Monitoring resilience of ecosystem services in Deltas. A global perspective

Internship report

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Summary

Climate change and socio-economic development are damaging delta making them more vulnerable ecosystems (Nobre, 2009; Zaldivar et al., 2008). The current status of deltas is not satisfactory in terms of resilience (Bucx et al., 2010) which is defined as the capacity of an ecosystem with different attractors to remain in a primary state even after perturbations (Holling, 1973). Hence, the aim of this study is to assess a set of relevant indicators to monitor resilience of ecosystem services in deltas as part of the Delta Monitor Program of Delta Alliance. The resilience of ecosystem services is defined as the capacity of an socio-ecological system to sustain a number of ecosystem services towards perturbations and continuing changes (Biggs et al., 2012). (1973). In order to assess the resilience of ecosystem services in deltas, the socio-ecological (SE) resilience is considered a wider definition for this study. On the one hand, the ecological resilience definition emphasizes the resistance-persistence of a system (Holling, 1996) against the amount of pressure a system can absorb and still remain within the domain of attraction (Carpenter et al., 2001). On the other hand, the socio-ecological definition of resilience introduces concepts like adaptability and transformability. Adaptability is the capacity of actors to manage the system against uncertainties. Transformability is when a system crosses a specific threshold into a new state (Walker et al., 2004). Furthermore, vulnerability is also related to resilience because is the sensitivity of the system against changes (Gallopín, 2006). Additionally, a society needs a strong institutional capacity to solve problems and achieve objectives (Fukuda Parr et al., 2002).

A set of 21 indicators was developed based on global monitoring systems . They were classified within five different domains of resilience: resistance or stability, adaptability, transformability, vulnerability and institutional capacity. Resistance domain includes the following indicators: protection status, trends in land use cover, red list index, trends in invasive species, agricultural GDP, fish over exploration, biodiversity used for food and medicine, freshwater quality, dam's density and water footprint. Adaptability domain includes: self-recovery and sustainability practices. Transformability only refers to restoration practices in deltas. Within vulnerability domain indicators such as: carbon and ecological footprint, nitrogen deposition, human health, well-being and tourism/recreation. Institutional capacity refers to the next indicators: access to sanitation and drinking water, participation among stakeholders, access to information, participation and justice, gender equity, multi-stakeholders platform, assessing the management effectiveness of protected areas and the progress of IWRM and ICZM plans.

The indicators were assess among 16 stakeholders (scientists, policy makers, economists, consultants and one farmer) with experience and knowledge on the Sacramento-San Joaquin delta in San Francisco, California. Additionally, three scientists from Delta Alliance of Taiwan filled the same survey via email. The size and diversity of the stakeholders sample is more representative for California than Taiwan. Therefore, more importance is given to the data collected among the stakeholders from California. As a result, stakeholders considered all the mentioned indicators are relevant for resilience besides agricultural GDP, carbon footprint and nitrogen deposition. Those indicators should be reformulated or changes and assess again the set of indicators in another delta with a different cultural, social, ecological and ethical contexts.

1. Introduction

Deltas are areas where a river deposits sediments in distributary channels when it flows into a water body (such as ocean, sea, or a lake). These areas are often chosen as human settlement. For instance, 13 out of 30 megacities worldwide are located on the coast. Deltas often are used for agricultural and/or industrial production and therefore they are important zones for a nation. Deltas sparsely populated have a good ecosystem and biodiversity value such as Danube delta. By contrast, in densely populated deltas high socio-economic development causes severe environmental impacts. Furthermore, if climate change impacts are added to the environmental impacts, river deltas become one of the most endangered regions. The environmental changes in deltas are caused by socio-economic development and transformation factors: urban and industrial sprawl, surface sealing, changes in land use, ground water pumping, grilling for oil and gas and intensification of agriculture. The climate change related impacts are: increase in flood risk, sea level rise, salt intrusion, increase in extreme weather events, coastal erosion and subsidence. The future population growth will affect public health and urban biodiversity. Climate change impacts will affect the distribution and the extent of ecosystems or habitats .

Deltas or estuaries are under constant pressure including habitat loss and pollution from their surrounding catchments (Nobre, 2009; Zaldivar et al., 2008). The increasing demand for their resources by changing land use, application of fertilizers and pesticides in watersheds or unsustainable forms of fishery and tourism are leading to their degradation. Degradation of goods and services in deltas has cascading effects on human health and well-being. Moreover, an inadequate management of these issues due to conflicts among stakeholders' interests increases the pressure on the system. Therefore, it is essential to understand the relationship between biodiversity, human health and well-being. Afterwards, this knowledge can be quickly translated into urban planning, management, policies and governance (Carpenter et al. 2009; TEEB 2010). Increasing resilience and the adaptive capacity of the population living within delta areas should be a priority. Furthermore, an assessment of the adaptation measures able to increase resilience should be carried out with stakeholders participation. Information exchange and knowledge sharing must happen at local, regional an international scale. Hence, an interdisciplinary approach is required to assess the resilience state of deltas with experts from diverse disciplines. The translation of experts knowledge into regulations, degrees and laws and, consequently their implementation will lead to an improvement of resilience and adaptation (Kuenzer and Renaud, 2012).

The Driver, Pressures, State, Impact and Response (DPSIR) framework has been developed to analyse environmental problems (OECD, 1993). This framework has been used by the Delta Alliance to assess the vulnerability of ten Deltas worldwide (Bucx et al., 2010). It is an integrated approach for environmental management and monitoring. Assessment is gathering information to identify the status and threats of an ecosystem. Monitoring is to use that information for management purposes (Ramsar, 2005). Delta Alliance affirms that the current status of ten deltas worldwide is not satisfactory in terms of resilience and sustainability (Bucx et al., 2010). The original concept of resilience is defined as the capacity of an ecosystem with different attractors to remain in a primary state even after perturbations (Holling, 1973). By contrast, sustainability is a normative concept based on intra or intergenerational justice when human well-being depends on natural capital and services. Thus, the concepts are related since resilience is considered as a necessary precondition for sustainability (Derissen et al., 2011).

Through the Delta Monitor, a recent program developed by Delta Alliance, resilience can be monitored, reported and compared among deltas at international level. Good practices in delta management can be identified all over the world and report the progress reached towards the UN Sustainable Development Goals. During this internship opportunity at Delta Alliance, a set of global indicators is developed to monitor resilience of ecosystem services in deltas as part of the Delta Monitor Program. Afterwards, indicators were assessed within the context of one or two different deltas in the world. The resilience of ecosystem services is defined as the capacity of an socio-ecological system to sustain a number of ecosystem services towards perturbations and continuing changes (Biggs et al., 2012). The objective is to create a resilience framework answering the following research questions: *which are the key indicators to monitor resilience of ecosystems services in deltas?* and *to what extend are all the indicators measurable and applicable on deltas worldwide?*. The structure of this paper is as it follows: after the *Introduction* section, some *Background* information is given to understand resilience *of* what and *to* what, how to measure resilience and other complementary concepts of resilience; next, the study area and the steps of the resilience framework are described in *Data and methods*; afterwards, the *Results* obtained through the interviews; it end with a *Discussion, Conclusions* and *Recommendations* sections.

2. Background

In this section important concepts are introduced such as resilience, the seven principles of the socio-ecological resilience concept, how resilience can be measured and other complementary concepts of resilience.

2.1. What is resilience?

Three different definitions have emerged from the ecological literature between 1960s and 1970s going from narrow to a broad concept (Wardekker et al., 2010). The first definition of resilience was given by (Holling, 1973), and he defined ecosystem *resilience as the magnitude of disturbance that a system can experience before it shifts into a different state (stability domain) with different controls on structure and function*. He made a distinction between ecological resilience and engineering resilience. Engineering resilience measures the rate at which a system reaches steady state after a perturbation, and it is able to return to equilibrium. He also stated that this definition is less appropriate to measure ecosystems resilience (Holling, 1996) since ecosystems face multiple stable states due to human activities (Nyström and Folke, 2001; Scheffer et al., 2001). A general definition of resilience can be *the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks* (Walker et al., 2004).

A delta and its ecosystem services can be considered a socio-ecological system as a result of the natural and human systems interaction (Folke et al., 2004). Thereby we have to define a border concept of resilience, the socio-ecological resilience which focuses on the interaction between disturbance and reorganization (Wardekker et al., 2010). Thus, socio-ecological resilience has three main properties: (i) *the amount of disturbance a system can absorb and remain within a domain of attraction; the capacity for learning and adaptation* and *the degree to which the system is capable of self-organizing* (Rockström et al.).

The social-ecological definition of resilience is chosen for this study because it gives a wider and complete understanding about resilience. Moreover, this definition emphasizes the ability of a system to build and increase its capacity for learning and adaptation after perturbations (Wardekker et al., 2010). Furthermore, this concept is used to enhance resilience of ecosystem services (Biggs et al., 2015). The social component of the system depends on the ecological component for livelihood and well-being (Kuenzer and Renaud, 2012).

2.2. Resilience *of* what *to* what?

Resilience is a dynamic property that depends on the processes and the context in which the system in embedded (Quinlan et al., 2015). The understanding of resilience can change depending on the temporal, social and spatial scale of the measurement. It is crucial to specify what system state is being considered (resilience *of* what) and what perturbations are of interest (resilience *to* what). Resilience can be applied to an entire system or focus on the certain variables of the system (Carpenter et al., 2001). For this particular study the focus will be on key ecosystem services that deltas provide, therefore we talk about resilience of ecosystem services in deltas to environmental and climate impacts that are threatening deltas.

2.2.1. "Resilience of what?"

Deltas offer many functions or services (MA, 2003) which represent the conditions and processes that sustain their species sustain and fulfil human needs. The ecosystem functions maintain biodiversity and the production of ecosystem goods (Daily, 1997). The term function has mainly an ecological meaning. Services are the 'useful things' that ecosystems 'do' directly or indirectly for people (Braat and de Groot, 2012). Therefore *ecosystem services are the direct and indirect contributions of an ecosystem to human well-being* (Kumar, 2010).

Figure 1 indicates the classification of ecosystem services according to Millennium Assessment (MA, 2003): *provisioning services* (food and water), *cultural services* (recreational, spiritual, religious and other nonmaterial benefits), *regulating services* (floods and drought protection, land degradation, and disease control), *supporting services* (soil formation, nutrient cycling and primary production). The *supporting* services are necessary for the production of all the other ecosystem services. Furthermore, they contribute to the human well-being by offering security, basic materials for life, health, good social relation together with the freedom of choice and action (MA, 2003).

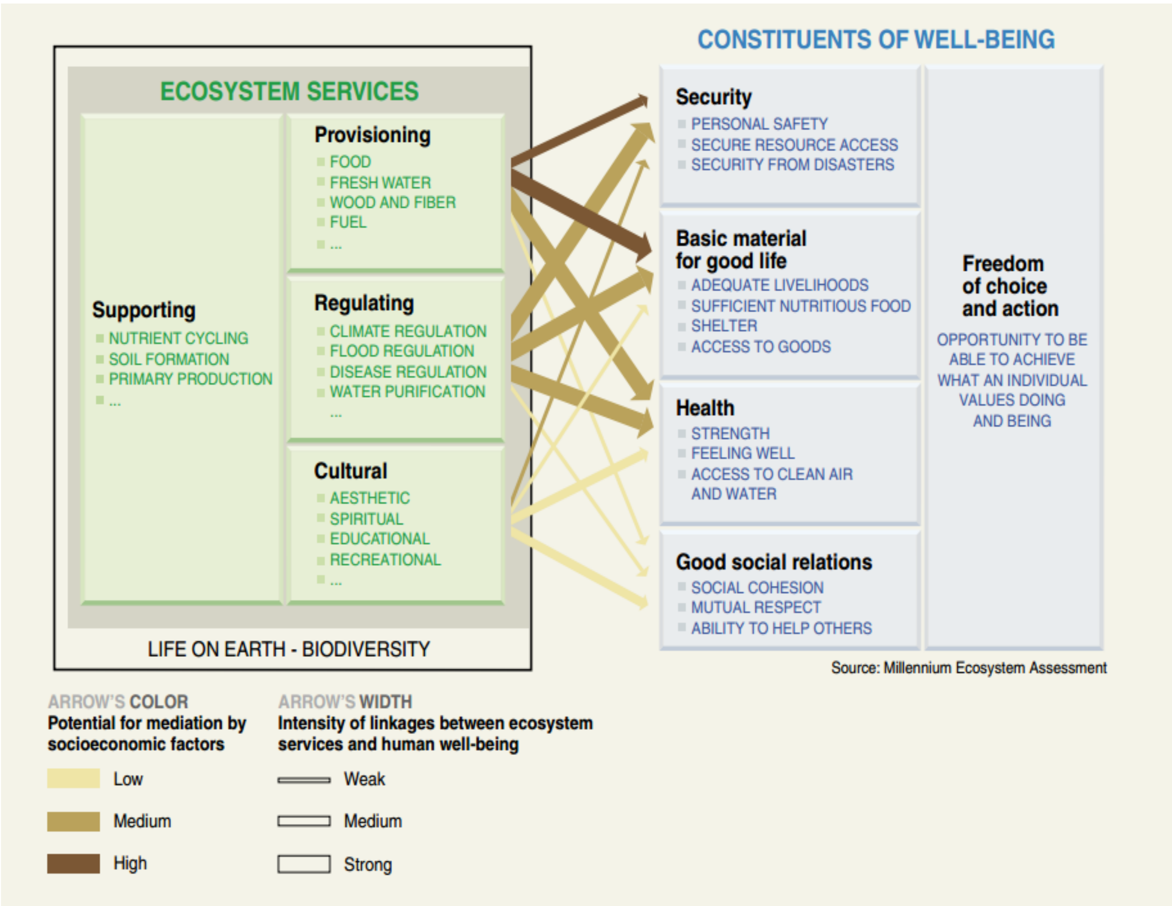

Figure 1. Ecosystem services diagram. Source: Millennium Ecosystem Assessment

The need to identify and quantify ecosystem goods and services is increasing since it is crucial for a sustainable management of environmental resources (Troy and Wilson, 2006). Moreover, decision making replies on a comprehensive understanding of the ecosystem functions and values (B Rashleigh et al., 2012). *Table 1* shows an overview of common ecosystem services in deltas which was created comparing several deltas: Nemunas River Delta (B Rashleigh et al., 2012) in Lithuania, Niger Delta in Nigeria (Adekola and Mitchell, 2011), Ganges Delta (Islam et al., 2015) part of India and

Bangladesh, and Danube Delta (Tucker, 2010) in Romania. Besides the Nemunas Delta, the remaining ones are part of the Delta Alliance network. The next table shows the main common ecosystem services that these delta provide.

Table 1. Common ecosystem services in Nemunas, Niger, Ganges and Danube Deltas *mentioned just in Niger Delta

Type of ES	Specific Ecosystem services
Provisioning	Food (agriculture)
	Fisheries
Regulating	Water quality and quantity
	Water regulation (flood regulation and other natural hazards
	Climate regulation through carbon sequestration
Cultural	Recreational and tourism
	Spiritual and inspirational
Supporting	Soil formation*
	Nutrient cycling*

The underlined services will be chosen as key indicators to assess the state of the delta to still provide them in the future. Therefore, the aim is to assess how healthy or resilient is a particular delta to still provide these specific ecosystem services.

2.2.2. "Resilience to what?"

Deltas are areas threatened by climate change impacts such as sea level rise and more extreme weather events and environmental changes such as population growth (Müller and Burkhard, 2012). and human development (Parry et al., 2007). Deltas are highly sensitive to sea level rise (Ericson et al., 2006) and changes in runoff (Parry et al., 2007) . IPCC projects that global sea level for RCP8.5 will rise 0.52 to 0.98 m by 2100 (Church et al., 2013). This projection may be even higher due to subsidence which will increase the potential for inundation (Parry et al., 2007). Furthermore, 40 deltas globally (including mega-deltas) are occupied by 300 million people with an average population density of 500 inhabitants/km^2. Urban sprawl is expected to increase in many of these deltas (Ericson et al., 2006). Additionally, human development increases vulnerability of deltas to the effects of climate change. Sediment loading rates and alteration of flow due to dams, navigation, flood control techniques are common human activities that are affecting the ability of a delta to cope with the impacts of climate change (Parry et al., 2007).

Socio-economic development, consumption and production and the corresponding changes are considered *drivers* which produce certain *pressures*. Climate change is an additional *pressure* to the human-environmental systems. These pressures change the *state* of the system which implies changes in the environmental, physical, biological and chemical conditions of the area. As a result of these changes, *impacts* on natural and human system emerge which refers to changes in the provision of goods and services and in the socio-economic system. Therefore, actions are taken by society and government to diminish the negative impacts of the human-environmental system. Those actions create a reaction within the system called *response*. Ecosystem services result from the linkage between ecosystems and biodiversity, and human system. The state of the ecosystems and biodiversity is described by the ecosystem properties (biophysical structures and processes as well as ecosystem functions) and they are considered the base for ecosystem services (Müller and Burkhard, 2012) (check *Figure 2* below). Therefore, e*cosystem services (ES) are the direct and indirect contributions of ecosystem to human well-being* (Kumar, 2010).

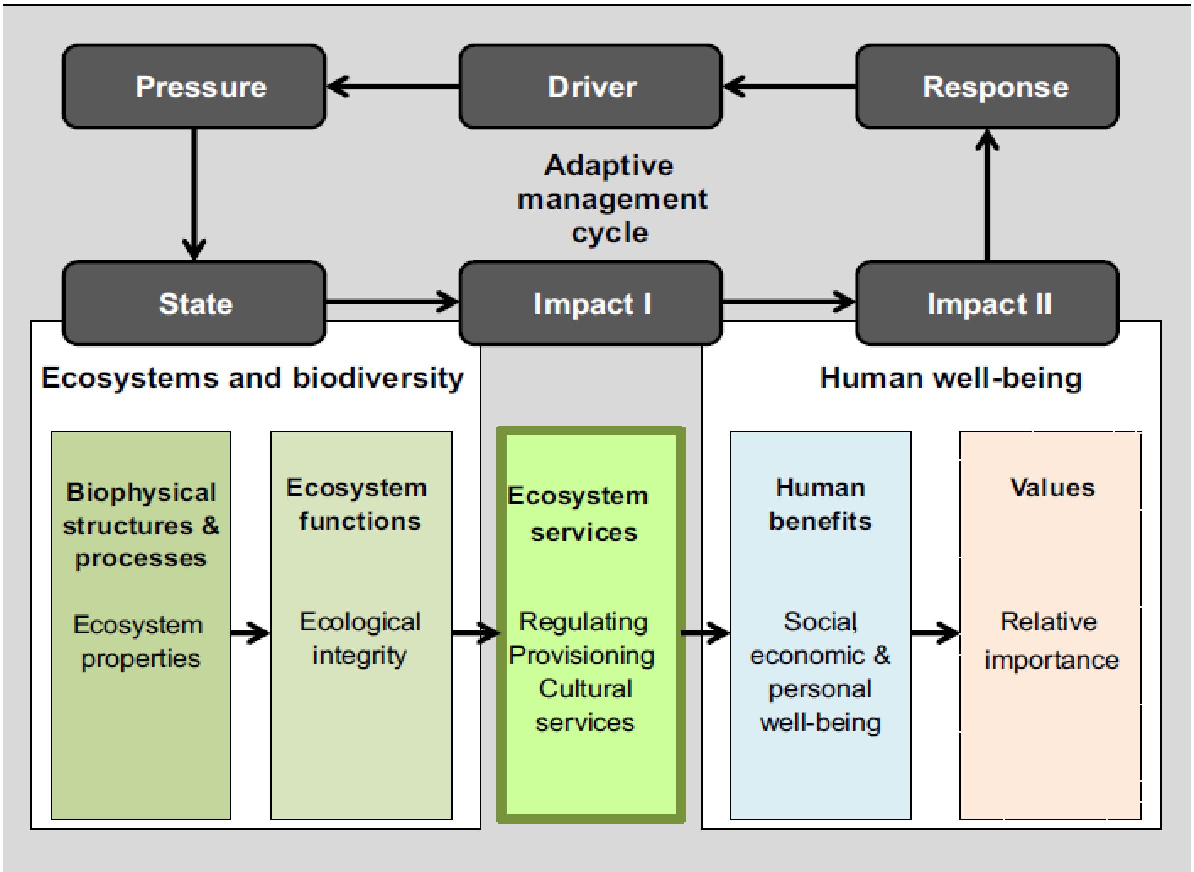

Figure 2. Ecosystem services as parts of the adaptive DPSIR management cycle for human (right side)-environmental (right side) systems (Müller and Burkhard, 2012).

The system goes out of the attraction domain when the mentioned drivers pass a certain threshold or tipping point. The system changes and it is not able to sustain itself remaining within the domain of attraction (see *Resilience definition* in the *Introduction*). As a consequence, the system would collapse if it reaches this point. This can be avoided by Adaptation Tipping Points (ATP): the magnitude of change due to perturbation under which current management strategies are no longer able to meet the objectives. Therefore, they are 'points of no return' which inform that alternative management strategies are needed (Kwadijk et al., 2010). Furthermore, the concepts of ecosystem goods and services are a concern for environmental scientists, managers and decision makers (Müller and Burkhard, 2012). They can influence the Drivers, Pressures, State, Impact and Response (DPSIR) framework through adaptive management strategies (check *Figure 2*). Adaptive management is used as a tool to identify uncertainties and establish methodologies to test them and learn about the system. It is a social and scientific process that includes past, present and future stakeholders. Its focus must be in developing new institutional strategies using scientific knowledge and theories to learn from them (RA, 2015).

2.3. The seven principals of socio-ecological resilience

These principles integrates properties of resilient socio-ecological systems and they can be used for measurements and assessment of resilience: 1) maintain diversity and redundancy; 2) manage connectivity; 3) manage slow variables and feedbacks; 4) foster an understanding of social-ecological systems as complex adaptive systems; 5) encourage learning and experimentation; 6) broaden participation; and 7) promote polycentric governance systems (Biggs et al., 2012). *Figure 3* illustrates that the seven principles for enhancing resilience can be divided in two classes: one focusses on resilience of a social-ecological system or its governance, and the second emphasizes the system structure or its dynamics.

