Universidad de La Laguna

Socio-environmental complexity, Insularity and Knowledge co-creation

Tesis Doctoral

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Socio-environmental complexity, Insularity and Knowledge co-creation

Bridging types of knowing to govern socio-environmental issues in insular and remote communities.

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Este trabajo se lo dedico en primer lugar, y sin ninguna duda, a mi madre, Esther.

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Menos samba e màis trabalhar

Keep paddling

A día de hoy, en Lisboa, febrero de 2020.

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Abstract

Human knowledge is not a static entity, but is a dynamic and cumulative learning process, which transforms and evolves through experience and communication. Human beings, and therefore human societies, are guided and governed based on the acquired and inherited knowledge. When we face complex environmental problems, the available knowledge is our best tool to overcome them and find solutions, and each individual, community or society applies the knowledge at hand, or at least, considered as useful.

This PhD research discusses that under complex environmental issues -in which there are varying degrees of uncertainty and urgency, such as the impacts of climate change, invasive agricultural species, or overfishing- techno-scientific data is not providing all the answers that humans and environment require. Therefore, an urgent need to mobilise other kinds of knowing in order to co-create knowledge and elaborate more efficient policies is proposed.

It is explored how relevant sources of situated environmental knowledge exist within communities that have subsisted and evolved under conditions of insularity and relative isolation, that is, in islands and remote territories. These types of spaces share a series of characteristics that allow their study under a unique perspective: insularity; in addition, they are suggested as "environmental-knowledge hot spots".

Under a Post-Normal Science paradigm, and in order to validate the value and usefulness of the knowledge these types of communities hold, this thesis applies an integrated approach consisting on institutional analysis and participatory processes to three different case studies. The studied cases range from the invasion of an agricultural pest that severely affects the cultivation of potatoes on the island of Tenerife (Canary Islands); the artisanal fishing as a response to overfishing in Tenerife; and finally, the impacts of climate change on small Arctic communities.

This research tries to illustrate the need to overcome scientific, social, cultural and institutional barriers in current environmental policy making processes. These processes must be based on trans-disciplinary and trans-epistemological approaches, allowing the inclusion and enhancement of other types of knowing into the cycles.

Resumen

El conocimiento humano no es una entidad estática, sino que es un proceso dinámico y acumulativo, que se transforma y evoluciona. Los seres humanos, y por ende las sociedades humanas, nos guiamos y regimos en base a los conocimientos que hemos adquirido y heredado. Cuando nos enfrentamos a problemáticas complejas, en nuestro caso ambientales, el conocimiento del que disponemos es nuestra mejor herramienta para superarlas y encontrar soluciones, y cada individuo, comunidad o sociedad, aplica el conocimiento del que dispone y que considera útil.

Esta tesis discute que bajo problemáticas ambientales complejas en las que existen diversos grados de incertidumbre, como por ejemplo el cambio climático, las especies agrícolas invasoras, o la sobrepesca, los conocimientos tecno-científicos no están aportando todas las respuestas y soluciones que se necesitan con urgencia. Se plantea por tanto la necesidad de contar con otros tipos de conocimiento ambiental a la hora de buscar alternativas y elaborar políticas más efectivas, estos son el conocimiento local y tradicional.

Bajo esta premisa, se plantea que dichos conocimientos existen y se manifiestan con gran claridad en aquellas comunidades que han subsistido y evolucionado bajo condiciones de insularidad y aislamiento relativo, es decir, en territorios insulares y remotos. Así mismo, se plantea que estos territorios son "puntos calientes de conocimiento ambiental", y que comparten una serie de características que permiten su estudio bajo una perspectiva única: la insularidad.

Bajo un paradigma de Ciencia Post-Normal y mediante la aplicación de un enfoque que integra análisis institucional y procesos participativos a tres casos de estudio diferentes, esta tesis pretende mostrar la importancia de los conocimientos que poseen dichas comunidades para aportar medidas y propuestas de acción. Los problemas estudiados varían desde la invasión de una plaga agrícola que afecta gravemente al cultivo de la papa en la isla de Tenerife (Islas Canarias), la pesca artesanal como respuesta a la sobrepesca en Tenerife, y los impactos del cambio climático sobre pequeñas comunidades árticas.

A modo de conclusión, esta investigación contribuye a ilustrar la necesidad de superar barreras científicas, sociales, culturales e institucionales en los actuales procesos de elaboración de políticas ambientales. Dichos procesos,

deben ser basados en enfoques trans-disciplinares y trans-epistemológicos, permitiendo la inclusión y valorización de otros tipos de conocimiento.

1. INTRODUCTION

This thesis comprises a compilation of three research articles, published on international scientific journals. In general terms, these articles explore ideas of co-creation, i.e. on bridging different types of knowledge to govern socio-environmental issues in insular and remote communities. We assume that bridging different types of knowledge into such processes can benefit in coping many of the challenges that small and isolated (insular) communities face.

Throughout this introductory section, we outline the increasing need and urgency for more knowledge in environmental policy shaping and making processes; in a second sub-section, the main research questions and hypothesis underlying the whole analysis are framed; and finally, the structure of the thesis is described.

1.1. Do we need more knowledge?

Policy-making is a process based on values (Alm, 2007), interests (Gerston, 2014; Braun, 2009) or power (Haas, 2004), but it is also based on knowledge (Owens and Rayner, 1999; Jones et al., 2009; Dilling and Lemos, 2011; Rayner, 2012).

Environmental decision and policy-making may be seen as cyclical processes according to the following sequential stages: a problem is identified, a policy response is formulated, the preferred solution is selected, the policy is implemented, and finally, the policy is evaluated (European Commission, 2015). The identification of the problem intended to resolve is a crucial step, since it will determine both the evolution of the subsequent processes and the policy outcomes. From the first step, and during the whole mentioned process, evidence-based scientific and technical support plays a central role informing and shaping the policies (Birkland, 2015).

In 1966, the psychologist Abraham Maslow pointed out that "If the only tool you have is a hammer, you tend to treat everything as if it were a nail" (Maslow, 1966, p. 15). Translating this sentence in the policy-making process, evidence-based techno-scientific knowledge might be understood as a hammer used to address environmental problems, which are treated as nails.

When facing complex issues, using of the same hammer to solve every problem seems to be inadequate and generalist because there are particularities that the hammer is not capable to discriminate. Liotta and Shearer gave an added value to Maslow's assertion, stating that "…when one only has a hammer, the problems that do not look like nails are ignored" (Liotta and Shearer, 2007, p. 59). In other words, there are socio-environmental issues conditioned by specific particularities that the current universal techno-scientific-based approach might be ignoring, such as those specific of insular and remote regions. In general terms, this thesis attempts to elude the dependency on a single hammer exploring the value and usefulness of alternative tools, approaches, methods and knowledges to govern socio-environmental issues in those spaces and territories.

This ambitious and challenging mission implies firstly, the fully acceptance of a high level of complexity, uncertainty and diversity when societies face complex environmental issues; and secondly the recognition that the current approach of techno-science-based environmental policy-making is not providing the answers that humans and environment require.

In the last decades, several authors have pointed out that the 'authoritarianism' of scientific knowledge system has been an obstacle to the evolution of the way in which environmental issues are defined, approached, and solved (Hulme and Lecture, 2012; Popper, 2014; Horgan, 2015). Scientific knowledge is commonly seen as objective, unbiased and rigorous, with precise measuring with specific apparatus and empirical testing of events and trends, confirming credibility and legitimacy (Mistry and Berardi, 2016). In a similar manner than the human rationality has been considered in the past as *conscious, unemotional, logical, abstract, universal, and imagined concepts and language as able to fit the world directly* (Lakoff, 2010, p.3), but this view has been stated as erroneous and false (Damasio, 1994).

Other authors, such as Nowotny et al., (2013, p.7) refer to the historical Cartesian dream of prediction and control in science:

> *"Predictability and control became the hallmarks of an accomplished modernisation arrogantly characterized by assertions of universalism, openness, rationality and efficiency".*

As Lakoff (2010) points out, the way in which societies frame the environment is key. Thus, current socio-environmental issues cannot be defined from a sole perspective, approach, or method, since they are extremely complex. For instance, Genetically Modified Organisms (GMOs) are not merely a scientific question; it would be more correct to uphold that they arise from human crafting but they stop to be strictly a techno-scientific matter from the moment in which they leave a closed laboratory or controlled land field and reach out the public space. Although this area of experimentation has been developed to solve specific agricultural problems (such as invasive pests or production deficits) it does not take into consideration the multiplicity of factors involved in the path that goes from their creation to their release in ecological, economic, social and policy spaces. Hence, linked to the development and implementation of these technologies, new issues arise, increasing the complexity of the issues for which they were created, and finally blurring the supposed solution they were asked to provide (Firn and Jones, 1999; Myhr and Traavik, 2003).

Climate change is another illustrative example. The scientific community has been studying and defining it for several decades, and a huge amount of strategies and actionable recommendations have been proposed to tackle it in plausible and even desirable ways. Nevertheless, the impacts of climate change are increasingly perceived, recognised and reported in many regions worldwide (Watson et al., 1996; Harley et al., 2006; McCarthy et al., 2001). We can confidently say that addressing climate change is above all a political and social affair.

Other example might be the dichotomy within the renewable energies and the fossil fuels, which is still creating a passionate debate at both global and local levels (Herring, 2006; Wilkinson et al., 2001; Chow et al., 2003). Although the harmful effects of extraction and abusing of fossil fuels as the main source of energy have been stressed by a huge number of academics, scientists, technical experts and international organisations (Wirl, 1995; Zecca and Chiari, 2010) there is not a clear position and a decisive strategy of change at policy levels (Foster, 2013).

Commonly, the problems are reduced to simple parts leading to a simplification of the reality in order to facilitate the accomplishment of particular interests and evade social contradictions (Bourdieu, 1975). Uncertainties, ignorance, economic, cultural or ideological interests, a

chaotic interrelation of actors, difficulties to obtain data, lack and inconsistency of models, incoherent scales of analysis, and so on, are variables influencing and feeding a complex situation in which a unique point of view is not able to provide effective resolutions (Fischer, 2000).

David Byrne (2002, p.19) brilliantly clarifies this persistence on simplification in his work *Complexity theory and the social sciences*:

> *"The search for linearly-founded laws is a search for predictive ability. If we can establish the relationships so that our formalised linear mathematical models are indeed isomorphic with the real world, and our ideal method for doing this is usually thought to be the controlled experiment, then we can predict what will happen in a given set of circumstances, provided we have accurate measures of the initial state of the system. Once we can predict, we can engineer the world and make it work in the ways we want it to. We can turn from reflection to engagement. This is a wholly honourable project so far as I am concerned. It is the technological foundation of modernity itself."*

Other scholars have pointed out that the heritage derived from social-political-historical dynamics maintains western knowledge monopoly in all forms of human expression, for instance, sociologists as Boaventura de Sousa Santos and Paula María Meneses (Santos & Meneses, 2014) stress this perspective in the following manner:

> *The understanding of the world is much broader than the western understanding of the world, and that is why the transformation of the world can also occur through ways or methods unthinkable for the West or Eurocentric forms of social transformation. That this great diversity of the world, which can be and must be activated, as well as transformed theoretically and practically in many plural ways, cannot be monopolized by a general theory. There is no general theory that can adequately cover all these infinite diversities of the world.*

> *…Now we are immersed in the thought of the epistemology of the north, and we are so accustomed to universalism and to the general theories that we need, above all, a general theory about the impossibility of a general theory. That is almost like talking about a negative universalism, to show that nobody has all the recipes, only and exclusively, to solve the problems of the world.*
>
> De Sousa Santos, B., and Meneses, M. P. (2014)

The point here is that reducing of the debates to a unique scientific stand point, will not solve the complexities described above and indeed, paradoxically, it will create new complexities. The recognition of the diversity of epistemologies in human knowledge is key to expand our worldview and understand that the contemporary environmental problems are not simple, and therefore, there is not a unique valid frame –or hammer- to approach and resolve them.

