence(s) of hazard(s) being realized, and their likelihood/probabilities. The combination of the probability of an event and its negative consequences. A function of probability, exposure and vulnerability. Exposure could be incorporated in the assessment of consequences, therefore it can be considered as having two components: the probability that an event will occur and the impact (or consequences) of the event.
Risk Analysis	Methodology to determine risk by analyzing and combining probabilities and consequences.
Risk Assessment	A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend. Comprises understanding, evaluating and interpreting the perceptions of risk and societal tolerances of risk to inform decisions and actions in risk management process.
Risk Management	The complete process of risk analysis, risk assessment, options appraisal and implementation of risk management measures (i.e. risk treatment).
Risk mitigation	The reduction of the likelihood of harm, by either reduction in the probability of hazard occurring or a reduction in the exposure or vulnerability of the receptors.
Risk perception	Subjective appraisal of people (individual or group) on the characteristics and severity of risk, reflecting cultural and personal values, experience and acquired information
Risk strategy	An organizational approach to risk treatment, well documented and accessible.
Risk Treatment	Management measures taken to reduce either the probability or the consequences of the hazard, or some combination of the two.
Stakeholders	Individuals or representatives of groups who are directly or indirectly interested in or affected by an issue or situation.
Susceptibility	The propensity of a particular receptor to experience harm. Also a condition that increases the likelihood that an environmental component will be exposed to a particular hazard.
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. Vulnerability is the result of the whole range of economic, social, cultural, institutional, political and even psychological factors that shape people‘s lives and create the environment that they live in".
Vulnerable groups	Human groups who are prone to show more adverse responses than other groups, given the same exposure.

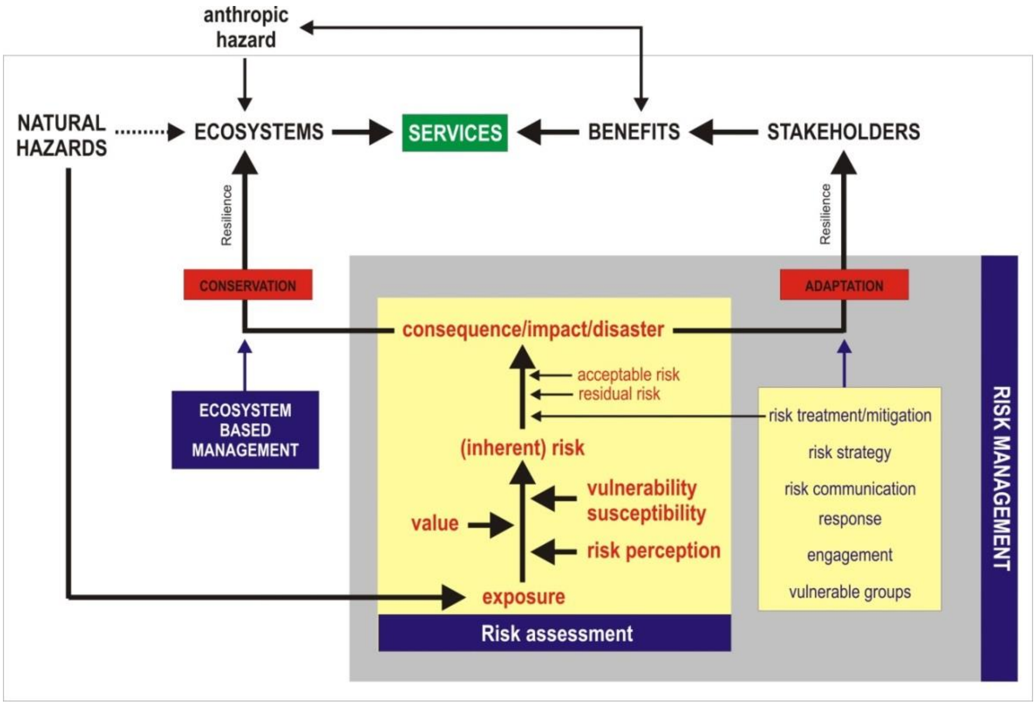


Figure 3. Fluxogram depicting key concepts and terminology related to Climate Change risk management (and other associated terms), according to the definitions and agreements of the interdisciplinary consortium in charge of this chapter.

2.3. The inclusion of risk perception in the integral analysis of risk

Risk management calls for integrated processes including all the stakeholders affected (e.g. populations, companies, government, and scientists), joining the main principles of ICZM. Disaster prevention could be truly effective only if all of the stakeholders cooperate in a spirit of partnership (Kron 2013). Communication and consultation are highlighted as relevant at each step of the process (see Fig. 2). However, this dialogue must be bidirectional, stressing consultation and not merely information from managers to stakeholders.

During the last decades the treatment of public affairs has progressively become more complex. While government agencies maintain significant influence on management they are just one of multiple actors. In many countries, societies have slowly advanced in the construction of more flexible forms of governance which are more effective and representative of the interests of diverse social groups. Key factors explaining why new models of governance are emerging include governments' action seeking to implement policies and programs more cost-effective and equitable as well as social demands which increasingly influence the decision-taking process.

It is extremely important to involve a wide range of stakeholders, particularly scientists with access to detailed knowledge and also those who are most vulnerable and often least consulted are heard. Since climate change affects women and men differently, it is important to consider gender issues such as the unequal power relationships between genders (CEDRA 2012). People's risk perception is based on the expected number of deaths or injuries, but also on how well the process is understood, how equitably the danger is distributed, how well individuals can control their exposure and whether risk is voluntarily assumed. People rank risks based on three major factors: the degree of dreadfulness of the event (e.g. determined by the scale of its effects and the degree to which it affects innocent bystanders), how well the risk is understood (or accepted as fate) and the number of people exposed (Slovic 2000).

