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General model of socio-economic vulnerability

WP's leader: NTNU

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1. Description of deliverable

We developed a model to analyze the vulnerability of coastal communities to the effects of climate change on the marine ecosystems. This model constructs over the VAS Model of Turner et al. (2003) and applies to the specific context of the interactions between climate change, marine ecosystems and coastal communities. The Turner's model describes vulnerability in terms of exposure, sensitivity and adaptative capacity (resilience). Our application of the Turner model is the key conceptual framework to the socioeconomic approximation of OCEAN-CERTAIN both, in general and as a guide for the applications that we will develop in the three case studies of the project (Norway, Turkey and Chile).

The model has an environmental and a socioeconomic component. The environmental side of the model is based on the shared knowledge of the partners of the project collected during a workshop held during the kick-off meeting in the project using a system thinking technique. The information collected was later analyzed and summarized in a simplified model using a Fuzzy-Cognitive Mapping technique. Both methods allowed us to understand what are the key elements of the marine ecosystem being affected by climate change in the context of the OCEAN-CERTAIN project and also the effects of these processes on the different resources that are important to coastal communities. These resources are the key elements that connect the environmental component with the socioeconomic component of the vulnerability model.

Once the resources and environmental services that could be affected by climate change are identified, we are able to analyze how different scenarios of climate change could potentially affect these resources and understand how wills this affect coastal communities. In this context, we re define the concepts of exposure, sensitivity and adaptative capacity in terms of our applications. First, we define exposure as the way in which the good and environmental services that are important for a given coastal communities are affected by climate change. Second, we define sensitivity as how relevant communities (particularly the three economic sectors that are the focus of our analysis: fishing, aquaculture and tourism) consider that these impacts are in terms of their welfare. Third, we define adaptative capacity in two terms. We consider private adaptative capacity as the way in which individual private users can adopt different strategies to cope with the effects of climate change on their resources and welfare. We define public adaptative capacity as the way in which the government or the organized community, either at the central or the local level, can develop strategies to cope and respond to the effects of climate change on the environmental good and services that are important for them. All these responses can in fact create feedbacks to the environmental side of the model reconnecting the socio-economic and the environmental components of the model.

In this document we briefly describe the way in which the Model of Socioeconomic Vulnerability has been developed, its main components and how the model will later be used to explore the measurement of adaptative capacity both from and objective and a subjective perspective during the stakeholder workshops and as the base for the decision support system that is one of the important products of the project.

This work was carried out as described in task 3.2 and more specifically the sentences *"In this task, researchers will construct/refine a general model of social vulnerability based on the Vulnerability Analyses for Sustainability (VAS)(Turner II et al. 2003). This general VAS model will, in subsequent tasks, be adapted to the individual, local case-studies, generating specific versions* *for each. The general VAS model will focus on the socio-economic vulnerability of coastal communities, especially on the three target sectors most directly impacted by changes in the food web: fisheries, aquaculture and marine-related tourism. Socio-economic vulnerability is recognized as a function of the sensitivity of the sector to the climatic and non-climatic stressors, the degree to which the sector will be exposed to these stressors (exposure) and the ability of the natural and socio-economic systems to adapt to changes (IPCC 2007). A large number of variables have been identified as determining adaptive capacity (see for example Füssel 2009 and Cutter et al. 2009 for an overview); in this general social vulnerability model, social cohesion/division and climate skepticism will be incorporated into it at the outset. Climate change poses many potential risks and some benefits to socio-economic systems, with the mix of risks and benefits changing over time and in relation to events (ie., the dimensions of climatic and non-climatic stressors and changes in the food web). The analysis will focus on the vulnerability of the fishing, aquaculture and tourism sectors, with particular attention paid to the degree to which tradeoffs might occur among these sectors, but will also on key areas of broader community vulnerability: socio-economic development, gender vulnerability and general health and welfare. The analysis will also take timeframe into account: both the pace of change and how far into the future stakeholders can plan are important. In the case studies, differences in the socio-economic and institutional characteristics of the three countries under analysis will be crucial to understanding different aspects of the general model: in evaluating the local models, the general model will be reexamined.".*

2. Summary of contribution of involved partners to deliverable

NTNU and TALCA carried out the natural scientist workshop during the kick-off meeting to identify the key conceptual relationships between climate change and the environmental good and services relevant for the three economic sectors of our project.

VITO and GRIFFITH took the results from the workshop and built a simplified model using FCM techniques to understand the impact of different variables and scenarios of climate change.

TALCA and NTNU reviewed the literature on vulnerability models to construct the specific vulnerability model for OCEAN-CERTAIN.

TALCA built the conceptual model integrating the knowledge from the literature and the knowledge generated within the OCEAN-CERTAIN project trough the scientist workshop.

TALCA built the methods to use the model to obtain objective and subjective measures of socioeconomic vulnerability and how the model will be later used by other tasks in the project.

3. Details part 1

3.1 Introduction

Climate change poses many potential risks but also some benefits to socio-economic systems, with the mix of risks and benefits changing over time and in relation to events. While much attention has been paid to socio-economic impacts of and impacts on climate change (see for example: Adger 2006; Burkett and Davidson 2012; IPCC 2007; Malone and Brenkert 2008; Turner II et al. 2003), less research has been done specifically on linking climate change to sectors most directly reliant on living marine resources (LMR). These sectors have in OCEAN-CERTAIN been prioritized to fisheries, aquaculture and the tourism industries.

Research on climate impact on coastal communities has most commonly focused on the impact of Sea Level Rise (SLR) (e.g. Catenacci and Giupponi, 2013), flooding and coastal erosion (e.g. Szlafsztein and Sterr, 2007), threats to infrastructure, flooding, loss of marsh land and the impact of severe storms (e.g. Sano et al., 2013). Preliminary calculations of the impact of some anthropogenically-induced climate changes in the oceans predict a dramatic impact on living marine resources and the income of those who harvest them (CLAMER-Marine Board 2011; Cooly 2009; Turley 2010, 49). All of these effects are critical to look closer at within the socio-ecological system, and within the framework of a vulnerability model.