In few words and asking the initial question, we do not need more knowledge, what is needed is the recognition, mobilisation, activation and engagement of other knowledges.

1.2. Research questions and objectives

Climate change, overexploitation of natural resources, and the invasion of alien species are common threats affecting all kinds of regions worldwide (Hulme, 2005; Barker et al., 2007; Pachauri et al., 2014). Nevertheless, those and other impacts have not been informed as equally severe in all regions (Pachauri and Reisinger, 2007), for instance, insular and remote regions have been reported as areas of particular sensitivity (Pelling and Uitto, 2001; Kelman and West, 2009) or as 'indicators' of the advance of the global environmental change (Foster, 1989; Diamond and Devlin, 2003). At the same time, the communities inhabiting these kinds of territories are increasingly experiencing rapid local changes that exceed their adaptation capacity and their options to develop adequate strategies (Krupnik and Jolly, 2002; Lazrus, 2012).

Since several decades, the most relevant scientific organisations and policy institutions at international levels, have alerted that these kinds of regions

must give sustainable and prompt responses to face those changes, in order to avoid further future negative consequences (Watson et al., 1996; Metz et al., 2009; Protocol, 1997, 2011; IPCC, 2015) such as the irreversible loss of biodiversity (Fosaa et al., 2004), effects on human health (Patz et al., 2005), the excessive pressure on local natural resources (Christensen and Mertz, 2010), or shocks on local economies (Amell et al., 2004), which could ultimately lead to dramatic phenomena of human migration or extreme poverty (McLeman and Hunter, 2010). But despite the efforts that these communities have made and are currently making to cope with those changes, the problems and impacts continue increasing without an apparent immediate solution.

This research focuses on the socio-environmental complexity inherent to the condition of insularity and explores the interrelation between insularity and site-based knowledge creation. The hypothesis that we wish to verify through this work is that insular communities, by the continuous and close interaction with environmental insular dynamics, have developed robust bodies of knowledge, which can potentially contribute together with scientific knowledge, to address current socio-environmental changes and elaborate different alternatives to policy action (Turnbull, 1997; Hamilton et al., 2012; Lauer, and Aswani, 2009; Raymond et al., 2010).

In this regard, it is proposed to overcome the current environmental decision-making framework, mainly grounded on scientific-technical knowledge, and incorporate other kinds of valid knowledges in a larger framework for better inform environmental decision-making processes. This statement is based on two pillars: firstly, the understanding that science is not necessarily or *de facto* the only way to frame, explore or govern the whole complexity and uncertainties of the on-going socio-environmental problems (Funtowicz and Ravetz, 1990; Funtowicz et al., 1999; Ravetz, 1999; Gallopin et al., 2001; Sarewitz, 2004); and secondly, the increasing recognition and relevance of other types of knowing, both to cope with local environmental changes, and to provide valuable knowledge to environmental policy-making processes (Taylor and de Loe, 2012; Usher, 2000; Fisher, 2000).

In order to identify the specific characteristics defining insular territories and their social-environmental conditions and vulnerabilities, as well as explore alternative sources of situated knowledge and their validity, the following series of framing questions are posed:

- What are the meanings and implications of insularity?
- How to approach complex socio-environmental issues in insular spaces?
- What is the pragmatic and tangible usefulness of bridging different types of knowledge in policy-making?

To support this research, three different case studies are presented and discussed:

This first case study examines the global expansion of an uncontrolled agricultural potato pest, namely Guatemalan potato moth, *Tecia* (*Scrobipalpopsis*) *solanivora* Povolny (Lepidoptera: Gelechiidae) (Povolny, 1973), and its social, economic and environmental impacts on the island of Tenerife (the Canary Islands) since the pest was discovered in the year 1999. In this paper, a Socio-Institutional Analysis is implemented in order to analyse the social, economic and ecological context surrounding the pest infestation, going beyond the techno-scientific measures. Successively, a participatory assessment involving the local actors is carried out with the aim of making explicit the perspectives and proposals of local potato farmers to address this issue.

The second case study focuses on the integration of local fishing communities into decision-making processes with the aim of promoting artisanal fishing on the Island of Tenerife (the Canary Islands), as a way to avoid overexploitation of marine resources, preserve the marine ecosystem and promote the socio-economic development of traditional cofradias (local fishers' organisations). A qualitative methodological framework, based on participatory problem-solution trees and series of focus groups, was implemented to both identify the main factors impeding the sustainable development of the artisanal fishing sector on the island and to elaborate collective proposals with policy implications.

The third case study is related to a quite different location: the Arctic. This paper carries out an analysis of the vulnerability of traditional coastal communities under risk of displacement in the Arctic region. Through a literature review we examine a concrete case located in Alaska in which rapid environmental degradation due to climate change is forcing entire villages to relocate. The ultimate aim of this work is to identify opportunities and pathways to engage local native communities in policy-making

processes, and enhance the value and potential of traditional knowledge to mitigate environmental impacts.

Through specific methodologies applied to each case study, we will specifically seek to:

- explore methods that allow capturing of the complexity and of identifying the different knowledge and actors involved in complex problematics.
- analyse how far have the studied communities been involved in policy-making processes in each case and carry out engagement processes to discuss our research questions.

Together the exploratory analysis and the case studies will furthermore help with understanding how different bodies of knowledge can be reconciled into co-producing fit for purpose governing strategies to address socio-environmental change in 'insular' regions.

1.3. Structure of the thesis

The thesis is structured in the following manner:

Section 2 explores the concept of insularity from the point of view of the interaction between the conditions of relative geographical isolation and socio-environmental dynamics and how this interaction influences the development of complex environmental issues. Additionally, we explore how insular communities interact with the environmental conditions through their experiential situated knowledge.

The theoretical framework in which the objectives and hypothesis are supported is developed in **section 3**.

Section 4 presents the methodological framework designed and implemented to achieve the thesis' objectives, exposing the materials and methods implemented for each of the case studies.

A brief overview of the case studies and the results are presented in **section 5.**

Section 6 shows an overall discussion of the results obtained after the implementation of the theoretical approach and the methodological framework in the case studies.

In the last section, the main conclusions from the whole work are presented.

Finally, some information and data about the journals metrics, in which the articles are published, is shown; and subsequently, the articles are annexed.

2. EXPLORING INSULARITY

As exposed in the introduction, this section carries out a literature review in which the concept of insularity is explored from a broad perspective. According to the literature, the most representative entity of the notion of insularity is an island space, but islands share geophysical conditions with other kinds of spaces, such as mainland remote and isolated regions.

In addition, our analysis shows that remote, isolated and insular spaces share other characteristics: a. we find similarities in social, cultural, political and economic dimensions; b. physical shortcomings, for instance, due to long distances; c. vulnerability to external stressors; and d. resilience capacity and adaptation to changes.

2.1. Islands

Island territories began to receive special attention in the scientific field during the nineteenth century, mainly within the disciplines of biogeography, when Charles Darwin established a differential evolution between the species that inhabited insular areas and those that had evolved in regions with a well-defined and wider geographical or terrestrial continuity (Darwin, 1879). Other authors such as Alfred Russel Wallace complemented and supported the theories of Darwin by parallel studies about genetic differentiation and selection linked to the insular environmental conditions (Wallace, 1902). Those prior theories were updated by further work, for instance, MacArthur *and* Wilson, (1963*)* developed their equilibrium theory of island biogeography, which opened the path to the creation of a paradigm about island biogeography studies (Lomolino, 2000).

Excluding continents, islands cover around 3% of the Earth's land surface (Glen et al., 2013), and are home to some 10% of the world's human population (Baldacchino, 2008). In terms of biodiversity, these spaces are considered as 'hotspots' due to their endemism richness (Brooks et al., 2002; Kier et a., 2009). But even though these regions cover a small portion of the earth, their importance and contribution to widen the knowledge about ecological, social and cultural dynamics has been highlighted during decades by researchers, academics and diverse scientific disciplines (Diamond, 1975; Adsersen, 1995; Vitousek, 2002; Baldacchino, 2006; Hay, 2006). As Kelman (2011) states, island case studies have contributed significantly to disaster research theory and application, including more recent work on climate change adaptation.

The discrete limits of islands are considered to be their main distinctive feature (Baldacchino, 2004) and due to the clearly delimited boundaries, the geographical isolation and the compact socio-political and cultural universe, island territories have been approached as 'laboratories' of study (Spilanis et al., 2009). For example, the fragility of biodiversity in insular spaces and their exceptional evolution, their vulnerability to natural hazards, the historical social and cultural dynamics, the modes of social organisation, the external dependence and the limited resources, among others, are factors that make up a relatively closed universe with differentiating particularities in comparison to other types of regions.

The classic definition of an island, that dictionaries and encyclopaedias generally give, has been 'a body of land entirely surrounded by water', nevertheless this characterisation appears to be excessively simplistic (Taglioni, 2011). In disciplines such as biogeography, island regions have been classified attending a series of geophysical constraints (MacArthur, 1972; Whittaker and Fernández-Palacios, 2007) (See table 1). Within this categorisation, Whittaker and Fernandez-Palacios (2007) divide islands into two broad categories distinguishing between *true islands* as land wholly surrounded by water; and *habitat islands*, as all forms of insular system that do not qualify as being 'real islands'. Attending to the definition provided by Vicente (1999) *habitat islands are suitable habitats for an organism that are surrounded by unsuitable areas such as mountaintops, lakes, host plants, or caves*.

Table 1 Types of islands according to Whittaker and Fernandez-Palacios (2007).

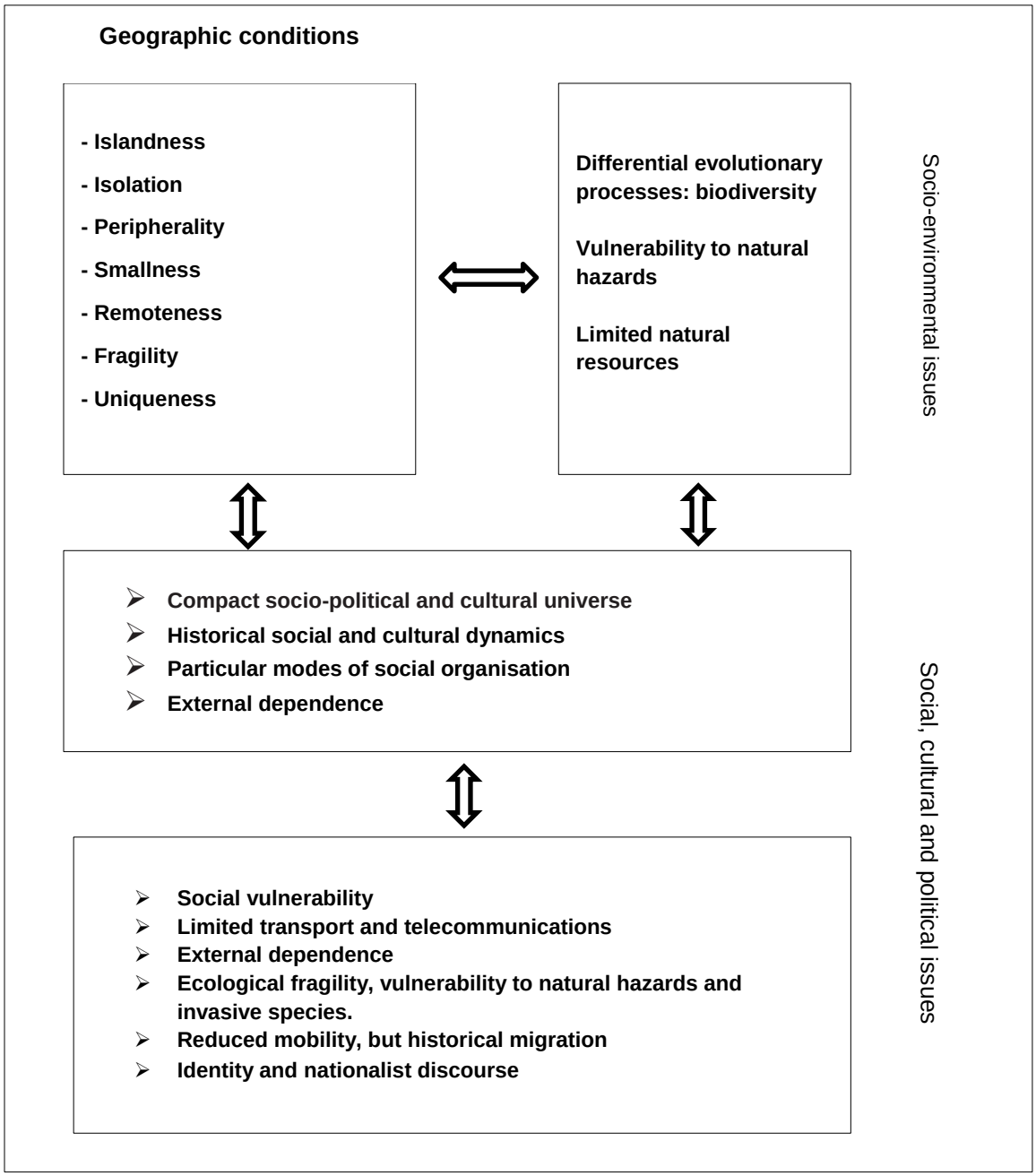
Type of island	***Examples***
Land surrounded by water	
Island continent	*Australia*
Oceanic islands	*Hawaii, Canaries*
Continental fragments	*Madagascar, New Caledonia*
Continental shelf islands	*British Isles, Newfoundland*
Islands in lakes or rivers	*Isle Royale, Barro Colorado island,Gurupá*
Habitat islands	
Patches of a distinct terrestrial habitat	
Isolated by a hostile matrix	*Great-Basin (USA) mountain tops surrounded by desert* *Woodland fragments surrounded by agricultural land* *Thistle heads in a field* *Continental lake (Baikal, Titicaca)*
Marine habitat islands	
	The fringing reef around an isolated oceanic island *Coral reefs separated from other reefs by stretches of seawater* *Seamounts* *Guyots (submerged flat-topped former islands)*