It is therefore highly reasonable to search for methodologies that take into account social differences, since social groups may be affected differently both by climate change as well as by risk management actions. Identifying different interest groups is relevant because they may also have different perceptions, response or adaptation modes to climate hazards. Furthermore, the relationships between different social groups are asymmetric and often characterized by inequality. Thus, misperception of these differences often leads to policies and actions that deepen inequities and increase vulnerability of the weakest groups (Fig. 4).

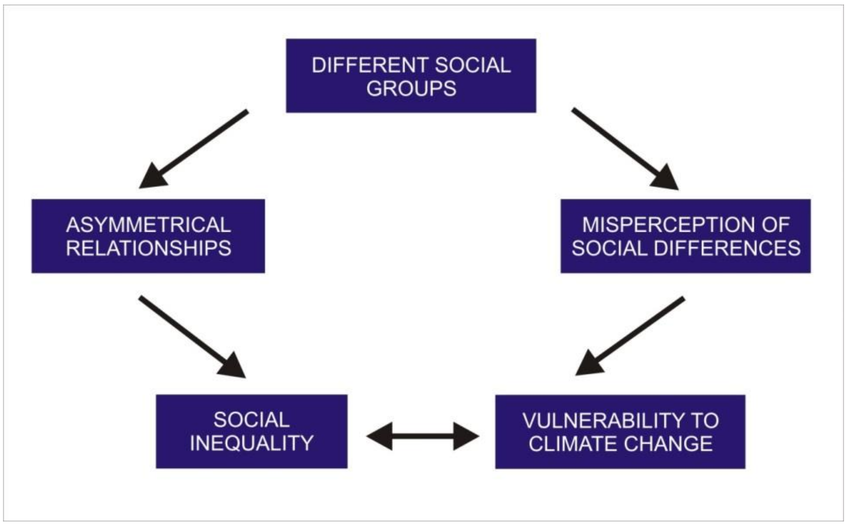


Fig. 4. Asymmetrical relationships among social groups leading to social inequality and how misperception of these differences increases the vulnerability to climate change of the weakest groups, through inadequate policies and actions.

Modified from Shaw et al. (2005), candidate risk perception indicators to these events include, among others, lives threatened during events, impacts on physical and psychological health and effectiveness of government’s and individuals’ prevention methods. Although quantification is an essential tool for risk management orientation, the complexity of social/environmental scenarios suggests the necessity integrating the perception of actors and social vulnerability to overcome the merely probabilistic quantification, assuming these are key factors influencing both the final impacts and the adaptive responses.

2.4. Ecosystem services as a vehicle for improving an integral approach to risk

During the past two centuries the dominant paradigm held that natural threats should be managed through better technical protection (Kron 2013). Traditional engineering approaches optimizing for coastal safety are often suboptimal with respect to other functions and are neither resilient nor sustainable. Historically, coastal protection has been based on hard infrastructures (e.g. walls, jetties, and groins) ignoring and even destroying coastal ecosystems that could provide the necessary protective function.

Natural coastal ecosystems are critical to human societies, providing a diverse range of goods and services that are vital to our wellbeing, known as ecosystem services (e.g. Costanza et al. 1997, MEA 2005). While scientists and environmentalists have discussed ecosystem services for decades, the UNEP's Millennium Ecosystem Assessment (MEA, 2005) marked a major milestone in the historical development of the ecosystem services concept. The MEA distinguished four categories of ecosystem services: Provisioning, Regulating, Cultural and Supporting services, while since then several categorizations have been developed concerning biodiversity conservation, integral environmental assessment or economic valuation.

The focus on environmental and resources management through the ecosystem services and their link to human well-being proposed by MEA has been pioneering in environmental research. It becomes much clear to identify how changes in ecosystems can affect human welfare. Damage to natural ecosystems will seriously jeopardize their ability to provide these critical goods and services, causing considerable economic and social consequences. One of the most significant contributions of the MEA has been the introduction of ecosystem services in the sustainability's global agenda. The modern concept of ecosystem services has progressed significantly in recent decades, incorporating economic dimensions and providing useful information to decision makers for implementing effective conservation policies which support human wellbeing and sustainable development.

Probably the protection of the coastal zone may be one of the most important ecosystem service provided by coastal marshes. Nonetheless, the real importance of this service and hence its true consideration was given after two recent natural disasters: the Indian Ocean tsunami (2004) and hurricane Katrina (2005). Especially after Katrina, both scientists and press highlighted the role of marshes as buffers in protecting coastlines, as well as their loss as possible explanation of the disaster. Quickly the protective service eventually provided by coastal marshes against extreme storm surge waves became a contentious issue When the effects of climate change clearly are being felt worldwide, new methods of both mitigation and adaptation are increasingly necessary; and ecosystems can be very helpful facing current and future global changes. Thus the protection of ecosystems and the services they provide can form an important part of climate change mitigation and adaptation strategies.

Nowadays, ecosystem-based solutions start to be an important component of collaboration between the hazard mitigation and climate change adaptation research communities (Munang et al. 2013). There is a growing interest in identifying where ecosystem-based approaches can fit into the preparation and response to climate change. The importance of ecosystem protection is increasingly recognized (e.g. EU Adaptation Strategy) highlighting the cost effectiveness and multiple benefits of ecosystem-based strategies that integrating climate and biodiversity policy can help to meet the challenges of a changing climate ensuring protection of vital ecosystems. However, concerning coastal risk management programs, natural ecosystems and the services they provide to human wellbeing have just occasionally been considered. The current practice of risk analysis still focuses on damages that can be easily measured in monetary terms. Hence risk assessment mainly deals with damage to assets, while social and environmental consequences are often neglected; this means that risk treatment frequently only manages a part of the total risk (Meyer et al. 2009).