This deliverable is in accordance with Task 2, in WP3: Constructing a generalized socio-economic model of vulnerability (obj.6). The aim of this deliverable was to adapt the Vulnerability Analyses for Sustainability (VAS)(Turner II et al. 2003) to the case of Ocean-Certain, thereby developing a generalized socio-economic model tailored to the cases of this project. The purpose of this generalization of the VAS model is to be able to use in for the three case areas of Ocean-Certain, namely Chile, Norway and Turkey. The importance of having a general vulnerability model lies in the fact that though climate change will vary in its impact on coupled natural and social systems because the vulnerability of both natural and socio-economic systems differ (Richards et al. 2012), there are still elements that are generalizable. Human responses (adaptation and mitigation) can both change vulnerability and can also vary independently, adding more uncertainty to understanding interaction effects and climate change models. There is therefore great help in having an identical starting point in the model preparation for the specific areas, making it easier to determine both differences and similarities across bio-geographical areas globally.

The general model will focus on the socio-economic vulnerability of coastal communities, especially on the three target sectors we identified as most directly impacted by changes in the food web for OCEAN-CERTAIN. Socio-economic vulnerability is recognized as a function of the sensitivity of the sector to the climatic and non-climatic stressors, the degree to which the sector will be exposed to these stressors (exposure) and the ability of the natural and socio-economic systems to adapt to changes (IPCC 2007). The analysis will focus on the vulnerability of the fishing, aquaculture and tourism sectors, with particular attention paid to the degree to which trade-offs might occur among these sectors, but will also on key areas of broader community vulnerability: socio-economic development, gender vulnerability and general health and welfare. The analysis will also take timeframe into account: both the pace of change and how far into the future stakeholders can plan are important. In the case studies, it will therefore be possible to identify differences in the socio-economic and institutional characteristics of the three countries under analysis, which will later be crucial to the understanding of different aspects of the general model.

In light of this, we will first present the state of the art of the vulnerability framework as it is used today, followed by presenting a simplified ecological model of the effects of climate change on marine ecosystems alone. This is followed by an adaptation of the vulnerability framework to socio-economic states in coastal communities in Norway, Chile and Turkey. Two methods of measuring socio-economic vulnerability for climate change in these scenarios will be suggested, and plans for having thse tested on the given communities will also be presented.

3.2 Materials and Methods

Socioeconomic Vulnerability

The combination of climate change and other stressors is having a profound impact on the oceans and coastal systems and will continue to do so the foreseeable future (Põrtner et al. 2014; Wong et al. 2014). The OCEAN CERTAIN project is exploring the impact of this combination of stressors on the microbial food web and the biological pump. Among the significant questions this raises is how these changes will affect human communities.

The OCEAN-CERTAIN brings the notion of "coupled systems" to the study of this question. That is, it recognizes the need to for climate change research to connect the natural and social systems. Social forces and factors are key drivers of ocean stressors such as overfishing, climate change and its many consequences (such as ocean acidification and temperature), pollution and nutrient loading.

Human communities must in turn also live with the effects of the many changes on the oceans that they have helped to produce. In addition, human responses to changes in oceans (and to other factors) also produce feedbacks to natural systems. The "coupled system" approach is a foundational characteristic of the work of the International Panel on Climate Change (see for example Wong et al. 2014, 5) and vulnerability and resilience studies (Adger 2006, 268) (Stockholm Resilience Center 207). Coupled natural and human (or social) systems are increasingly known as socio-ecological systems (SES) (Ostrom; Redman, Grove & Kuby 2004; Stockholm Resilience Center 2007).

There is broad agreement that climate change, in combination with other stressors, will impact natural systems to different degrees, in different ways and at varying rates of speed. There is also broad agreement that human communities vary with respect to how climate change (or another "hazard") will affect them. These ideas lie behind much of the work on vulnerability, which has roots in research on risk, hazards and disasters, entitlements and human ecology (or political ecology) traditions (Agder 2006, 271; Cutter 2009, Fussel 2009) and which together identify a wide array of variables that may influence the way coupled systems experience and respond to changes.

In grappling with the complexities that vulnerability assessment presents, OCEAN CERTAIN builds on the basic definition used by the IPCC in 2007: *"the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extreme".* Vulnerability is in turn a function of the character, magnitude and rate of climate change and the variation to which a system is exposed, its sensitivity and its adaptive capacity" (Parry et al. 2007). It is this trinity, exposure, sensitivity and adaptive capacity, which provides the starting point for OCEAN CERTAIN'S work.

OCEAN CERTAIN's basic vulnerability model is based on the definition and conceptual model (or framework) of vulnerability found in Turner II et al.

(Turner II et al. 2003). They define vulnerability as "the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor" (2003, 8074). This definition is in turn derived from work on risks and hazards, climate impacts and resilience (Turner II et al. 2003, 8074). It explicitly incorporates a "coupled systems" approach. While there are other definitions and refinements (see for example IPCC 2012) (IPCC 2014) – perhaps to a confusing degree (Füssel 2009, 4), this definition incorporates implicitly or explicitly three key components that are at the heart of most variants: exposure, sensitivity and the system's response. Agder's review of the literature provides our definitions of two of the three terms: *Exposure* is the nature and degree to which a system experiences environmental or socio-political stress. The characteristics of these stresses include their magnitude, frequency, duration and areal extend of the hazard (Burton et al., 1993). *Sensitivity* is the degree to which a system is modified or affected by perturbation (page 270). Turner et al.'s third basic concept is "resilience" rather than adaptive capacity. This is the ability of a system to "handle" or "bounce back" from changes (or perturbations), retaining its defining structures and functions (Turner 2003, 8075). In more recent parlance, it is the ability of the system to resist "transformation" or "a change in the fundamental attributes of natural and human systems" (IPCC 2014, 5). In turning to the concept of resilience, Turner et al. are explicitly embracing the idea of coupled systems; adaptive capacity is understood to be the capacity of both human and natural systems to adapt to disturbances.