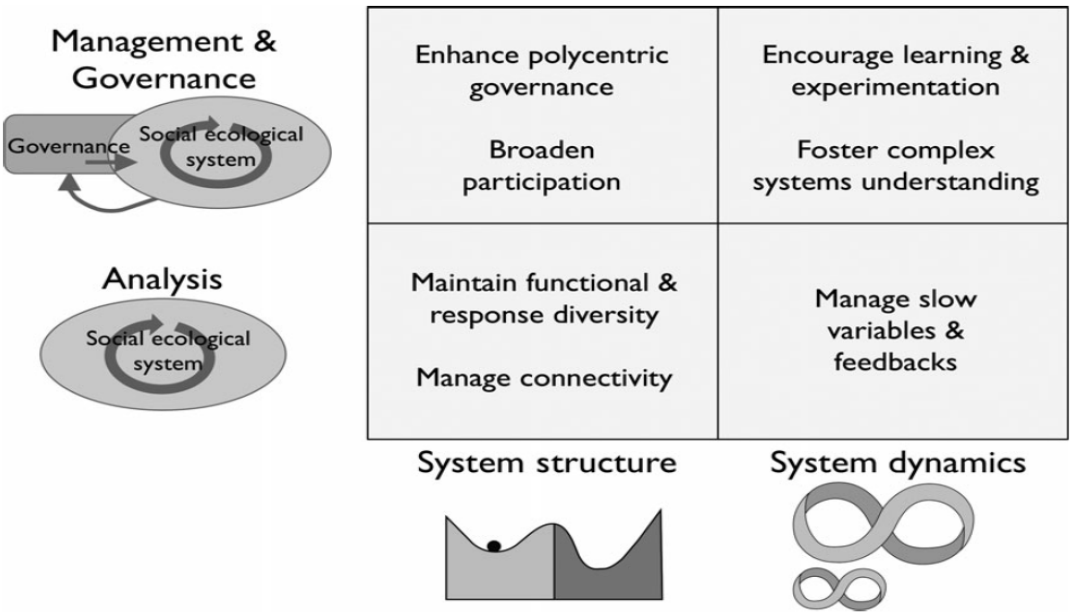

Figure 3. Division of the resilience strategies (Biggs et al., 2015)

They are complementary, so they can be combined or not. These principles of socio-ecological resilience were used to assess the resilience of ecosystem services (Biggs et al., 2015).

1. <u>Maintain diversity and redundancy</u>. Systems with many different components are more resilient than systems with few components. Redundancy relates to the fact that multiple components of the system can perform the same function. This characteristic of the system compensates the loss or failure of others components. The presence of diverse users and managers of the resources enhances the community ability to detect and understand the ecological changes and adapt to them. Particular attention should be given to important functions or services (key species or actors). Additionally, ecological diversity is essential for ecosystem services such as pollination, pest control, nutrient cycling and waste assimilation. For instance, in the coast of East Africa households have a diverse livelihood income: fisheries, tourism, agriculture or casual labour. If they will specialise in one activity their livelihood will be less resilient (Simonsen, 2014).

2. <u>Manage connectivity</u>. Connectivity in a social-ecological system refers to the interaction among resources, species or actors across patches, habitats or social domains. Connectivity can influence resilience by facilitating recovery or preventing a disturbance. Thus, connectivity maintains biodiversity. However, roads and dams construction induces fragmentation within the system reducing connectivity. This principle can also be applied in human social networks to share information and build trust. It can be applied by making connectivity maps. For example, the Yellowstone-to-Yukon project in North America is a conservation planning that reconnects large habitat patches recovering wildlife with ecological corridors.

3. <u>Manage slow variables and feedbacks</u>. In an ecological system, when the water quality decreases this is linked to slowly changing variables such as the phosphorus concentration which depends on

the fertilizer brought by runoff. In the social context, slow variables are legal systems, values and traditions. Nevertheless, if the system suffers too much disturbances passing the threshold, it can shifts to a different state or configuration. In Tanzania, for example, population growth and droughts are depleting crop production. People are getting poorer to buy fertilizers for the soil fertility, so they are trapped in a vicious cycle. However, rainwater harvesting and conservation tillage can help restore soil fertility and therefore increase crop production reducing poverty.

4. Foster complex adaptive system thinking. Within a socio-ecological system, many connections happen at the same time on different levels. Furthermore, complexity implies unpredictability and uncertainty. One example is the Kruger National Park in South Africa where the management moved from strategies to keep ecosystem conditions, such as elephant populations and fire frequencies. They use thresholds as warning signals when a component of the system (e.g. elephant numbers) is approaching a critical point. The aim is to reduce human intervention (investment) and increase the variety of ecosystems and habitat types.

5. Encourage learning. A socio-ecological system is always changing, therefore constant knowledge is needed to adapt and manage new changes. Learning is part of the decision making process. This can be done through participation, providing a suitable context for sharing knowledge and to put knowledge into practice. One example can be a wetland in Sweden (Kristiandstad Vattenrike) which was degraded in the 1970's. However, thanks to a collaborative process including local population and politicians, the perception of the wetland changed and now it has become a UNESCO Biosphere Reserve.

6. Broaden participation. Active participation of all stakeholders is crucial to build socio-ecological resilience. Participation facilitates the capacity of learning and building trust. For instance, public participation raises awareness about threats to Great Barrier Reef in Australia. As a result, public support to improve conservation plans increased as well.

7. Promote polycentric governance. This implies collaboration across institutions and scales to improve connectivity and learn from each other. In this way, governance structures can deal with changes because they are tackled by different experts. It builds trust and social capital, ant it develops strong leadership. Coordination among scales and governance units is needed. An example can be the 20 different groups and actors that have contributed to the decision-making processes about pressing environmental challenges in southern Arizona region.

2.4. How to measure resilience?

The variety of resilience definitions and their applications in specific contexts determine how it is assessed or measured (Carpenter et al., 2001). Resilience is a property of complex adaptive systems which is not easily measurable (Quinlan et al., 2015). For this research on how to monitor resilience of ecosystem services in deltas worldwide, we need a definition of resilience that can be measurable. An operational definition of resilience is: "a system that can tolerate disturbances (events and trends) through characteristics or measures that limit their impacts, by reducing or preventing the damage and disruption, and allow the system to respond, recover, and adapt quickly to such disturbances" (Wardekker et al., 2010). When the system reaches a certain threshold or tipping point, the system is not resilient anymore. In this situation, adaptation tipping points (ATP) are 'points of no return' which inform that alternative management strategies are needed (Kwadijk et al., 2010). If a system is not resilient, it does not have too much sense to monitor resilience. Thus, resilience would be an expired concept.

Ecological approach aims to measure resilience looking at slow variables when an ecosystem reaches certain thresholds or tipping points before shifting into other stability domain (Quinlan et al., 2015). This approach emphasizes the resistance-persistence of a system (Holling, 1996) against the amount of pressure a system can absorb and still remain within the domain of attraction (Carpenter et al., 2001). It is fundamental to understand the relationship between biodiversity, scale and resilience. This can be assessed by evaluating species distributions, spatial modelling tools among others (Angeler, 2016). Engineering approach suggests to use time of recovery concept in relation to ecosystem's properties as an indicator to measure resilience and monitor regime shifts through early warning indicators. These indicators are used to identify abrupt changes and long transitions of ecological systems (Angeler, 2016). Hence, the emphasis is on return time to recover, efficiency and equilibrium of the ecosystem (Pimm, 1984). The social approach focus on the adaptive and learning capacities of individuals or communities to cope with external stressors (Adger, 2000). Other approaches suggest to combine different resilience metrics such as wealth and health measurements. Furthermore, resilience can be measured over time having a baseline as a starting point. It acknowledges the changes in livelihood and environmental variables of the system dynamics (Quinlan et al., 2015). A major distinction between socio and ecological research tools to measure resilience is the application of quantitative tools for ecological resilience and qualitative tools for socio resilience (Angeler, 2016).

The resilience approach aims to improve the system's capacity to cope with disturbances and stressors. It is a flexible approach that translates the resilience concept into concrete options for local actors and it tackles many uncertainties of climate change adaptation (Wardekker et al., 2010). In order to assess resilience, we must know the system configuration and the disturbances that affect the system (Carpenter et al., 2001). In this research the concept of resilience is made operational through indicators.

2.5. Resilience and complementary concepts

- "Resilience" is often used with the "adaptive capacity" concept which has also multiple meanings. Adaptive capacity reflects the learning capacity of the system regarding its response to disturbances (Carpenter et al., 2001).
- Vulnerability is *the extent to which an individual, community, sub-group, structure, service or geographic area is likely to be damaged or disrupted by the impact of a particular disaster hazard* (Kotze and Holloway, 1996). Regarding wetlands (being a delta considered a wetland), we refer to biophysical and social vulnerability. Concerning biophysical vulnerability, a hazard relates to physical manifestations of climate change (such as droughts, floods, storms, heavy rainfall, changes in the mean values of climatic variables). Moreover, it depends on the hazard impact and the resulted damage. Furthermore, social vulnerability depends on poverty, inequality and marginalisation and it influences biophysical vulnerability (Brooks, 2003). Vulnerability is a dynamic property that changes according to the local conditions, such as the size of the system, the stability and diversity of the vegetation, as well as the adaptive capacity of local communities and institutions (Gitay et al., 2011). A fundamental distinction between vulnerability and resilience is that vulnerability refers to the capacity of a

system to preserve its structure while resilience refers to its capacity to recover from non-structural changes in dynamics (van der Leeuw, 2001).

Increasing resilience and the adaptive capacity of a population should be a priority. Tools are needed to assess the vulnerability and resilience of complex deltas as social-ecological systems in an easy way. This should be done for a local context with the participation of many stakeholders as possible (Kuenzer and Renaud, 2012). When resilience is enhanced, a system is more likely to tolerate disturbance events without collapsing. Furthermore, people have the capacity to anticipate future changes and influence resilience of social-ecological systems. By contrast, if resilience is reduced, vulnerability increases and its capacity to cope with disturbances or changes in the system will also be reduced. When there is a shift in the state of the system, taking back the system to its previous state can be complex, expensive, and sometimes impossible (Scheffer et al., 2001).

3. Data and methods

In this section, on the one hand, study area where the resilience indicators were assessed is described briefly. On the other hand the steps followed to build the resilience framework are explained.

3.1. Study area

Since the objective of this study is to develop a set of indicators that can be applied worldwide to monitor resilience of ecosystem services in deltas, these indicators must be assessed in different deltas part of the Delta Alliance network. However, due to a lack of time I was decided to do the fieldwork only in one delta and additional interviews via skype with stakeholders from other Delta Alliance wing. The fieldwork was done for a period of one month within the Delta of California located in San Francisco, United States. The data collected during the fieldwork will be compared with information gathered through questionnaires done via email in Taiwan.

3.1.1. Delta of California, San Francisco, U.S.

The Delta of California (*Figure 4*) is created where the Sacramento and San Joaquin rivers bring water from Sierra Nevada to a large valley floodplains of 3000km^2 before discharging its waters into the San Francisco Bay. In the old days the delta was a huge wetland formed out of low islands, channels, woody debris piles and marshes. It is the largest delta of the Pacific coast (Luoma et al., 2015).

Nowadays, the Delta is a complex network of dams, pumps, canals, drains and reservoirs managed by local, state and federal institutions to offer flood protection, water supply and environmental conservation. Moreover, approximately 570.000 people live in the urban areas at the edge of the Delta. They mostly use the delta for transportation, recreation and water consumption. Furthermore, the Delta is the heart of California's agriculture economy, it produces most of the fruits and nuts, and a high percentage of vegetables consumed in U.S. Additionally, it provides shelter to more than 750

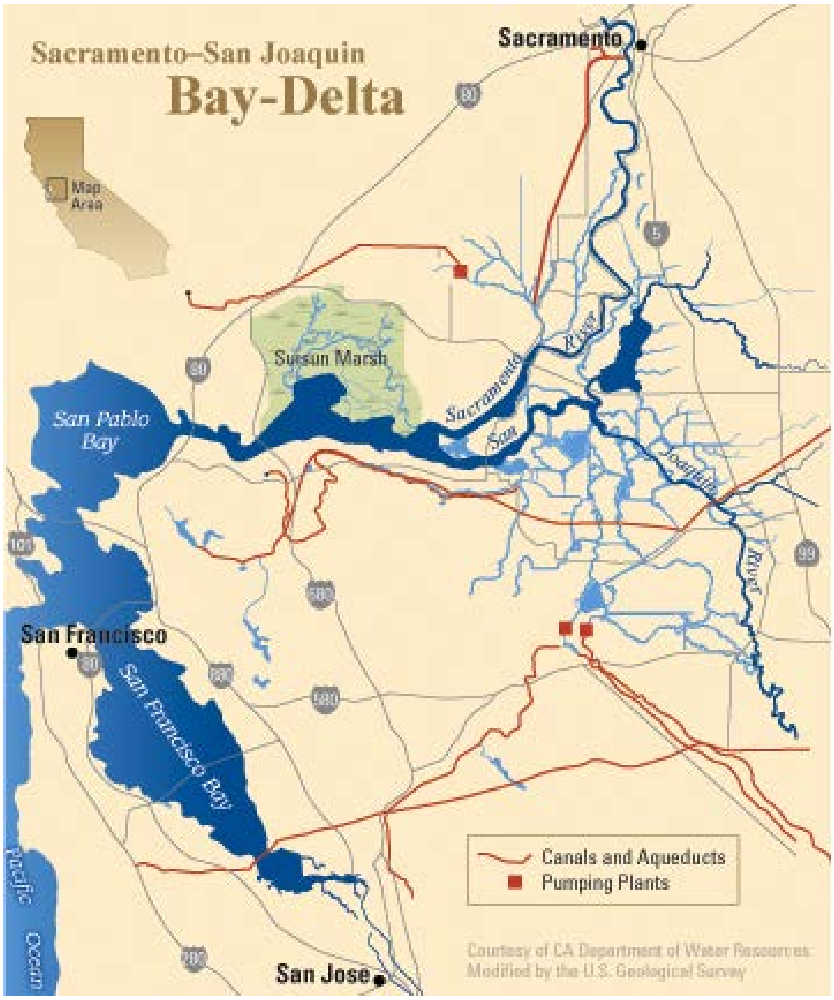

Figure 4. Sacramento and San Joaquin Delta in California, U.S. (*Google images*)

species of plants and animals (Luoma et al., 2015).

The main problems that the Delta is facing at the moment are: water supply, management infrastructure degradation, native ecosystems and species are declining, water quality is threaten and a complex delta management system (Luoma et al., 2015).

3.1.2. Taiwan Wing , Delta Alliance

Taiwan is an independent island since 1950 (*Figure 5*). The United States is the most important friend and protector of Taiwan (BBC, 2016). According to the Human Development Index of UN, Taiwan is a developed country ranked as the 21st among 188 countries in the world. This index measures life expectancy, education and income. Although, Taiwan is not consider as a member of United Nation, the Government collected the statistics to calculate its own index. The index score for 2014 was 0.88 which is close to 1, being 1 the best score within the ranking (Chang, 2014) .One of the main drivers of economic improvement in the past years is that Taiwan became top in computer technology production (BBC, 2016).

Taiwan has joined the Delta Alliance in 2014 and encompasses four deltas: Keelung (Delta City), Lenyeng, Choshuichi,and Kaoping (Delta City) (www.delta-alliance.org). The deltas are not going to be described individually because it is not the purpose of this study. It should be highlighted that the main challenges that those deltas are flood risk and climate change. Different institutions and stakeholders are working on local strategies to build social resilience and urban resilience (www.delta-alliance.org).

Figure 5. Taiwan situation

3.2. Methodological approach for resilience

The methodology of this research is based on a comprehensive literature review and data collection through interviews in the field. The methodology is presented in ten steps within a research framework diagram (*Figure 6*). The purpose of this research framework is to come up with a set of indicators to monitor resilience of ecosystem services in deltas. *Figure 6* below is a diagram that shows the steps required to develop a potential set of indicators and the link between the steps.

A theoretical background (*step 1*) is required to define concepts such as socio-ecological resilience, ecosystem services (ES) in deltas and resilience indicators. This literature review is a starting point to establish the objective of the indicators (*step 2*), to look for feasible indicators used globally in monitoring resilience according to their objective and to whom they will be addressed (*step 3*). Moreover, once objective is clear and type of indicators are selected, key questions are formulated for the key indicators (*step 4*). Next, the list of indicators is assessed (in the Delta of California, San Francisco, U.S.) through interviews to stakeholders with diverse backgrounds (*step 5*). Afterwards during the interviews period, the list of indicators is checked and improved (*step 6*). Then, the data collected is analysed (*step 7*), interpreted and discussed in a written report (*steps 8 and 9*) for Delta Alliance. Furthermore, the set of indicators should be tested and refined in different deltas in order to become a global set of indicators that can be applied worldwide (*steps 9 and 10*). However, it is not the objective of this internship research since 4 months is not enough time to assess the list of indicators in more than one delta. Thus, steps 1-8 are reported in blue because they are part of this research and steps 9 and 10 are red because they are out of the study scope.

The outcome of the research framework is a set of indicators to monitor resilience of ecosystem services in deltas (*step 9*). Nevertheless, this list should be assessed in other deltas with different social, economic and cultural context and different scale (*step 10*) to develop a robust and comprehensive set of indicators. When *steps 9* and *10* are accomplished, the process of defining indicators should pass through *steps 4* to *9* (*Figure 6*) again when they are assessed for a different delta. Overall, a global set of indicators to assess resilience of ecosystem services in deltas may help Delta Alliance for future decision making regarding delta management and sustainable development. Each Delta Wing part of Delta Alliance could use this set of indicator to monitor how resilient is the state of their deltas in terms of ecosystem services and take actions based on the monitoring outcomes.

Step 1: Theoretical background

A literature review was done to explore a theoretical background to build conceptual pillars as a basis for this framework. The theoretical framework of this research is created upon concepts such as: ecosystem services in deltas, socio-ecological resilience and its seven principles, and how to make the definition of resilience operational. These concepts were explained in the *Background* section. The challenge now is to combine and bring together different concepts and approaches to assess the resilience of ecosystem services creating an integrated framework.

The concept of resilience has changed a lot since it was firstly defined by Holling (1973). In order to assess the resilience of ecosystem services in deltas, the socio-ecological (SE) resilience is considered a wider definition for this study. Moreover, this definition was used to assess the resilience of ecosystem services by Biggs et al., (2012) who defined seven principles of enhancing SE resilience. On the one hand, the ecological resilience definition emphasizes the resistance-persistence of a system (Holling, 1996) against the amount of pressure a system can absorb and still remain within the domain of attraction (Carpenter et al., 2001). On the other hand, the socio-ecological definition of resilience introduces concepts like adaptability and transformability. Adaptability measures the system's capability and adjusts constantly its properties, functions and processes in order to anticipate and respond to natural and human pressures maintaining the system within a specific domain (Angeler, 2016). This term has been used in ecological and social sciences.

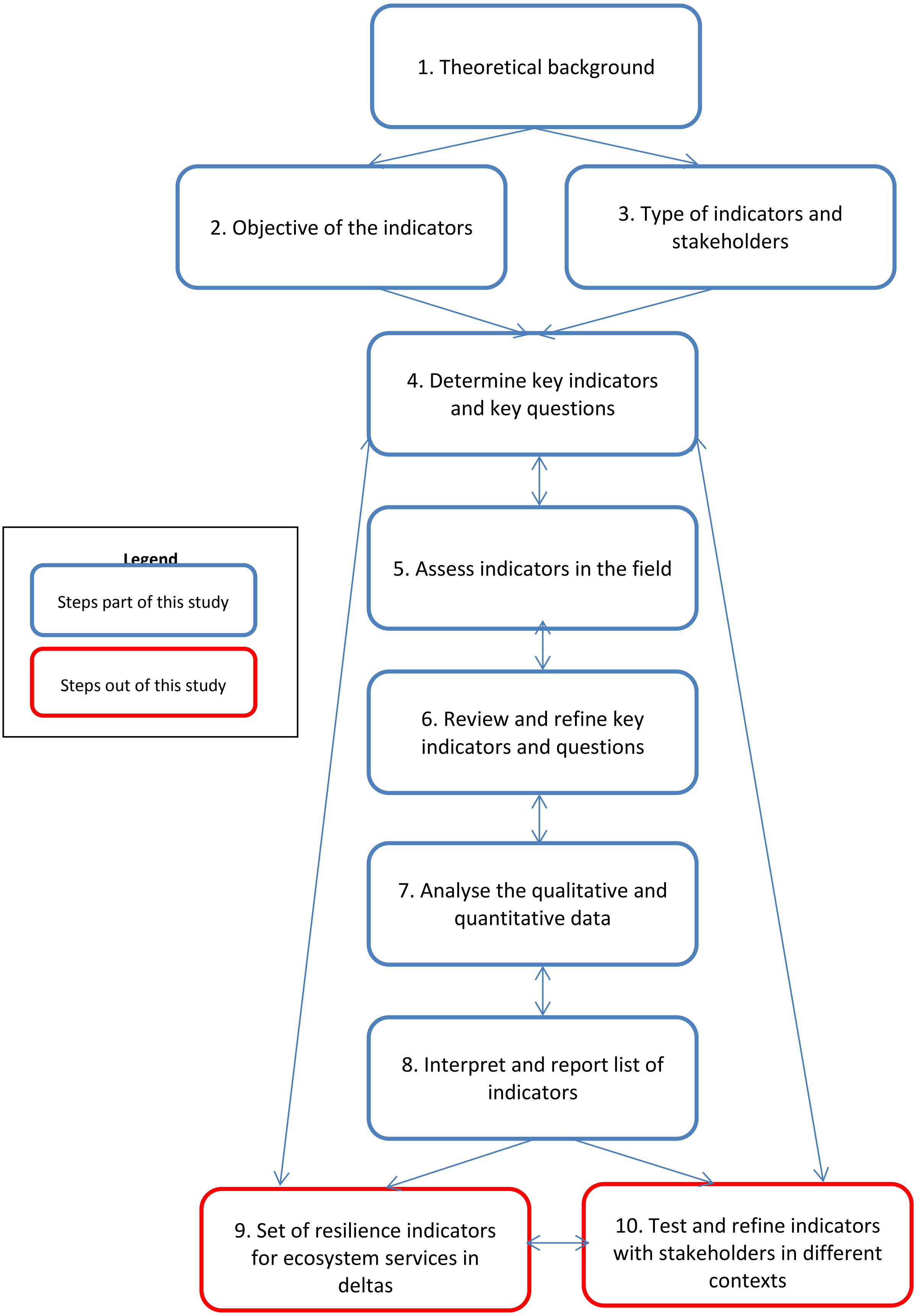

Figure 6. Methodological approach diagram

Taking into account the seven principles of socio-ecological resilience and the previous aspects of resilience five different domains are chosen to assess the resilience of ecosystem services in deltas: resistance or stability, adaptability, transformability, vulnerability and institutional capacity (see definitions in *Glossary, Appendix A*). Furthermore, few main ecosystem services of deltas are selected to include as indicators to assess how resilient is the state of the ecosystem regarding these particular ecosystem services: food (agriculture and fisheries), water quality and quantity, climate regulation and recreation. Research will be done to select several indicators within each resilience domain in order to embrace for aspects of the socio-ecological resilience within a delta ecosystem.