2.5. A regional approach linking social perception and risk analysis to assess vulnerability of coastal socio-ecological systems to climate change

2.5.1. A regional project and three pilot sites

Low-lying coasts in Latin American countries are highly vulnerable to climate variability and extreme climatic events (rain, windstorms and sub-tropical cyclones, and associated storm surges). The increase of sea-level exerts extra vulnerability to low-lying coastal areas already subjected to increasing storm surges and heavy precipitation (Magrin et al. 2007). The coastal area of Southern South America is diverse and ecologically stunning, providing a diversity of ecosystems, and receiving freshwater from heavily populated watersheds, thus posing substantial risks (Seeliger and Kjerfve 2002). These effects have been shown to cause substantial modifications of the ecosystems' resources, resulting in social impact at diverse scales since communities and institutions have severe difficulties to deal with such changes. These social, economic and environmental consequences may be synergistically magnified by Climate Change.

On the Atlantic coast of southern Brazil and eastern Uruguay, low-lying coastal plains formed by sediment accretion, especially during last Holocene period, are susceptible to the effects of flooding and represent a risk to urban areas. Many human groups reveal scarce capacities to cope with further losses of ecosystem services. Although there is an increasing regional recognition of the supporting role played by ecosystem services for human welfare, the perception by communities and managers is still inadequate. Areas under risk will be magnified by rising sea levels and the increase in frequency and intensity of storms. Coastal vulnerability to Climate Change has been suggested to generate diverse social and environmental impacts in the region (IPCC 2007).

Impacts at diverse social scales are boosted also because regional communities and institutions still lack capacities and integrated management approaches to deal with climatic long-term changes. Nevertheless, because of the relative homogenous regional culture, opportunities to foster cooperation towards an Atlantic Southern Cone integrated coastal management model are assumed to exist (Menafra et al. 2009). An opportunity to join regional efforts to design and implement management strategies require identifying lessons learned and sharing previously isolated experiences for strengthening impact mitigation of climate changes effects.

To address these topics at a regional scale (coastal area of Southern South America, specifically southern Brazil and eastern Uruguay), an on-going research project is specially addressing the interdependence between risk perception and vulnerability of coastal communities to flooding and other extreme events, as well as their perception of the relevance of ecosystem services in reducing the consequences of Climate Change. This effort is supported by a grant from IDRC-Canada (106923-001). Universities from Uruguay, Brazil, Canada and Portugal strengthened an existing consortium addressing integrated coastal management to enable carrying on this research project. The goal of the study is to contribute to develop resilience to Climate Change in selected coastal wetland ecosystems and communities of the Atlantic Southern Cone of Latin America especially threatened by extreme climatic events, and to improve recognition of the role of ecosystem services in coping with and adapting to Climate Change.

Three coastal sites were selected, namely Valle de Itajai-Santa Catarina and Estuary of Lagoa dos Patos-Rio Grande (in Brazil) and Laguna de Rocha-Rocha (in Uruguay). Specific information on relevant socio-ecological features, ecosystem services and climatic hazards from the three sites are detailed below. Some of the topics now addressed by this consortium have been previously assessed in each of the specific sites, through diverse approaches by co-authors of this chapter. Now, the innovative aim is to develop a regional analysis of these issues, using previous existing information and improving and standardizing the previous experiences, from where to derive lessons learned on a broader scale. Tables 2 and 3 contain comparative listings of major ecosystem services and climatic and anthropic drivers, in the three sites.

a) Itajai Valley – Santa Catarina (Brazil)

The Itajai Valley is located in the northern portion of Brazil, being drained by the largest river in the state of Santa Catarina, the Itajairiver. Floods in the region in the nineteenth century were recognized as a recurring phenomenon. People migration process and occupation on the banks of the rivers turned the situation more complex because of the intense urbanization process. In the last 30 years countless lives and material losses occurred from major floods (1983, 1984, 2008 and 2011). Society and government efforts with the purpose of seeking diagnose, plan and implement actions and non-structural actions to mitigate the problems has taken place (e.g. regional economic-ecological zoning strategies, municipal master plans oriented by precautionary principles, National Policy on Climate Change).

In this context lies the city of Itajai, the most important fishing port in Brazil and second largest exporter of containers. The municipality has an area of 289 km² and a population of 190,000 inhabitants. It is located in a vast coastal plain in the central portion of the north-central coast of Santa Catarina. Its high urbanization further contributes to economic losses due to flood. The floods of 1983 and 1984 severely affected Itajai, and in 2008 ca. 90% of the city was flooded. In 2011 the floods affected more than 60% of the area. To mitigate the existing problems, recent governmental initiatives led to developing models, strategies and tactics not based on the recognition of local features. There is an urgency of analyzing different low costs regional planning options, including education, and to propose strategies based on models involving society, governments and private sector, along a local process of integrated management and governance explicitly recognizing climate change.

Relevant research done at the Itajai Valley include contributions on major climatic hazards (Polette et al. 2012), present coastal challenges (Ferreira and Polette 2009), main management tasks (Polette & Vieira 2009), and environmental education (Acauan and Polette 2011).

Table 2. Listing of ecosystem services in three coastal pilot sites in Brazil and Uruguay.