Turner et al.'s approach has additional characteristics that make it particularly suited for the OCEAN-CERTAIN project. It is a conceptual framework that is well-suited to a case study approach, appreciative as it is of the wealth of factors that can affect the three primary dimensions of vulnerability. Turner et al. emphasize the importance of "multiple interacting perturbations and stressors/stresses and the sequencing of them". The framework is sensitive to place but also locates any given place in its larger context of "nested scales and scalar dynamics of hazards, coupled systems and their responses" (8075). In harmony with Christoplos et al. and the Commission on Climate Change and Development (2009), Turner et al. explicitly include institutional structures in their conceptualization of adaptive capacity (page 8075). In addition, they also explicitly include feedbacks to both environmental and human conditions. As Cutter (2009, 4) notes, this is a framework that well suits a qualitative assessment.

In this deliverable, we will build over the framework developed in Turner et al. 2003 and Adger (2006) to adapt it to the impacts of climate change on the food web and the biological pump and the subsequent impacts on environmental good and services that are important for a given community, as well as to the feedbacks created by these communities to the natural system when dealing with the adaptation and mitigation of the effects of climate change.

Discovering shared knowledge using a System Thinking Technique

The first step to begin the application of Turner's model to the three cases of interests in the OCEAN-CERTAIN project is to create a clear and concise conceptual model of the different effects that climate change will have on the biological pump and the marine food web and how this will eventually affect the coastal communities. To understand this complex process, we performed a workshop with all the scientists involved in the OCEAN-CERTAIN consortium during the Kick-off meeting in Amsterdam on November 25th-27th, 2014. During this workshop a shared mental map of the different concepts and their relationships was built. Later on, this map was refined and simplified using a Fuzzy Cognitive Mapping technique. We will now describe these two methods that were crucial to create the environmental component of the general model of socioeconomic vulnerability.

The system thinking method consist in an open discussion among the participants of the workshop that allows to identify key variables, relationships and priorities of the group with regards to a main question being asked and a number of drivers previously chosen by the research group. This discussion, that took approximately 30 minutes, allowed us to generate common knowledge among the group of scientist that participated in the meeting. A facilitator inaugurated the group discussion by posting pre-determined "drivers" (factors that may impact the system without being impacted by the system), which serve as the initial basis of discussion. The workshop facilitator then used a white board to post the factors that stakeholders say are important determinates of whether and how climate change will affect the marine environment and coastal communities. The facilitator then drew lines indicating the connections among the original drivers and the factors identified by the participants. This exercise yields a complex pictorial representation of the group's shared conceptual model.

The project identified seven drivers that were to serve as the vantage point of the Systems Thinking exercise of the scientists' workshop. These were: 1) Reduction in light; 2) Changes in Micro and Macro Nutrients; 3) Increases in Temperature; 4) Acidification; 5) Deoxygenation; 6) Pollution; and 7) Overfishing. The workshop yielded a mutually constructed mental model of how the socioecological system works and also the information involved in the discussion among workshop participants as they worked the map out together. The result of this map is clearly untractable for a modelling perspective (see Figure 2 in the Results section) but it is the basis for the simplified version of the environmental model developed using a Fuzzy Cognitive Mapping technique.

Simplified Model using Fuzzy Cognitive Mapping

A combination of modelling techniques supports the integration of the design of the Decision-Support System (DSS) in WP5 with the outcomes of WP3. One of these techniques is Fuzzy Cognitive Mapping (Kosko, 1986). Fuzzy Cognitive Maps or FCMs (Kosko, 1986; Kok, 2009) are directed, causal graphs which can be used to describe the dynamic feedback behavior of systems of varying complexity and help bridge the gap between qualitative and quantitative knowledge. Rather than predicting the time-dependent changes FCMs can be used to analyze the key feedback mechanisms and causalities of systems by step-wise iteration. The design of FCMs starts by identifying the key state variables and causal linkages. Depending on the nature of the problem, available resources and time this task can be carried out by different teams of domain experts, stakeholders and representatives of the decision-making institutes. If necessary, FCMs of subsystems or FCMs representing different viewpoints are easily unified into a joint FCM. The result is a graphical representation of the system structure including the causalities and state variables. The explicitness and transparency of these conceptual models of systems often surpasses that of complex, inter-disciplinary discussions or narrative storylines as used in e.g. participatory modelling such as those developed during our system thinking exercise with scientists of the OCEAN-CERTAIN project. However, FCMs take conceptual modelling one step further by assigning weights to the causalities in the system and applying matrix algebra to derive the change of the system state. Repeated, step-wise iteration of the model and analysis of the resulting changes can help understand the role of system feedback and effectiveness of management options under different scenarios. Evolvement of the system until an equilibrium state is reached or until the system shows periodic behavior can be useful to understand the dynamics. Figure 1 shows an example of an FCM for the conflict between fish farming and catch fisheries with a semi-qualitative representation of the changes of selected state variables obtained after multiple, step-wise iterations of a FCM model.

For example, in this simple model the direct and indirect pathways for climate change impacts in the context of other stressors can be explored. In Figure 1, Climate Change is shown as a driver and direct determinant of Jellyfish blooms, the latter which has been linked to anthropogenic drivers (Purcell, 2007) with flow-on impacts on the ability of fishers to derive Fishing Income for both wild-caught stock and fish farming as explored by Tiller et al., (2014). Simultaneously, non-climatic elements within the same system related to fisheries management (e.g. Degree of MSP), economics (e.g. Fish Price) and ecological health (e.g. Fish Stock Size) are included, providing an integrated assessment.