Other classifications make reference to terms as "continental insularity", in contrast to "oceanic insularity", to allude to relatively isolated spaces in which biodiversity have evolved following particular patterns due to their isolation (Anthelme et al., 2014).

But insularity cannot be defined only from a geographical perspective since it entails a series of broader implications, as Hache (1987) encourages, insularity is more than a mere geographical status, being the combination of a geographical condition with a series of social, economic, political and cultural manifestations.

As shown in figure 1, island spaces have been defined by other series of characteristics. According to Eurisles (2002), insularity can be considered as a permanent phenomenon of physical discontinuity, which implies a certain degree of isolation. Moreover, insular spaces have been recognised as areas of particular sensitivity due to a set of conditions such as their isolation, fragility, uniqueness and generally small size (Olson and Dinerstein, 2000; McElroy, 2003; Ghina, 2003; Briguglio, 2003). Other authors allude to further characteristics which define an island space, such as islandness (Bonnemaison, 1990; Baldacchino, 2004; Baldacchino and Milne, 2008; Campbell, 2009), peripherality (Deidda, 2016), smallness (Taglioni, 2011; Lewis, 2009) and remoteness (Deidda, 2016); or have been approach from a dichotomist perspective, considering insularity as a concept which combines the two seemingly opposing facets of isolation and connectivity (Sicking, 2014).

Figure 1. Interplay among features of insularity and social-environmental-cultural spheres



These complex interrelations are intrinsic to the environmental, social-cultural and economic systems.

2.1.1. Social-environmental conditions of insularity

As shown in figure 1, the linkages of insularity and economic development are not separated from conditions of remoteness, smallness and peripherality (Deidda, 2016) which restraint the availability of resources

such as water, energy or land (Corral-Quintana et al., 2016). Scarcity of natural resources is a constant in these kinds of territories and it is interrelated to other factors such as a high human population density, which subsequently increases the threat to biodiversity (Cincotta et al., 2000; Luck, 2007). Additionally, local dynamics such as urban sprawl and intensive construction, uncontrolled wastes, marine and coastal pollution, mass tourism or industrialisation processes are influencing the ways of life and the ecosystems of these spaces constituting significant challenges to insular and remote communities (Schwarz et al., 2011).

such environmental and social stresses are clearly recognisable, for instance, in the case of local insular fisheries (Adrianto et al., 2005; Casiwan-Launio et al., 2011; Corral and Romero Manrique, 2017). Aspects such as high population densities, increasing external market demands or unregulated fisheries, generate excessive pressure on the local fisheries resources that might lead to overexploitation (Dalzell and Adams, 1997; Newton et al., 2007; Zeller et al., 2015) or marine species extinction (Pauly et al., 2013). In parallel, the condition of relative isolation implies also a great distance to major markets and high vulnerability to external shocks producing a low economic resilience capacity (McCarthy et al., 2001).

Following McCarthy et al., (2001) the limited physical size reduces adaptation options to climate change and implies a high susceptibility to natural hazards impacts, such as hurricanes, tropical cyclones and associated storm surge, droughts, tsunamis, and volcanic eruptions; and even to the presence of invasive alien species.

Veitch et al., (2011) explain, with an overwhelming clarity, the relation between human settlements and invasive species in a big island such as New Zealand:

> *There could not be a better place to make this point than New Zealand. European colonisation took place in an era of some knowledge about the complex impacts of introduced and invasive species. But it had little impact on those who sought to recreate their home country on the other side of the world amidst a completely different native biodiversity. The results were predictable, and within short time the colonists were both engaged in trying to mitigate the impacts on their economic endeavours*

> *while continuing to introduce problem species. Don't look for the logic!*
>
> *…*
>
> *One hundred and forty years on, taxpayers, ratepayers and landowners in New Zealand are forking out some $800 million a year, every year, just to control the menu of animal and weed pests that threaten our native biodiversity.*
>
> *How has this happened? Stupidity, ignorance, and a selfish ethic provide some of the reasons. So does the disconnect with nature that urbanisation brings, but there is also an institutional tool that helps to drive this behavior.*
>
> Veitch et al., (2011, p.2)

Often, management strategies have been based on controlling the spread of invasive species for short or long periods, removing samples of threatened endemic species by the invaders and hold them in safe locations (Veitch et al., 2011) or creating controlled protected areas (Spatz et al., 2014; Simberloff, 2008). In any case, Glen et al., (2013) highlight that eradication of invasive species is more feasible on islands than on continents due to the geographical boundaries, nevertheless, these particular spaces enclose several complexities.

For instance, the case of invasive agricultural pests is a clear example of a complex problematic in which the presence of a small invader insect impacts on social, economic, ecological and cultural dimensions at local levels on island regions (White et al., 2008; Corral et al., 2017). In the Canary Islands, the presence of the Guatemalan Potato Moth has impacted on several local social-ecological systems, such as the local economy causing a reduction of potato production; the landscape due to the abandonment of crop lands; and the local agro-biodiversity, affecting to endemic genetic potato varieties (Romero Manrique et al., 2016; Corral et al., 2017).

2.1.2. Social-cultural and political characteristics of insularity

In terms of social characteristics, social exclusion and limited access to employment and education are commonly linked aspects to remote, difficult to access and sparsely populated regions, aggravating the individual risks of social exclusion (Papadakis and Kyvelou, 2017). Insular spaces are also conditioned by limited transport options and reduced mobility, in contrast

with a historical migration (both emigration and immigration) phenomenon (King and Connell, 1999).

Migration has been a historic constant dynamic for islanders (King and Connell, 1999) for instance, due to social-economic causes (Godenau, 2012), but currently, due to climate change, displacement and migration are extremely serious risks for insular communities. Environmental displacement refers to situations "where people are forced to leave their homes or places of habitual residence as a result of a disaster or in order to avoid the impact of an immediate and foreseeable natural hazard. Such displacement results from the fact that affected persons are (i) exposed to (ii) a natural hazard in a situation where (iii) they are too vulnerable and lack the resilience to withstand the impacts of that hazard"[1]. Given the complexity of this phenomenon, migration and relocation are increasingly recognised as an adaptation strategy to deal with climate and environmental related effects.

From the perspective of the islanders, their vision about their own development and future is particular and influenced by the insularity. For instance, Schwarz et al., (2011) carried out an integrated assessment of the perception that the local community of the Solomon Islands have about their level of vulnerability and resilience capacity. The participants identified *future* sources of threat as shown in table 2.

Table 2 Future threats of Solomon Islands, identified by local communities.

Generic category	Detail of the types of answers included in the generic categories
Climate-related changes and natural disasters	Natural disasters/sea level rise/high tide
Malthusian scenario	Population increase/young mother with 2–4 children/population control
Social cohesion erosion	Community collapse/alcohol and drug consumption/disobedience/independency of young/selfishness/disrespect/culture degrading
Land dispute and inter-community conflict over resources	Outsiders – Bougainville disturbance/land dispute/land shortage/unresolved conflict/gold mining negative effects
Local economic crisis	Price increase/lack of money/poverty/high food prices

[1] Platform on disaster displacement, follow-up to the Nansen Initiative. Online: https://disasterdisplacement.org/?q=the-platform%2Fkey-definitions

Household-level issues	Wild pig/illness/pigs destroying food gardens/crop not growing well
Fisheries-related issues	Less fish/reef resources/marine resource shortage

Source: Schwarz et al., (2011)

As shown in table 2, numerous answers given by the islanders are consistent with the factors exposed in figure 1, *climate-related changes and natural disasters*, *the erosion of social cohesion, economic crisis,* and *Malthusian scenario* are related to social-economic and ecological vulnerability; the limited availability of natural resources is coherent with the categories *fisheries-related issues* and *land disputes.* The presence of outsiders seems to be a concern within the respondents within the category '*Land dispute and inter-community conflict over resources*', which might reveal a closed cultural and nationalist identity.

This latter issue might indicate that the insularity, as a particular micro-cosmos, influences also the identity of the inhabitants generating a kind of socio-cultural distinction respecting other territories and societies, following Klaus and Stephen (2003), the complex interplay of physical and social meanings of insular spaces has profound implications for territorial nationalism.

Nationalism is linked to identity and territorialism, according to Coller (2006) nationalist movements prosper because they have been able to generate a consensus about the nature of the community, its territorial limits, its defining elements (identity domains), its history, and the like. This shared 'consensus' is shaped by a 'collective identity', that DiMaggio (1997, p. 274) defines as *a shared representation of a collectivity*.

Thus, identity is a social construct liked to the territory, a multi-dimensional classification or mapping of the human world and our places in it as individuals and as members of collectivities (Ashmore *et al.,* 2004). Following Jenkins (2014) the identification (identity) and interests are not easily distinguished processes, moreover, the interrelation between them have implications even in the political discourse, as Connell and King (1999) state:

> *Islanders are constantly reminded that their way of life and their identity have much to do with insularity and isolation on the one hand, and with migration and mobility on the other.*
>
> *(Connell and King 1999, p. 2)*

Insularity and mobility have been considered as two opposite concepts, but as Cubero (2011) states, those concepts have to be understood as two interrelated dynamics that operate simultaneously in the process of constituting insular social identities. In this sense, there is an intention of promoting the islander feeling and identity among the population because it constitutes a way in which hidden political interests might be achieved, as Jacoby (2000) points out, politicians attempt to define or frame issues in ways that maximise support for their own positions emphasising the differences between 'us' and 'the others'. This differentiation is masked in the political interests, as Jenkins (2014, p. 12) states: "*who we think we are is intimately related to who we think others are, and vice versa",* thus, the notion of identity involves two opposite criteria of comparison between persons or groups: similarity and difference.