ECOSYSTEM SERVICES		
ITAJAI	**RIO GRANDE**	**ROCHA**
Inland artisanal and coastal industrial fisheries	Food supply from industrial and artisanal fisheries and shrimp intense production	Traditional artisanal fisheries and shrimp natural production
Water supply (watershed basins)	Water for domestic, agriculture and industrial consumption	Water supply for nearby seaside
Riparian services (riparian wetlands taking excess of nutrients and protecting river margins from erosion)	Saltmarsh services (taking excess nutrients and protecting the estuarine margins from erosion)	Freshwater marsh and saltmarsh services (nursery areas, taking excess nutrients and protecting lagoon margins and coastal front from erosion)
Organic production of the low river and soil formation (supports productive ecosystems like agricultural areas, marshes, and beaches)	Organic production of the estuary and soil formation (supports multiples productive ecosystems like low-energy agricultural areas, marshes, seagrass beds and algal mats, and beaches)	Organic production of the lagoon and soil formation (supports multiples productive ecosystems like extensive cattle grounds marshes, freshwater macrophyte beds, seagrass beds, and beaches)
Biodiversity (riparian ecosystem and Atlantic rain forest)	Biodiversity (freshwater and brackish wetland, and lowlands)	Biodiversity (freshwater and brackish wetland, and prairies)
Cultural spiritual and intellectual needs (local people and intensive tourism)	Attractive landscapes suitable for recreation and tourism activities	Astonishing pristine landscape offering recreational, aesthetic, and cultural services

Table 3. Relevant climatic hazards and anthropic pressures in three coastal pilot sites in Brazil and Uruguay.

CLIMATIC HAZARDS AND ANTROPHIC PRESSURES		
ITAJAI	**RIO GRANDE**	**ROCHA**

El Niño phenomenon (1982/83 and 1997/98) First hurricane ever observed in the South Atlantic demolished over 3,000 houses in southern Brazil	The combination of high tides with the passage of fronts from South can produce meteorological tides that can easily double its highs, producing severe storm surges with strong erosion effects Storm surges can block the large estuary water discharge and produce floods during severe rain periods	Storm surge formation producing coastal impacts Flooding in upstream county city (Rocha city) and coastal villages (La Riviera, Puerto Botes) and cities (La Paloma) Coastal erosion and morphological modification of lagoon's mouth
Unregulated urban growth along the Itajai river, demographic pressure, poverty and rural migration Low investment in infrastructure and services	Recent populational increase due to new port development Lack of adequate urban infrastructure and services A myriad of social and economic activities going on simultaneously	Potential touristic development (in nearby La Paloma city) towards the lagoon's coastal fragile stripe Promotion of urbanization in potentially flooding areas Artificial opening of the lagoon (natural hydrology modification)
Inter-sectoral un-coordination of leading agencies and stakeholders in the region	Improper integrated management to deal with the complexity of the present situation	Intensive unplanned tourism at the protected area and lagoon Lack of a local management plan and scarce monitoring

b) Estuarine region of Lagoa dos Patos - Rio Grande (Brazil)

The estuarine region of Lagoa dos Patos, located at the southern Brazilian coast, may be considered as an environmental system with a high ecological, economic and social importance. Lagoa dos Patos is a coastal system of impressive dimensions. Having an area of 9,913.93 Km^2, it is classified as the largest coastal lagoon of the "choked" type (with a restricted connection to the sea) in the globe. The estuarine region, approximately limited by coordinates 52°14'46" - W 31°41'40" S and 51°58'24" - W 32°11'59" S, encompasses important urban centers of the Brazilian southern shore, such as the cities of Pelotas and Rio Grande, as well as a substantial pool of production, transformation, and business activities. In ecological terms, it may be classified as a typical estuary of a transition system between ocean and continent, thus suffering the influence of processes, sources, and controls from both. There is great use diversity and density in the water body itself and by the margins of the estuary of Lagoa dos Patos, including urban occupation, port and industrial activities, an important summer resort and tourist activity, as well as environmental protected areas, artisanal and industrial fisheries. These issues are tightly related to impacts by Climate Change-related events.

Recently, new discoveries of important oil and gas fields concentrated in the Exclusive Economic Zone in the southeast region of Brazil – a deep-ocean, subsalt formation known as pré-sal – have generated a big thrust in the sector related to the exploration, refining, and transportation of those energy sources. Similarly, the new and important phase in Brazilian oil production has significantly stimulated the national shipbuilding sector, with ships for oil and gas exploration and transportation, and the development of port areas to provide logistic support to the endeavor. In the estuarine region of Lagoa dos Patos, where the Port of Rio Grande is located the installation of an offshore naval construction pool has brought a sizeable enhancement to local economy, and may generate considerable environmental impacts on estuarine ecosystems.