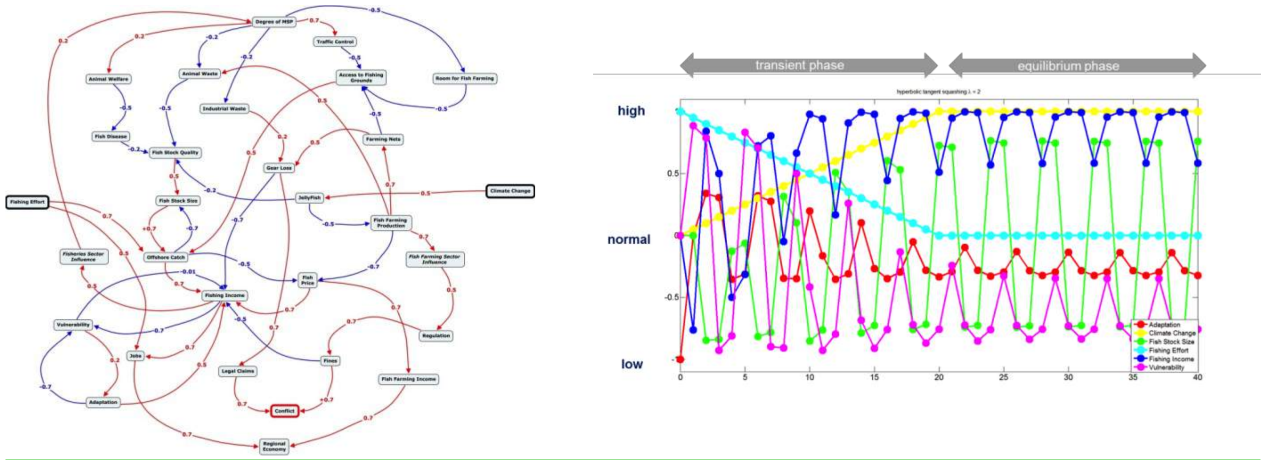

Figure 1: Example of a FCM for the conflict between fish farming and catch fisheries (presented at the MBER Open Science Meeting, Bergen, June 23-27, 2014).

The combination of semantic, conceptual networks with iterative computation of state changes makes this semi-qualitative modelling technique transparent in nature, adaptable to problems of arbitrary complexity and highly interactive. The design, analysis and improvement of FCMs can be supported by involving stakeholders and local managers in the process. FCMs can be used to compare the behavior of key variables under different scenarios in a more consistent way, or to analyze the sensitivity to changes in the system structure. This can help improve the model architecture underlying the design of a DSS.

3.3 Results

System Thinking Shared Conceptual Map among OCEAN-CERTAIN Scientists

The results of the system thinking exercise conducted during OCEAN-CERTAIN kick-off meeting is presented in Figure 2. As this diagram is built in real time during the workshop discussion, it might contain a number of replicated relationships and concepts. Therefore, a careful analysis is required piece-by-piece to obtain clear knowledge from this exercise. One of these analysis is the cause-effects diagrams of different concepts. For example, Figures 3 presents the way in which the biological pump is affected by different variables in the system and Figure 4 shows how an increase in the ocean temperature will have effects over many variables in the system. All these concepts and later worked to build a simplified version of a model that considers the main variables and concepts involved in the system and the way in which climate change will affect the environmental system and how this will create impacts over environmental good and services that are important for coastal communities, and in particular, for the fisheries, aquaculture and tourism sectors within these communities.