Then the territorial identity differentiates between 'islanders' and 'others' -inhabiting other kinds of territories different than islands-; and the similarity is not only applied to the intra-islander social group or community, but it is extended to other communities inhabiting other islands, therefore the identification arises from the territorial condition, identifying other islanders as similar. This phenomenon is not recent, Constantakopoulou (2005) studied the existence of a common islander identity in the Aegean in the Classical and Hellenistic periods and found out that the islanders identified themselves with their islands rather than with their individual poleis (city-state):

> *Examination of attestations of island identity suggests that, although the ways in which this kind of identity was felt and expressed were probably diverse, the geographical separation of islands allowed for islanders to overcome probable local tensions and individual differentiations and seek ways of self-identification and of expression of political-religious-economic collaborations alternative to the polis.*
>
> *(*Constantakopoulou, 2005, abstract)

In summary, According to this exposed reasoning, the consciousness and identity of 'islander' arises as the complex interplay between numerous aspects, such as the historical dynamics, the availability and accessibility to local resources, the socio-cultural sphere and the local political interests, and all these elements are at the same time shaped by the territorial-

geographical component. As Briguglio (1995) states, islands face singular disadvantages due to their small size, insularity, remoteness and proneness to natural disasters. But are all those shortcomings exclusive of island regions?

2.2. Other kinds of insularity: remoteness

Islands vary by geography, physical, climatic, social, political, cultural and ethnic character and the stage of economic development (McCarthy et al., 2001), but as we have exposed, they share numerous characteristics that both influence their development and shape the mind-set of insular inhabitants. In the case of natural sciences, evolutionary biologists, theoretical ecologists and conservation biologists opened the concept of insularity when started to consider insularity as insular environments, ranging from oceanic islands to fragments of once-contiguous natural systems, for instance isolated habitats (Wilcox, 1980; Drake et al., 2002).

Through the development of this work, we attempt to argue that remote, including continental, social spaces share the same characteristics with a similar extent. Moreover, we defend that is not the island's physical boundaries the factor determining an insular condition, but the relative social-cultural characteristics of remoteness, connectivity, mobility and isolation.

Insularity itself is not only an environmental condition, but a *social situation, a potential symbol in a cultural geography* (Robb, 2001). From this viewpoint, is worthy to insist on the idea of the insularity as a process historically contingent and socially constructed (Knapp, 2008) in interrelation with geographic and territorial conditions.

As we have shown in the previous sub-section, island spaces are characterised by the following conditions:

- isolation (Olson and Dinerstein, 2000; McCarthy et al., 2001)
- peripherality (Deidda 2016)
- smallness (Briguglio, 1995; Taglioni, 2011)
- remoteness (Deidda, 2016)
- fragility (Hilker, 2012)
- uniqueness (King, 2002)

As Jodha (2005) states, the natural vulnerabilities lead to social vulnerabilities, and in fact, remote and isolated mainland communities share similar historical, social and economic shortcomings with island regions:

- Social vulnerability and poverty (Conner, 2005; Jodha, 2005; Duncan and Lamborghini, 1994)
- Physical isolation, particularly from larger urban centres (Hugo et al., 1999).
- Health issues (Clark et al., 2002; Charania and Tsuji, 2012)
- Limited transport and telecommunications (Roberts, 2004; Nutley, 2003)
- High costs and difficulties in transportation, construction and the provision of services (Slack et al., 2003)
- Historical migration phenomena (Kramer et al., 2009; Stockdale, 2004)
- Colonisation and nationalism (Bashford, and Strange, 2003; Coates and Powell, 1989)
- Limited availability of natural resources and high costs to exploit (Grose et al., 1998; Paleta et al., 2014; Beal et al., 2016)

According to Slack et al., (2003) the risks are magnified when the communities are remote or spatially isolated, therefore, these exposed features make the different in an equivalent manner than geographical distance affects to islands, for instance, Hugo et al., (1999) carried out a study in Australia in which developed a remoteness index of 11.338 localities based on their degree of accessibility to big urban centres and services, establishing a correlation between local economic decrease rates of those studied populations and their remoteness condition.

Beaton and Campbell (2014, p. 1) resume in one sentence several characteristics listed before when describe the historical, and still current, situation of many remote communities in Canada: *remote and rural First Nation (Indigenous) communities are in a constant struggle to maintain their autonomy in a settler colonial political and economic structure attempting to force community members' migration off their traditional lands to urban centres*. Nonetheless the historical indigenous self-organisation and resistance, the colonialist project still continues (Watson, 2009).

The case of the Arctic communities is a clear example of remote communities determined by a strong identity, geographical isolation, and a

past history marked by colonisation. As Geml et al., (2012) pointed out, despite the overwhelming social and economic changes that have occurred in the Arctic over the past fifty years, many native communities in the whole region continue to rely on the utilisation of terrestrial and marine resources for their survival, and claiming for their self-determination and self-government of their territories.

Migration in the Arctic region has been a constant historical phenomenon. Arctic peoples have moved through the land, navigated the sea, and crossed the ice, using knowledge of routes that was passed down through the generations, facilitating activities such as hunting and fishing (Manrique et al., 2018).

Nevertheless, many Arctic communities have had to leave their traditional places due to other reasons. Forced relocation or resettlement processes have been common within the Arctic communities due to several factors, such as industrial development projects (Greymorning, 2018; Carson, 2016) or colonisation processes (Damas, 2002). For instance, the construction of new hydroelectric power stations in the Kola region in the far northwest of Russia, forced to the Kola Sámi people to relocate (image 1). As Greymoming (2018) relates, native villages of the Kola Sámi region were forced to relocate very quickly, the residents received notification that they were to leave their villages as soon as possible without the opportunity or capacity to influence that governmental decision.

Image 1. Eastern Sámi family camp in Seitsul Island, Kola Peninsula, in late 1800s.

Photo: Courtesy of the Snowchange Coop, 2014 (online: http://www.snowchange.org/efforts-in-the-skolt-sami-areas-of-naatamo-watershed-finland/eastern-sami-atlas/)

Those industrial processes continue nowadays, even with more intensity, due to the increasing geopolitical and commercial interests in the region (Ebinger and Zambetakis, 2009; Konyshev and Sergunin, 2012) notwithstanding, the current migratory phenomenon has another additional face.

As in island territories, 'Climigration' (Ketola, 2015) also known as 'climate-related migration' (Bronen, 2010), is a dramatic phenomenon produced by the impacts of climate change on vulnerable communities, specially isolated and remote. In the field of climate change science, this phenomenon has been identified as a function of exposure to the impacts of climate change, the sensitivity of communities or socioeconomic systems to such impacts, and the capacity of those exposed to adapt (McLeman and Hunter, 2010).

This phenomenon constitutes a huge challenge to the exposed communities since they have to deal with rapid changes, but also to the international policy institutions, political bodies, researchers and academics, NGOs and all the actors involved in the development of climate change adaptation measures. As Lewis (2009) states, insularity and vulnerability are correlative, and resilience is best reinforced by adaptation of traditional skills and coping systems within development policies and programmes.

In summary, islands, isolated and remote territories around the planet might differ in numerous aspects, such as high, size, latitude, landscape, geomorphology, etc. but they share a common characteristic: their influence on the minds of their inhabitants, shaping their ways of life, their survival, their adaptation capacity and their cultural manifestations. As Cajete (1999, p. 6) states:

> *"The environment was not separate or divorced from native peoples' lives, but rather was the context or set of relationships that tied everything together. They understood ecology not as something apart from themselves or outside their intellectual reality, but rather as the very centre and generator of self-understanding"*
>
> (Cajete, 1999, p. 6)

Likewise, communities inhabiting these kinds of spaces share similar characteristics and vulnerabilities in their interaction with the environment

and have been forced to develop adaptation strategies to environmental changes.

But what are those strategies based on?

2.3. Insularity and site-based experiential knowledges

Following Maru et al., (2014) two main common and apparently contradictory narratives about communities inhabiting remote regions are dominant within the scientific and academic literature:

1. The first is related to resilience. Communities in remote regions possess a significant resilience capacity to face climate change and scarcity of resources. This capacity provides them with the necessary skills to develop adequate adaptation strategies.
2. The second is related to vulnerability. Due to the exposed disadvantages of insularity, isolation and remoteness, these communities are more vulnerable to the impacts of climate change.

This is an interesting paradox, but are those narratives mutually excluding?

Beginning by the second narrative, and as we exposed before, insular spaces are characterised by fragile and unique ecosystems, and the impacts of climate change are more evident on these regions than others. Therefore, vulnerability due to the rapid environmental changes is a weakness affecting these communities; in contrast, the first narrative is coherent with the idea that remote communities hold a robust knowledge for adaptation, deeply linked and co-shaped by the interaction with their closest ecological dynamics (Berkes, 1993; Inglis, 1993; Folke, 2004) that enhance their resilience capacity.

Supporting this latter perspective it might be presumed that, on the opposite side, the urbanized populations disconnected from their environments have lost their capacity to deal with environmental uncertainty (Jiang et al., 2008; Alberti, 1999), but it is not that simple. We may argue that those different societal entities have developed different capacities to deal with environmental changes using different ways of knowing.

Scientific knowledge became such an integral part of the European culture in the seventeenth and eighteenth centuries during the Industrial Revolution (Jacob, 1997). The origin of modern science and modern technology was motivated from the empiricism of Francis Bacon and the rationalism of Rene

Descartes (Popper, 2014) and later by modern political and economic theory of John Lock, Adam Smith and Thomas Jefferson (Studley, 1998; Capra 1982). This kind of knowing is used by societies which have lost their direct contact with the closest environment, developing specific methods and technological tools to deal and adapt to changes (Berkhout et al., 2002; Tompkins et al., 2010). Due to its European origin is commonly so-called in literature also as 'western knowledge' or 'western science' by numerous academics (Bala and Gheverghese, 2007; Tsuji and Ho, 2002; Agrawal, Heyd et al., 1996).

This body of knowledge has its own origins and history, and it is protected under the umbrella of the supposed western rationality, of the industrial logic and of the economic and political power. But aside this sphere, there are other means to explain, observe and cope with the surrounded environmental dynamics.

2.3.1. Examples of situated experiential knowledges: traditional and local knowledge

Insular and remote communities have historically dealt with the limitations derived from their insularity and remoteness conditions. Co-existing with fragile and unique ecosystems, and with a limited availability of resources, these communities have learnt to interact with their closest environment managing their local natural resources and developing adaptation strategies to climate changes during centuries and generation through generation.

Those inhabitants have had an extremely dependence on their closest environmental context and its natural resources to survive, develop, or even migrate (Manrique et al., 2018). Their knowledge is deeply linked to the closest ecosystems, deeply rooted in its environment (Banuri and Apffel-Marglin, 1993).

Mazzocchi (2006) refers that there are numerous different references for the same concept in the literature: traditional knowledge, traditional ecological knowledge, local knowledge, indigenous knowledge, folk knowledge, farmers' knowledge, fishers' knowledge, tacit knowledge, among other terms, and no decisive consensus in this sense has been established.

In any case, a brief description can be provided:

Traditional knowledge has been highlighted as an invaluable way of knowing essential to the economic and cultural subsistence of native

communities (Arrow, 1996; Purcell, 1998; Vinyeta and Lynn, 2013). This body of knowledge is co-created by the interaction of the communities with the ecological conditions in order to develop effective local adaptation strategies (Berkes, 1993, Gadgil et al., 1993) and is transferred generation by generation through cultural transmission (Berkes et al., 1995).

Many disciplines, academic, authors and researchers recognise traditional knowledge as a crucial element to the adaptation and resilience capacity of local communities when facing environmental changes (Inglis, 1993; Berkes, 2004; Folke, 2004; Berkes and Turner, 2006; Ruiz-Mallén and Corbera, 2013; Pulsifer et al. 2014; Muir, 2015; Manrique et al., 2018). Thus, its role in the development of new strategies and actions towards climate change adaptation and resilience might be of huge relevance.

Traditional knowledge may represent in many cases the only source of information for the past environmental conditions in the Arctic (Schlosser et al. 2016).

Figure 2. Some iconic cases of uses of traditional knowledge in health and status of the sea environments.