Step 2: Objective of the indicators

Indicators are designed and used to assess temporal patterns in the status and trends of ecosystems, habitats and species. They assess the pressures, threats, state and impacts of ecosystems and the responses to them (Ramsar, 2005). The set of socio-ecological resilience indicators is used to assess the health of the ecosystem (ecosystem diversity, species richness, water quality and quantity, etc) including the social dimension (Bergamini et al., 2013). Their role is to offer an overview of the resilience state of deltas to guide the decision-making regarding undesirable changes (Ramsar, 2005). They may help to identify the most urgent environmental problems to address through policy strategies (Russi D., 2013). Moreover, they can be used by scientists, conservation and development agencies to support the management and adaptation of the ecosystem in order to increase resilience in deltas (Bergamini et al., 2013).

Furthermore, the following principles should be taken into account to select the socio-ecological resilience indicators that can be applied at site scale (delta):

- They should be easy to understand and measure by local stakeholders.
- Expressed on a Likert (1-5) scale to provide a simple way of quantifying people's impressions and opinions.
- They should capture all the ecosystem services considered relevant in a deltas.
- They should encompass the 7 principles of the socio-ecological resilience.
- The indicators may assess state of the ecosystem in terms of Drivers, Pressures, State, Impact and Response (DPSIR) framework used to analyse environmental problems (OECD, 1993). In the indicators table it will be indicated what component of the DPSIR cycle is each indicator representing.

Step 3: Identify type of indicators and stakeholders

Existing monitoring systems were used to look for global indicators that can be applied worldwide in assessing the pressures, state, benefits and responses of ecosystem services in deltas. Few monitoring systems were found browsing in *Google Chrome* using key words such as: "assessing ecosystem services", "monitoring systems", "socio-ecological resilience indicators" or "ecosystem health". The monitoring systems used select suitable indicators based on the previous resilience domains are the following ones:

- ✓ The Environmental Performance Index (EPI) was created to provide a global view of environmental performance by country and to inform decision-making. The EPI is constructed through the aggregation of 20 indicators combined into nine categories: climate & energy, biodiversity & habitat, fisheries, forests, agriculture, water resources, water and sanitation, air quality and health impacts. For more information check the link (http://epi.yale.edu/chapter/methods).

- ✓ The Biodiversity Indicators Partnership (BIP) is a global initiative which developed global indicators for monitoring and assessing biodiversity. Biodiversity is a pillar of the services that ecosystems can provide. The Partnership brings together international organisations working to extend this set of indicators to fulfil the goals of the Aichi Biodiversity Targets (http://www.bipindicators.net/globalindicators) (UNEP-WCMC, 2012).
- ✓ The World Water Assessment Programme (WWAP) of UNESCO developed indicators for water resources, its uses and management (http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/temp/wwap_pdf/WWDR4_Indicators_Table_6-1.pdf). Many of these indicators can be used to assess the pressures, state, benefits and responses of an ecosystem. However, instead using them to assess the water quality of the system, these indicators can be adapted to assess the pressures, state, benefits and responses that affect the health of a delta. If a delta is in good health that implies it is able to still provide ecosystem services.

The selected indicators are assessed using semi-structured interviews. The structure of the questionnaire consists of open-end questions. For each indicator or sub-indicator one key question is formulated. The aim of the interview is to assess the relevance of the indicators in terms of monitoring resilience of ecosystem services in deltas. The interviewee will answer the questions according to their personal knowledge and experience. Therefore, answers can be subjective depending on the stakeholders perspective regarding resilience. However, the selected stakeholders should have background and experience in nature conservancy, ecosystem services, restoration and experts in resilience. The approached stakeholders are working in research institutes, nationals and internationals NGOs, researchers and teachers at the university, Delta State Agencies and Consultancies in environmental issues. *Figure 7* shows the contacted stakeholders in percentage and the manner that they replied.

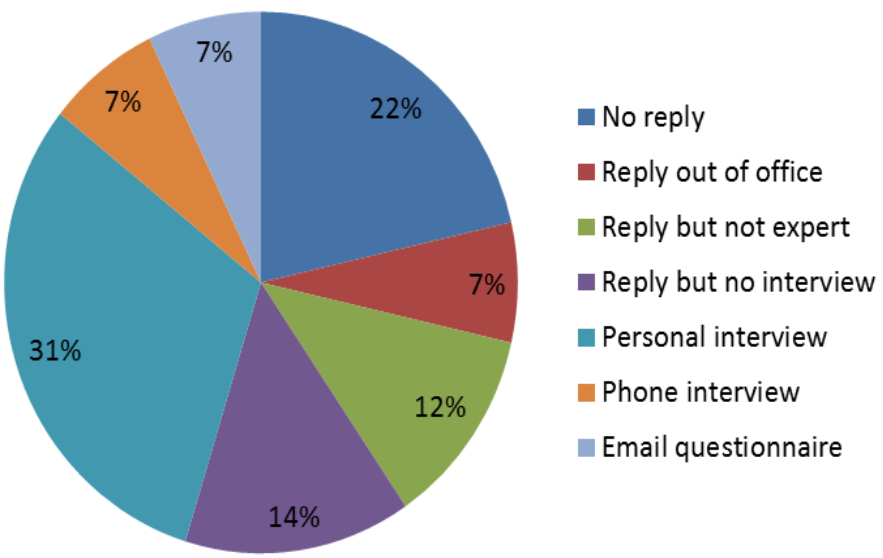

Figure 7 Total n° of stakeholders

The total number of stakeholders approached is 42 from which 22% (9 individuals) did not reply, 7% (3 individuals) had set the automatic reply "out of office", 12% (5 individuals) replied that they are not experts in the topic, 14% (6 individuals) showed interest for the interview but the interview did not take place at the end, 31% (13 individuals) were interviewed personally, 7% (3 individuals) were interviewed on the phone and 7% (3 individuals) preferred to fill the questionnaire via email because of distance and time difference issues.

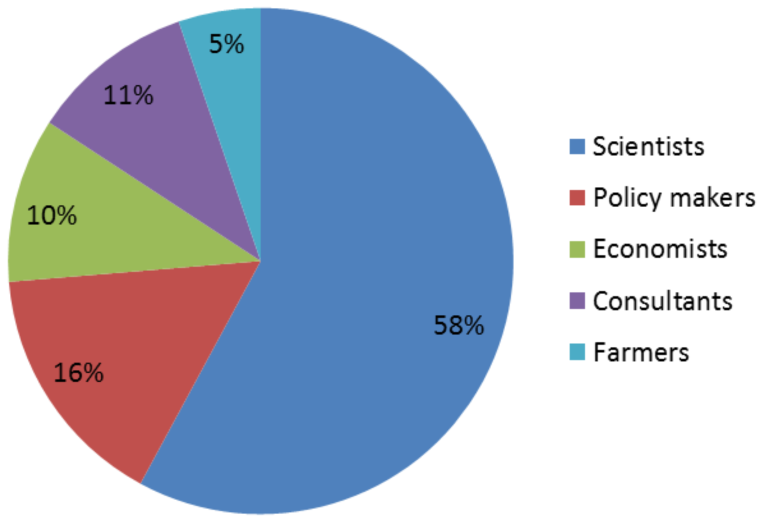

Figure 8. Groups of stakeholders

Nevertheless, the interviews were conducted to 19 people from different professional groups (*Table 2*). Therefore their perceptions and answers are expected to be diverse based on their personal experience and knowledge about resilience, ecosystem services and deltas. Sixteen people were interviewed within the Delta or California, in San Francisco. The remaining 3 people are part of the Taiwan Delta Wing who answered the questionnaire via email. The interviewed stakeholders represent the following groups: 58% scientists (11 individuals), 16% policy makers (3 individuals), 10% economists (2 individuals), 11% consultants (2 individuals) and 5% farmers (1 individual) (*Figure 8*). *Table 2* shows the total number of interviewees, the groups that they are part of, the organization where they work, the main responsibilities they have within the organization, the date that the interview took place and what type of interview was.

Table 2. Background and main responsibilities of the interviewees, date and type of interview

Interviewees	Stakeholders' group	Organization	Background and responsibilities	Date	Type of interview
Interviewee 1	Economist	University of California, Berkeley. Independent Science Board of CALFED	Professor Emeritus of Ecological Economics and Energy and Resources Founding member and former president of the International Society for Ecological Economics.	29-6-2016	personal
Interviewee 2	Scientist	San Francisco Estuary Institute (SFEI)	PhD in Conservation Biology from Berkeley University. Co-director of SFEI's Resilient Landscapes Program from 2015	5-7-2016	personal
Interviewee 3	Scientist	University of California, Berkeley Environmental Science, Policy, and Management. Delta Independent Science Board	Teacher at University of California, Berkeley. Specialist on adaptive monitoring restoration within the Board	5-7-2016	personal
Interviewee 4	Policy maker	Bay Conservation & Development Commission	Specialized in policy and management of technical planning issues: climate change, water quality and sediment management. Legislative coordinator. Conservation and development.	6-7-2016	personal
Interviewee 5	Scientist	San Francisco Estuary Institute	Experience in estuary ecology, entomology, ecosystem management and ecosystem design. Founder of SFEI 15 years ago.	7-7-2016	phone
Interviewee 6	Scientist	Delta Conservancy/ State Agency	Executive director. Responsibilities: restoration projects, get funding, engage with local communities and economic development	12-7-2016	personal
Interviewee 7	Scientist	Center for Watershed Sciences, UC Davis	Professor of fish biology at US Davis	12-7-2016	phone
Interviewee 8	Farmer	Director of farmers association of 1 mill acres.	Intermediator between water regulators and farmers	12-7-2016	personal

Interviewee 9	Scientist	Delta Stewardship Council Agency	Deputy executive officer of Delta Science Program director	13-7-2016	personal
Interviewee 10	Scientist	Delta Stewardship Council Agency	Adaptive management science advisor. Ecosystem restoration adaptive management	13-7-2-16	personal
Interviewee 11	Policy maker	Delta Commission	Social background, land use policy, agricultural land use policy	13-7-2016	personal
Interviewee 12	Consultant	Founder of Live Edge Adaptation Project (LEAP)	Landscape Architecture, educator, consultant, designer, planner	15-7-2016	personal
Interviewee 13	Consultant	Arcadis, San Francisco	Vice President for the San Francisco Bay area operations, activities over water, environment; buildings and transportation.	19-7-2016	personal
Interviewee 14	Policy maker	The Nature Conservancy	Director of the Climate Change Program: nature-based solutions to climate change and adaptation to its impacts	20-7-2016	personal
Interviewee 15	Scientist	California Institute for water resources	Researcher and policy, environmental policy and economics. Within the Institute he is the coordinator of water issues between universities, government, non-profit organizations and civic society.	20-7-2016	personal
Interviewee 16	Economist	San Francisco Estuary Institute	Geomorphologist, climate change adaptation within Resilient Landscapes Program	21-7-2016	phone
Interviewee 17 to 19	Scientists	Center for Sustainability Science, Academia Sinica	Integrated Research on Disaster Risk International Centre of Excellence (IRDR ICoE) – Taipei Delta Alliance - Taiwan Wing. Future Earth - Taiwan	28-7-2016	Email

Step 4: Determine key indicators and key questions (*Table 8, Appendix B*)

The following indicators are selected and classified according to the five domains of socio-ecological resilience (check *Glossary, Appendix A*). A total of 21 indicators (including sub-indicators) were selected. However, similar indicators were grouped resulting in 14 main indicators. Each indicator or sub-indicator related to one key question. Four indicators (or 9 sub-indicators) are assigned to resistance or stability domain of the ecosystem. The adaptability domain has 2 indicators while the transformability domain just one indicator. Within the vulnerability domain 2 indicators are assigned and within the institutional capacity domain has 2 indicators (or 5 sub-indicators). *Table 8, Appendix B* shows the main indicators with their corresponding sub-indicators, a definitions of each indicator or sub-indicator, the questions related to them and the way questions should be answered. Additionally, an example of the questionnaire is included in the *Appendix C.*

Step 5: Assess indicators in the field

The purpose of the field interviews was to assess the effectiveness of the indicators among different groups of stakeholders. The indicators with their corresponding questions were tested among 16 stakeholders with experience and knowledge on the California Delta. The delta is called Sacramento-San Joaquin and it is located between Sacramento and San Francisco Bay in California. The interviews were conducted within a period of one month (from 27th of June until 22nd of July 2016). Additionally, 3 scientists from Taiwan Delta Wing showed interest to fill the questionnaire by email. Therefore, in this way the list of indicators were assessed in two deltas with different cultural and social contexts although the number of interviewees is higher for the California case study than the Taiwan case study (check *Table 2* and *Figure 8*).

All the interview questions have the same structure which is the following (check *Questionnaire example* in *Appendix C*): the interviewee should say if the indicator is relevant or not (*Yes/No* answer), *why* they think so, *how can it be measured*, and give a score of relevance from 1 to 5 according to the Likert scale (being 1 very low, 2 low, 3 medium, 4 high and 5 very high relevant). The duration of the interview was estimated to be between 40 and 45 minutes. All the interviewed were recorded with the permission of the interviewees. Afterwards, the recordings were transcribed to a *Word* document.

Step 6: Review and refine key indicators and questions (*Appendix C*)

The interviews and dialogue with experts, who can be potential users of the indicators, provided data that can be interpreted and analyzed afterwards. This process of data collection is essential in order to review and refine the list of indicators and related questions making them more robust and more useful.

After the first interview some adjustments were made adding few more indicators and questions (check *Questionnaire example, Appendix C*). Some indicators were suggested by interviewee 1 and the remaining were based on personal perception regarding what important indicators were missing. Therefore, literature research was done during the first week of the fieldwork to improve the content of the questionnaires while waiting for replies from the contacted stakeholders. Additional indicators were chosen from the same source of information described in *step 3*. The added indicators are listed above in *Italic* fond to differentiate them from the indicators used only for the first interview (*step 4*) (*Table 7*, *Appendix B*) or they it is specified in the *Questionnaire* *example* that they are added later with red colour. Then, the adjusted list of indicators during the first week was used for the rest of interviews.

Step 7: Analyse the qualitative and quantitative data

On the one hand, the *why* and *how to measure* questions provide qualitative data. All answers are summarized within a number of categories using specific words given by the stakeholders. This summary is included in the *Table 8, Appendix D*. The qualitative data is analyzed looking for similarities and discrepancies among the answers given for *why* and *how to measure* per indicator. Similar answers are grouped within categories to convert this information into a narrative.

Table 3. Score for the relevance of the indicators

Score	Description
1	Very low
2	Low
3	Medium
4	High
5	Very high

On the other hand, scoring the relevance of the indicators from 1 to 5 is the quantitative data. *Table 3* shows the corresponding relevance of the indicators according to the Likert scale. The scores given by interviewees are averaged per indicator or question taking into account the number of people who answered that specific question. The relevance of the indicators will be shown using yellow stars The number of stars ☆ will be equal to the value of the scores mean per indicator.

The indicators that will be on average <u>equal or higher than 3</u> will be considered as <u>relevant indicator</u> to monitor socio-ecological resilience in deltas.

Step 8: Interpret and report list of indicators

The interpretation and description of the list of indicators will be developed in the *Results* section. The agreement and disagreement among stakeholders are classified within categories to simplify the analysis of the interviews (*Table 8, Appendix D*). The data collected through interviews will be presented and discussed per indicator or sub-indicator. On the one side, the outcome of the interviews realized upon the Delta of California in San Francisco will be explained first. On the other side, the data extracted from the questionnaires filled by three scientists of the Taiwan Wing will be described. And finally, a comparison between both case studies will be done.

After the qualitative and quantitative data analysis, the resulted list of indicators will be presented in a summary table in the (*Table 9, Appendix E)*. The table will include information about the quantitative relevance of the indicator, *why* the indicator is relevant or not and *how* can it be measured.

Step 9: Set of resilience indicators for ecosystem services in deltas

A set of indicators that can be applied in monitoring the resilience of ecosystem services in deltas is the core objective of this study. The list of indicators assessed among the stakeholders in the Delta of California is compared with data obtained from Taiwan. For the final list of indicators will be selected the indicators that have a score ≥3, and that can be measurable. Therefore, the resulted list of indicators depends on the scale and the context of the delta where they are applied. This set of indicators are suggested to Delta Alliance to monitor resilience of ecosystem services as part of the recent Monitor Program in deltas. Further, they can share this set of indicators with other Delta Wings part of the Delta Alliance network to assess resilience of ES in their delta, report the state of the ecosystem and keep track of it over time.

Step 10: Test and refine indicators with stakeholders in different contexts

Afterwards, the set of indicators should be shared widely with other stakeholders from different countries to scale down the indicators to their specific needs and problems within the delta related to ecosystem services. The indicators should be tested and reviewed in different contexts in order to come up with a global set of indicators to monitor resilience of ecosystem services in deltas worldwide. However, *steps 9* and *10* are in red color because they are out of the scope of this research. Therefore, further research is needed to be done in others deltas. Every time this list of indicators is tested and refined should follow the *steps* from *4* to *10* of the framework (*Figure 6*).

4. Results

The outcome of the interviews will be presented through 2 case studies. The first one is based on personal and phone interviews conducted during a fieldwork of one month to the delta of California, in San Francisco. This is the core mean of data collection for the current research. The second source of information was provided by three scientists who are part of the Delta Alliance Wing in Taiwan. They filled via email the same questionnaire that was used for the interviews conducted in California.

4.1. Case study 1: Delta of California, San Francisco, U.S.

The data collected through interviews will be presented looking at similarities and differences in the answers given by the interviewees which will be exposed individually for each indicator. The analogous answers for an indicator or question are grouped within a specific category (*Table 8, Appendix D*).

Next figures show in a visual way the relevance of the indicators and how many interviewees proposed how to measure them. *Table 4* includes the indicators' name and their numbers correspond to the same numeration used within *Figure 9* and *10.*

Table 4. Name of the indicators numbered in Figure 9 and 10

1.1. Protection status of the ecosystem 1.2. Trends in coverage of protected areas 2.1. Red List Index 2.2. Trends in invasive species 3.1. Agricultural GDP 3.2.Fish overexploitation 3.3. Biodiversity used for food and medicine 4.1. Freshwater quality 4.2. Dam's density 4.3. Water footprint 5. Self-recovery 6. Sustainable practices 7. Restoration practices	8.1. Carbon footprint 8.2. Ecological footprint 8.3. Nitrogen deposition 9.1. Human health 9.2. Well-being of communities 10. Tourism and recreation 11. Access to improved sanitation and drinking water 12.1. Access to information, participation and justice 12.2. Gender equity 12.3. Multi-stakeholders platform 13.1. Management effectiveness of protected areas 13.2. Progress of IWRM and ICZM

Figure 9 shows the interviewees answers regarding the relevance and effectiveness of the indicators in monitoring resilience in deltas. *Figure 10* reveals that more or less half of the interviewees suggested a way to measure almost all the indicators. Blue colour shows how many interviewees considered the indicators relevant, red colours shows who did not have knowledge (NK) about the indicators or they did not find it relevant (NR) and green colour who preferred not to answer (NA) or skip the question.