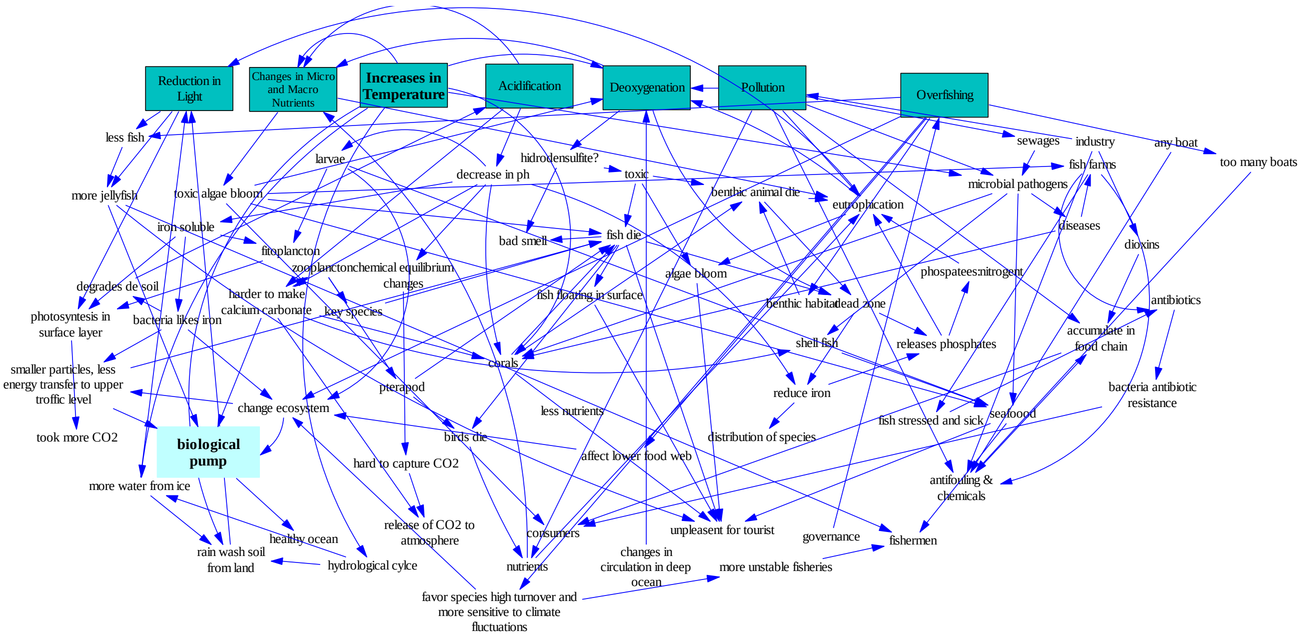

Figure 1: Shared Conceptual Map from the System Thinking Exercise

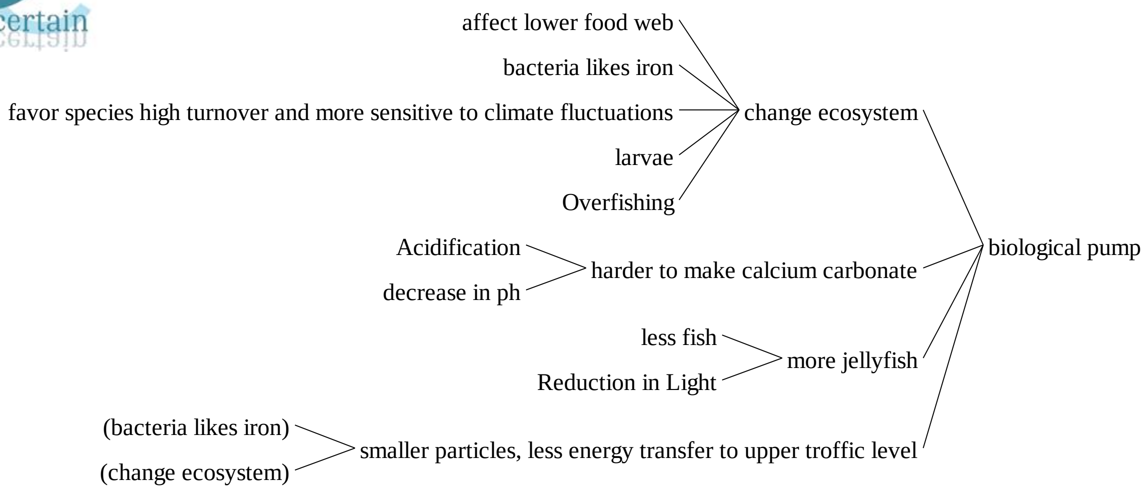

Figure 3: Causes Tree for the Biological Pump from the System Thinking Exercise

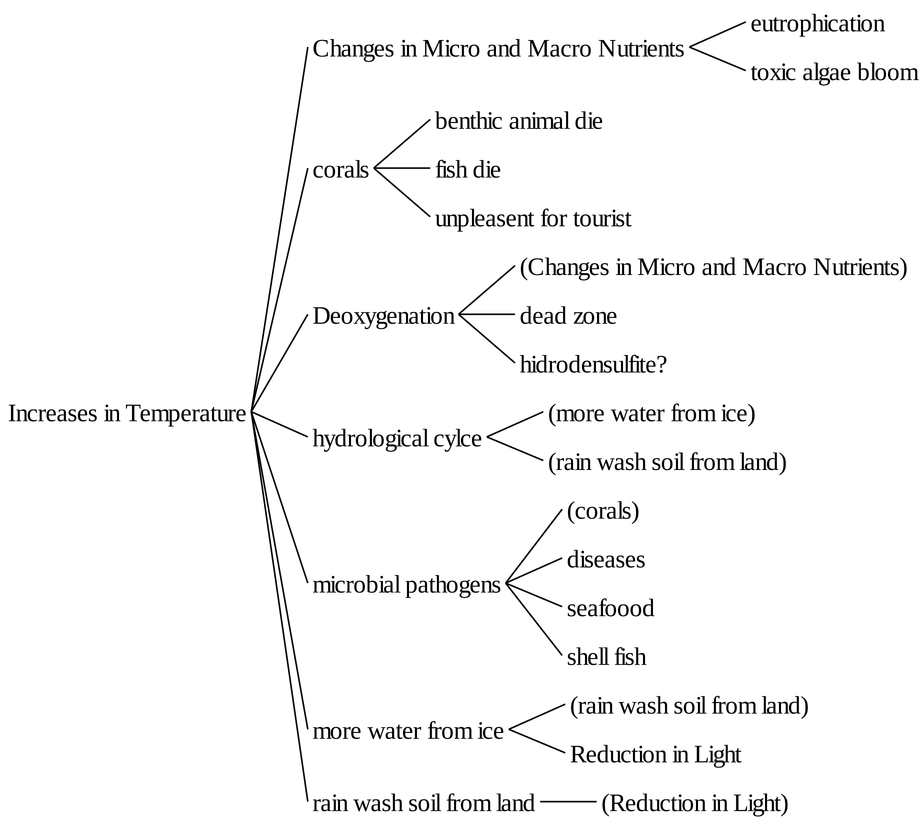

Figure 4: Effects of Increase in Ocean Temperature from the System Thinking Exercise

The Fuzzy Cognitive Map simplified Model

Based on the concepts and relationships identified in the System Thinking Exercise, the researchers from VITO (WP5 leaders) build a simplified version of the relationships between the most important concepts, identifying system stressors, ordinary state variables and indicators of the state of the system. The diagram that simplifies all the concepts is presented in Figure 5.

In this diagram the relationship between variables is much clearer than in Figure 2. We can now observe a number of variables within the ecosystem that will be affected by climate change and the diffusion patterns of these variables as well as the feedbacks that are generated among them, in a simplified way.

Based on this simplified model we were able to identify the main environmental variables that will be affected by climate change and that will have an impact on environmental good and services that are relevant for the fisheries, aquaculture and tourism sectors. This will be the basis for the socioeconomic model of vulnerability that we will present next.