Traditional ecological knowledge – TEK is a globally accepted method of observing change which is deeply embedded in all small-scale and traditional fishing communities. It has been defined in literature often as a deep engagement with the seas and the shoreline environments. Ranging from a single successful fishing expedition to whole coastal cultures, these human endeavours are dependent of this "quiet" knowledge of the local environment, species, weather, waves, oral histories, harvest sites and seasonal behavior of animals and fish.

An iconic (NON-Cherish site) example from the past, of uses of TEK in detecting changes in the sea ecosystems, is the case of the seal hunters and fishermen from the North Baltic Sea in 1969.

The thick snow pack in the inner archipelago prevented seal hunters from going out to the open sea ice for seal hunting in March 1962. Photo: Eero Murtomäki

The sealers of Kvarken, Finland shared their observations of falling seal pup stocks to scientists. They passed the carcasses of ringed seals to researchers who could detect the presence and the extent of PCB and DDT in the meat of the seals. And further to this detected the impacts of these chemicals to the uterus of the female seals, thus alerting to a fall in stocks and the reason for it. The initial observations had been conveyed by the people possessing TEK of the local conditions.

The second emblematic case from the Baltic are the observations of the professional traditional fishermen of Pori region, for example Into Sandberg, who detected the eye-less Baltic Herring close to the coast. He went on to share the reports of the blind fish to researchers such as Pekka Nuorteva. He then could link the origin of this with pollution from a new industrial plant upstream close to Pori that had released uncontrollable waste waters to the Baltic sea water, impacting the herring stocks.

Two seal hunters relaxing after a success in hunt and two ring seals caught in the Western Ice of the Bothnian Bay (right) in 1960s. Evald Geust,

Both of these older examples point to a "first line of observation" by those fishermen, whose livelihoods and close connection with the sea, knowledge of the behaviour of fish and local environment, alarmed the public and authorities to new negative changes within the marine environment and on the coasts of Finland.

All of the above make TEK a holistic approach between human societies and nature.

Source: Mustonen et al., 2018

Local knowledge differs from traditional knowledge in the sense that the former has been derived from more recent human environment interactions (e.g. a few generations) rather than being embedded in deeper cultural practices (Raymond et al., 2010). Local knowledge is defined in literature as the knowledge held by a specific group of people about their local

ecosystems (Olsson and Folke, 2001; Folke, 2004; Gadgil et al., 2003; Brosius, 2006; Cleveland and Soleri, 2007). This includes the interplay between organisms and their environment (Olsson and Folke, 2001).

There are numerous examples in the literature that stress the usefulness and benefits that local and or traditional knowledge provide when introducing into decision-making processes. For instance, Thornton and Scheer (2012) demonstrated the effectiveness of traditional knowledge to improve understanding of marine systems and foster adaptive management as they change; other authors and studies stress the value of integrating local and scientific knowledge for fisheries management (Mackinson, 2001; Corral and Manrique, 2017). The potential and usefulness of traditional and local knowledges have been also reported when improving and developing fisheries management strategies and policies by local communities about aspects such as the local ecosystem, ecological dynamics, the behaviour and abundance of fish and other marine fauna, among others (Johannes, 1998; Neis et al., 1999; Saenz–Arroyo et al. 2005; Silvano and Begossi, 2012; Silvano et al. 2006; Silvano and Valbo-Jørgensen, 2008). Other studies have been carried out for diverse objectives such as wildlife management and conservation (Gilchrist et al., 2005); agroecosystems management (Bellon, 1995). Additionally, these kinds of knowledge may be of particular importance when extensive scientific studies may be impractical or difficult to carry out, such as in remote regions (Gilchrist et al., 2005; Johnson et al., 2015; Ferguson, 2000).

Figure 3. Local knowledge in the Canary Islands .

Local knowledge in the Canary Islands is well represented in traditional activities such as management of agro-ecosystems and artisanal fishing.

Potato crops on the island of Tenerife have an undeniable economic, social, cultural, scenic, historical and environmental significance.

Potatoes are grown mainly at an altitude of between 500 and 1000 metres above sea level in the north of the island.

Potato agro-biodiversity is represented by ancient varieties with names such as *antigua*, *de color* or *bonita*. These resemble varieties from Peru, of which they are direct descendants. They are most likely selections, hybrids or variants of those early tubers that were brought to the Islands from America and have contributed to a biodiversity that is unique in the world.

Artisanal fishing in the Canary Islands is threated by several sources: recreational fishing licences have tremendously increased in the last decades; tourism infrastructures invade the coastal spaces; and coastal urbanisation patterns are challenging small-scale fishery.

Traditionally, canarian small-scale fishers had some control and appropriation of territories and resources through knowledge that they only had (Chuenpagdee, 2011).

For artisanal fishers, defending the social boundaries of the group was essential in order to preserve their accumulated knowledge. this "secrecy" allowed them to transmit precise knowledge about the configuration of the seabed, the ecological niches, the points on the coast used to locate fishing spots at sea by triangulation (*las marcas*), or many other variables (Chuenpagdee, 2011).

(Photography: Francisco Rojas Fariña; Source: Rincones del Atlántico http://www.rinconesdelatlantico.es/)

It is necessary to understand traditional and local knowledge as different sources of information than scientific knowledge since they respond to different questions and might provide divergent, but valid, perspectives and solutions. According to Agrawal (2014) indigenous knowledge differs from Western or scientific knowledge on:

- substantive grounds--because of differences in the subject matter and characteristics of indigenous and Western knowledge;
- methodological and epistemological grounds--because the two forms of knowledge employ different methods to investigate reality;
- contextual grounds--because traditional/indigenous knowledge is more deeply rooted in its environment

Some shared characteristics might be acknowledged in order to capture the essence of these kinds of knowledges, following Raymond et al., (2010), a broad comparison between different types of knowledge might be done according to the following settings: (1) locally specific or generalised across regions; (2) formalised; (3) expresses expertise; (4) is articulated in ways accessible to others; and (5) is embedded in traditional cultural rules and norms derived from longstanding association and feedback with ecological processes.

In any case, categorise, define or classify the different kinds of knowledge is like building walls on the sea because the boundaries of these intangible notions or concepts are permeable, as a result, there is not a universal classification.

Summary

We have stressed that there is a techno-scientific dominance when framing and approaching environmental issues in decision and policy-making spheres.

Using a unique source of knowledge to gain information leave aside other relevant and useful types of information which can complement scientific analysis and policy proposals. in this sense, local and traditional knowledges may fill the gaps.

The condition of insularity is deeply linked to environmental knowledge: insular and remote communities hold robust bodies of knowledge. This sort of information is valid and useful when techno-scientific methods are not able to cope with the complexity and uncertainty.

To identify, mobilise and involve other knowledges, we need to use approaches which contemplate and recognise the knowledge diversity, as well as facilitate the involvement of different knowledge-holders. In this regard, Post-Normal Science appears as an adequate perspective.

3. THEORETICAL FRAMEWORK

As we learn from our mistakes our knowledge grows, even though we may never know, that is, know for certain.
Since our knowledge can grow, there can be no reason here for despair of reason.
And since we can never know for certain, there can be no authority here for any claim to authority, for conceit over our knowledge, or for smugness.

Karl Popper (2002, p. 12)

THEORETICAL FRAMEWORK

In the previous section we have reviewed the distinctive features of insularity and how environmental issues evolve in interdependence with both the social-cultural characteristics and the territorial conditions. As we showed, this kind of spaces entails their own particular dynamics, thus, the universal character of scientific approach is not sufficient to encompass the local complexity and uncertainty involved when socio-environmental issues arise.

This thesis is framed along the theoretical lines of the so-called Post-Normal Science (PNS), a framework first described by S. Funtowicz and J. Ravetz in 1990, characterised by a holistic vision of current socio-environmental problematics.

PNS constitutes an important theoretical milestone within which participatory approaches in policy related issues have been framed and evolved over the last decades. This section explores the characteristics of the PNS framework in order to show its relevance and coherence to address complex environmental issues occurring in insular spaces, such as those related to invasive species putting in risk the local food security; the overfishing and the human impacts of climate change in the Arctic.

3.1. The Post-Normal Science framework

Post-normal science (PNS) is a problem-solving framework developed by Silvio Funtowicz and Jerome Ravetz in 1993 to establish a new conception of the management of complex science-related issues (Funtowicz and Ravetz, 1993).

As we have pointed out, historically and in a classical way, environmental problems have been defined and addressed under the umbrella of the certainty provided by techno-scientific methods (Gray et al., 2010). This positivist approach tries to isolate the problem to be studied from its broader context in order to provide an optimal solution (Byrne, 2002; Ramos-Martin, 2003; Marshall and Picou, 2008). However, Funtowicz et al., (1999) have rightly pointed out that nothing can be managed conveniently under conditions of isolation since the problems are mutually intertwined in different scales of space and time, and the uncertainties and values burdens affect both the data as well as the results (Funtowicz and Ravetz, 2001).

During the last decades of the 20th century, several scholars warned about the limitations of scientific knowledge, since not all cases can provide a diagnosis or an accurate solution (Funtowicz and Ravetz, 1993; Fairhead and Leach, 1995). Some scientists interested in the interface between social and ecological systems also argue that western paradigms and systems of knowledge are currently not able to deal with the full complexity of environmental management (Johannes, 1998; Ludwig, 2001).

These critical voices and visions against the inappropriate and useless reductionisms have been making a call for the establishment of approaches based on a complex understanding of the problems (Nowotny et al., 2013), in this sense, Brown (2008, p. 3) points out:

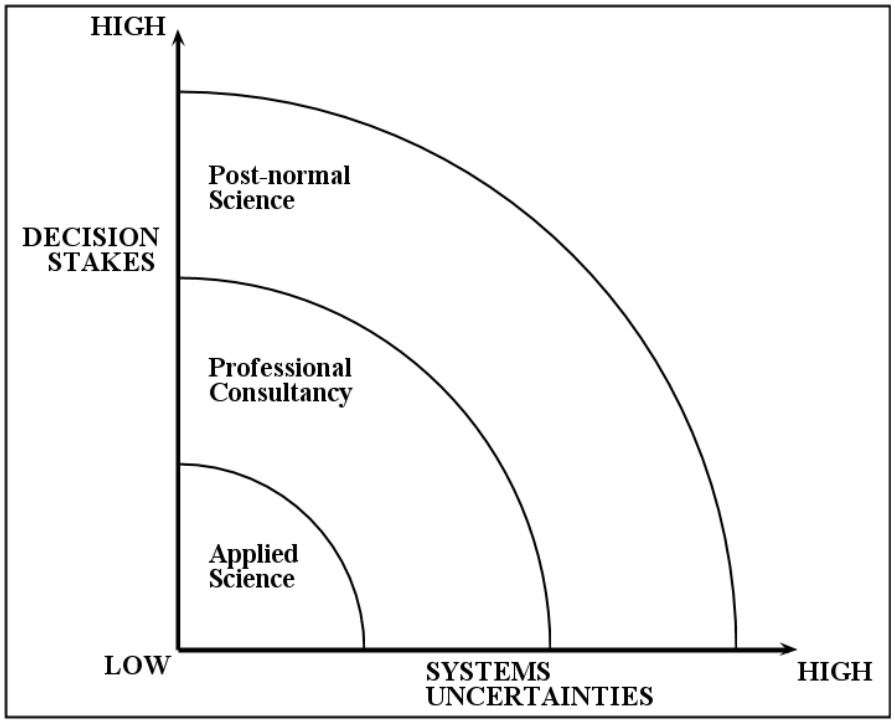
> *This 'Scientific Enlightenment', emerged from the 17th century, has led to our addressing complex problems through a particular problem-solving style. Problem resolution by objective reasoning and reducing issues to their component parts led to semi-miraculous feats, such as eliminating smallpox and placing a man on the moon. On the other hand, the dominance of this way of thinking has blocked the development of other ways of resolving the many wicked problems that cannot be solved through this process.*

From these premises, there is a need to overcome the classic linear problem-solving approaches to embrace perspectives more focused on the analysis of the complexity of socio-environmental problematics. This can only be achieved with recognising the existence of other ways of knowing and knowledge beyond the techno-scientific. Due to the inherent complexity of current environmental problems, a hermetic group of scientists can only provide partial solutions (Funtowicz and Ravetz, 1997; Funtowicz and Strand, 2007). The alternative proposed by Funtowicz and Ravetz is that quality assurance of policies relies on open dialogues between all the involved actors, allowing extended participation in decision and policy making rather than on experts alone peer review.