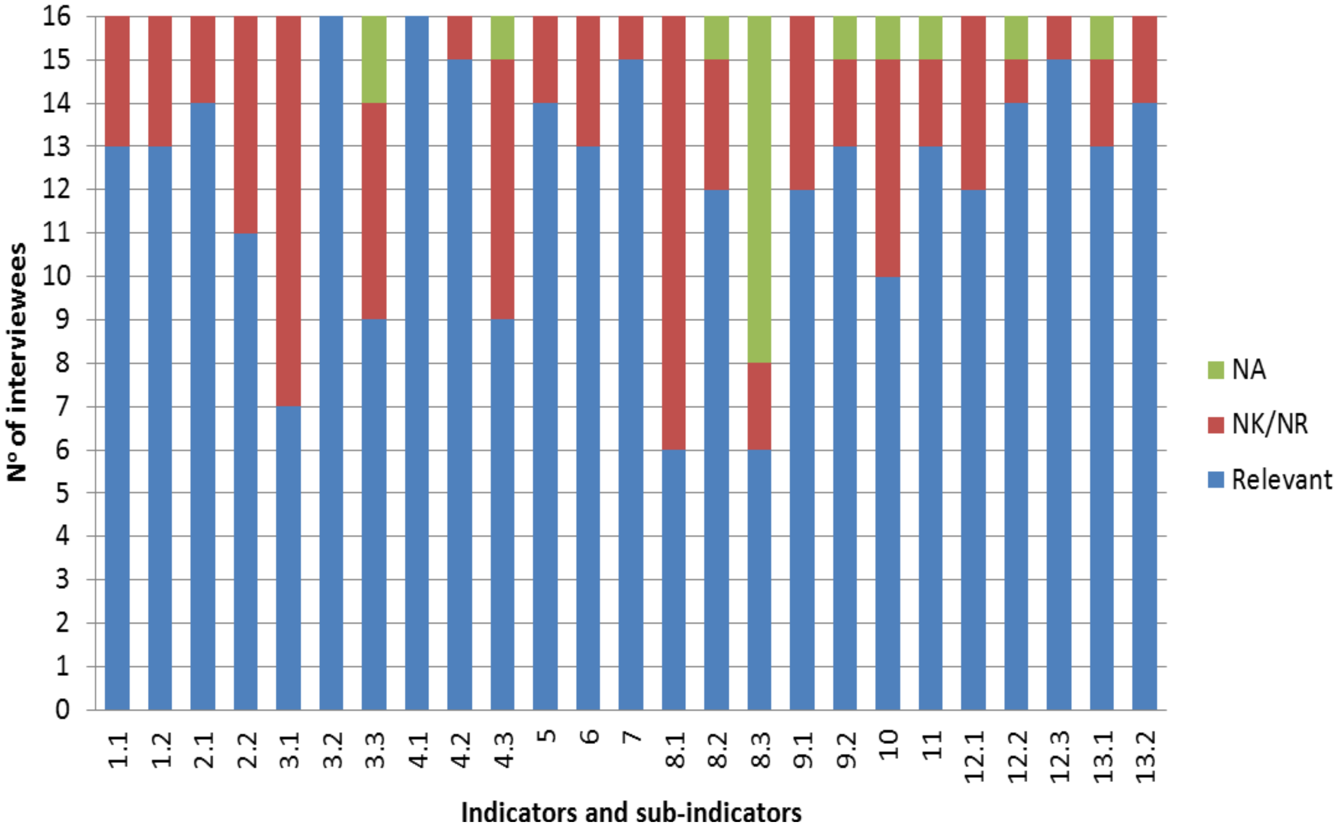

Figure 10. The relevance of the indicators. NA=No answer. NK/NR=No knowledge/No relevant

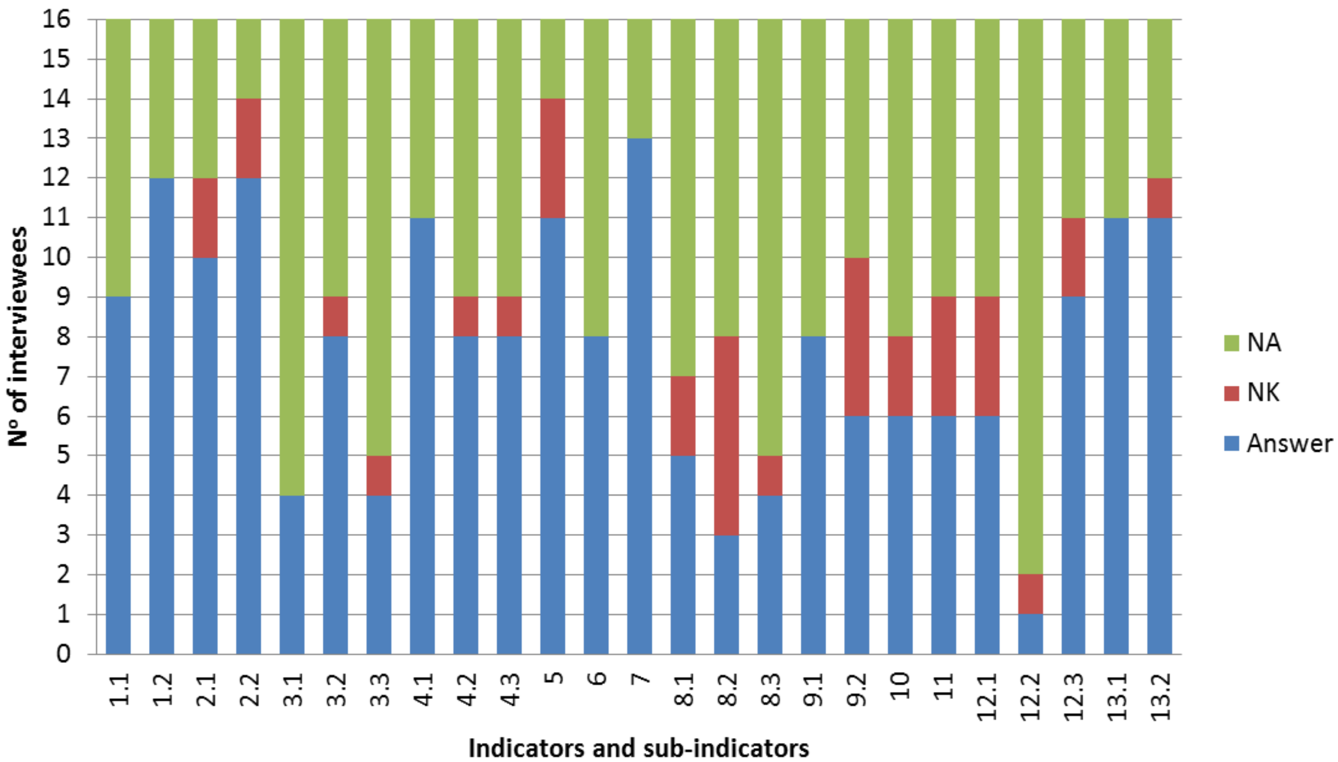

Figure 9. Answer on how to measure the indicators. NA=No answer. NK/NR=No knowledge/No relevant

The qualitative data is given as a logical narrative taking into account all answers classified in categories. Furthermore, the quantitative data shows the relevance of the indicators as an average of the scores given by the interviewees. The value of the averaged scores from 1 to 5 is shown filling stars with yellow colour and it is place on the right side of each indicator. An indicator will be considered relevant if it was given on average a score ≥3. The number used between brackets indicates the interviewees that states the cited information. The numeration of indicators coincides with the numeration used for the graphs of *Figure 9* and *Figure 10*. Indicators are listed within the resilience domains explained in the previous section and the blue test boxes summaries the main funding for each indicator. At the end of each indicator a text box summarizes the main findings.

4.1.1. Resistance or stability

The indicators and sub-indicators of this domain are:

1. Status and trends of the ecosystem

1.1. Protection status of the ecosystem

Most of interviewees agreed protection status is a relevant indicator for resilience (*Figure 9*). If a delta or part of a delta is under a protection status the resilience of the ecosystem will be enhanced (6). It is important to keep the balance between human communities living in the protected areas and the ecosystem (8). If protected areas are well managed the system will be in better health (7). However, the level of authority that protection agencies have will determine how effective could be the protection status over certain areas (12&16). Therefore, State and Federal protection laws (equivalent to national protection in Europe) are more effective in protecting delta than local or international protection convention (2,4&11). However, some interviewees disagreed that protection of certain areas will increase the ecosystem's resilience because it cannot mitigate the impacts of climate change (1&9). Half of the stakeholders suggested how this indicator can be measured (*Figure 10*). A majority of interviewees proposed to map the size of protected areas and compared it with the size of unprotected areas (8,14-16). Others suggested monitoring of species, populations, habitat and food resources of a specific protected area over time (5,12&13). Some proposed to evaluate public policies (1&5) and to what extend countries that share a delta have reached consensus over protection regulations (3).

Protection status is considered a relevant indicator for resilience when it implies State or Federal (National in Europe) protection rather than international. It can be measured by GIS mapping or monitoring species, populations, habitat and good resources over time.

1.2. Trends in coverage of land uses

Almost all Interviewees agreed that changes in the coverage of land uses is a relevant indicator to improve the health of the ecosystem (*Figure 9*) but it depends what kind of land use changes take place. When industrial, urban and agriculture are transformed into wetlands or natural habitat will make the system more resilient (2,3,6-8&11-16). Likewise, the proportion, connectivity and distribution of the land cover as well as the size of past land covers are significant (5). Nevertheless, if changes in land involves displacement of people somewhere else does not help resilience. By contrast, this indicator is not relevant because in 50 years resilience will be an expired concept (9) because of climate change impacts (1). Many interviewees suggested that this indicator can be measured in terms of resilience by monitoring programs to figure out differences in wildlife before and after changes in land cover (2,5,8,12&14-16) (check *Figure 10*). Important to look at redundancy, diversity and abundance of habitat to measure resiliency (16). Other proposed to measure the area of protected zones in ha (1,7&16) or to map the protected areas (2,3&13). When monitoring systems do not provide sufficient data some scientific research is needed (2). However, one interviewee said that available accommodation space is needed in order to make any changes in land covers (9).

Changing land use cover is a relevant indicator if industrial, urban or agriculture areas are transformed into wetlands or natural habitat. Additionally, proportion, connectivity and distribution of this areas are significant for resilience. It can be measured in term of resiliency through monitoring wildlife before and after the changes. Beside that measuring the size of protected areas in ha, map them and knowing what is the accommodation space are also useful

2. Status and trends of fauna and flora species

2.1. Red List Index

Many of the interviewees were not familiar with the Red List Index (Hurlimann) (2,3,9&16) because there are State and Federal laws which protect local species (2) while RLI is an international list of species categories created by IUCN. Therefore, it depends on who develops the list of species and the authority of that entity (10). Nevertheless, they agree that the Red List or other similar list is a <u>relevant</u> indicator (*Figure 9*) because it provides information about important species present in the delta (1,5,6&10). Additionally, it indicates about the health of the ecosystem (7,11&13). On the other hand, some interviewees did not find it an useful indicator because looking at individual species you lose the interaction and synergies between species of the system (8&15). A majority of the interviewees proposed to measure this indicator by monitoring individual key species (3,6,7,9&13-16) as well as distribution, abundance and valid rates of species (9) (check *Figure 10*). Monitoring can be combined with observations (5), population surveys over time (6&9) and remote sensing for suitable habitat (9).

The Red List Index or another similar list can be a relevant indicator because it is a source of information about key species present in the delta. However, some say that focusing on individual species we lose the interaction and synergies between the system's species. It can be measured mainly by monitoring key species combined with observations, population surveys and remote sensing.

2.2. Trends in invasive species

Invasive species is considered a <u>relevant</u> indicator since their presence has a negative impact on the system (2-4,6,11-13&15) (check *Figure 9*). They threaten local species (2,4,6&11), change food web dynamics (2,6&11), affect humans (11) and could even collapse the whole system (2). Few stakeholders thought that it is less relevant because the conditions of the system where invasive species live are going to shift to another state as a result of climate change. Therefore, if invasive species adapt to the new conditions they are not invasive anymore (3,10,11&16). This indicator can be measured by monitoring the diversity, trends and effects of invasive species (2,4,6,12,15&16) (check *Figure 10*). Moreover, it can be useful to calculate the ratio between invasive and not invasive (7), map the presence and distribution of invasive species (9) and do individual species surveys (5).

Invasive species are important because they threaten local species, change food web dynamics and affect humans as well. However, others argue that it is less relevant if climate change impacts are taken into account. Monitoring diversity, trends and effects of invasive species is the way to measure it.

3. Provisioning services: Food

3.1. Agricultural GDP

More than half of the interviewees answered that agricultural GDP is not a relevant indicator for resilience (*Figure 9*). It is a complicated indicator, it depends how important is agriculture within the nation (1-3,5,6,14&16). It is used as a market indicator and not a measure of human well-being or happiness (1). Not may stakeholders found this indicator measurable (*Figure 10*). If agriculture production is large in the delta area it would be useful to measure the ratio between delta's AGDP and others deltas' AGDP (10), compare AGDP with the state GDP (10,11&13) or compare costs of agriculture with costs of other sectors present in the delta (3,9&16).

Agriculture GDP is not a relevant indicator because it is used more as a market measure than human well-being. It can be useful to compare it with state GDP or the costs of other sectors only if agriculture production is large in the delta area.

3.2. Fish overexploitation

Fish overexploitation within the delta is considered a relevant indicator by all stakeholders (*Figure 9*). Many agreed that it is a direct measure of the ecosystem's health (8,9&16) and thus of resilience (3,4&14-16). Deltas offer nursery for fish (12) being a very important indicator for resident fish rather than migratory species (2&10). Half of the interviewees agree that this indicator is measurable (*Figure 10*). It can be operationalized by calculating the percentage of fish taken out within the biological limits (4,14&15) and monitoring individual species (6&13). Also as the ratio between the fish population of marine reserves and fish population outside marine reserves (3).

Fish overexploitation is a relevant indicator. It is a direct measure of ecosystem health and therefore resilience. It can be quantified by calculating the percentage of fish taken out within the biological limits or monitoring individual fish species.

3.3. Biodiversity used for food and medicine

Half of the interviewed people claim that biodiversity used for food and medicine is a relevant indicator (*Figure 10*). It is an indicator of environmental degradation (6,7,11,12&15), so when biodiversity is lost, ecosystem services decrease (4). The relevance of this indicator depends on the application context (2,13&14), for instance it is not helpful for the Delta of California (2&13). Only few people were optimistic on how to measure it (*Figure 10).* They proposed monitoring biodiversity used for food as a result of a particular activity (6&7). Looking at food services and medicine that come out of a particular region (3).

Biodiversity is always a good indicator but it depends on the context where it is used as food or medicine. Monitor specific food services or medicine that come out of a particular region is a way to measure this indicator.

4. Provisioning services: Water quality and water quantity

4.1. Freshwater quality

Freshwater quality is one of the most relevant indicator for ecosystem's health and all liveable organisms (3-5,7,9,10&14-16) (check *Figure 9*). Water quality is also essential for supplying water to people, agriculture and fish (6,7,11,13&15). However, even if the water has a good quality some measured parameters could still be a problem for certain species, such as temperature or sediments loading (1&2). Likewise, this indicator is relevant for decision making (8). Many interviewees agreed that this indicator is measurable (*Figure 10)* through monitoring systems in place which estimate the amount of pollutants, salinity (1,7,12,14&15), toxic forms of algae blooms (9) or the maximum daily load for certain pollutants (6). Afterwards measurements of water quality can be compared with historical flows (7).

Freshwater quality is a key indicator for the health of the ecosystem and all liveable organisms and thus for resilience. It can be measured mainly by monitoring system in place.

4.2. Dam's density

Almost all interviewees affirm that dam's density is an important indicator for resiliency (*Figure 9*). Not only dam's density but also their size (2&16). Dams change the water flow (1,3&15) and therefore determine water availability into the system (3&7), reduce sediments loading (4&12) and organic matter downstream (12). As a result, subsidence is an emerging problem in the Delta of California (12). Additionally, they also block migratory fish to go upstream (9&15). It is a good indicator in the negative way because they modify the system having negative and positive impacts. Overall, dams reduce ecological resilience (4&7) and increase socio-resilience (10&13). The effect of dams in terms of resilience can be known on different ways (*Figure 10*): ratio between actual and historical flow (1,3&12), monitoring changes of the hydrograph (9) such as % of diverted flow (4), volume of water stored behind the dam over time (10) or monitoring species and water quality (14).

Dams' density is a good indicator of resilience in the negative way since it modifies completely the ecosystem functions (change the water flow, reduce nutrients and sediments downstream). Thus, they reduce ecological resilience and increase socio-resilience. Their effect can be measured mainly comparing actual flow with historical flow.

4.3. Water footprint

★★★☆☆

Half of the interviewed stakeholders agreed that water footprint can be a valuable indicator of resilience (*Figure 9*). This indicator informs who possess water, which is the supply source (1), who is consuming it (6). It is an indirect indicator of economic activity (13) and it gives an idea about the stressors of the system (15). If water footprint is compared with the GDP of the delta it shows the value of water and the efficiency of its use (16). On the other side, some stakeholders do not find it a practical indicator for resilience (3) because its value is too small in the delta (5) and likewise deltas are small parts of any nation area to worry about water (9). Instead water footprint per capita in the delta interviewees proposed to measure (*Figure 10*) only the water exported (1&3) and compare it with the natural flow or human use (4). Moreover, water use in a district can be calculated dividing water supply by the people who are paying for that water (10). Furthermore, another way could be to measure reduction of water per capita for food and other sectors (13&15).

Water footprint can be a useful indicator because it gives an idea about the stressors of the system and how water is used. However, it does not say too much about resilience, it is not a good indicator of the ecosystem's health. Better to measure water exported, water supply per capita in a district, and water use for food or other sectors.

4.1.2. Adaptability

The indicators of adaptability domain with an ecological and institutional dimension are:

5. Self-recovery

★★★★☆

Self-recovery is part of the conventional definition of resilience (1,2,13&16). It can be used as a relevant indicator (*Figure 9*) but depends on the type of disturbances and their effects (4). However, it is not useful if the system already passed the limits of recover by itself because the system is not resilient anymore (3&6). Stakeholders proposed to measure it monitoring the most important ecosystem services before and after a perturbation (2-4,6-10,12&14) (check *Figure 10*).

Self-recovery is a relevant indicator but not useful if the system already passed the tipping points. It can be operationalized by monitoring important ecosystem services before and after a perturbation.

6. Sustainable practices

Assessing sustainable practices for agriculture seems to be a <u>relevant</u> indicator for almost all stakeholders (*Figure 9*). Many interviewees stated that it depends what sustainable agriculture is regarding practices applied and the context where they are applied (4,7-10,12&16). Sustainable practices can decrease the pressure on the system (1) improving the overall health (13&14) making it more resilient. Others disagreed saying that sustainable agriculture is a small part of the whole agriculture area to have a positive impact into the system (3&6). Moreover, with climate change impacts sustainable agriculture is inefficient for resiliency (5). It can be measured in terms of resilience through monitoring attributes of sustainable agriculture (9&10) such as water used and fertilizers applied (2), water quality and biodiversity after a perturbation (7) (check *Figure 10*). Those can be combined with estimations of maximum daily load from agriculture at the discharge points (6) and the percentage or sustainable vs no sustainable agriculture (6&15).

> *Sustainable practices is considered a relevant indicator because when they are well applied they can decrease pressure on the system and improve its health. By contrast, due to climate change that impact of sustainable practices will be low. It can be measured by monitoring specific attributes of sustainable agriculture (water quality, fertilizers, biodiversity).*

4.1.3. Transformability

7. Restoration practices

Almost all interviewees confirmed that restoration practices is an <u>important</u> indicator for resilience (*Figure 9*). Restoration enhances the ecological health of the ecosystem (4,14&15) specially when they are planned with a future vision instead looking how the ecosystem was functioning 150 years ago (1&12). Restoration is relevant for learning even though outcomes are not as expected (3,16). Additionally, restoration has to be linked to specific management goals (5&9). Restoration outcomes can be assessed by monitoring the diversity of species over time (1-5,11-14&16) (check *Figure 10*). This can be combined with measuring the acres restored (4&8) and mapping the area with GIS (2).

> *Restoration is important since it improves the ecological health of the ecosystem as well as ecological resilience. Its outcomes can be measured looking at the diversity of species and the functions of habitat over time.*

4.1.4. Vulnerability

8. Environmental health

8.1. Carbon footprint

Carbon footprint (CF) is <u>not</u> considered a <u>relevant</u> indicator for resilience by multiple stakeholders (*Figure 9*). The carbon footprint in a delta is usually lower than outside the delta (1). The effect of greenhouse gas (GHG) emissions is too global (1,4&9-12), so they do not have local effects in deltas.

It could be a good indicator for sustainability and compare it with the national CF only if the size of the delta would be 80% of the nation area (9). One interviewee was more optimistic saying that reducing GHG emissions is important to mitigate climate change impact if Carbon footprint addresses not only CO_2 but also CH_4 and NO_2 (14). Another interviewee claimed that is better to split agriculture footprint per capita from city footprint per capita when deltas are less populated (16). Only few interviewees suggested how to quantify the carbon present in a delta (*Figure 10*). Since one of deltas' functions is to sequester carbon (1&5), we can measure biomass (1,3&5) or the GHG emissions produced (3&6).

Carbon footprint is not a good resilience indicator because the effect of greenhouse gas emissions is too global. Even though they are reduced at local level it does not have too much impact at global level. Carbon can be quantified through biomass or GHG emissions measurements.

8.2. Ecological footprint

★★★★☆

More than half of interviewees claimed that ecological footprint (EF) is a better indicator for resilience than carbon footprint (*Figure 9*). Ecological footprint takes into account more ecosystem services than carbon footprint (3,5&7). It informs about the state of the ecosystem (6&13), it is a more local (11) and long term (8) measure. Since not many stakeholders were familiar with the ecological footprint concept, they did not know how to measure it (*Figure 10*). Few suggested it can be done by monitoring programs of ecological indicators (5&15). In addition, knowing the percentage of natural habitat lost we estimate what ecological processes have been altered (6).

Ecological footprint is a relevant indicator because it takes into account more ES, informs about the state of the ecosystem. It can be measured by monitoring ecological indicators.

8.3. Nitrogen deposition

★★★☆☆

Nitrogen deposition is an important indicator for the health of the ecosystem (2,4&7) because N can be a limiting factor in deltas (3&10). Nitrogen presence in soil and water has cascading effects on primary production, eutrophication, harmful algal blooms and food web chain (9). Considering that the main source of N is agriculture (6), this indicator is already included within the indicator of *Sustainable practices* for agriculture. Therefore, it was left out after the interview number 11 (*Figure 9*). The interviewees that answered this question agree to do chemical analysis of N forms: total N (3), ammonia, ammonium and nitrate (7) and urea (9) (*Figure 10*).

Nitrogen deposition is not a useful indicator for assessing resilience. Since the main source of N is agriculture because it is already included in the Sustainable practices for agriculture indicator.

9. Human health and well-being

9.1. Human health

★★★★☆

Human health of people living in delta areas is recognized as a relevant indicator for socio resilience (*Figure 9*). Human health and ecosystem health should be in balance, so if people are healthy that means ecosystem is in good shape as well (3,6,6,8&13-16). Nevertheless, some interviewees acknowledged that ecosystem's health is not related to human health (1) because it is mainly a result of industrial and environmental justice problems (2). Not many interviewees knew how human health can be measured (*Figure 10*). Some of them suggested that it can be estimated checking public statistics on human health (15) to identify diseases of people living within or around the delta (2,3,7&15), mortality and mobility rates (3) and hospital visits (15). Additionally, water (4&5) and air (5&6) monitoring methods can be carried out.

Human health of people living in a delta is a relevant indicator because if an ecosystem is in good shape people living there are also healthy. This indicator can be measured by checking public health statistics on diseases, mobility, mortality, hospital visits.

9.2. Well-being of communities

★★★★☆

Well-being of communities dependent on a delta is a relevant indicator for resiliency (*Figure 9*). Many stakeholders found a correlation between ecosystem health, human health and well-being (7& 13-15). If people are happy they engage more with their environment (2) spending more money to support the system (16). Others said that it informs about how sustainable are delta communities (2&6) because it is an economic measurement (12&16). It can be measurable (*Figure 10*) using an index of well-being (4) for the following parameters: health outcomes (2,14&15), economic status (6&14) and ecological footprint (14&15) among others. It can be combined with measuring microbes or bacteria in the environment (2), doing surveys about well-being to people (15). Moreover, Bhutan Happiness Index can be used to show that after a certain threshold if human basic needs are met any additional resources do not make people happier (9).

Well-being of communities dependent on a delta is considered a relevant indicator for socio-resilience. There is a correlation between ecosystem health, human health and well-being even though some interviewees argued that well-being is an economic measure. It can be measured using an index of well-being or the Bhutan happiness Index.