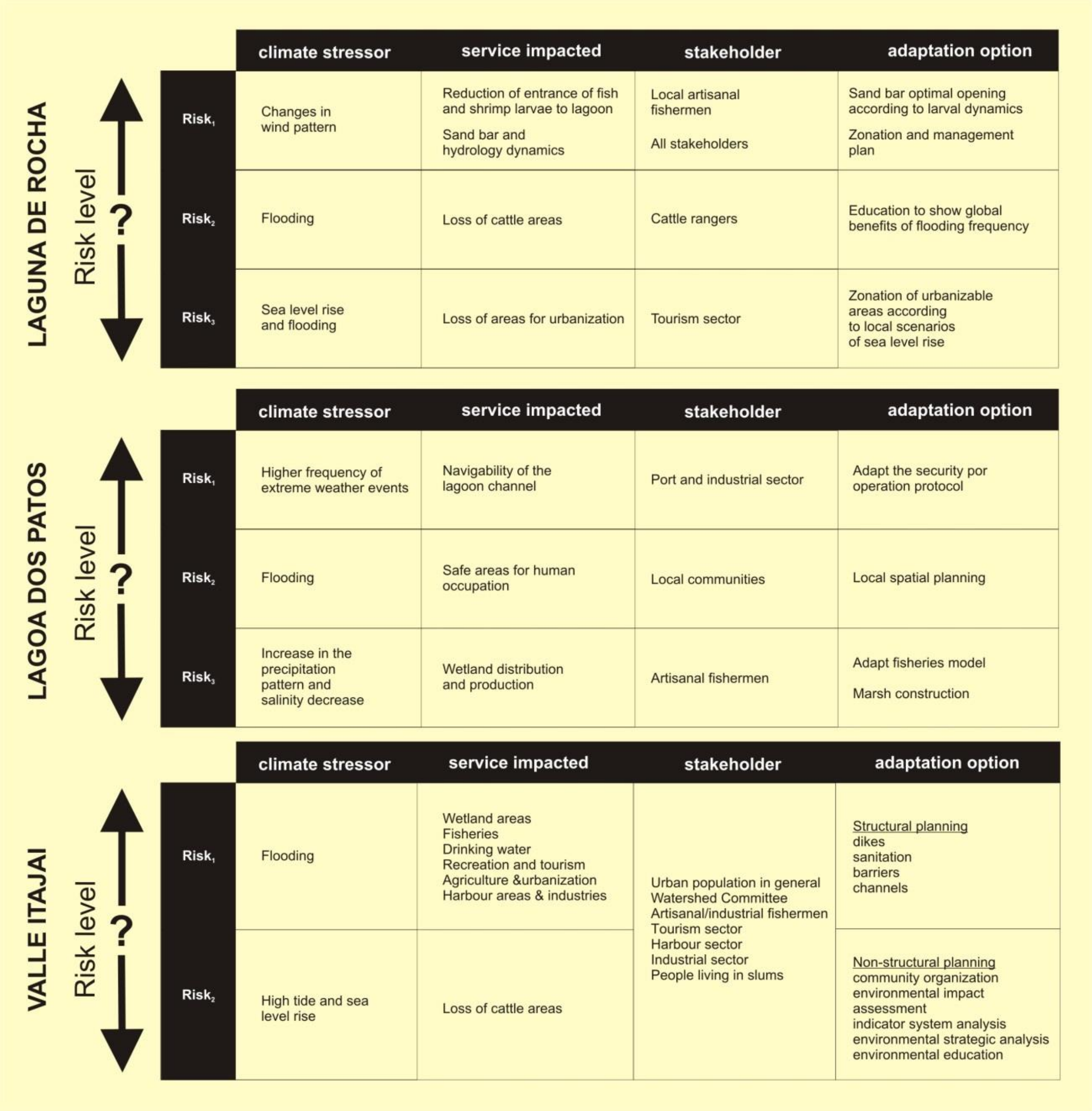
Research done at Lagoa dos Patos, relevant for our proposal, include studies on socio-ecological effects of climate (Janeiro et al. 2008, Leão et al. 2010) and management (Asmus and Tagliani 2009).

c) Laguna de Rocha – Rocha (Uruguay)

The Atlantic coast of Uruguay, which has recorded the increasing trends in temperature, precipitation and sea level rise, includes four important coastal lagoons with intermittent connection to the ocean, which belong to one of the largest systems of coastal lagoons on the planet, extending northward to Brazil and southward to Argentina. Most of these coastal lagoons are Natural Protected Areas according to national and international agreements like UNESCO-MaB, the RAMSAR Convention and others. These highly productive systems sustain important traditional artisanal fisheries, provide relevant ecosystem functions such as reproductive and feeding areas for fish and shrimp of commercial relevance, constitute feeding and resting areas for neartic migratory birds, and provide habitat for endemic vertebrate and plants species. Other ecosystem services include hydrological control, soil generation and maintenance, buffering of basin contamination and aesthetic values for ecotourism.

Laguna de Rocha is the second largest coastal lagoon of Uruguay and presently the most studied aquatic ecosystem in the country. Land use in the basin (that includes the capital city and nearby tourist seaside towns, with ca. 40,000 inhabitants; up to 80,000 in summer) is mainly extensive cattle rising on natural prairies, but forestry with exotic pines and eucalyptus, artificial prairies and intensive agriculture have increased 5-10% in the last decade. These towns commonly suffer flooding events. Traditional tourism is increasing around the fragile sandbar area and environmental impacts, including eutrophication, coastal erosion and natural habitat degradation, increased threats to endangered species, loss of scenic values, water quality degradation and alteration of the natural hydrology can be predicted. The sand-bar is opened artificially to reduce flooding of adjacent grasslands used for livestock grazing and to permit the entry of important marine larvae, especially commercial shrimp and fishes. Biodiversity and ecosystem services of Laguna de Rocha and its basin are thought to be heavily threatened by climate change.

Relevant research in Laguna de Rocha includes ecosystem services (Nin 2013), effects of climate on ecosystem services (Fanning 2012) and basin management (Rodríguez-Gallego et al. 2012).



LAGUNA DE ROCHA

	climate stressor	service impacted	stakeholder	adaptation option
Risk$_1$	Changes in wind pattern	Reduction of entrance of fish and shrimp larvae to lagoon Sand bar and hydrology dynamics	Local artisanal fishermen All stakeholders	Sand bar optimal opening according to larval dynamics Zonation and management plan
Risk$_2$	Flooding	Loss of cattle areas	Cattle rangers	Education to show global benefits of flooding frequency
Risk$_3$	Sea level rise and flooding	Loss of areas for urbanization	Tourism sector	Zonation of urbanizable areas according to local scenarios of sea level rise

LAGOA DOS PATOS

	climate stressor	service impacted	stakeholder	adaptation option
Risk$_1$	Higher frequency of extreme weather events	Navigability of the lagoon channel	Port and industrial sector	Adapt the security por operation protocol
Risk$_2$	Flooding	Safe areas for human occupation	Local communities	Local spatial planning
Risk$_3$	Increase in the precipitation pattern and salinity decrease	Wetland distribution and production	Artisanal fishermen	Adapt fisheries model Marsh construction