These authors propose to open up decision-making processes to include what they have called "extended peer communities", i.e. the wider sphere of partakers consisting of different actors that can provide diverse perspectives and solutions to address the issue of concern, instead of an expert-based decision making alone. This implies changes in decision making practices, favouring those that value involvement of all the persons or social groups with different affections towards the issue of concern, e.g. interest, influence and/or being affected by the issue or its resolution.

PNS gives a broader approach to decision-making processes, adapting them to current situations in which classical science is not able to solve on its own the complexity of problems characterized by a high level of uncertainty, values in dispute, and a plurality of legitimate perspectives, frequently confronting each other (Funtowicz and Ravetz, 1994; Ravetz, 1999). This framework does not deny the usefulness of normal science: when uncertainties and stakes are lower, an expert-based approach and traditional problem-solving strategies, such as applied science or professional consultancy, may be effective (Figure 4).

Figure 4. Post-Normal Science diagram.



Source: Funtowicz and Ravetz, 1993

According to figure 4, the level of complexity and risk in decision making processes increases in a direct correlation with the uncertainty of the system. At low levels of risk and uncertainty it is possible to apply the methods of normal science (applied) since they are capable to control variables and provide concrete answers to concrete problems.

When complexity increases, a Post-Normal approach becomes necessary since a number of variables that cannot be controlled by means of the classical scientific method are introducing uncertainties in the system. In these situations, the important aspects are the quality of the process and the quality of the information (Funtowicz and Ravetz, 1994; Ravetz, J., 1999) rather than finding a unique "solution" or "truth".

In line with this postulate, uncertainty and complexity are considered as challenges to contemporary science, which is immersed into a crisis period since it cannot provide what it was made for: to give one unique solution. Finally, the post-normal science framework arises in an ongoing context of paradigms shift (Kuhn, 2012). This approach provides a different and wider insight that does not refute the importance of mainstream science, but considers it as part of a more extended and inclusive body in which other

kinds of knowledge (and actors and practices) interplay, such as what is designated as the local and traditional knowledge.

Post-Normal Science is not rigorously a new type of knowledge, but a new framework in which different bodies of knowledge interact, collaborate, and give rise to new co-created knowledge. As Funtowicz and Ravetz (1999) emphasised, Post-Normal Science is "an insight rather than a theory" and, as Dankel et al., (2017) point out, can flexibly accommodate a number of different approaches to science for governance.

Current socio-ecological issues occurring in insular and remote spaces are characterised by the conditions which define a post-normal science situation: irreducible complexity, deep uncertainties, multiple legitimate perspectives, values dissent, high stakes, and urgency of decision-making (Funtowicz and Ravetz, 1993, 2008). Thus, the PNS perspective is the proposed key theoretical framework underlying the work done in this thesis to address complex problematics in a small island such as Tenerife, and in an isolated region such as the Arctic.

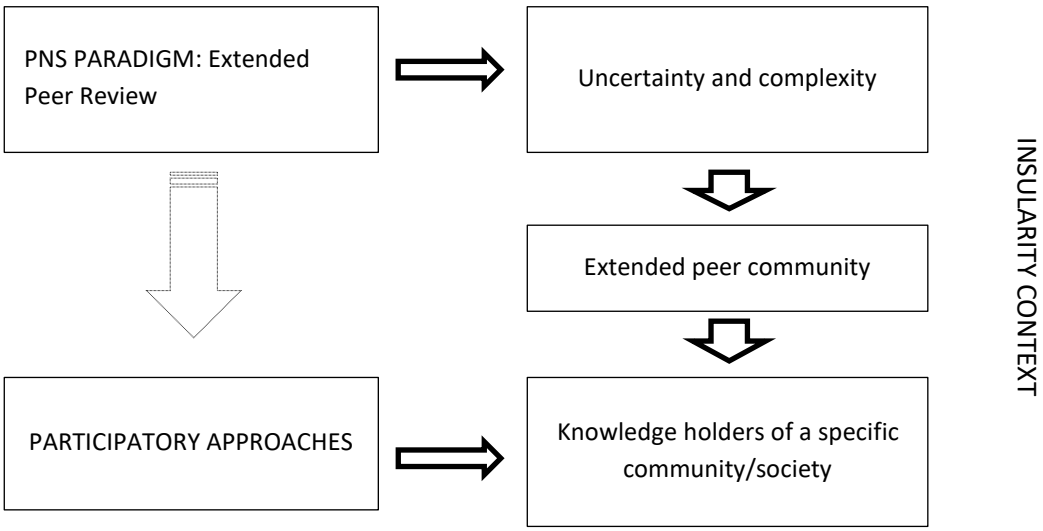
3.3. Post-normal Science in practice: the participatory angle

As Strand (2017) points out, the dichotomous nature of PNS can be described as both descriptive, describing urgent decision problems – post-normal issues – characterised by incomplete, uncertain or contested knowledge and high decision stakes; and normative, proposing a style of scientific inquiry and practice that is reflexive, inclusive and transparent in regards to scientific uncertainty and moving into a direction of democratisation of expertise.

One of the key principles of PNS is the recognition of multiple perspectives and commitments. It sustains that as policy processes become dialogic, knowledge becomes 'democratised', by legitimating what Funtowicz and Ravetz (1993) described as 'extended facts' supplied by the 'extended peer community'. Participatory approaches to create and mobilise environmental knowledge are commonly heralded for their potential to enhance legitimacy and quality of decision-making processes, especially under conditions of uncertainty (Ascough et al., 2008; Waltner-Toews et al., 2008; Hage et al., 2010; Fish, 2011). In practice, a PNS lens requires the deployment of participatory approaches (Van den Hove, 2000; de Marchi and Ravetz, 2001; Blackstock, 2007). As Funtowicz and Ravetz (2003) pointed out, in complex

systems, there can be no single privileged point of view for measurement, analysis and evaluation.

Figure 5. General approach implemented in this research.



Decision Support Systems have evolved over the last decades, moving from simpler and more concrete forms towards more integrated systems in which participation plays a key role (Guimarães and Corral, 2002). The inclusive participatory framework showed in figure 5, allows achieving the following goals (De Marchi and Ravetz, 2001):

- to frame policy issues in broad terms, including all sectors of society and the natural environment;
- to render the style of decision-making more responsive to democratic principles;
- and to improve the quality of decisions by incorporating different perspectives and accessing a variety of resources.

3.2. Some experiences using participatory approaches

Abundant studies and projects about natural resources planning and management have been carried out in which actors participation is introduced as a factor providing for more robustness to the outcomes. For instance, Luvet et al. (2012) implemented a participatory process in a case study focused on the ecological restoration of a degraded river in Switzerland, with the objective of intervening in the restoration process by using the knowledge of the community. Likewise, in a watershed restoration

project, Mustonen (2013) explored local knowledge to gather information about pre-industrial fisheries, fish ecology and behaviour, and bird habitats.

Other examples has been carried out in rural areas with small communities, for example, Miranda (2009) analysed to what extent the participation of the local community in a development project implied the incorporation of local knowledge and the demands of the community to legitimise a land use planning process. In a protected natural reserve in Mexico, Porter et al. (2006) carried out a participatory process to find out to what extent diversification of productive activities influences the satisfaction of the economic needs of families living in the study area.

Recently, Favretto et al. (2014) implemented a participatory practice to assess the effect of jatropha on food security, poverty and energy security in Mali. They concluded that through the participatory process, small-scale producers could procure their benefits while reducing potential land tenure conflicts.

There are several examples conducted in insularity contexts, for instance, Fazey et al. (2010) carried out collaborative work with the communities of the Solomon Islands in order to analyse their capacity to respond adequately to the changes that affect their traditional quality of life; Kelman et al., (2012) developed a study in which they combined disaster research, "insularity" criteria and participatory research, with the aim of exploring strategies to deal with disasters in small islands, concluding that the "insularity" dimension offers greater possibilities for disaster risk reduction research than has been valued. Mata et al. (2014) complemented a techno-scientific approach of land spatial planning using a Geographic Information System with the Participatory Rural Appraisal (PRA) approach, in order to analyse the factors that determine the selection of grazing areas. The researchers proven that inefficient planning produced negative environmental impacts and high economic costs for local farmers.

Steenbergen (2013) conducted a participatory study on marine conservation strategies of various small islands in eastern Indonesia. These authors showed a gap between science-based conservation approaches and local communities' traditional practices, concluding that the integration of conservation initiatives into communities' fishing traditional practices through external interventions does not necessarily result in a more sustainable use of the local marine resources.

Using participatory approaches in Mittimatalik, (Nunavut, Canada) Gagnon and Berteaux (2009) documented traditional ecological knowledge about local species and found out that this kind of knowledge go beyond the spatial and temporal scales of current scientific data regarding those studied species, for instance, the Arctic fox.

Overall, these types of projects show that complementing technical and scientific knowledge and studies, by widening the knowledge we can acquire about the environmental dynamics, facilitates the development of more robust fit for purpose strategies and policies.

It must be noted that despite the claims and benefits of public participation that have been stressed, the added-value is not always recognised and obvious (Cooke and Kothari, 2001). Notwithstanding, as Ravetz (2004) states, the outcomes are not as important as the way in which the problems are framed, that means that the results of decisions depend on the quality of the process.

The following section shows the specific methods used during this research within the theoretical framework that we have exposed. The Post-Normal approach is applied here in a descriptive mode since the issues studied require the elaboration of a complexity-based framing. This standpoint shows how the complexity involved in each case influences the relationship among science, policy-making and the communities involved.

Summary

As we have seen, PNS recognises the value and usefulness of knowledge diversity when decisions are urgent. This diversity is relevant and necessary if we want to explore and develop knowledge co-creation processes.

Through different methodologies, PNS allows the identification different knowledge-holders and their engagement in assessments and decision-making processes.

4. THE METHODOLOGICAL FRAMEWORK

'That expression "public", which everyone brings on their lips always in support of their own opinions; that wild card of all parties, of all judgements; is it a meaningless word? or is it a real and effective entity? According to the much that is spoken about it, according to the role it makes in the world, according to the epithets that are lavished on it and the considerations that are kept, it seems that it must be someone.

The public is "enlightened", the public is "indulgent", the public is "impartial", the public is "respectable": there is no doubt, then, that the public exists.

And so then, "who is the public and where is he found?".'

Mariano José de Larra

¿Quién es el público y dónde se le encuentra?

El Pobrecito Hablador, nº 1, 18 de agosto de 1832.

THE METHODOLOGICAL FRAMEWORK

One of the main goals of this research is to explore spaces for knowledge co-creation. In insular and remote territories, the methodological framework requires tools capable to save the distances, capture the regional/local complexity, and identify the different knowledge-holders.

There is a huge amount of methodologies able to engage knowledge-holders in decision and policy-making processes. This section shows the methods selected during the development of this research in order to involve the communities in each case.

To achieve this goal, a general methodological framework has been designed in order to provide a coherent structure to the whole research, is what we have called *the toolbox*.