10. Tourism and recreation

★★★☆☆

A majority of stakeholders claimed that tourism and recreation can be a relevant indicator for resilience (*Figure 9*). Deltas have a recreational value (5,6&8) since recreation is one of the ecosystem services of deltas (10). It can have a positive impact as an economic driver (6,9&12-14) although it depends on the type of tourism (1,4&7). This indicator is measurable (*Figure 10)*

Tourism and recreation is claimed to be a relevant indicator for resilience. Deltas have recreational value, thus this is one of the ecosystem services it offers. We can count the number of tourism or the dollars spent per year.

counting the number of tourists (5,6,12&13) or the dollars spent per year (5,12&14).

4.2.5. Institutional capacity

11. Access to improved sanitation and drinking water

Access to improved sanitation and drinking water is considered to be a relevant indicator for socio resilience (*Figure 9*). Sanitation and drinking water are basic human rights (4&11). In order for people to live in healthy places (2) there should be a balance between socio and ecological systems (3,6&7). This indicator provides information about bad policies in place which can be used to base decisions on (12&16). Less than half of stakeholders claimed that this indicator can be measurable (*Figure 10*) looking at the availability of water (4), accessibility of water in meters (5) or percentage (9,10&12). Additionally, monitoring water quality is useful to compare the quality of drinking water with the water quality of natural system (7).

Access to improved sanitation and drinking water is a relevant indicator for socio-ecological resilience. Sanitation and drinking water are considered basic human rights. It can be measured by looking at availability and accessibility of water or comparing water quality of drinking water with the quality of natural systems.

12. Participation and collaboration among stakeholders

12.1. Access to information, participation and justice

Access to information, participation and justice is considered a relevant indicator by many stakeholders (*Figure 9*). People can have more power if they are well informed, so they can make better choices (4&5). However, before having access to information they should have access to education (12) although this is conditioned by the context (14&16). This is mainly an indicator of governance processes within the delta area (1,10&15). When a system is well managed the overall health improves (13&15). By contrast, some interviewees disagreed because providing this right to society can slow down the process (6). It is measurable (*Figure 10*) by looking at people awareness and engagement (4), compare management regimes with people's expectations (5). This can be done counting people participating (9&15), doing surveys (6&9) or looking global health at World Health Organization for data on happiness, health, access to resources, safety, well-being, human rights (12).

Access to information, participation and justice is a significant indicator for socio-resilience but is influenced by the conditions of the context. When people have information they have more power. It can be measured by counting people that are participating, doing surveys or comparing management regimes with people's expectations.

12.2. Gender equity

Gender equity in terms of access to information, participation and justice is an essential indicator for socio-ecological resilience (*Figure 9*) specially in developing countries where women have less power (1,2,6&13). Some interviewees sustained that women must have the same rights because they are the perpetuation engine of society (12,14&15). Many stakeholders considered this as relevant indicator for resilience but only one suggested how can it be measured (*Figure 10*). This particular interviewee said that you can look at: what age women get married, if they chose freely their partner, how many children they have (boys or girls) and the mortality rate of children (12).

Gender equity is an essential indicator for socio-resilience specially in developing countries. Women are the perpetuation engine of society. It can be measured by looking at what age women get married, number of children, mortality rate of children and access to education.

12.3. Multi-stakeholders platform

The existence of multi-stakeholders platforms could be a relevant indicator of socio resiliency (*Figure 9*). Many interviewees claimed that having functioning platforms enhance the success in archiving outcomes based on objectives (2,12,13&15). Others declared that platforms are useful because they improve integration (3), awareness (4) and ecosystem's health (7). Overall, a multi-stakeholders platform is a democratic expression for participation (5) but it can slow down the process (14&16) like the previous one. It can be measured by counting the number of people participating (1&13) and the diversity of groups they belong to (10&12). Likewise, looking at the number of partners of a project or report (2&12) or comparing the management practices with the ones suggested by the coalitions of people (5) (check *Figure 10*).

Having functioning multi-stakeholders platform is considered a relevant indicator for resiliency. They enhance the possibilities of archiving successful outcomes based on the plan's objectives and therefore improving the overall health of the ecosystem. It can be measured counting the number of people and the groups they belong to.

13. Assessing management plans

13.1. Assess the management effectiveness plans of protected areas

Assessing the management effectiveness of protected areas is an important indicator because it informs if plans are a success or failure in terms of resilience (8,10,12,13&15) (check *Figure 9*). Moreover, it says how aware are people about the health of the ecosystem (7). However, it depends on the type of management plans, if they are adaptive management plans they acknowledge changes and uncertainties (7). It can be measurable through monitoring the goals of the management plan over time (2,5-10, 12&15) (check *Figure 10*).

Assessing the management effectiveness plans of protected areas is claimed to be an important indicator. It informs if plans are a success or failure in terms of resilience. It can be measured my monitoring the goals of management plans over time.

13.2. Assess progress of integrated water resources management (IWRM) and integrated coastal zona management (ICZM) plans ★★★★☆

This indicator is relevant for socio-ecological resilience according to almost all interviewees (*Figure 9*). If these integrated plans focus on resilience, ecology and sociology (4-6,9) they are good. Additionally, integration aims for the best outcomes (2) with a long term perspective (3). Plans are good learning processes (1). Many stakeholders suggested to measure the effectiveness of integrated plans through monitoring the outcomes of plans (3-6,8,9,12&14). Likewise, the activities or inter-agencies can also be monitored looking at costs and people's engagement (1,6&14). Additionally, these methods can be complemented with comparing the project scale with the natural system scale (2) (check *Figure 10*).

Integrated plans aim for the best outcomes having a long term perspective. Thus, if they are well designed they increase ecosystem's health and resilience in deltas. It can measurable through monitoring the outcomes of plans.

A summary table for the main findings as a result of the interviews conducted within the Delta of California can be found in *Table 9, Appendix D.* The table includes score and relevance of the indicators and methods how to measure them.

An overview of Sacramento-San Joaquin Delta

An overview of the California delta will be exposed briefly taking into account the examples that stakeholders gave for each indicator. The numbers between brackets represent the interviewees who provided that information. An extended version of the overview with quotes extracted from the transcripts is placed in *Appendix F*.

1.1. Protection status. The Delta of California is not a resilient delta anymore, the only way to make it more resilient is by engineering solutions (9). The Delta is protected at State level by BCDC (Bay Conservation & Development Commission) (4), the Delta Commission (10), the Delta Stewardship (10&13) and at Federal level by the Environmental Quality Act (SEQA) (13).

1.2. Changes in land use. The Delta was a massive wetland of 70.000 acres (28.328ha) (8). There are already huge improvements in the health of the estuary from restoring agriculture to wetlands (currently 30.000 acres (12.150ha) and the objective is to reach 50.000 acres (20.235ha) (2). Increasing more marsh land restoration is the objective to keep up with the effects of sea level rise (10).

2.1. Red List Index (Hurlimann). In California, instead the RLI is being used the Endangered Species Act which classifies species in endangered, threatened and special status (5,10&14).

2.2 Invasive species are a huge problem in the Estuary of the Delta because they are threatening the local species (2). However, they will not be a problem anymore if climate change is taken into account (4).

3.1. Biodiversity used for food and medicine. Not a very useful indicator for California because there is not too much human consumption from the delta. (2,5&12).

3.2. Agricultural GDP. Agriculture is a primary production within the delta but it is still small compared to the national GDP (1&3-5). It can be relevant only for the local community (6). Therefore, this indicator is not very much applicable for a State like California, it could be a better indicator for developing countries (1).

3.3. Fish overexploitation. This indicator is not useful for the Delta of California because there are not native fish anymore in the delta (2,4,6,10&12).

4.1. Freshwater quality. The water quality of the delta is very good (16). The main problems that affect water quality are: temperature (1&2), sediments leaching (1,2&3), mercury (3,5,6), nitrogen and phosphorus (3,5&11). Nevertheless, the main problem now is salt intrusion (6,11&12).

4.2. Dam's density. The Delta of California is 100% dammed (4&6). The resilience of dams to failure is measured (5) by the Army Core of Engineers (12).

4.3. Water footprint. California is exporting a lot of water through agriculture (1&3) and water supply to the South of California (5&6). 90% of the agriculture produced within the delta goes out of the State, which makes it difficult to measure (3). Not too much water is used within the delta (3&5), a lot of water is pumped to the southern of California which has lowered the groundwater level by 40 feet (12m) (6).

5. Recovery. This indicator is not applicable for the California delta because the system is not resilient anymore, it is beyond the tipping points (3,6,12&16).

6. Sustainable practices. There are some sustainable practices going on (3) but they are not very effective. Agriculture brings other problems such as land subsidence (2) and selenium contamination (6). The agriculture should move out of the delta, that will be sustainable (14).

7. Restoration practices. A lot of restoration is being done in the delta to increase the resilience of existing native population (1,2&4)

8.1. Carbon footprint. It can be applied for the Sacramento-San Joaquin delta because the delta has a lot of peat soils (6) but not all deltas have peat soils. In California the carbon is measured looking at carbon sequestration and biomass (1).

8.2. Ecological footprint. Interviewees were not familiar with this concept.

8.3. Nitrogen is a huge problem in the delta, it is a liming factor (1,3&10).

9.1. Human health. This is not a problem in California, sometimes in summer bloom algae can emerge and they are toxic for humans (6).

9.2. Well-being of communities. There are small communities in the delta who are concern about flood control issues. They are declining because they cannot develop (6).

10. Tourism sector. It is not a big deal in California (1), it is used to bring some economic benefit to the delta (6).

11. Access to improve sanitation and drinking water. This is not very applicable in California because everybody has access to water and sanitation. There are regulatory agencies who establish how much water can be taken out of the system (6).

12.1. Access to information, participation and justice. The small communities have been excluded from local plans because they have different interests than the State (sustain economy and water supply to 25million people). Engaging with local communities slows down the process (6).

12.2. Gender equity. It does not apply in California.

12.3. Multi-stakeholders platform. In California is required by law (1). Multi-stakeholders platforms are effective in achieving restoration projects (1) or increase awareness on vulnerability and potential adaptation measures (4). There are several multi-stakeholders platforms in California: BCBC, Delta Stewardship, Delta Commission.

13.1. Management effectiveness of protection plans It is hard to do (2,6&10) due to lack of money to manage protected areas (2). Delta Commission distinguishes between inputs, outputs, outcomes and a way to measure all of them. The inputs are more directly linked to actual actions, the outputs are more tangible and easy to measure and outcomes are hard to measure. And then you have to measure other drivers to figure out if what you are measuring is an indicator of outcome or caused by that action or something else (10).

13.2. Assessing the progress of IWRM and ICZM plans. CALFED was an integrated delta program to address the California water system for the entire watershed of the Sacramento-San Joaquin delta. The program focus was to fix everything within the delta and it still failed. Currently, there is a California Action Plan with guidelines on how to deal with all the delta's issues: efficiency, water reuse and desalinisation. The Delta of California is a complex system, so when trying to integrate all the elements of the system is a challenge (6).

In order to improve the outcome of this research an additional delta was chosen to fill the same questionnaire used for the interviews in California. Therefore, staff working for Delta Alliance Wing in Taiwan fill the same survey via email.

4.2. Case study 2: Delta of Taiwan

Three scientists from the Delta Alliance Wing of Taiwan had the willingness to contribute with my research on how to monitor resilience of ES in deltas. Due to fact that I could not travel to Taiwan and interview them personally, they sent it by email. Therefore, *Table 5* summaries given by the stakeholders form Taiwan as a result of discussing why indicators are relevant, how to measure them and what score of relevance is more appropriate.

Table 5 Summary table of indicators relevance for Taiwan

N°	Indicator/ sub-indicator	Score	Relevance of the indicator	How to measure it
1.1.	Protection status	☆☆☆☆☆	Official legal laws or regulations that protect the delta area	Areas under national or international protection status / total delta areas

1.2.	Land use changes	★★★★☆	It reveals how industry and human activities changes within the delta	Proportion of different land uses within the delta
2.1.	Red List Index	★★★★☆	It shows extinction risk of species over time	RLI calculations
2.2.	Invasive species	★★★★☆	Degradation of certain ecosystem services	N° of invasive species. N° of threaten local species
3.1.	Agriculture GDP	★★☆☆☆	It cannot show agriculture performance	AGDP/TGDP (total) of a delta
3.2.	Fish overexploitation	★★★★☆	Sustainable use of resources is important	Annual responsible catches/total catches
3.3.	Biodiversity for food and medicine	★★★★☆	Shows how resilient is a system against stressors	Simpson's indices
4.1.	Freshwater quality	★★★★☆	Life support	many indicators, turbidity, COD, BOD, E. coli, etc.
4.2.	Dam's density	★★☆☆☆	Some dams are good for sustainability and some not	Dam/km^2
4.3.	Water footprint	★★★☆☆	Reflects sustainability but it is difficult to measure	tons/km^2/yr; % of volume used to total input in delta area
5.	Self-recovery	★★★☆☆	Direct measure of resilience	difficult
6.	Sustainable practices	★★★☆☆	Contributes to the stability of ecosystem services	Area sustainably cultivated /total agricultural area (organic agriculture and nature farming...)
7.	Restoration practices	★★★★☆	Improves ecosystem's health	Area under restoration/potentially degraded area
8.1.	Carbon footprint	★★★★☆	Reveals differences between the sectors of the delta	Difficult
8.2.	Ecological footprint	★★★★☆	Reveals differences between the sectors of the delta	Difficult
8.3.	Nitrogen deposition	★★☆☆☆	A nitrogen input/output mass balance could be a better index	kg N/ha/yr

9.1.	Human health	★★★★☆	Essential for society sustainable development	mortality and morbidity rates
9.2.	Well-being of communities	★★☆☆☆	Difficult to define in terms or sustainability	Difficult
10.	Tourism and recreation	★★★☆☆	Tourism will degrade the environmental sustainability	numbers of tourists visit the delta areas/per year
11.	Access to improved sanitation & drinking water	★★★★☆	Relevant for residents health	prevalence of sewage construction (%), prevalence of sanitation water supply (%), waste water treatment ratio (%)
12.1.	Access to information/ participation/ justice	★★★☆☆	Covers environmental needs with governmental support	Follow the implementation of National Legislation on Access to Inf/part/just
12.2.	Gender equity	-	-	-
12.3.	Multi-stakeholders platforms	★★★☆☆	Communication/negotiation can enhance efficiency	Difficult to evaluate and subjective
13.1.	Management effectiveness of protected areas	★★★☆☆	To ensure that they are well protected	Difficult
13.2.	Progress of IWRM and ICZM plans *	★★☆☆☆	Difficult to say if they work or not in practice	Difficult

*IWRM=Integrated water resources management/ ICZM=Integrated coastal zone management

The stakeholders found almost all indicators relevant unless agriculture GDP, dam's density, nitrogen deposition, well-being of communities and assessing the progress of IWRM and ICZM plans. Some indicators were considered relevant giving them a high score but stakeholders thought they are difficult to measure. Additionally, many interviewees did not answer the gender equity indicator.

4.3. Comparison between California and Taiwan deltas

The indicators were assessed in different cultural and ethnical contexts in order to have a wider perspective of opinions. In addition, both case studies differ in scale, climate and geographical conditions. However, the size and diversity of the interviewed sample is far more representative for California than for Taiwan. Therefore, more importance will have the information collected through interviews in California than Taiwan for the selection of the final set of indicators.

Figure 11 shows a comparison between the score relevance given by the 16 stakeholders interviewed in California and the 3 stakeholders from Taiwan. The indicators names related to the numbers used for the graph are the same listed in *Table 4* above. As a starting point there are many similarities in the scores given for some indicators.

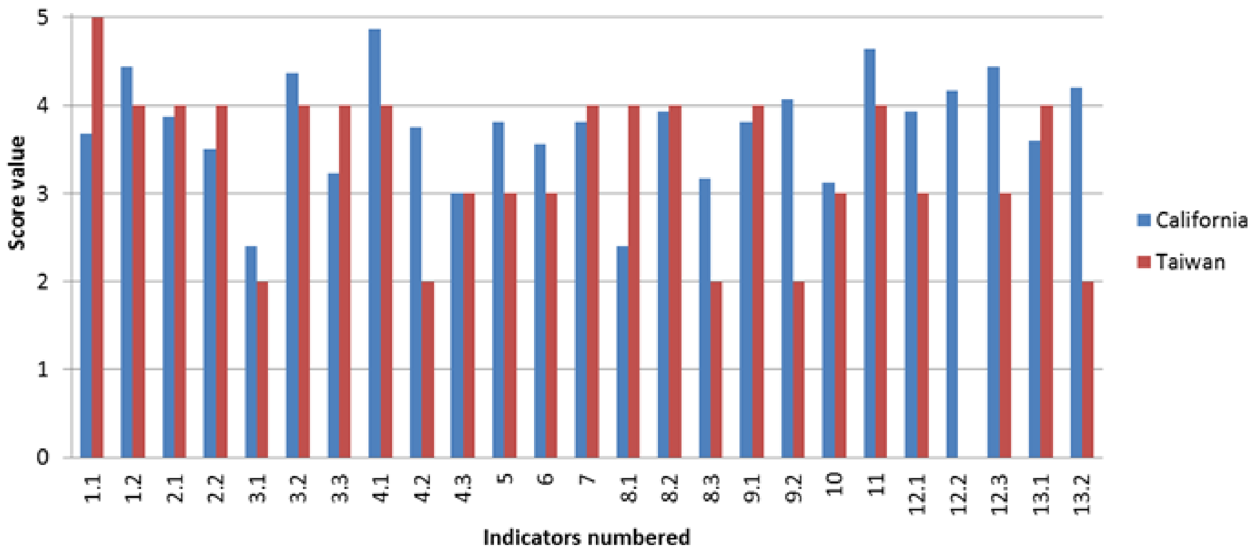

Figure 11. Score comparison between California and Taiwan per indicator

The largest differences in score relevance correspond to the following indicators:

- *1.1. Protection status of the ecosystem.* Stakeholders from Taiwan considered it very highly relevant with score 5 on the Likert scale. Likewise, interviewees from California also thought that it is a relevant indicator but they claimed that the effectiveness of having a protection status depends on the type of protection and the governance entity. Stakeholders from both case studies proposed a way how to measure it (Check *Case study of California* and *Table 5*).
- *8.3. Nitrogen deposition.* Scientists from Taiwan considered this indicator low relevant because it is better to call it nitrogen input instead nitrogen deposition. Besides it, this indicator was left out from the interview as it was explained previously.
- *9.2. Well-being of communities.* In Taiwan this indicator is considered low relevant because stakeholders did not perceive any link with sustainability and measuring is a challenge. On the other hand, it is considered high relevant in California because stakeholders agree on a linkage between ecosystem health, human health and well-being.
- *12.3. Multi-stakeholders platform.* Taiwan and California found it a relevant indicator to enhance the health and efficiency of the system but in Taiwan they considered it hard to measure the success of having active platforms.
- *13.2. Progress of IWRM and ICZM.* This indicator is low relevant for Taiwan because it is difficult to put into practice and measure the outcomes of integrated plans. On the other side, in California interviewees agreed this indicator is important for resilience since integrated plans seek for the best outcomes which can be monitored.

4.4. Final set of indicators

Table 6 shows the relevance of the indicators based on the qualitative and quantitative data collected through interviews and compared it with the survey received from Taiwan. The data from California prevails over the data from Taiwan because the stakeholders group is higher and more diverse for the Delta of California than for Taiwan. According to *Table 6,* all indicators are relevant for resilience besides *Agriculture GDP (3.1), Carbon footprint (8.1.)* and *Nitrogen deposition (8.3.).*

Table 6. Final set of relevant indicators for resilience comparing California and Taiwan

N°	Indicators and sub-indicators	Relevance California	Relevance Taiwan	Overall relevance
1.1.	Protection status	✓	✓	✓
1.2.	Land use changes	✓	✓	✓
2.1.	Red List Index	✓	✓	✓
2.2.	Invasive species	✓	✓	✓
3.1.	Agriculture GDP	✗	✗	✗
3.2.	Fish overexploitation	✓	✓	✓
3.3.	Biodiversity for food and medicine	✓	✓	✓
4.1.	Freshwater quality	✓	✓	✓
4.2.	Dam's density	✓	✗	✓
4.3.	Water footprint	✓	✓	✓
5.	Self-recovery	✓	✓	✓
6.	Sustainable practices	✓	✓	✓
7.	Restoration practices	✓	✓	✓
8.1.	Carbon footprint (CF)	✗	✓	✗
8.2.	Ecological footprint (EF)	✓	✓	✓
8.3.	Nitrogen deposition	✗	✗	✗
9.1.	Human health	✓	✓	✓
9.2.	Well-being of communities	✓	✗	✓
10.	Tourism and recreation	✓	✓	✓
11.	Access to improved sanitation & drinking water	✓	✓	✓
12.1.	Access to information/participation/justice	✓	✓	✓

12.2.	Gender equity	✔	--	✔
12.3.	Multi-stakeholders platforms	✔	✔	✔
13.1.	Management effectiveness of protected areas	✔	✔	✔
13.2.	Progress of IWRM and ICZM plans *	✔	✘	✔

The relevance of the indicators is based on the stakeholders perception and their background. Thus, relevance of an indicator can be different depending on the stakeholders group and the social and cultural contexts where the indicators assessed.

5. Discussion

The aim of this research is to assess a set of key indicators for monitoring resilience of ecosystem services in deltas. In order to accomplish this, interviews were conducted among different stakeholders groups with a broad and diverse backgrounds involved in delta management, delta research or delta development. The purpose of the interviews was to figure out to what extend the indicators are relevant and measurable for deltas worldwide to monitor resilience of ecosystem services. The interviews were addressed to 16 stakeholders from the Delta of California, in San Francisco. In addition, 3 stakeholders from the Delta Alliance Wing in Taiwan collaborated via email filling the same questionnaire. Both countries differ in cultural, ethical and social contexts, so stakeholders opinions and perspectives can differ consistently.

In this section the final set of indicators is discussed first. The relevance of the indicators and the relation between them will be explained within the resilience domain that they are part of. In the second part of this section the procedure of the data collection either through interviews or email survey.

5.1. Final set of indicators

The final list of indicators is a result of comparing stakeholders answers from California and Taiwan (*Table 6*). The relevance score and stakeholders answers from the Delta of California prevail over the Delta of Taiwan because of the following reasons. Firstly, the interviewed stakeholders sample is larger for California than for Taiwan. Sixteen stakeholders were interviewed during the fieldwork in California and three stakeholders from Taiwan answered together one questionnaire. Secondly, the stakeholders from California have a diverse professional experience and knowledge related to delta resilience: scientists, policy makers, economists, consultants and one farmer (*Table 2, Figure 8).* Nevertheless, the three stakeholders form Taiwan are all scientists (*Table 3*). Thirdly, a personal interview provides the opportunity for discussion and exchange more information than a survey via email. Furthermore, stakeholders are more spontaneous during a personal interview. They answer the questions on the spot without taking too much time to think about the content. On the other hand, the scientists from Taiwan filled the questionnaire discussing together each indicator. They sent back the filed questionnaire in a period of almost three weeks of time. Therefore, if stakeholders meet to agree on the answers the collected information is less significant because the individual opinion and perspective are lacking. *Table 6* summarizes the relevance of the indicators for both study cases and the overall relevance.