VALLE ITAJAI

	climate stressor	service impacted	stakeholder	adaptation option
Risk$_1$	Flooding	Wetland areas Fisheries Drinking water Recreation and tourism Agriculture &urbanization Harbour areas & industries	Urban population in general Watershed Committee Artisanal/industrial fishermen Tourism sector Harbour sector Industrial sector People living in slums	Structural planning dikes sanitation barriers channels
Risk$_2$	High tide and sea level rise	Loss of cattle areas		Non-structural planning community organization environmental impact assessment indicator system analysis environmental strategic analysis environmental education

Figure 5. Prospective analysis to identify the most important risks to climate change in three pilot coastal sites along the Southern Cone of Latin America. Without an objective, but socially meaningful, quantification of the risks, the uncertainty of which of them are to be prioritized reduces the effectiveness of the management efforts.

d) Prospective analysis of risks

Derived from the information on the most relevant ecosystem services and hazards in each pilot site (Tables 2 and 3) we performed a prospective analysis to tentatively (and non-quantitatively) identify the major risks to climate change

(Fig. 5). As seen, in the three sites the climate hazard that apparently would impose major effects on ecosystem services and stakeholders is flooding, although due to different causes like precipitation, storm surges and sea level rise, among others. Changes in wind pattern and induced changes in salinity are also indicated as relevant hazards in some of the sites.

Ecosystem services affected include a large and diverse list where the loss of productive areas both for agriculture and fisheries, as well as for urbanization and industrial development are highlighted, especially in Itajai and Lagoa dos Patos. Only in Laguna de Rocha ecosystem natural functions are listed as under thread (sand bar dynamics and hydrology) although in Lagoa dos Patos the loss of wetland areas is also emphasized. Stakeholders potentially impacted by these losses are diverse, from traditional fishermen to port industry, including the tourism sector and poor settlements, among others. Optional management practices to be taken include structural and non-structural actions, as well as coastal zonation, adaptation of fisheries models and operational port protocols, and environmental education.

Nevertheless, this analysis lacks of a quantitatively approach to enable prioritizing the risks, in order adequately rank the management options to be adopted. Without objective and socially meaningful risk quantification the effectiveness of the management efforts are significantly reduced (Dovers et al. 2008). For these reasons and because of the problems arising when risk is analyzed with no support from stakeholders' interests and opinions, the interdisciplinary consortium carrying on the regional project developed a new methodological framework, taking into account these shortcomings, with the aim of adequately linking the approaches of risk analysis and risk perception (see next section).

2.5.2. Methodological development

The proposed framework consists of several steps, from defining critical ecosystem services to be selected for detailed analysis of risk and perception, to finally obtaining a socially prioritized set of risks that can help managers to decide where to focus management efforts for adaptation. For the explanation we will follow the schematic depiction showed in figure 6. As seen in the scheme and explained below, there are three entries where social perception feeds the risk analysis: Phase 1 (qualified informants to develop an inventory of ecosystem services), Phase 2 to 3 (selection of relevant services), Phase 4 (valuation of services and vulnerability assessment of diverse social groups).

Initially, some agreements must be made on several topics and specific strategies to be followed, by the interdisciplinary consortium. For example on ecosystem services we decided to follow the classification proposed by Fisher et al. (2009) that differentiates ecosystems (i.e. functions) which provide services, which in turn generate social welfare. To classify ecosystem services we decided to use a combination of classifications including Fisher et al. (2009), the MEA (2005) and Costanza (2008). Another relevant initial agreement is the definition of the spatial extent of the analysis, which I our case, given we had three different sites, included taking into account the provisioning area of the services, as well as the affectation and benefits area. The decision also took into consideration ecological, management and operability of the project. These initial definitions are open to any kind of agreement, but it is critical to take place before the further application of the framework.

The first step of the framework consists of the delineation of an inventory of ecosystem services in the working area previously defined (Phase 2 in the scheme of figure 6). This must be done as a cooperative effort between scientists and local stakeholders (Phase 1), to obtain the inventory derived from the existing literature (Phase 1b) for the area, as well as from traditional local knowledge. Even if an inventory developed by the academia do already exists for the location under analysis, a series of interviews to qualified informants (Phase 1a) should be carried out to complete it, or at least confirm that no relevant information for the local stakeholders is missing. The inventory needs to link climatic forces (hazards) with ecosystems (and ecosystem functions) affected. Then, based on the ecosystem functions, ecosystem services, as well as their associated benefits and stakeholders can be listed. The potential links between these sequential elements (climate forcing, ecosystems/functions, services, benefits and stakeholders) can be quantified, especially those critical links between ecosystems/functions and services, using the categorical method proposed by Maynard et al. (2010) based on expert opinion. When the inventory is defined in its wholeness, a decision on which is the critical set of ecosystem services to be addressed in detail can take place (Phase 2 to 3).

It is highly probable that this decision is taken by scientists or managers, but it is relevant that this is done as an artisanal balance taking into consideration not only the scientific opinion by specialized academic staff (e.g. based on climatic scenarios and its potential effect on ecosystems) but also on stakeholders' opinion (i.e. local traditional knowledge), which will obviously prioritize those critical issues that mostly affect their wellbeing (influenced by their past life experience and the adaption actions they already made, individually or as a community). Seeking for this balance is not an easy task, but represents a critical point where a major effort and time must be placed to enable the rest of the framework to be both ecologically and socially relevant. Considering the amount of connections and the number of links between all the sequential elements of the inventory, for the validation of this methodology, one or at least two ecosystem services must be selected, depending on the availability of information and resources at each study site.