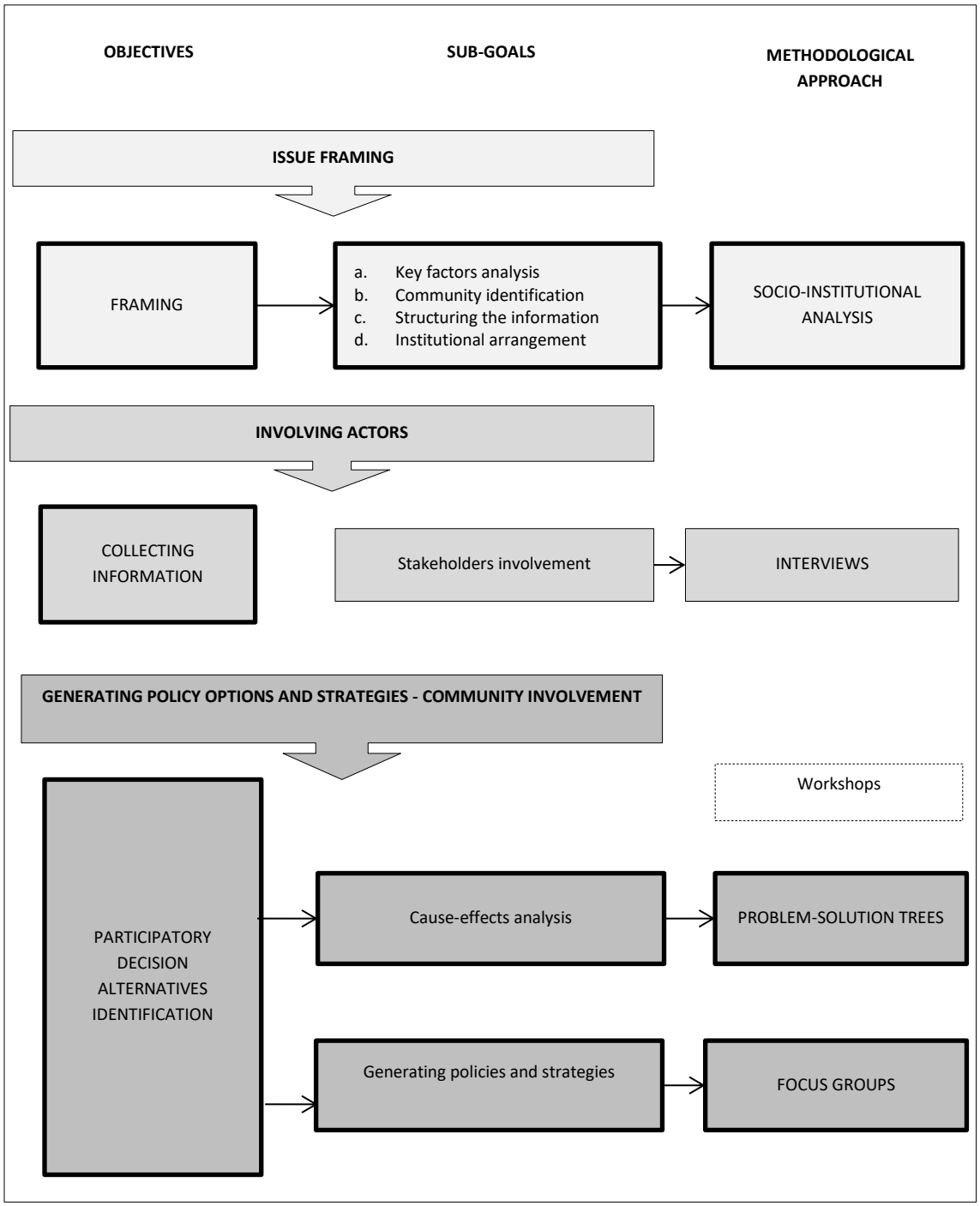
4.1. The toolbox

Knowledge is an individual intellectual process (Ackerman, 1996) but also a social collective phenomenon (Moulaert, 2013; Blumer, 1971) but is only directly observable by its external manifestations (language, tools, cultural expressions, etc.). To conduct this research we needed to choose among methods that, on the one hand facilitate the open expression of the knowledge-holders, and on the other hand provide a fully understanding of the complexity of the issues under study. In parallel, we needed tools which could guide the research outputs to a significant change of the previous status of those issues, involving the different knowledge-holders and ultimately, providing novel or innovative alternatives.

'The toolbox' (figure 6) shows the rationality of the technics selected and applied according to the specific objectives of the research.

The process of application of the methodology is increasingly inclusive. That means that the first steps are focused on the procurement of a big amount of information by a more individualistic manner (a Socio-Institutional Analysis is applied), as the information is being obtained, the process becomes more participative and the interviews are taking relevance. In a third step, the information that is obtained comes directly from the discussion and debate of actors involved into the problematic.

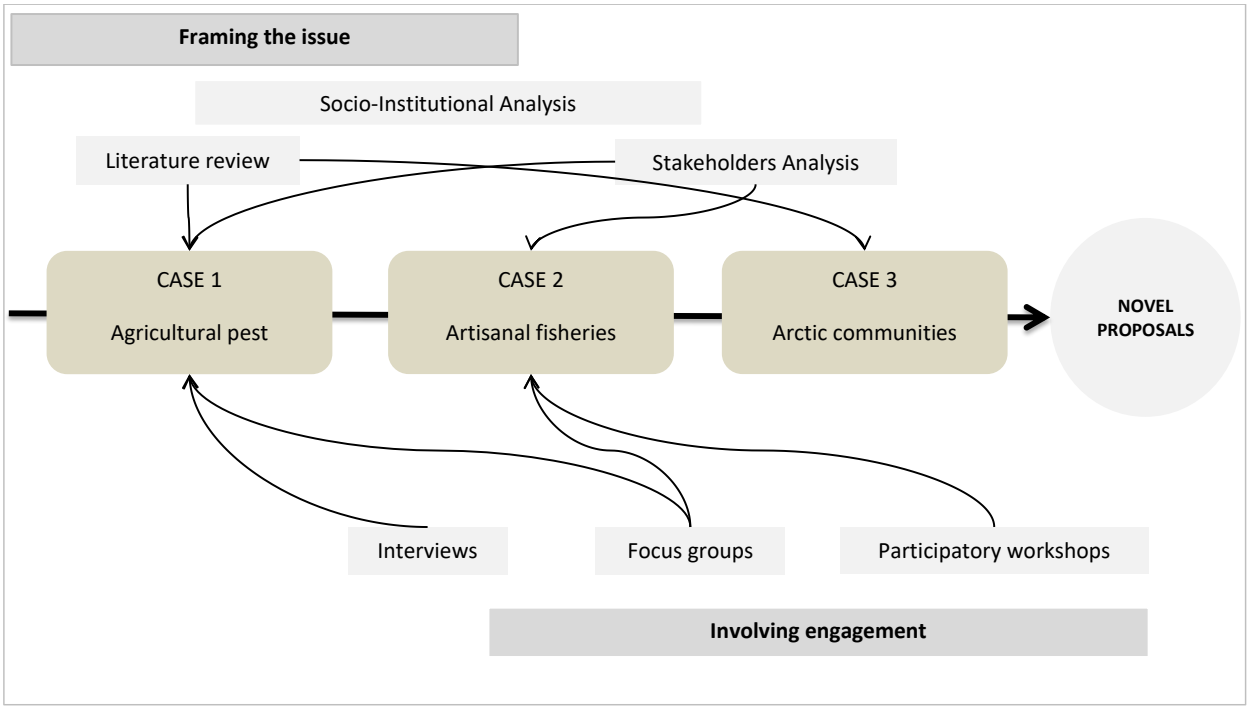
Figure 6. General methodological approach.



The figure 6 shows a broad scheme of the methodological approach to facilitate the understanding of the framework implemented. Under this general approach, three consecutive objectives emerge, on the first step, a broad framing of the problematic is necessary to understand the problematic as a whole so as the several variables influencing the issue. To this end, the

Socio-institutional Analysis is a useful methodology since it provides a historic and institutional perspective, providing an identification of the actors involved so as their interrelationship and power relations; the second step is focused on the involvement of the main relevant actors identified in the previous step, thus, more interactional and inclusive methods are needed to achieve this goal. The methods selected have been the semi-structured interviews, the focus groups, and participatory workshops (in which a concrete technic called "problem-solution tree" was implemented); the third step corresponds to the ultimate objective, that is to obtain, from the whole process, novel or innovative actions to cope with the problematic (figure 7).

Figure 7. Methods applied in each case study.



As explained in the introductory section, this research is composed by three case studies, each of them with a different thematic, history, evolution, actors, region, etc. thus, depending on the their own characteristics, so as on the possibilities and available resources to face each of them, a different combination of technics has been applied.

Case study 1 explores the introduction of an exotic and extremely invasive pest affecting the potato crops in the island of Tenerife. This work, as the others, is not focused only on the micro-scale, which is the soil level or the local agricultural context, and goes further, carrying out an analysis of the

main social context in which the pest finds facilities to spread, affecting the economy, the landscape, the local genetic varieties of potatoes, among other variables. To face this problematic, three technics were applied: a Socio-Institutional Analysis, a focus group composed by farmers, and a series of interviews.

Case study 2 is focused on the analysis of the overfishing problem in the island of Tenerife and the potentiality of the artisanal fishing to equilibrate the issue towards a more sustainable fishing activity. To this end, the technics implemented were the Socio-Institutional Analysis, a series of heterogeneous focus groups, and participatory workshops.

Case study 3 explores how local indigenous communities in the Arctic region adapt to environmental changes using their traditional knowledge, additionally, analyses the level of integration of this kind of knowledge into international policy and scientific spheres. To reach significant and useful results, an intensive literature review was carried out.

But before submerge into each case study, is desirable to provide a description of these methods one by one.

4.2. Framing the issue

With the aim of avoiding the partial vision that characterises the micro-level focus, which would lead us to miss influencing and relevant variables, is appropriate to widen the approach using appropriate methods that would permit us to establish a broad framing of the whole problematic.

Establishing a coherent issue framing is the first step of the whole analysis. This step constitutes an important basis to understand and collect the relevant information and identify the variables influencing the problematic, and depending on how it is made, the rest of the analysis can vary. For this reason is important to carry out a correct framing.

This analysis results in several outputs, such as a the identification of interested and affected actors, a deepened understanding of the strategic choices made by those actors in the context of the institutional setting, the power relations arena, or the existence of other perspectives rather than the dominant one. All these elements constitute the universe sphere in which the problematic evolves, and additionally enlighten other hidden alternatives to tackle the topic.

But previous to the active involvement of actors is necessary to carry out an analysis of the social context, to this end, the Socio-Institutional Analysis has the capacity to meet these needs.

4.2.1. Socio-Institutional Analysis

The Socio-Institutional Analysis (SIA) allows the creation of a broad framing of the problematic previous to the active involvement of the community.

The Socio-Institutional Analysis is an integrated method that combines some social research techniques such as the literature review and the analysis and mapping of the involved actors (Salgado et al., 2009; Corral-Quintana et al., 2016; Hernández González and Corral Quintana, 2016). From this combination of techniques comes a complete analysis of the reality of the problem to be studied and facilitates the extraction of valuable information to develop more consensual decisions, since it identifies the actors involved in the problem allowing them to make contributions in function of their knowledge. This technic is not only a static picture of the past or the present, SIA is a means to generate understanding of the institutional arrangements.

Socio-institutional analysis (SIA) framework aims at framing complex issues as well as identifying the relevant stakeholders involved in a problematique (Corral Quintana, 2000). SIA is considered as an exploratory process to analyse different structures and social relationships through the analysis of the institutional context and the identification of the actors involved in the problematic from a historic perspective (Corral Quintana, 2000). Providing a precise approximation of the prevailing social and institutional arrangements, understood as the social context shaped by institutions that define citizens' rights and obligations (Bromley, 1989; Commons, 1961; Schmid, 1972).

Theoretical aspects of SIA either justifying the necessity of these approaches (Ostrom, 1990; 2005) or suggesting guidelines (Ingram et al., 1984) or frameworks of analysis (Imperial, 1999; Koontz, 2006) have been discussed in the literature.