In the following paragraphs the relevance of the final set of indicators is presented within the resilience domains that were explained in the *Resilience Framework* section. Moreover, the importance and the inter-dependence among the indicators within the same domain is described according to the interviews findings. The numbers between brackets and in *Italic* refer the indicators used in the questionnaire and all the tables of this report.

1) Resistance or stability. Resistance-persistence concept is a complementary aspect of resilience. Persistence is the amount of external pressure the system can absorb without collapsing (Carpenter et al., 2001). Accordingly, when certain areas of a delta are under protection status (*1.1.*) the pressures due to human activities will decrease making the ecosystem more resilient. Likewise, tracking land uses changes (*1.2.*) within the delta is useful for planning and decision making towards resilience. Furthermore, the ecosystem's structure, functions and processes are altered by external perturbations affecting its biodiversity as well. Therefore, monitoring trends of native (*2.1.*) and not native species (*2.2.*) present in the system is essential. Biodiversity should be controlled and monitored because it is a pillar for key ecosystem services in deltas: nursery for fish (*3.2.*), food and medicine (*3.3.*). In the same manner, deltas provide other services such as water supply for all liveable organisms which should have good quality (*4.1.* and *4.3.*) and enough quantity (*4.2*. and *4.3.*).

2) Adaptability (ecological and institutional dimension) is the capacity of the system to adjust towards external pressures and internal processes coping with changes (Gunderson, 2001; Holling, 2002; Walker et al., 2004). So, the self-recovery of an ecosystem (*5.)* is a direct measure of resilience. Furthermore, for a human system, adaptability is the capacity of actors to manage resilience (Walker et al., 2004) through sustainable practices (*6*.) for instance. In this research sustainable practices are considered to be applied only for agriculture since it is one of the key services in deltas. Sustainable practices decrease pressures improving the overall health the ecosystem.

3) Transformability is the capacity to create a new way of living when existing conditions make the system overcome a specific threshold or tipping point into a new state. (Walker et al., 2004). Restoration practices (*7.*) are needed to recover the ecosystem from degradation, damage, or destruction (Zedler and Kercher, 2005) Restoration practices improve the health of the ecosystem and therefore its ecological resilience. Even though changes may happen at smaller scales enables resilience at larger scales since they are good learning processes (Folke et al., 2010).

4) Vulnerability is defined as "the susceptibility of a system to harm, a potential for a change or transformation when the system experiences perturbations" (Gallopín, 2006). Environmental health and human health can be affected when the ecosystem and its populations are exposed to external stressors. Therefore, the ecological footprint (*8.2.*) is an indicator of ecosystem state and it takes into account more ecosystem services than the carbon footprint (*8.1.*). When the ecosystem is in good health it is expected that people's health (*9.1.*) and well-being (*9.2.*) will also be in good conditions. Furthermore, tourism (*10.*) is one of the services that deltas provide and it could have a positive or negative impact on the ecosystem Therefore, it's worthy to include this indicator to monitor resilience in deltas.

5) Institutional capacity is the way in which individuals, organisations and institutions interact in the public sector and within society at all levels (Keohane, 1989). Some institutions are in charge of providing access to drinking water and sanitation (*11.*) which are human basic needs. Additionally, man and women (*12.2.*) should have the same access to information and participation in decision making at all levels (*12.1.*). A multi-stakeholders platform (*12.3*) is an example of facilitating access to participation and collaboration for all interested stakeholders. Furthermore, assessing the effectiveness of existing plans (*13.1*. and *13.2.*) can help to reformulate and improve those plans towards resilience. 5.2. Interview procedure

At the starting of each interview the topic and the purpose of the research, the duration of the interview and the settings of the questionnaire were explained. In the following paragraphs a brief reflection is presented based on the experience during and after the interviews done in California:

All personal or phone interviews were recorded and transcribed in order not to miss any key information from the collected data. Stakeholders gave the permission to be recorded. As a result, the collected data presented in the *Results* section can be trustworthy because the information cited between brackets belongs to the interviewed stakeholders.

- The duration of an interview was expected to be around 40-45 minutes. However, in fact the duration of the interviews was between 33 minutes and 2 hours. Some interviewees went straight to the point given concrete answers resulting in a short interview. Others offered much more elaborated answers or trying to justify their opinions they were going out of topic.
- The content of the answers during the interview could be influenced by the conditions in which the interview took place. For instance, many of the interviews took place during the working hours or during lunch time. This might affect their concentration because they sometimes rushed to finish the interview due to their schedule. Moreover, the interviews conducted outdoors in a cafeteria or terrace were more informal than in the office. It was feeling more as a conversation. Unfortunately, in those conditions I found more difficult to concentrate on the topic and to record the interviews. In addition, I encountered for several interviews that stakeholders were relaxed at the beginning of the interview taking their time to give a comprehensive answer and rushing at the end skipping some questions. Therefore, not all stakeholders answered all the questions of *why indicators are relevant* for resilience (*Figure 9*) and *how can it be measured* (*Figure 10*).
- Even though in the introduction of the interview I was explaining that the relevance of the indicators should be answered keeping a global perspective of context application, many interviewees were easily switching to the local context of California. They were always giving examples referring to the Delta of California. Sometimes, the relevance score was also in relation to the local delta. So, when that was the case, I had to interrupt the interviewee to remain him/her to keep a global vision of the indicators. Despite of it, this is a valuable outcome as well since the indicators that stakeholders found less relevant for the Delta of California it means that they are context dependent
- The data resulted from the interviews was compared and analysed looking for agreement and disagreement among the stakeholders on indicators relevance and measurement methods. Despite the fact that resilience concept is highly dependent on the processes and the contexts of the system (Quinlan et al., 2015) there is a large agreement on the relevance of the indicators in terms of resilience (*Table 6*). All stakeholders who agreed on a specific category of answer are mentioned with numbers between brackets in the *Results* section. Likewise, having interviewees with a diverse scientific background and knowledge on deltas, resilience and ecosystem services, any patterns were found in answers given by the stakeholders from a specific group (*Table 2, Figure 8)* Furthermore, since agreement was found among the 16 stakeholders, it is assumed that the number of interviewed people is enough to decide on the final set of indicators.

The outcome of this research can be used by Delta Alliance as a part of their recent Delta Monitor Program. The final list of indicators (*Table 6*) should be assessed in different delta contexts in order to be applicable worldwide, as it was already explained. Afterwards, when a global set of indicators is accomplished it can be used by each Wing part of Delta Alliance network to report the resilience state of the delta to still provide ecosystem services in the coming years.

6. Conclusions

The objective of this study was to assess to what extend the proposed indicators are relevant for monitoring the resilience of ecosystem services in deltas worldwide and how they can be measured. This set of indicators can be used by Delta Alliance as part of their Delta Monitor Program to report the state of each delta wing and use that information for management purposes. Interviews were conducted to 8 scientists, 3 policy makers, 2 economists, 2 consultants and one farmer form the Delta of California, in U.S. Additionally, other 3 scientists from the Taiwan Wing of Delta Alliance filled the same questionnaire via email. Afterwards, the outcome of the interview was compared.

The main findings of this study show that from the proposed 21 indicators and sub-indicators stakeholders agreed that the majority are relevant to monitor resilience of ecosystem services in deltas (*Table 6*). Moreover, they also proposed different ways how they can be measured. The following indicators and sub-indicators are considered relevant because they have got a score equal or higher to 3: protection status, land use changes, Red List Index, invasive species, fish overexploitation, biodiversity for food and medicine, freshwater quality, dams' density, water footprint, self-recovery, sustainable practices, restoration practices, ecological footprint (EF), human health, well-being of communities, tourism and recreation, access to improved sanitation & drinking water, access to information/participation/justice, gender equity, multi-stakeholders platforms, management effectiveness of protected areas and assessing the progress of IWRM and ICZM plans. Only three indicators were considered less relevant with a score below 3: agriculture GDP, carbon footprint (CF) and nitrogen deposition. The reasons of why they are or not considered relevant and how to measure them are presented in the *Results* section or in a summary table of the *Appendix E*. The outcome of the interviews conducted among stakeholders with diverse background is a set of relevant and measurable indicators for resilience. Therefore, the research questions mentioned in the *Introduction* section have been answered.

In order to come up with a global set of indicators they should be assessed in different deltas with diverse contexts. Additionally, the stakeholders should have very different backgrounds to get a broader perspective of the concept resilience in deltas and ecosystem services.

7. Recommendations

In this section some recommendations are given which could improve the outcome of this study. Those can be taken into account for further research to review and refine the set of indicators in different contexts following the steps of the *Resilience Framework*. The recommendations are also twofold such as the *Discussion* section. On the one side, recommendations related to the set of indicators and on the other side, recommendations related to the interview procedure are given.

7.1. Indicators

These recommendations are given to improve the indicators that stakeholders thought are relevant and to develop new indicators to be assessed in other deltas.

- The indicators should be assessed in minimum 2 deltas in order to do a fair comparison among the outcome of the interviews. Moreover, the social, cultural and environmental contexts of the deltas should differ in order to figure out which indicators are context dependent, which are globally applied and why.

The following indicators resulted to be less relevant for monitoring resilience of ecosystem services in deltas: *Agriculture GDP (3.1), Carbon footprint (8.1.)* and *Nitrogen deposition (8.3.)*.Even though

- *Agriculture GD*P got on average score of 2.5. This indicator could be relevant if it is compared with the State or national GDP of the costs other sectors only when agriculture production is large enough within the delta area. Therefore, it depends on the size of the delta as well as on the importance of agriculture at national level. This indicator could show the importance of agriculture at national level or compared with other production sectors (water, levee maintenance or others ecosystem services) within the delta area. If the ratio between Agriculture GDP and State or National GDP is high that means that deltas are not very relevant because the agriculture area is too large. Hence, this can be an opposite indicator of resilience. It can be useful depending on how the question is formulated and to what is AGDP compared to.

- *Carbon footprin*t also got on average score of 2.5 being less relevant for resilience. Carbon footprint is a measurement of greenhouse gas emissions (GHG) in the delta area. However, in the delta area usually GHG emissions are low than outside the delta. Since one of the ecosystem services that deltas provide is carbon sequestration it would be more useful to monitor carbon sequestration measuring *biomass production* or *measure the concentration of GHG emissions*.

- *Nitrogen deposition* was considered a low relevant indicator for resilience because the term *deposition* is incorrect. Deposition refers mainly to N from the air and not from soil or water. The major N source within a delta comes from agriculture, so a correct term to use would be N input. Another way to formulate this indicator would be: *chemical analysis of N forms* (total N, ammonia, ammonium, nitrate and urea).

- As a result of interviews, stakeholders proposed other indicators that might be relevant to monitor resilience in deltas. Firstly, *sediment leaching* because it is a huge problem in the Delta of California and other deltas in general. Due to the dams construction, which are changing the natural flow of the river, sediments are retained. Deltas do not receive any more sediments to feed its branches. Therefore, sediments are needed to fill the delta and maintain its biodiversity. Secondly, if the delta lost a large area of natural wetlands it might be relevant for resilience to calculate the r*atio of wetlands still present compare with the historical wetlands*. Thirdly, certain stakeholders suggested to measure the *net productivity* of the system instead carbon footprint to know carbon concentration within the system. And lastly, *a ratio between permanent species vs migratory or transitory s*pecies (birds and fish mainly) should add more information besides the fish overexploitation and invasive species indicators.

7.2. Interview procedure

- All interviews, either personal or by phone, should be transcribed in order not to lose any key information. There are applications that allow to record a phone conversation. So, I recommend to record all interviews if someone else is going to assess these indicators or similar indicators in a different context. Ask always stakeholders at the beginning of the interview for permission to be recorded.
- Time was a pressure for interviewees sometimes and that made them rush for some questions without going into depth with their answers. Moreover, the interviewee was often going out of the topic. That was making me loose time for other questions and that will pressure them as well on elaborating their answers for the coming questions If I would have to do again the same interviews in a different place I would tell the interviewee that he/she has maximum 2 minutes per question and I would demand for a very concrete answer.
- Certain interviewees were losing the global application of the indicators. Therefore, there may be some uncertainties within the answers on the relevance of the indicators or the way to measure them. Perhaps the interviewee answered having in his/her mind the practicality of the indicator for the Delta of California before I had reminded him/her to keep a global view. Thus, I recommend to ask back the interviewee every few questions if his/her answer is related to that particular delta or if other deltas are taking into consideration.
- Even though the number of interviewed stakeholders from the Delta of California was enough to find agreement and disagreement among their answers, it would be preferable a larger number to deep in the topic. In order to be scientifically sound and improve the results of the research you could: increase the number of interviewed stakeholders from each group (except scientists which is already larger than the rest, *Figure 8*) and assess the same list of indicators in other deltas which are part of the Delta Alliance network.

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Appendix A. Glossary

Resistance or stability. Ecological systems and their services can be transformed by human activities (resource exploitation, pollution, land-use change) and possible climatic impact into less desired states (Folke et al., 2004). All these are considered pressures that make the system more vulnerable or less resilient. Resistance-persistence concept is a complementary aspect of resilience which may be defined as the amount of external pressure needed to bring about a given amount of disturbance in the system (Carpenter et al., 2001). Therefore, to assess long-term persistence, resistance has to be considered as the complementary attribute of resilience (Gunderson, 2001; Holling, 2002).

Adaptability (ecological and institutional dimension) is part of resilience. The future of human well-being may be seriously affected if a critical threshold is overcome resulting in a stability loss of the system (Rockström et al., 2009). Adaptability is the capacity of actors in a system to manage resilience (Walker et al., 2004) against uncertainty and surprise (Gunderson, 2001; Holling, 2002; Walker et al., 2004). It is the capacity to adjust responses towards external drivers and internal processes allowing for sustainable development (Gunderson, 2001; Holling, 2002; Walker et al., 2004). Indicators of adaptive capacity should address the ability of SE systems to cope with changes. In biotic systems, adaptive capacity is related to genetic diversity, biodiversity, and the heterogeneity of landscape mosaics (Peterson et al., 1998). For human system adaptive capacity is related to learning which is fundamental notion for adaptive management. The development of institutions in charge of learning through monitoring programs and update assessment can enhance sustainability (Carpenter et al., 2001).

Transformability "is the capacity to create untried beginnings from which to evolve a fundamentally new way of living when existing ecological, economic, and social conditions make the existing system untenable" (Walker et al., 2004). A system transforms when it crosses a specific thresholds into new state. When changes happen at smaller scales enables resilience at larger scales since it can offer the opportunity for innovation and a source of experience and knowledge. Society may seriously consider this as a way to enhance resilience of SE system at smaller scale to contribute to resilience at larger scales (Folke et al., 2010). Indicators that represent slowly changing variables or thresholds can be used. For instance, soil Phosphorus (P), sediment P, the frequency of large runoff events, Nitrogen (N) concentration in the water (Carpenter et al., 2001). Additionally, indicators to measure restoration projects of initiatives such as green infrastructure or ´Building with Nature' can be part of this domain. The restoration means ecosystem recovery from degradation, damage, or destruction (Zedler and Kercher, 2005).

Vulnerability is defined as "the susceptibility of a system to harm, a potential for a change or transformation when the system experiences perturbations" (Gallopín, 2006). According to Adger (2006) vulnerability originates from the social and the natural sciences because its components are: exposure to perturbations or external stresses, sensitivity to perturbations and the capacity to adapt to them.

Institutional capacity is defined as "the ability to perform functions, solve problems and achieve objectives'' (Fukuda Parr et al., 2002). It is the way in which individuals, organisations and institutions interact in the public sector and within society at all levels (Keohane, 1989).

Institutional capacity has the following levels: individual, organisation, network of organisations, public governance and society (norms, values and practices) (Willems, 2003).

Appendix B : Indicators and questions form

Table 7. Indicators and questions form

Indicators	Resilience domain	Type of ES	Indicators Description	Questions	Answer	Additional comments or questions
1. Status and trends of the ecosystem /natural area **1.1 Protection status of the ecosystem** **1.2. Trends in coverage of protected areas**	Resistance-ecosystem diversity	State, response Benefits	1.1. Areas that are protected for their ecological or cultural importance at national or international (World Heritage, Ramsar, UNESCO MAB) level (EPI, 2016) 1.2. Coverage protected areas (Islam et al.) indicator helps to track progress in the establishment of a comprehensive protected area network (UNEP-WCMC, 2012)	*1.1. In your opinion, being the delta or part of the delta area under a national or international protection status is a relevant indicator for monitoring the resilience of ecosystem services?* *1.2. Do you think that changing the coverage proportion of the different land use categories is a relevant indicator for assessing resilience of ES in deltas?*	1.1. Yes/No, why and how can it be measured? 1.2. Yes/No, why and how can it be measured?	
2. Protection status of fauna and flora species: **2.1. Red List Index** **2.2. Trends in invasive species**	Resistance-species diversity	Trends in RLI pressure and state	2.1. The RLI measures the overall rate at which species move through IUCN Red List categories towards or away from extinction. It is calculated from the number of species in each category (Least Concern, Near Threatened, Vulnerable,	*2.1. In your opinion, is the Red List Index a relevant indicator to assess resilience of ES in deltas?* *2.2. In your opinion, having invasive species that threatens local species within the delta area is a relevant indicator?*	2.1.Yes/No, why and how can it be measured? 2.2. Yes/No, why and how can it be measured?	Red List Index for the world's mammals, birds, amphibians and corals. The extinction of the two latter is

			Endangered, Critically Endangered, Extinct), and the number changing categories between assessments (BIP, 2010). 2.2. List Category Invasive species of fauna and flora that are threatening the local species (Ramsar, 2005)			increasing.
3. Food **3.1. Agricultural GDP** **3.2. Fish overexploitation** ***3.3. Biodiversity used for food and medicine***	Resistance - diversity of local food production	State Trends in pressure form unsustainable fisheries State and pressure Benefits	3.1 Agriculture GDP (Gross Domestic Product, in %) as share of total AGDP provides an estimate of the relative importance of agriculture in the country's economy with regard to generating national income (UNESCO, 2016) 3.2. Proportion of exploited fish stocks outside safe biological limits ((UNEP-WCMC, 2012) 3.3. The use of wildlife for food and medicine and the impacts on ecosystem integrity and ecosystem goods and services Measures the change over time in the conservation status of animals used for food and medicine, and a baseline for the conservation status of medicinal plants (UNEP-WCMC, 2012)	*3.1. Is the agriculture GDP compared to with the national/national GDP a relevant indicator?* *3.2. Do you think that the proportion the exploited fish stock outside the safe biological limits is a relevant indicator?* *3.3. Do you consider that biodiversity for food and medicine is a relevant indicator?*	3.1. Yes/No, why and how can it be measured? 3.2. Yes/No, why and how can it be measured? 3.3. Yes/No, why and how can it be measured?	
4. Water quality	Resistance	State and	4.1. Water quality status	*4.1 Do you think that water*	4.1. Yes/No, why	Which are the

and water quantity **4.1. Freshwater quality** **4.2. Dam's density** **4.3. Water footprint**		pressure State, impact State, impact	(Ramsar, 2005) based on the Global Water quality index of UNEP based on the T, DO, pH, EC, major ions and SS (UNEP-WCMC, 2012) 4.2. Fragmentation and flow regulation of rivers: Dam Density (UNEP-WCMC, 2012) 4.3. Water footprint of the Delta (m^3/yr, m^3/ton or l/kg) area compared with the National Water footprint. Tracks the human use and the pollution of freshwater resources (Galli et al., 2012).	*quality of freshwater ecosystems is a relevant indicator? (Parameters: T, DO, pH, EC, major ions and SS)?* *4.2. Do you consider that dam's density in the delta catchment is a relevant indicator?* *4.3. Do you think the water footprint of the delta area compared with fair water footprint share per community is a relevant indicator?*	and how can it be measured? 4.2. Yes/No, why and how can it be measured? 4.3. Yes/No, why and how can it be measured?	main source of contaminants that reach the delta's water?
5. Self-recovery	Adaptability	State	5. The ability of the ecosystem to recover by itself (Bergamini et al., 2013)	*5. Can the ability of the ecosystem to recover by itself be considered a relevant indicator?*	5. Yes/No, why and how can it be measured?	Hazards such as: pollution, floods, hurricanes.
6. Sustainable practices	Adaptability (institutional)	Response	Area of Agricultural Ecosystems Under Sustainable Management 'area of agricultural ecosystems under sustainable management' reflects the well established cause-effect relationship between the presence of resources-conserving "sustainable" management practices and improvements in biodiversity status (UNEP-WCMC, 2012).	*6. Do you consider implementation of sustainable agriculture practices is a relevant indicator?*	6. Yes/No, why and how can it be measured?	
7. Restoration practices	Transformability	Response	7. Restoration practices and plans such as green	7. *In your opinion, are the restoration practices applied in*	7. Yes/No, why and how can they be	Any examples of restoration

			infrastructure or Building with nature. Restoration policies (Zedler and Kercher, 2005)	*the Delta area a relevant indicator?*	measured?	projects?
8. Ecosystem health **8.1. Carbon footprint** ***8.2. Ecological footprint*** ***8.3. Nitrogen deposition***	Vulnerability	State, impact Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture Pressure	8.1. The Carbon Footprint measures in Kg of CO_2 the total amount of GHG emissions that are directly and indirectly caused by an activity or are accumulated over the life stages of a product measured. It informs about the GHG emissions (Galli et al., 2012) 8.2. The Ecological Footprint measures humanity's demand on the biosphere in terms of the area of biologically productive land and water required to provide the resources we use and to absorb our carbon dioxide emissions. This area is reported in global hectares (Taleghani et al.) – hectares with world average productivity. The Footprint of a country includes all the cropland, grazing land, forest and fishing grounds required to produce the food, fibre and timber it consumes, to house its infrastructure and to absorb its waste(UNEP-WCMC, 2012)Ecological Footprint informs on 'environment, health and quality of life (Galli et al.,	*8.1. Do you consider the average Carbon footprint per person in the delta compared with the national/state Carbon footprint is a relevant indicator to assess resilience of ES in deltas?* *8.2. Do you consider the average Ecological footprint in the delta compared with the national/state area Ecological footprint is a relevant indicator?* *8.3. What about nitrogen deposition?*	8.1. Yes/No, why and how can it be measured? Yes/No, why and how can it be measured? Yes/No, why and how can it be measured?	Could you mention which gas is more prejudicial? (CO2, CH_4, N_2O, or fluoride gases (HFC, PFC or SF_6))