After defining these critical ecosystem services potentially affected by climate change, which are also relevant for the local community, the next phase represents the central section of the proposal. Phase 4 corresponds to the risk assessment process, which includes both the risk analysis and the stakeholders' risk perception analysis. Even both analyses have their own methodologies they are linked through the valuation of the ecosystem services and the inclusion of the stakeholders' vulnerability, as detailed below.

By modifying the methodological development proposed by Lozoya et al. (2011), a risk analysis (Phase 4a in Fig. 6) has to be performed for each ecosystem service ($R_{ES\text{-}V}$) based on three components: a) the effective provision of that service (EP_{ES}), b) the valuation of the service (VAL_{ES}), and 3) the stakeholders' vulnerability (VUL_{STK}) (see equation 1). This calculation gives an estimation of the risk for each ecosystem service due to a number of hazards, weighted by the differential vulnerability of the respective stakeholders.

$$R_{ES\text{-}V}=EP_{ES} \times VAL_{ES} \times VUL_{STK}$$ (equation 1)

It is important to state that some methods included in this phase (e.g. intensity of hazards, valuation, vulnerability, etc.) can be substituted by other specific methods, but it is relevant that these changes are discussed and agreed in advance by the interdisciplinary consortium.

a) Effective provision of the service (EP_{ES})

The effective provision of the service (EP_{ES}) is determined as the summation of the relative contribution of each ecosystem (RC_{EC}) to the existence of that service, weighted by the intensities of the hazards ($\sum I_H$) affecting (positive or negatively) each ecosystem (see equation 2).

$$EP_{ES}=\sum(RC_{EC} \times \sum I_H)$$ (equation 2)

Considering that several ecosystems could be providing the service concerned, their relative contribution (RC_{EC}) can be estimated based on the methodology proposed by Maynard et al. (2010), and then added up to obtain the total effective provision.

The intensity of each hazard (I_H) affecting each ecosystem can be estimated considering the likelihood of occurrence of the hazard (L_H) and its consequences on each ecosystem (CS_{EC}) (e.g. area reduction, functionality reduction, etc.) (see equation 3).

$$I_H=L_H \times CS_{EC}$$ (equation 3)

Given that several hazards can affect one ecosystem at the same time or space (even producing synergies) their intensities must be also combined to obtain the total intensity affecting the each ecosystem ($\sum I_H$).

b) Service valuation (VAL_{ES}) and stakeholders' vulnerability (VUL_{STK})

For each stakeholder associated to each of the services selected, a risk perception analysis must be carried out (Phase 4b in Fig. 6). In our case, this will be performed by a combination of directed key-stakeholder interviews, surveys and workshops with relevant stakeholders. From this analysis, ecosystem services valuation and stakeholders' vulnerability are derived, to feed in the rest of the risk assessment process.

Commonly, an economic valuation of the service is used, based on classical methodology of environmental economics (Costanza et al. 1997, TEEB 2010). Nevertheless, as part of the methodological development arising from this framework, the interdisciplinary consortium decided to modify this step by replacing the economic valuation by a "social valuation", i.e. based on the relevance of the environmental service for the stakeholders (VAL_{ES}). This will be done through the principles of the analytical hierarchical process (Banai-

Kashani 1989), where each interviewed stakeholder (or eventually reaching a consensus in cases of small communities or specific cases of homogeneous opinion) define, on a 1 to 9 scale, how much important are different services, from their viewpoint. Eventually, according to the capacities of the project, an economic valuation can be done in parallel, and results compared or analyzed separately.

A final step in Phase 4 addresses the vulnerability of stakeholders (VUL_{STK}) involved with each service and hazards. It is clear that some groups are to be more vulnerable in losing a specific service by climate drivers. This differential vulnerability among stakeholders can be assessed by different methods which will not be addressed here, but could include a range of approaches used elsewhere. The quantification of the vulnerability will finally allow to weight results of the risk analysis, to be used in the decision process on which are the priority issues to be addressed in terms of management, including budget distribution and normative support, among others.

According to Pizarro (2001) the concept of vulnerability seems to be the most appropriate for understanding the transformative impact caused by increased exposure to risks, allowing centering the discussion on increasing social disadvantages, by focusing on the relationships between i) the physical, financial, human and social assets available to individuals and groups, ii) use strategies and iii) the set of available opportunities delimited by the market, the state and civil society. Vulnerability analysis emphasizes on quantity, quality and the diversity of assets (physical, financial, human and social) that can be mobilized to address environmental dynamics.