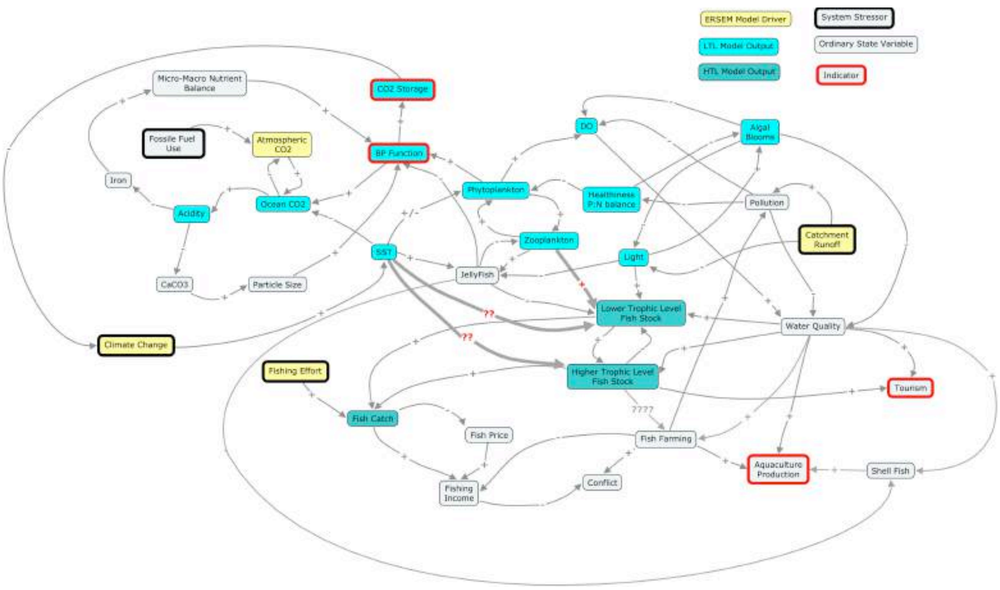

Figure 5: Simplified Model built by VITO using FCM techniques.

The Socioeconomic Vulnerability Model: A general view

Based on the shared knowledge generated by OCEAN-CERTAIN scientist during the system thinking exercise, greatly simplified in the FCM diagram present in Figure 5, we are able to identify the ways in which climate change will affect environmental variables that are important from a socioeconomic perspective, because they are key for the provision of environmental goods and services to the fisheries, aquaculture and tourism activities. This conceptual model is the first piece of our general model of socioeconomic vulnerability that will adapt Turner's model of VAS to the OCEAN-CERTAIN project. The second important component of our model lies within the socio-economic side. In this aspect four concepts are important to understand socioeconomic vulnerability of a community to climate change:

(1) Environmental exposure: We call environmental exposure to the extend in which local environmental goods and services are affected by climate change.

This exposure will be different in specific locations due to local conditions and ecosystem dynamics within each region under analysis. This is part of the environmental component of the vulnerability model.

(2) Socioeconomic sensitivity: We describe socioeconomic sensitivity in terms of how local communities, in particular the fisheries, aquaculture and tourism sector, are affected by the changes being experimented in the environmental goods and services being affected by climate change. For example, two locations such as Norway and Chile could be equally affected in terms of the impact of climate change in shellfish resources. Nevertheless, in Chile local communities will be much sensitive to these changes due to a higher dependence of local fishermen on these resources.

(3) Socioeconomic Entitlements: Socioeconomic entitlements are the resources and institutions that stakeholders have to cope with the effects of climate change on the environmental goods and services in which they depend. Different communities will have a different set of ways to deal with the effects of climate change, which will in fact be important to mitigate and to adapt to the effects of climate change.

(4) Public Policy and Private Responses: These are the specific ways of action that can be taken at a private (individual) or public (collective) level to deal with the effects of climate change. There will be a number of possible responses that could happen in the future under different scenarios, ranging from small costless adaptation strategies and policies to much more radical and costly adaptation strategies, such as changing economic activities or moving to a different city due to the effects of climate change. Also, from a public perspective the public action could range from do nothing to develop adaptation and mitigation plans to deal with the effects of climate change on coastal communities.

Figure 6 presents a conceptual framework that includes all these concepts together creating two submodels within the vulnerability model. The first sub-model will understand the natural science side of the socioecological system analysing how climate change will create an impact on environmental good and services that are present in a given location. The second sub-model will understand how local communities feel these effects (sensitivity), the resources they have to deal with these effects (entitlements) and how public and private stakeholders respond to these effects (responses). These two submodels will be crucial to understand the coupled socioecological system and the feedbacks that exist between the two components of the model.

A more specific representation of the general model of socioeconomic vulnerability is presented in Figure 7. Here, we identify 8 variables that are important within the natural ecosystem and that will potentially be affected by climate change: the food web, the biological pump function, the sea surface temperature (SST), the amount of CO2 in the ocean, the ocean acidification process, the water quality, water pollution and the existence of algae blooms. All of these variables will be affected in different ways in specific locations of analysis and generate impacts over environmental goods and services, such as Fish, Shellfish, Algae, Mammals and other Ecosystem Services that could specific to each location. This effects will be responsible for the "exposure" part of the vulnerability model. The "sensitivity" of different communities to changes in these resources is the next level of analysis in our vulnerability model. Here, different stakeholders, such as artisanal fishermen, industrial fishermen, aquaculture companies, processing plants, tourism industry and the general community could feel their selves affected in different ways by the changes in the quantity or quality of the environmental goods and services that are important in each location. Once they feel an effect they face different entitlement, resources and public institutions that could allow the local stakeholders to take actions to deal with the short and long run effects of climate change on their communities. The different actions that they can eventually take and the capacity they have to actually take actions that allow the community to cope with the effects of climate change will determine their private and public adaptative capacity.

All these concepts together will in fact define the vulnerability of a given community to the effects of climate change. A community will be vulnerable to climate change when the natural marine ecosystem be affected by the different stressors involved in the climate change process, when these changes create impacts over goods and services that are important for stakeholders, when these stakeholders are sensitive to the changes experimented in these resources and when they have limited responses, public and private, to these effects. Different degrees of effects in these different levels will create different vulnerability of the communities under analysis, both at a national and at a local level.

3.4 Discussion

The general model of socioeconomic vulnerability presented in Figure 7 collects the different concepts involved in the analysis of vulnerability in the literature as well as the specific aspects involved in the analysis of socioeconomic vulnerability within the context of the OCEAN-CERTAIN project.