		Pressure	2012) 8.3. Nitrogen deposition Landscapes receiving more than 10 kg N/ha/yr are especially vulnerable to negative impacts (UNEP-WCMC, 2012)			
9. Human health and well-being **9.1. Human health** **9.2. Well-being of communities**	Vulnerability	State, impact, benefit State, impact, benefit	9.1. Risk of water and air pollution to human health (EPI, 2016) 9.2. It demonstrates the link between well-being and vulnerability to the loss of biodiversity (UNEP-WCMC, 2012).	*9. 1. Can the human health affected by water and air pollution within the delta be considered as a relevant indicator?* *9.2. Do you consider well-being of communities directly dependent on ecosystem a relevant indicator?*	Yes/No, why and how can it be measured? Yes/No, why and how can it be measured?	
10. Tourism and recreation	Vulnerability	Benefits, pressure	Number of tourists per year (Russi D., 2013)	*10. Do you consider that the impact of the tourism sector within the delta areas is a relevant indicator?*	Yes/No, why and how can it be measured?	
11. Access to improved sanitation & drinking water	Institutional capacity	Impact, response	The proportion of the population (total, urban and rural) with access to an improved sanitation facility (for defecating) (UNESCO, 2016)	*11. In your opinion, can access to improved sanitation and drinking water be considered a relevant indicator?*	Yes/No, why and how can it be measured?	
12. Participation and collaboration among stakeholders **12.1.Access to**	Institutional capacity	Response	12.1. Proportion of countries with strong, intermediate or weak access to information, participation and justice (UNESCO, 2016).	*12.1. Can the access to information, participation and justice be considered a relevant indicator?* *12.2. What about gender equity*	12.1. Yes/No, why and how can it be measured? 12.2. Yes/No, why	Do you have any examples of a multi-stakeholder platform already

information, participation and justice **12.2. Gender equity** **12.3. Multi-stakeholders platform**			12.2. Gender equity (Bergamini et al., 2013) 12.3. Multi-stakeholders platform (Bergamini et al., 2013)	*to access information, participation and justice?* *12.3. Do you consider that a multi-stakeholders platform to enhance collaboration and cooperation among stakeholders can be considered a relevant indicator?*	and how can it be measured? 12.3. Yes/No, why and how can it be measured?	existing in the management of the California Bay?
13. Assessing management plans **13.1. Management effectiveness of protected areas** **13.2. Progress of integrated water resources management (IWRM) and integrated coastal zone management (ICZM) plans**	Institutional capacity	Response	13.1. Indicates the proportion of protected areas (by area) for each country where management effectiveness evaluations have been conducted recorded (UNEP-WCMC, 2012) 13.2. Assessment of progress in implementation of national or federal integrated water resources management (UNESCO, 2016) Assessment of progress in implementation of national or federal integrated coastal zone management (UNESCO, 2003)	*13.1. Do you think that management effectiveness evaluation of protected areas is a relevant indicator?* *13.2. Do you consider that assessing the progress of IWRM and ICZM plans a relevant indicator of assessing the resilience of ES in deltas?*	13.1. Yes/No, why and how can it be measured? 13.2. Yes/No, why and how can it be measured?	

Appendix C: Questionnaire example

A short introduction is given at the beginning of the interview regarding a personal background, objective and purpose of the interview and the collected data, ask for permission to record the interview

Date

Name of the interviewee

Organization

Profession and responsibilities

RESISTANCE Type of indicator: Status and trends of the ecosystem

1.1. *Protection status*. In your opinion, being the delta or part of the delta area under a national or international protection status is a relevant indicator for monitoring the resilience of ecosystem services?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

1.2. *Coverage of land uses*. Do you think that changes in the in coverage proportion of different land uses (industrial, urban, agriculture, among others) in the delta area is a relevant indicator for assessing resilience of ES in deltas?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

RESISTANCE Status and trends of fauna and flora species

2.1. *Red list index.* In your opinion, is the Red List Index a relevant indicator to assess resilience of ES in deltas? It is calculated from the number of species in each category (Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct), and the number changing categories between assessments

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

2.2. *Invasive species*. In your opinion, having invasive species that threatens local species within the delta area is a relevant indicator?

Yes /No

Why natural migration of species. What is invasive and what is migration. Similar to the Red list index

How can it be measured?

Very low	Low	Medium	High	Very high

RESISTANCE Type of indicator: Food. Agriculture GDP/ fish overexploitation

3.1. Is the agricultural GDP within the delta compared to with the national/state AGDP a relevant indicator?

Yes/No

Why no cost-benefit, compare with other costs.

How can it be measured?

Very low	Low	Medium	High	Very high

3.2. Do you think that the proportion of exploited fish stock outside the safe biological limits is a relevant indicator?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

3.3. Do you consider that biodiversity for food and medicine is a relevant indicator? (Added later)

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

RESISTANCE Type of indicator: Water quality and water quantity

4.1. Do you think that water quality of freshwater ecosystems a relevant indicator? (Parameters: T, DO, pH, EC, major ions and SS)?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

For discussion: What is the main source of contaminants that reaches the delta's water?

4.2. Do you consider that dam's density in the delta catchment is a relevant indicator?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

4.3. Do you think the water footprint, expressed as the average water footprint per capita in the delta, compared to the fair water footprint share per community is a relevant indicator? The water footprint measures the water consumption and the volume of water polluted.

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

For discussion: Could you suggest any other indicator to measure the water quantity of the delta?

ADAPTABILITY Type of indicator: Recovery

5. Do you consider the self-recovery of the ecosystem after natural hazards can be considered as a relevant indicator?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

ADAPTABILITY Type of indicator: Sustainable practices

6. Do you consider that agriculture areas under sustainable practices is a relevant indicator?

Yes/No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

TRANSFORMABILITY Type of indicator: Restoration practices

7. In your opinion, are the restoration practices applied in the Delta area a relevant indicator?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

For discussion: What kind of restoration projects and policies are more important and why?

VULBERABILITY Type of indicator: Air quality/ Carbon footprint

8.1. Do you consider the average Carbon footprint per person in the delta compared with the national/state area Carbon footprint is a relevant indicator? The Carbon Footprint measures in Kg of CO2 the total amount of GHG emissions that are directly and indirectly caused by an activity or are accumulated over the life stages of a product measured. It informs about the GHG emissions (Galli et al., 2012)

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

8.2. Do you consider the average Ecological footprint in the delta compared with the national/state area Ecological footprint is a relevant indicator? The Ecological Footprint measures humanity's demand on the biosphere in terms of the area of biologically productive land and water required to provide the resources we use and to absorb our carbon dioxide emissions. This area is reported in global hectares (Taleghani et al.) – hectares with world average productivity (BIP, 2010) (Added later)

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high x

8.3. What about nitrogen deposition in wet and dry areas? (Added later)

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

For discussion: Could you mention which gas is more harmful? (CO_2, CH_4, N_2O, or fluoride gases (HFC, PFC or SF_6))

VULNERABILITY Type of indicator: Human health impact/Well-being

9.1. Can the human health affected by water and air pollution within the delta be considered as a relevant indicator?

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

9.2. Do you consider well-being of communities directly dependent on ecosystem a relevant indicator? (Added later)

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

VULNERABILITY Type of indicator: Tourism and recreation

10. Do you consider that the impact of the tourism sector within the delta areas is a relevant indicator?

Yes/No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

INSTITUTIONAL CAPACITY Type of indicator: Access to improved sanitation/Access to improved drinking water

11. In your opinion, can access to improved sanitation and drinking water be considered relevant indicators? (Added later)

Yes /No

Why

How can it be measured?

Very low	Low	Medium	High	Very high

INSTITUTIONAL CAPACITY Type of indicator: Access to information, participation and justice. Multi-stakeholder platform

12.1. Can the access to information, participation and justice be considered a relevant indicator?

Yes /No

Why money

How can it be measured?

Very low	Low	Medium	High	Very high

12.2.What about gender equity to access information, participation and justice? Should it be included in the indicators list?
Yes /No
Why money
How can it be measured?

Very low	Low	Medium	High	Very high

12.3. Do you consider that a multi-stakeholders platform to enhance collaboration and cooperation among stakeholders can be considered a relevant indicator?
Yes/No
Why?
How can it be measured?

Very low	Low	Medium	High	Very high

For discussion: Do you have any examples of a multi-stakeholder platform already existing in the management of the California Bay?

INSTITUTIONAL CAPACITY Type of indicator: Assessing management plans

13.1. Do you think that assessing the management effectiveness of protected areas is a relevant indicator? (Added later)
Yes/No
Why
How can it be measured?

Very low	Low	Medium	High	Very high

13.2. Do you consider that assessing the progress of IWRM and ICZM plans a relevant indicator of assessing the resilience of ES in deltas?
Yes /No
Why?
How can it be measured?

Very low	Low	Medium	High	Very high

Additional comments or suggestions

Appendix D: Type of categories

Table 8. Categories of answers per indicator

Cate-gories	1.1. Protection status		1.2. Trends in coverage of protected areas		2.1. Red List Index		Trends in invasive species	
	Why	**Measure**	**Why**	**Measure**	**Why**	**Measure**	**Why**	**Measure**
1	Relevant Federal (2), local (city/county) and federal (4) jurisdiction protection rather than international. Better state protection (11)	public policy evaluation (1&5)	when natural areas (wetlands) or natural habitat are increased to improve the system's health (2,3,6-8&11-16)	area of protected habitats in ha (1,7&16)	It is a source of information about important species (1,5,6&10)	monitoring individual key species (3,6,7,9&13-16) and their distribution, abundance and valid rates of species (9)	Depending on the type of species: natural or unnatural invasive (1)	monitoring systems (diversity with and without invasive) (1), number, trends and effects (2-4,6,12,15&16)
2	good management of protected areas keep the system in good health (7)	legal framework consensus over protection regulations on EC across borders (3)	if it doesn't involve displacement of people (4)	mapping, GIS (2,3&13)	State and Federal law protect local species (2)	combine monitoring with observations (5)	invasive species can collapse the system (2)	field surveys from individual restoration projects (5)
3	to keep the balance between human communities and the ecosystem (8)	type of monitoring programme (5,12&13)	proportion, connectivity, distribution and the size of the past land covers (5)	monitoring systems, programs (2,5,8,12&14-16)	health of the system (7,11&13)	population surveys over time (6&9)	with climate change the concept of invasive species changes (3,10,11&16)	ratio between native and no native species (7)
4	governance and authority of protecting entities (12&16)	mapping the size of protected areas (8&14-16)		scientific research (2)	It depends on the authority of the entity that develops the list of species (10)	remote sensing for suitable habitat (9)	stress or have negative impact on the system (3,8,12,13&15): food web (2,6,11), threaten local species (2,4,&11), recreation and humans (11)	mapping their presence, distribution over time (9)

5		scientific research (5)		accommodation space to know flexibility for changes (9)	taking into account climate change is not an important indicator anymore (16)		authority of policies	areas with aquatic weed difficult to enter by boat (11)
6				% of habitat lost (16)	Not familiar (2, 3,6,9&16)			

Table continuation

Cate-gories	3.1. Agricultural GDP		3.2. Fish overexploitation		3.3. Biodiversity for food		4.1. Water quality	
	Why	**Measure**	**Why**	**Measure**	**Why**	**Measure**	**Why**	**Measure**
1	GDP is a market measure (1)	happiness index (1)	relevant for native (resident) fish, not migratory (2&10)	monitoring systems (6&13)	depends on the context of the delta (2,13&14)	Quantitative approaches of food services and medicine that come out of a particular region (3)	it is important for the ecosystem health and the organisms (3-5,7,9,10&14-16)	monitoring system in place (pollutants, salinity, nutrients) (1,7,12,14&15) the toxic forms (2) like algae blooms (9), discharge points (4). Maximum daily load (6)
2	it depends on the local context and the importance of agriculture (1-3,5,6,14&16)	crop value/crop+ other sectors value (3,9&16)	depending on the species (5)	ratio of fish population of marine reserves/fish population outside marine reserves (3)	less biodiversity decreases ES (4)	Monitoring systems. Measuring trends or loss in that biodiversity as a result of a particular activity (6&7)	supply water to people, agriculture and fish (6,7,11,13&16)	compare the measurement with the historical flows (7)
3	not relationship with resilience (8)	ratio of the delta AGDP/other delta's AGDP (10)	an indicator of ecosystem's health (8,9,16)	% of fish taken out within the biological limits (4,14,15)	it is an indicator of environmental degradation (6,7,11,12,15)		It is important but some parameters are still a problem for some species, like T or sediment leaching (1,2)	
4	if agriculture production is large in the delta is useful to compare it with the	AGDP/ state GDP (10)	delta is a nursery for fish (12)				it is relevant for decision making (8)	

	state GDP (11&13)							
5	Better to compare the net cost of agriculture with other costs (water, levee maintenance or other ES (16)		direct measure of resilience (3,4&14-16)	catch per unit effort (9)				
6				demand vs supply fish costs (12)				

Table continuation on next page

Cate-gories	4.2. Dam's density		4.3. Water footprint (WF)		5. Self-recovery		6. Sustainable practices	
	Why	**Measure**	**Why**	**Measure**	**Why**	**Measure**	**Why**	**Measure**
1	dams change the fluctuations and the frequency of flows (1,3&15)	ratio between actual flow and historical flow (1,3&12)	informs whose water is and where is coming from (1)	better measure water exported (1&3)	it is part of the conventional definition of resilience (1,2,13&16)	monitor the important ES before and after a perturbation (2-4,6-8 10,12&14)	they decrease pressure on the system (1)	existing monitoring systems (2,7,9&10)
2	dams density and size (2&16)	% of flow diverted (4)	it informs about the water consumption (6)	compare the water exported with the natural flow or human use (4)	it is important but depends on the type of disturbances (4)	remote sensing (9)	depending on how sustainable agriculture is defined (4,7,8-10,12&16)	in % of sustainable agriculture vs not sustainable (3,15)
3	dams determine water availability (3&7)	monitoring of the hydrograph (9)	water used per day per person over time (10)	in a district divide the water supply/ people using the water (10)			will improve the overall health of the system (13&14)	maximum daily load from agriculture (6)
4	reduce the sediment loading (4&12)and organic matter to go downstream, subsidence (12)	volume of water stored behind the dam (10)	Because if WF is low means that there is more equity who is getting what, how, when and where (12)	the subsidence of the land in m or feet (12)				through pesticides and fertilizers use, farming techniques (13)
5	highly modified system (8,16)	monitoring of species and water quality (14)	it's an indicator of economic activity (13)	reduction of water use per capita for food and other services (13&15)				

6	good to base decisions because they blocks the access to migratory fish upstream (9&15)		gives an idea about the stressors of the system (15)	ratio between current flow into the Bay with the historical flow (16)				
7	Reduces resilience (4&7) and increases social resilience (10&13)		if WF is compared with the GDP of the delta shows the value of water and how efficient was the use of water (16)					

Table continuation

Cate-gories	7. Restoration practices		8.1. Carbon footprint		8.2. Ecological footprint		8.3. Nitrogen deposition	
	Why	**Measure**	**Why**	**Measure**	**Why**	**Measure**	**Why**	**Measure**
1	relevant if they are planned with a future vision (1&12)	monitoring (1-5,10-14&16)	delta produces and sequesters carbon (5)	carbon sequestration (1&5)	it takes into account many more ES (3,5&7)	monitoring (5&15)	important for health of the ecosystem (2,4&7)	Chemical analysis of N forms: total N (3) ammonia, ammonium and nitrate (7) and urea (9)
2	relevant for learning process (3,16)	GIS mapping (2)	the effect of GHG emissions is too global (1,4&9-12)	biomass (1,3&5)	informs about the state of the system (6&13)	% of habitat lost (6)	it can be a limiting factor (3&10)	
3	enhance ecological health of the system (4,14&15)	acres restored (4,8)	if CF includes also to CH_4 and NO_2 besides CO_2 is relevant to address climate change (14)	measure GHG produced (3,6)	looks at the long term when CF is a daily measure (8)			
4	if they are linked to policies (5&9)	density of the restoration practice (8&13)	deltas are food supply for people (16)		a locally measure, not global like CF (11)			
5		money spent over time (15)						

Table continuation

Cate-gories	9.1. Human health		9.2. Well-being		10. Recreation		11. Sanitation & drinking water	
	Why	**Measure**	**Why**	**Measure**	**Why**	**Measure**	**Why**	**Measure**
1	balance between human health and ecosystem health (3,6,8&12-16)	diseases of people living in or around the delta (2,3,7&15),mortality and mobility rates (3)	it helps to engage people if they have good health conditions and well-being (2)	measure health, microbes or bacteria (2)	depends on the type of tourism (1,4&7)	monitoring (1&14)	preference to live in healthy places (2)	availability of water (4)
2	used for decision making (9)	water (4&5) and air monitoring methods (5)(6)	informs about the sustainability of the communities of the delta (6)	index of well-being (4): health outcomes, economic status, ecological footprint (14&15), through surveys (15)	deltas have recreational value (5,6&8) with a positive impact (6,13&14)	number of tourists (5,6,12&13)	balance between socio and ecological systems (3,6&7)	accessibility to water (5) in m and % of people (9,10&12)
3		public statistics of human health (14)	correlation between community health and ecosystem health (7&13-15)	resources of the community, children going to school(6)	when tourism sector is compared with agriculture or manufacturing sectors (9)	dollar spent per year (5,12,14)	Sanitation & drinking water are human rights (4&11)	monitoring the water quality (7)
4		hospital visits (15)	it's an economic measure (12&16)	Bhutan happiness index (9)	it's one of the ES of deltas (10)		gives information about bad policies to base decisions on (12&16)	
5					economic driver (12&15)			

Table continuation

Cate-gories	12.1. Information/participation/Justice		12.2. Gender equity		12.3 Multi-stakeholders platform		13.1 Protection plans	
	Why	**Measure**	**Why**	**Measure**	**Why**	**Measure**	**Why**	**Measure**

1	indicator of governance process (1,10&15)	measure awareness and engagement (4)	relevant in countries where women have less power (1,2,6&13)	age at which women get married (12)	success in achieving objectives and outcomes (2,12,13&15)	number of people participating, observations (1&13)	can be relevant for large areas (3)	monitor the plan's goals over time (2,5-10,12,15&16)
2	people can have bigger influence if they are informed (4)	compare management regimes with people expectations (5)	more equity means more resilient (4)	freedom to choose the partner (12)	for integration (3)	number of partners of a project or report (2&12)	depends on the type of management plan (4) adaptive management acknowledge changes, uncertainties (5&16)	
3	delta citizens have bigger responsibilities upon policies (5)	surveys (6&9)	women are the engine of perpetuation of the society (12,14&15)	number of children (girls and boys) (12)	awareness (4)	comparison of management practices with the suggested by the coalitions of people (5)	indicates people's awareness about the health of the system (7)	
4	access to education is vital (12)	head counts, observations (9&15)		mortality of children (12)	it's a democratic expression (5)	diversity of groups involved (10,12)	informs if plans are success or failure in terms of resilience (8,10,12,13&15)	
5	is relevant but depending on the context (14&16)	global health at WHO: happiness, heath, access to resources, safety, well-being, human rights (12)		access to education of children (12)	wide management improves the system's health (7)	number of existing platforms (14&15)		
6					provides participation (10&11)			
7					it is relevant but it slows down the process (15&16)			

Table continuation

Cate-gories	Integrated Resources Water Management & Integrated Coastal Zone Management	

	Why	Measure	Suggestions	Suggested indicators
1	plans are good for the learning process (1)	monitoring of the inter-agencies activities (1): costs (6&14), people's engagement (4&14)	time and space where indicators are applied is important (1,3,9&15)	sediment leaching (2)
2	integration means to get the best outcomes (2)	compare scale of the project with the scale of the natural system (2)	select the key ecosystem services that are essential for the delta (5)	% of historical wetlands still present (2)
3	it has a long term perspective (3)	monitoring the outcomes of plans (3-6,8,9,12&14)	define success and a way to measure it (5)	net productivity of the system (3)
4	depends on the plans that focus on resilience (4), ecology, sociology(4-6&9)		understand the trade-offs between the ES (5)	permanent species vs migratory or transitory species (fish, birds) (15)
5	value in a democratic society (12)		take climate change into account when selecting the indicators (9)	
6	implementing those plans increase the resilience of the system (15&16)		It maters who is the authority in charge of monitoring, protecting (10)	
7			monitor the fallow land (12)	
8			compare developed with developing countries (14,15)	

Appendix E: Summary table of indicator relevance for California

Table 9. Summary table of indicators relevance for California

Nº	Indicator/ sub-indicator	Score	Relevance of the indicator	How to measure it
1.1.	Protection status	★★★½☆	State and Federal (National in Europe) protection rather than international	GIS mapping/ monitoring species, populations, habitat and good resources over time.
1.2.	Land use changes	★★★★½	Relevant if industrial, urban or agriculture areas are transformed into natural habitat	Monitor wildlife/Size of protected area in ha
2.1.	Red List Index	★★★★☆	It informs about the state of key species in the delta	Monitoring key species/ observations/population surveys/remote sensing
2.2.	Invasive species	★★★½☆	They threaten local species, change food web dynamics and affect humans	Monitoring diversity, trends and effects of invasive species
3.1.	Agriculture GDP	★★½☆☆	It's a market measure than human well-being	AGDP with the state GDP/ AGDP with the costs of other sectors within the delta
3.2.	Fish overexploitation	★★★★½	Direct measure of ecosystem health and resilience	% of fish taken out within biological limits/ monitoring individual fish species
3.3.	Biodiversity for food and medicine	★★★☆☆	Biodiversity is always a good indicator but depends on the context	Measure food services and medicine that come out of a particular region
4.1.	Freshwater quality	★★★★★	Life support	many indicators: pollutants, salinity, toxic algae blooms, maximum daily load.
4.2.	Dam's density	★★★★☆	They modify ecosystem's functions. They reduce ecological resilience and increase socio-resilience	Compare actual flow with historical flow/monitor changes in the hydrograph
4.3.	Water footprint	★★★☆☆	Gives an idea about the stressors of the system but not about ecosystem's health	Water exported/water supply per capita in a district/or water use for food or other sectors
5.	Self-recovery	★★★★☆	Direct measure of resilience but not useful if the system already passed the tipping points	Monitor important ecosystem services before and after a perturbation
6.	Sustainable practices	★★★½☆	Decrease pressure on the system improving its health. Not so relevant due to climate change	Monitoring specific attributes of sustainable agriculture: water quality, fertilizers, biodiversity

7.	Restoration practices	★★★★☆	Improves ecosystem's health and the ecological resilience	Monitoring diversity of species and functions of habitat over time
8.1.	Carbon footprint (CF)	★★⯨☆☆	The effect of GHG emissions is global so it is not useful to measure CF in the delta	Measure biomass or GHG emissions
8.2.	Ecological footprint (EF)	★★★★☆	Informs about the state of the ecosystem and it takes more ES into account than CF	Difficult
8.3.	Nitrogen deposition	★★★☆☆	Nitrogen deposition is not a good indicator, better nitrogen input which is already included in Sustainable practices indicator	kg N/ha/yr
9.1.	Human health	★★★★☆	Ecosystem is heathy people living here as well	Public health statistics on diseases, mobility, mortality, hospital visits
9.2.	Well-being of communities	★★★★☆	Correlation between ecosystem health, human health and well-being	Index of well-being / or Bhutan happiness Index
10.	Tourism and recreation	★★★☆☆	Tourism is one of the ES in deltas, although depends on the type of tourism	numbers of tourists visit/ or dollar spent per year
11.	Access to improved sanitation & drinking water	★★★★⯨	Sanitation and drinking water are considered basic human rights	Availability of water/ accessibility of water in m/ compare water quality of drinking water with the quality of natural systems.
12.1.	Access to information/participation/justice	★★★★☆	People with information have more power, more influence, although it is context dependent	N^{o} of people participating/ surveys/ or comparing management regimes with people's expectations
12.2.	Gender equity	★★★★☆	Important in developing countries. Women are the perpetuation engine of society	what age women marry/ number of children/ mortality rate of children/ access to education
12.3.	Multi-stakeholders platforms	★★★★⯨	Successful outcomes based on the plan's objectives. Improves the health of the ecosystem	N^{o} of people and the groups they belong to
13.1.	Management effectiveness of protected areas	★★★⯨☆	Informs if plans are a success or failure in terms of resilience	Monitoring the goals of plans over time
13.2.	Progress of IWRM and ICZM plans *	★★★★☆	Integrated plans aim for the best outcomes having a long term perspective	Monitoring the outcomes of plans

Appendix F: An overview of Sacramento-San Joaquin Delta

RESISTANCE Type of indicator: protection status of the ecosystem/nature area

1.1. In your opinion, being the delta or part of the delta area under a national or international protection status is a relevant indicator for monitoring the resilience of ecosystem services?