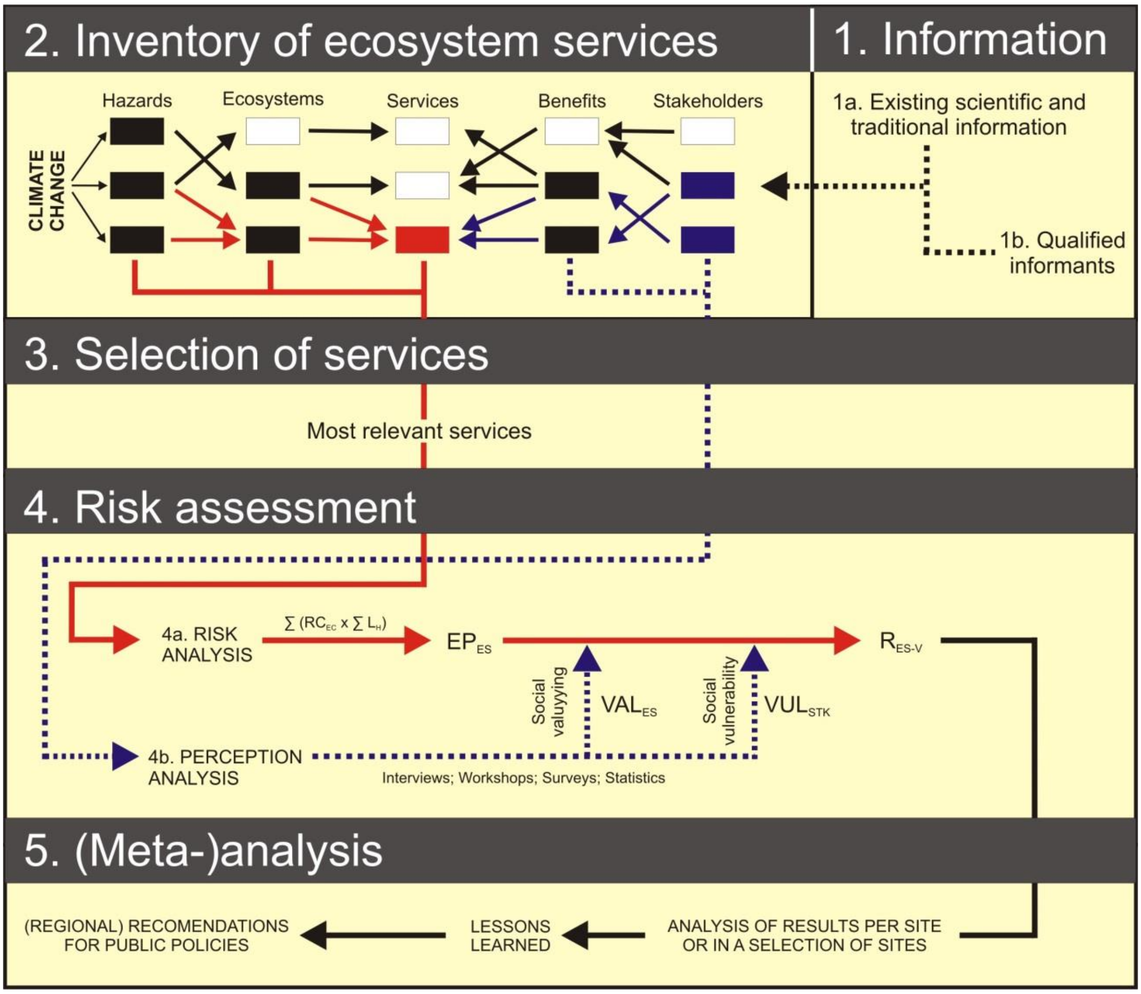


Figure 6. Methodological proposal for integral risk assessment (doted arrows indicate key points of the framework where social and non-academic perspectives do feed the risk analysis; colored boxes in 2. show an example of how to link one ecosystem service with its climatic hazards, the ecosystems that support that service as well as the related benefits and stakeholders; red doted arrows show the rational pathway from hazards, ecosystems and services to the risk analysis; blue doted arrows show the rational pathways from stakeholders to the perception analysis) (for abbreviation and other explanations see section 2.5.2).

In our case, a further Phase (Phase 5 in figure 6) of the framework will be pursued, which will allow the regional consortium to derive a series of lessons learned and recommendations based on a meta-analysis of the results from the three cases (Itajai Valley, Lagoa dos Patos estuary and Laguna de Rocha). These three cases represent a regional gradient which allow for an interesting analysis on how the reduction of wetland areas (i.e. the sequence Itajai → Lagoa dos Patos → Laguna de Rocha) and their associated services, not only due to climate forces but also due to anthropogenic pressures (e.g. urbanization and industrialization), can impact the welfare of local communities and stakeholders, and hence reduce their resilience.

3. PERSPECTIVES AND CONCLUSIONS

The methodology proposed above derives from an interdisciplinary process lasting several months in which experts from several countries, various academic institutions and a diversity of disciplines developed and adapted a framework that allow prioritizing different risks associated to climate change, according not only to the impacts on ecosystems but also on their services and the human groups that get benefit from them. The framework will now be tested in the three pilot coastal sites along the Southern Cone of Latin America (Laguna de Rocha in Uruguay, and Itajai Valley and Lagoa dos Patos estuary in Brazil). Understanding the link between social vulnerability to Climate Change impacts and the social perception of the risk and as well as of the relevance of coastal ecosystem services will be valuable to coastal communities, grassroots organizations, governments and managers at all administrative levels. Regional level innovative recommendations for enhancing coastal communities' awareness about the importance of wetland ecosystem services for mitigating the effects of flooding and events will could be derived for the improvement of environmental public policies of the region and involved nations, based on the strength of lessons learned on a regional perspective. This, local communities affected by Climate Change will be the major beneficiaries through a better local application of more adequate public policies.

On a more global perspective, in responding to the need for an improved science-policy and science-society interface to manage coastal systems the most sustainable way, the framework presented in this chapter aims to evaluate in a more realistic way the possible effects of climate forces on ecosystems and coastal populations. For it, perception and valuation of local stakeholders are included from the very beginning as a main component of the risks assessment. Community consultation and the need of bottom-up approaches in coastal management have been highlighted since the 1990s as an essential component of the ICZM process. Yet, participation could be seen as more than a democratic right of stakeholders. Cooperation and true engagement is an important condition for successful management, improving equitability and transparency in processes, avoiding the gap between decision-makers and affected communities, and thereby the failure of planning measures (Jentoft 2000).

This approach is of great importance at present, when climate change aggravates chronic social vulnerabilities, since ecosystem services losses reduce welfare and development opportunities, especially for poorest communities (Malik 2013). On the other hand, considering the relevance of ecosystems and their services to human welfare, as well as its central role in current management and adaptation strategies, it seems essential to place them in the center of the risk management. Thus, this approach may lead to more reliable results in which management decisions can be based on, and to improve public policies for better and equitable adaptation strategies, highlighting the central role of healthy ecosystems to cope with climate change.

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