This general conceptual model can be utilized to analyse and estimate socioeconomic vulnerability to climate change of a given location or coastal community. We consider that this can be done from an objective or subjective perspective.

In the first case, the analysis should be based on mathematical and functional relationships for the different variables within each component of the model. For example, we can define a variable that is a proxy for measuring the welfare of a given community such as income or employment. We will measure the vulnerability using the probability that this variable is under a given threshold considered crucial in each location (for example, subsistence income or average unemployment rate). To estimate a measure of the vulnerability of the community we need to build functional relationships between the variable of interest (income, unemployment or other) and the different concepts that are present in the model. For example, we need to specify the different actions that the relevant stakeholders can take (both private and public, such as fishing effort and public subsidies), depending on the value of a number of state variables (such as the level of fish stock). Then, we can run different scenarios provided by the effects of climate change, and estimate how often the state variables are in values that generate responses from public and private sectors and create an effect over the variable of interest. In particular, we will be interested on how often the variable of interest will be under the specified threshold, in relative terms (for example, from 100 scenarios 10 times the variable of interest is under a given threshold, we will say that vulnerability of this community is 10%). This will be a measure of how vulnerable a community is to different scenarios to be developed using the models from WP2-WP4 in OCEAN CERTAIN.

The second case is to analyse perceptions of vulnerability within a certain community. In this case, we will explore what are the important relationships for different stakeholders, how they consider their important resources will be affected, what are the actions they could take and what are the policies responses that could eventually happen. Based on these, we can build scenarios and explore their beliefs about those scenarios and how probable they consider that the variable of interest will be under a given threshold in each one of these scenarios. This is the type of analysis that are constructed using the Bayesian Belief Networks (BBN) techniques that will be applied during stakeholder workshops in the OCEAN-CERTAIN project. Therefore, the model combined with the BBNs will allows us to directly assess the perceptions of vulnerability of different groups of stakeholders in each case study (Norway, Chile and Turkey).

3.5 Conclusion

We have built a general model of socioeconomic vulnerability to the effects of climate change on coastal communities based on the VAS framework of Turner et al. (2003) and the concept of Vulnerability in Adger (2006). We have built an integrated model that considers the environmental responses of the ecological process within the marine ecosystem based on knowledge generated using a system thinking mental map technique during a workshop with scientists involved in the OCEAN-CERTAIN project. This model has been refined and simplified by VITO using a FCM technique designed to build a Decision Support System for the project. Based on these environmental effects of climate change, we have analysed how environmental goods and services that are important for local communities could be affected by climate change (exposure), how dependent the local communities are of these resources (socioeconomic sensitivity) and how the community can develop public and private strategies to cope with the negative effects of climate change (adaptative capacity). We have also discussed how this general model can be applied to measure the vulnerability of a given coastal community to climate change, using an objective measurement method, based on actual knowledge and available information, or a subjective method based on the perceptions and knowledge of local stakeholders.

The model developed will be crucial for the next steps of the socioeconomic analysis in the OCEAN-CERTAIN project as it will allow us to be the connecting framework to analyse the different case studies and to perform the stakeholders workshops to understand the local differences and similarities on socioeconomic vulnerability to climate change.

The model will also allow us to focus the analysis on the aspects that are important for the construction of a decision support system that will be useful for local policy makers and to understand the strategic interactions among stakeholders, which are crucial aspects of the OCEAN-CERTAIN project and future tasks and deliverables.