The delta of California has national protection (Interviewee 2). BCDC is protecting the system at local level (city/county) or regional (New York State Department of Environmental Conservation) with a focus on CC adaptation (Interviewee 4). Our delta is an inland delta and it doesn't have the function of delta anymore. The federal and the state agencies are in chard of ES. We have jurisdictions that are responsible of a broader group of ES including natural services by biodiversity and wildlife support. ES have been restricted to commercial and recreation uses. These jurisdictions rise us the question of what shall we do with the delta to still provide those ecosystem services. For example, there are species of fish that now are endangered or moving to extinction, the federal policies requires in a delta some of this natural focuses to be restored by law in order to protect or restore those species (interviewee 5). We have multiple jurisdictions overlapping and it some way that is challenging (interviewee 6). There is nothing resilient in this delta anymore, the only way to make it more resilient is by engineering solutions. Delta Stewardship Agency is investing in strategies to figure out what levees to prioritize in terms of protection. But the delta will never look like it was 20 years ago. It is a good indicator to show that this delta is not going to resilient. It should be protected 150 years ago because right how it is not going to make a difference thinking about the impacts of CC. To make it resilient you have to build up peat soil, elevate the subsided islands. With the next catastrophe event the system will shift to a new stage that may or not be resilient, something that we don't know (Interviewee 9). In the Bay area the BCDC and Delta Commission have different authority and protection roles that don't overlap (interviewee 10).

In California although the delta is not in very good state is well protected compared to other deltas. Through the California environmental quality act (SEQA) that dictates how impact should be mitigated in the delta, we have the delta protection commission, delta stewardship council, there is a strict monitoring system in the delta (interviewee13). In Europe international protection is good but in US it is better federal protection is good versus the state protection (interviewee 16).

1.2. Do you think that the change in coverage proportion of the different land use categories in the delta area is a relevant indicator for assessing resilience of ES in deltas?

There are already huge improvements in the health of the estuary from restoring agriculture to wetlands (currently 30.000 acres of wetlands and the objective is 50.000) (Interviewee 2). We are trying to restore 30% of the historical wetland (Interviewee 4). In this country there is a Federal Agency, the US Geological survey, it maintains the national land cover. Every state adds more detail about that land cover going down to the local jurisdiction (interviewee 5). Our delta used to be a massive wetland (70.000 acres). The displacement of people it is not a good solution, there are 25 mill people living in LA who need water. The government of California is proposing tunnels that go around the delta and they allow the water to go with its natural flow. That could improve a lot the delta, it is a highly modified system (interviewee 8). We want to establish more marshes to keep up with the effects of SLR, however the current land use limits this opportunity (interviewee 10). Our framework (resilient landscapes, Estuary institute of SF) focus more on create functioning landscapes not only habitat (interviewee 16).

<u>RESISTANCE Protection status of fauna and flora species: Red List Index/ Invasive species</u>

2.1. In your opinion, is the Red List Index a relevant indicator to assess resilience of ES in deltas?

Not used in California (Interviewee 1&2). We use key species indicator (Interviewee 3). Not familiar with the Red list index of the IUCN (Interviewee 4). The State of California has a database that predicts the distribution of species, based upon the natural history of species within the delta. There is a team of ecologists working on and different agencies and the models predicts the distribution of species (Interviewee 5). In the US we have the Endangered Species Act where species are put in categories of endangered, threatened, special status. The listing has authority that the Fishing Wildlife Agency has to protect those species and it is powerful authority (interviewee 10). You don't use the red list in California, we use the State endanger species act and US federal list which are more detail that the IUCN red list (interviewee 14). In California we are expecting to see large changes in elevation and latitude of certain species. We should be thinking how they are gonna move and what habitat they need to move into as opposed to protected the last remaining ones in a certain place (interviewee 16).

2.2. In your opinion, having invasive species that threatens local species within the delta area is a relevant indicator?

This is a huge problem in California. There are invasive species form Asia, from the East coast. They are threatening the local species and changing the food web. In the fresh part of the Estuary the ecosystem is collapsed because of water extraction and invasive species (Interviewee 2). They are not going to be a problem anymore if we take climate change into account, the system will change or shift with climate change and the native species will no longer be resilient if they don't shift with the local conditions (interviewee 4). It is expected that 90% of the biomass will be invasive species (interviewee 6). Due to CC and T increase we know that species will move to the north, to higher elevation. The ecosystem is changing with CC and other human stressors and it is going to continue changing. In 100 year it will be another ecosystem, is that resilient or not? We dont know (interviewee 10). National Marine Fisheries (NMF) have some good data and Fishing Wildlife has some good data. Nature Conservancy they do also studies on how to monitor invasive species (interviewee 12).

<u>RESISTANCE Type of indicator: Food. Agriculture GDP/ fish overexploitation</u>

3.1. Do you consider that biodiversity for food and medicine is a relevant indicator?

There are not too many species used as food or medicine in the delta (Interviewee 2). There is little human consumption from the delta (maybe some fish) (Interviewee 5). The rivers that were feeding the delta with water used to provide salmon fisheries that are declining (interviewee 6). Our food system is geared towards 5 principals: corn, wheat, berry, alfalfa and fish. This is an indicator of lack of diversity in our landscapes, monoculture (interviewee 12).

3.2. Is the agricultural GDP within the delta compared to with the national/state AGDP a relevant indicator?

In the US the agriculture GDP is very low compared to the national GDP. In developing countries could be a better indicator (Interviewee 1). The AGDP is very low in California compared to the state AGDP (interviewee 3&4,5). California was a massive wetland rich in peat soils which makes the Sacramento-San Joaquin Valley an enormous agriculture production sector. It still produces several hundred millions of dollars and it is an important economic component in California. We support 90% of fruits and nuts to the whole country. We often get political battles about what is the value of agriculture in the delta. The delta also supplies water to the south of California (25mill people). GDP is big in California but the AGDP is relevant for the local community (interviewee 6). Agriculture is a primary production in the delta. Moreover, California produces more agriculture products than other states (Interviewee 11). The central Valley exports a lot of agriculture and that lowers the biodiversity(interviewee 12). In the California delta there are two things: one is agriculture in the delta and agriculture that depends on the delta's water. So much water of the delta is exported to other places in big aqueducts and pipe lines. If you take out the agriculture from the delta will have relatively low impact in the State (interviewee 13).

3.3. Do you think that the proportion of exploited fish stock outside the safe biological limits is a relevant indicator?

In our delta is not a problem because there are not native fish anymore (Interviewee 2). We did good job in SF in cleaning the water, we have a very good water quality (Interviewee 4). The salmon is very relevant because it is migrating up to the delta. Other fisheries don't exist anymore in the delta (interviewee 6). There are not resident fish living in the delta anymore (interviewee 10). The Bay and estuary were important nursery for ocean fish and they've been destroyed, we can see that in the fish stock and fish population. They cannot go upstream anymore because of the dam (interviewee 12).

<u>RESISTANCE Type of indicator: Water quality and water quantity</u>

4.1. Do you think that water quality of freshwater ecosystems a relevant indicator? (Parameters: T, DO, pH, EC, major ions and SS)?

California has problems with temperature and sediment leaching that affect the water quality (Interviewee 1, 2) Mercury, ammonium from sewage, sediments and the toxics they contain, natural erosion form the mountains, pesticides, lack or excess of nutrients, keeping a nutrients balance such as phosphorus, specially nitrogen (interviewee 3). In this delta water quality is measured in 2 ways: discharge points form treatment plants or agriculture and ambient water quality Nutrients (N, P), mercury and selenium (interviewee 5)

Impacts on the water quality in the delta of California: mercury which concentrates in the fish and cascades on the food chain. Agriculture and municipal runoff affects the nutrients balance and therefore the food web. Salinity intrusion from the bay which will increase with the CC. We dammed all the rivers altering the flow of the water, we pump water out. The system is human operated to maintain enough flow and the water quality. The challenge to provide water to 25mill people in the south, to fish, to agriculture and drinking water is temperature control. There is a state agency making sure that the water is meeting the standards and who operate the system. In California we reverse the system, the rivers are low in summer and more water in winter. We store water in the winter to release it in summer (interviewee 6)

Large amount of water is exported for agriculture using pumps. As a result, the main problem of the freshwater is the salt intrusion which is a problem for plants, human consumption and crops. The system is highly regulated, it is more natural in winter when it rains. There are sewage plants that discharge high amount of ammonia with an impact on the water quality (interviewee 11). We had a long period of droughts the last years and salinity is also increasing (interviewee 12). In the US there are water quality standards measured by government agencies (interviewee 14). We have good water quality but the system is not resilient because it is highly engineered delta. First you need to know how the delta operates and know if the indicator shows something (interviewee 16).

4.2. Dam's density

Dams mess up the system, the whole delta catchment is full with dams. The system is 100% human modified, they cut the peaks and retain sediments (interviewee 4). We measure the resilience of the levee to failure, their ability to withstand earthquakes and flood heights (interviewee 5). All the streams that flow into Sacramento and San Joaquin river are leveed, the system is all human operated (interviewee 6). Army core of engineers and the local water boards have the data about dams (interviewee 12)

4.3. Do you think the water footprint, expressed as the average water footprint per capita in the delta, compared to the fair water footprint share per community is a relevant indicator? The water footprint measures the water consumption and the volume of water polluted.

California actually is importing water because we have 8 million people living but our agriculture exports a lot of water (Interviewee 1). The problem in California is not the individual use, it is the agricultural use. So, 80% of the water is used for agriculture products, it is diverted for that where is less than 20% used for industrial and water consumption. So, the water footprint unless you are expanding it to include agricultural input which is very difficult to do. In California, most of the rice and almonds are shipped out, they are not consumed here. That is why makes it difficult to look at the water footprint for the state because if something is going out of the country. 90% of the agriculture produced in the delta is shipped to other states or countries, maybe only 1-2% is consumed in the delta (Interviewee 3). The delta is used as a way to transport water to the South of California. However, these people do not use the water from the delta. It is difficult to quantify the water of the delta (interviewee 5). The south of California is consuming a lot of water and agriculture as well. We need to reduce that water footprint (interviewee 6). Pumping freshwater has lowered the central valley by 40 feet (12m) since the middle of the last century. That is an enormous geomorphic change in the State because of the enormous water footprint. That water is also carrying bad components from agriculture and transporting nitrogen in pathways that are not sustainable also (interviewee 12). I don't see the use in California but yes in other deltas (interviewee 13).

<u>ADAPTABILITY Type of indicator: Recovery</u>

5. Do you consider the self-recovery of the ecosystem after natural hazards can be considered as a relevant indicator?

The delta of Sacramento is beyond the tipping point, it cannot recover to its natural state anymore. So, this indicator it is not useful in California (interviewee 3). Our delta has a limited wat to recover, it is in the point that we are losing native species (Delta Smelt which was used as a specie indicator). Deltas are systems with the ability to sustain after perturbations because species develop strategies over time to maintain diversity. But sustainability is affected by the way we changed the system pushing it to the limits. It is not resilient anymore (interviewee 6). The system is too artificial to say something about the resilience of the ecosystem (interviewee 12). It's a highly modified system, it's not resilient anymore (interviewee 16).

ADAPTABILITY Type of indicator: Sustainable practices

6. Do you consider that agriculture areas under sustainable practices is a relevant indicator?

We have BMP (best management practices) where people take track of them, there is also wildlife friendly agriculture where people are trying to in the seasons. The problem we have is that the areas used for agriculture are subsidising, it is already 10 feet or more below sea level. Farmers dry to soils for agriculture and to get water supply. Additionally, it is not possible to do sustainable agriculture because burning peat soils huge amount of CO2 is emitted to the atmosphere (Interviewee 2). Over time we reduce a lot the amount of input from agriculture and we are still working on that. We have a problem with Selenium which is increasing naturally and it is introduced in the system because we pump out water. I causes major ecological catastrophes in the past (interviewee 6). The agriculture should move out of the delta to be sustainable, it is not sustainable in the delta (interviewee 14).

TRANSFORMABILITY Type of indicator: Restoration practices

7. In your opinion, are the restoration practices applied in the Delta area a relevant indicator?

Trying to change the objective of the restoration projects with a vision into the future and not into the past. All the restoration projects applied until now were with a backward looking manner, 150 years ago (Interviewee 1). We are restoring wetlands in our delta (Interviewee 2). We do a lot of restoration specially to increase the resilience of the existing native populations (interviewee 4). Our role (Delta Conservancy) is to restore agriculture areas into wetlands.

VULBERABILITY Type of indicator: Air quality/ Carbon footprint

8.1. Do you consider the average Carbon footprint per person in the delta compared with the national/state area Carbon footprint is a relevant indicator?

In California we look at the carbon sequestration, at the biomass, how to keep the carbon in the soils because the peats soils have a lot of carbon, but they have been degraded a lot over the last 50 years (Interviewee 1). The population density in the delta is low (interviewee 3). The delta of California is highly organic because of the peat soils, there is an emissions of 8-9 tons per year/acre just from oxidation which is much higher that other parts of agriculture in the state (interviewee 6). It is a specific measure for peat soils, like the delta of Sacramento, but not all deltas have peat soils (interviewee 14).

8.2. Do you consider the average Ecological footprint in the delta compared with the national/state area Ecological footprint is a relevant indicator?

The drivers in our system are the species that are listed as threatened or endangered, and there is common knowledge that 90 to 95% of the habitat has been converted and most of the ecological processes have been significantly altered (interviewee 6)

8.3. What about nitrogen deposition in wet and dry areas?

The nitrogen deposition isn't a big deal in the delta of California (Interviewee 1). It is a limiting factor in the delta of California (interviewee 3). Nitrate and ammonium are a big deal here from sewage treatment plants and pipes (interviewee 10).

For discussion: Could you mention which gas is more harmful? (CO_2, CH_4, N_2O, or fluoride gases (HFC, PFC or SF_6)) methane and carbon oxide. Methane specially (interviewee 3) Mercury and toxic algae (interviewee 6)

VULNERABILITY Type of indicator: Human health impact/Well-being

9.1. Can the human health affected by water and air pollution within the delta be considered as a relevant indicator?

It is not a problem in California (Interviewee 2, 4). We've got blooms algae in summer which are toxic and it is probably a result of water quality and temperature. That can have direct people effect and animals (interviewee 6).

9.2. Do you consider well-being of communities directly dependent on ecosystem a relevant indicator?

We have a lot of communities in the delta who have constrains because of flood control issues. That affects the economic vibrancy of the community, most of them are considered dying communities because they cannot grow, they cannot develop and they are stating and declining (interviewee 6)

VULNERABILITY Type of indicator: Tourism and recreation

10. Do you consider that the impact of the tourism sector within the delta areas is a relevant indicator?

For us it is not a big deal (interviewee 2). We are trying to bring some economic benefit to the delta with historical, ecological value of the delta, wine tourism (interviewee 6). In the US any town has a board that has a Chamber of commerce where you can find information about the number of tourist in that area (interviewee 12).

INSTITUTIONAL CAPACITY Type of indicator: Access to improved sanitation/Access to improved drinking water

11. In your opinion, can access to improved sanitation and drinking water be considered relevant indicator?

In the central Valley there are some people still getting water out of the well. So, they have limited water in the dry period (Interviewee 4). As a state agency (Delta Conservancy) we are supposed to bring all different partners together. The regulatory agencies have tried to establish how much water we can take out of the system without making the species going extinct (interviewee 6).

INSTITUTIONAL CAPACITY Type of indicator: Access to information, participation and justice. Multi-stakeholder platform

12.1. Can the access to information, participation and justice be considered a relevant indicator?

BCDC work with local communities trying to engage them, to increase their awareness (interviewee 4). That is one of your major roles. A fundamental problem is that the communities have been excluded from this plan because they will never archive the State interests. But the State interests is making sure that the economy of California persists and continue to supply water to 25mill people and all the agriculture. They thought that you will never be able to do what you need to do to fix the delta if you have the delta community participating in the discussion because they don't want to see anything changed. It took one year to accomplish (interviewee 6).

12.2. What about gender equity to access information, participation and justice? Should it be included in the indicators list?

It doesn't happen in our system but I can see that in developing countries.

12.3. Do you consider that a multi-stakeholders platform to enhance collaboration and cooperation among stakeholders can be considered a relevant indicator?

In California it is required by law. The delta independent science board announce the meetings 10 days in advance to invite all the stakeholders. They have to listen to all groups that are participating in the meetings before the decision is taken. The meetings are hold during the working hours in Sacramento (Interviewee 1). It is the way how we achieve a lot of the restoration projects in the Bay (Interviewee 2). We are pushing people for resilience, we are working with local governments and local communities to increase awareness on vulnerability and potential adaptation measures. Our goal is to come up with an adaptation plan (interviewee 4)

For discussion: Do you have any examples of a multi-stakeholder platform already existing in the management of the California Bay?

INSTITUTIONAL CAPACITY Type of indicator: Assessing management plans

13.1. Do you think that management effectiveness evaluation of protected areas is a relevant indicator?

There are many protected areas but not enough money to manage them (Interviewee 2). In our system the biggest challenge is the flow into the system to meet agriculture and species needs. Managing the system is key but it is really hard to identify in a heavily altered system how you manage effectively. (interviewee 6). We distinguish between inputs, outputs, outcomes and wat to measure all of them. . The inputs are more directly linked to the actual action, the outputs are more tangible and easy to measure and outcomes are hard to measure. And then you have to measure other drivers to figure out if that thing you are measuring is an indicator of outcome or caused by that action or something else (interviewee 10). In America politically we are still not allowed to talk about climate change in many places, in the South. People don't talk about CC, they talk about events, big storms, floods, levee failures. Washington is not ready to embrace CC as a factor for leading policy innovation. Probably more important in other countries because their economy is linked to what they call catch-up growth. Instead of innovating in their own right to increase quality life, they are trying to model after countries like US, or Japan. Fishing game, EPA, FIMA are committed to track data based on matrix for any given environment (interviewee 12).

13.2. Do you consider that assessing the progress of IWRM and ICZM plans a relevant indicator of assessing the resilience of ES in deltas?

Every year we have a science meeting for Bay and Delta science, one year is held in the Coast and one year in the Bay (Interviewee 1). There is not overlap between the ocean and the Bay people (interviewee 2). There is a delta plan that belongs to the Delta Stewardship Council (interviewee 5). The previous program I worked on it was the CALFED delta program. That was a 8billion dollar/30 years program to address the California water system from the entire watershed from Sacramento, San Joaquin system and the delta. For 10 years we worked on the CALFED delta program and it tried to fix everything and it failed and then we decided that the big problem is just the delta and we spent 8 years trying to fix that and it's failing too. In our system things are so complex that there is no way to answer that. I think integration is a great thing, we have to try to address all these things but the issues are so big that when we try to integrate them we almost fail out of complexity. We made progress but to make a change we need this big progress to be sustainable. The California Action Plan came out a couple of years ago and that really is an interesting experience. It is a high level document that says everything we need to do for the California's water system: efficiency, reuse, desalinisation, deal with delta issues, all these things that we need to do collectively (interviewee 6). California state department of WR they have a program of integrate regional water management. They have a way of measuring that, they require urban and agricultural agencies to provide plans on how they gonna do it and I think what they do is to measure again those plans (interviewee 10).

Additional comments

What question I rise up is if the current monitoring system will still be effective in 10 or 30 years (Interviewee 1). Sediment leaching can be a relevant indicator. And wetlands as an indicator, we use a lot how many and how much wetlands have been recovered (% of the historical wetlands recovered) (interviewee 2). For any delta to provide feasible levels of multiple services, none of the services can be maximized. That happened in this delta, they maximized the service called water supply to the detriment of many other services. And now we are realizing that and we are striving to get back other services, and it is very difficult (interviewee 5).