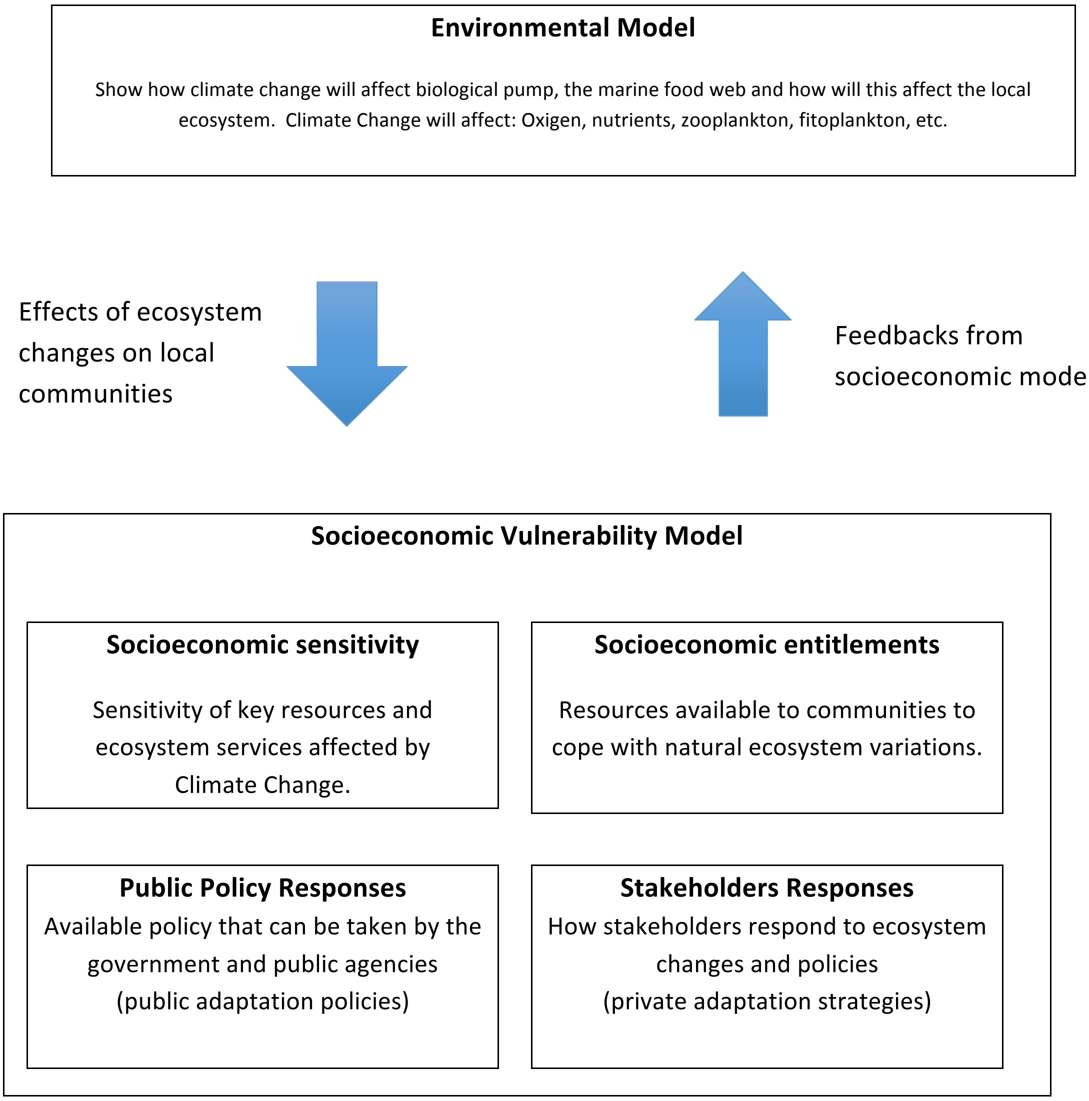

Figure 6: General Structure of the environmental and socioeconomic models of vulnerability.

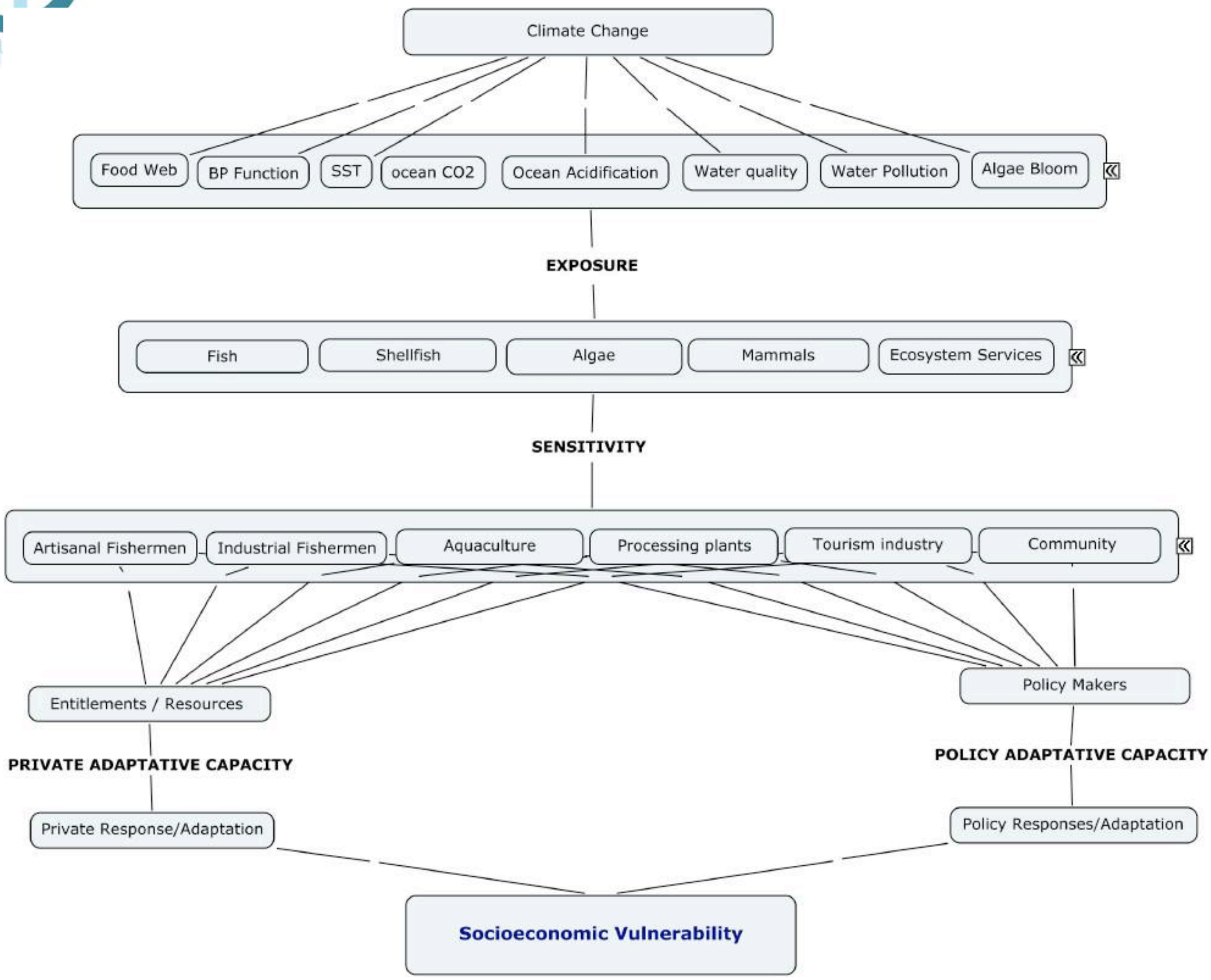

Figure 7: The OCEAN-CERTAIN general model of socioeconomic vulnerability.

4. Dissemination & exploitation

This deliverable is the base for a paper that is currently be written under the name of "The effects of "The effects of climate change on marine ecosystem and coastal communities: An integrated environmental and socioeconomic vulnerability model". This paper is planned to be the first output of research in the WP3, integrating also knowledge from other work packages.

The results from this paper will also be used to build a simplified conceptual model to explain to stakeholders the framework of the analysis in our project, connecting the environmental impacts of climate change and the socioeconomic consequences.

The socioeconomic vulnerability model is the base for the applications in the three case studies, particularly in the use of stakeholder workshops to estimate socioeconomic vulnerability and climate change scepticism in each location.