SIA has been widely used for different purposes, projects and objectives, for instance, to implement more inclusive governance processes into natural resources management and planning (Salgado et al., 2009); to evaluate the citizens' risk perception of earthquake hazards (Kikelomo and Wilkinson,

2010); or to analyse policy recommendations in agricultural land uses (Mulleta et al., 2014).

This proposed approach aimed at tackling the problem at hand from a broad perspective, paying particular attention and giving specific relevance to the following aspects: (a) the social context in which policies are developed and decisions are made, and (b) the actors involved in the process, so as their interests and behaviour (Corral Quintana, 2000).

In order to contextualise the problematique, identify all possible relevant variables, and to analyse the social, environmental, economic and governance interrelationships, social research techniques, such as literature review and stakeholder analysis were implemented.

4.2.1.1. Literature review

The *literature review* is based on the extraction and identification of key information through the systematic consultation of different sources including scientific and other types of legislative documents, press and media, scientific articles and other relevant type of documentation.

According to Corral (2000), three basic sources are generally used to define the problem and identify the actors involved. The first one is the analysis of the press, with the collection of articles published in the press at the local, regional or national level, the publications of political groups and non-governmental organisations, which have information related to the case study. A second source of information is the documents, both formal and informal, related to the case. Thus, the analysis of the existing legislation and its evolution, for a period considered relevant in the study, will allow knowing the institutional framework in which the studied problematic evolves and develops.

The precise interpretation of these elements and the certain analysis of the interactions that arise from them allow improving the understanding of the processes in which policies are shaped and decisions are taken.

4.2.1.2. Stakeholder identification and mapping

Stakeholders analysis and mapping refers to a wide range of useful tools for the identification and description of the groups involved in a given problem, as well as for the analysis of their interrelations, interests and ability to influence decisions (Cummings and Doh, 2000; Reed et al., 2009). Basically,

this method allows the understanding of how the characteristics of stakeholders – individuals, groups and organisations – influence decision-making processes (Brugha, and Varvasovszky, 2000). To identify the preferences and interests that cannot be explained and forecast on the basis of a *homo-economicus* rationality (Corral Quintana, 2000) but are conditioned by rules, by the institutional arrangements, by values and habits, and interactions with other actors. This sub-objective is therefore about identifying the stakeholders, a static element of the decision-making processes, and identifying the interactions and potential conflicts between them.

There is a wide range of techniques to identify and map stakeholders and interested actors, for instance, organising participation; creating ideas for strategic interventions, including problem formulation and solution search; building a winning coalition around proposal development, review and adoption; and implementing, monitoring and evaluating strategic interventions (Bryson, 2004).

This method is useful in a wide variety of situations and objectives, for instance, when conducting a policy analysis, predicting policy development, implementing a specific policy or project (Varvasovszky and Brugha, 2000) or even to develop policy-oriented institutional mapping (Aligica, 2006).

4.2.2. Engagement

In a previous stage, the methodology has been useful to identify the relevant actors so as the social context in which those actors interact, how they interact and make decisions within the issue in order to influence decision-making processes, however something else is missing.

The Socio-Institutional Analysis can provide us with relevant information and data, such as the actors involved, their institutional role and responsibilities, or how has the issue been faced in the past, but there is a part of the whole picture that is not possible to reveal only attending to the written story. This 'other' information is sensitive and hidden, and might be fundamental to complete the scene, thus we need to introduce other analytical tools.

Contrarily to the previous methods, at this point we need a more interactional action in order to integrate and assemble values, interpretations, past experiences and expectations on the future from the point of view of the relevant actors. Engagement allows eliciting hidden

points of view, as well as giving more relevant information. To gather this kind of information, the interview method comes to be an adequate resource since allows the elicitation of the different points of view and interests from the participants and its integration into the whole analysis. Likewise, this methodology permits to the actors to propose novel actions thanks to the interaction and positive confrontation of the different points of view, experiences and knowledges.

4.2.2.1. The Interviews

As Holstein and Gubrium (2004) point out, the interview conversation is a pipeline for transmitting knowledge. This kind of conversation or dialogue may vary "from highly structured, standardized, qualitatively oriented survey interviews, to semiformal guided conversations, to free-flowing informational exchanges, all interviews are interactional". The interview method allows the development of a conversation between the researcher and the respondent in which the last one have the possibility to expound and provide experience and knowledge. As Hollway and Jefferson (2008) state, during an interview process, the interviewer imposes on the information in three ways: "by selecting the theme and topics; by ordering the questions and by wording questions in his or her language", and these ways determine the type of the interview implemented.

In a semi-structured interview, the researcher provides a flexible structure based on the research objectives and allows room for the respondent's more spontaneous descriptions and narratives (Brinkmann, 2014) in this sense, the interviewer's responsibility is to be a good listener leaving the interviewee a role of a storyteller, rather than a mere respondent (Holstein and Gubrium, 2004; Hollway and Jefferson, 2008).

This interactive person-to-person method is valid to obtain relevant and sensitive information that might be difficult to achieve through other means, such as a literature review. In this case, the analyst interprets and explores the information hidden behind the "official narrative" of the narrator.

The interviews are a valid tool, in conjunction with others or either as a solely tool, to generate socially robust knowledge (Nowotny, 1999; Gibbons, 1999; Weingart, 2011), by either filling the gaps in the analysts' understanding or providing a different perspective on the issue (Corral et al., 2015) allowing experts to reflect their take on events and offer them the

opportunity to voice social actors' opinions on the problem (Hernández-González and Corral, 2017).

4.2.2.2. Group dynamics

As Lopes and Videira (2013) state, deliberative approaches are necessary to support emerging policy initiatives and decision-making processes, and under conditions of uncertainty and complexity, stakeholders' involvement increases the chances of policy acceptance (Papadopoulos, and Warin, 2007). Regarding to environmental issues and climate change risks, it has been highlighted that public participation is a key goal in formulating adaptation responses to climate change (Few et al., 2007).

In any case, when planning and conducting participatory processes it is vital to pay closer attention to who is participating, in what and for whose benefit (Cornwall, 2008) because these kind of social processes might result in bad practices or limited outputs if the methods are not correctly developed and implemented (Buuren, 2009).

4.2.2.2.1. Focus groups

A focus group is a kind of group interview made up of people who are involved in a problematic, a development policy or a strategic intervention (McLafferty, 2004). Its objective is focused on gathering information about opinions, attitudes and experiences or even to explain actors' expectations regarding policies or strategies.

This methodology is interesting for the evaluation of projects or programs, especially for field studies between beneficiaries and intermediate actors. Using it at the end of a program to evaluate its impact, allows understanding, analysing and dissecting the basis of the opinions expressed by the participants.

It is a means to quickly gather information and points of view. When it joints actors with different positions, it allows both the expression and explanation of the different points of view, as well as the deepening of their opinions.

4.2.2.2.2. Participatory Workshops

Participatory workshops are important processes for integrating different perspectives and create knowledge. It is a useful mean to evaluate how different stakeholders (previously identified) perceive and conceive a given

problematic (Knapp, et al., 2011). As a result, different perspectives and alternatives might be achieved by these set of methods.

The usefulness of carry out participatory workshops has been also stressed in projects related to diverse objectives, for instance, in agricultural issues, Norton et al., (2010) highlighted that the integration of key technical and management activities, so as the participation of a wide range of stakeholders including farmers, researchers, extension officers, crop consultants, government agencies, and industry, are required actions to achieve successful and long-term implementation of pest management strategies; in marine conservation and planning, providing relatively accurate data regarding fish abundance (Wheeler et al., 2008; Douvere and Ehler, 2007); for valuing marine and coastal ecosystem services (Lopes and Videira, 2013).

This technic has been used in the context of this thesis during the second case study, in which participatory workshops were carried out with the local fish community, using a method denominated "problem-solution tree".

Problem-solution tree methodology is useful to 'determine the root causes of a main problem' (Snowdon et al., 2008). The first step consists of defining the focal issue to be analysed. Then progressively, participants build up levels of causal factors (represented as roots) and illustrate in a visual manner the issue with its interrelated causes and effects.

In second round of workshops the process is similar to the previous step, but in this case the information is structured and turned from negative statements (problems) into positive statements (solutions and objectives).

Problem and solution trees methodologies have been developed and applied to a wide range of cases, for instance, to study fish nutrition issues in Solomon Island (Albert and Bogard, 2015), or to assess fishery livelihoods and adaptation to climate change (Iwasaki et al., 2009), these experiences demonstrate the capacity of this method to represent a comprehensive "image of reality" and convert problems into coherent solutions.

Summary

In practice, bridging a diversity of knowledges implies the involvement of different knowledge-holders. Such processes require necessarily participatory actions and methods, but also methods which allow the elaboration of a broad understanding of the issues under study. In remote and insular territories, these tools are important since these spaces embrace specific characteristics not easy to extrapolate to other regions. In this sense, SIA appears as a valid method to understand and cover the complexity of each territory; while the participatory tools allow the direct engagement of the knowledge-holders.

In the following section, we show how we applied these tools in the real case studies in which we based our hypothesis, as well as the outcomes they provided.

5. DESCRIPTION OF THE CASE STUDIES AND RESULTS

'You probably wish to deduce, prince,' said Alexandra,
'that moments of time cannot be reckoned by money value,
and that sometimes five minutes are worth priceless treasures.
All this is very praiseworthy;
but may I ask about this friend of yours,
who told you the terrible experience of his life?
He was reprieved, you say;
in other words, they did restore to him that 'eternity of days.
' What did he do with these riches of time?
Did he keep careful account of his minutes?'
'Oh no, he didn't!

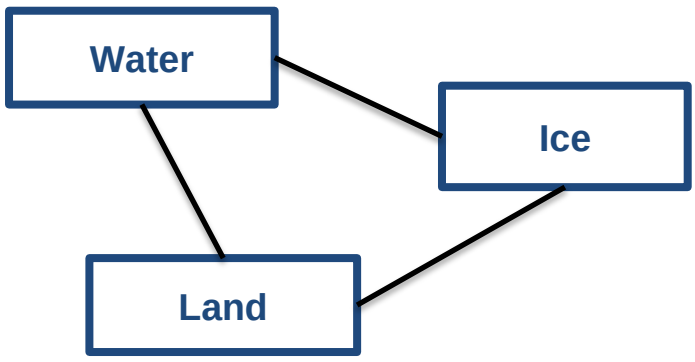
(Alexandra Ivanovna)
The Idiot, Dostoievsky, F. (2003, pp. 87)

DESCRIPTION OF THE CASE STUDIES AND RESULTS

In this section, the case studies that compound this Thesis are briefly described in order to facilitate the understanding of the whole work and discussion of results achieved. These three case studies correspond to each of the published peer reviewed papers included in the Annex.

Instead of *quantities*, this chapter tries to capture the role of *qualities* in the outcomes that the participants involved in the case studies made explicit through the knowledge they shared. This chapter does not show numbers, statistics, balances or equations. Not everything is measurable or valued using numbers in accordance to the words of Alexandra Ivanovna from *The Idiot* novel.

Islander and remote communities are deeply linked to environmental elements. Through history, they have learnt to observe, predict and know different dynamics, such as the ecosystem changes, weather patterns, or local flora and fauna, etc. This way, the land, the sea, and the Ice constitute key elements for their survival. The case studies are related to these elements.



Insular and remote communities develop a close and deep relation with natural elements

PLOWING THE SOIL

Differentiated agrobiodiversity, local agricultural practices, invasive species, among other elements, are constitutive aspects increasing complexity in insular territories. Within this context, farmers play an important role.

The widespread of agricultural pests: the case of Guatemalan Potato moth -*Tecia solanivora*- in the island of Tenerife (the Canary Islands)

> *Corral, S., Romero Manrique D., Guimarães Pereira, A., and Cuenca, E. (2017). Assessing the complexity of the spreading processes of agricultural pests: the case of the Guatemalan potato moth in Tenerife. Land Use Policy, 69, 338-348.*

This first case study examines the global expansion of an agricultural pest, which affects the cultivation of potatoes, and its incidence in the island of Tenerife. The impacts of the plague on diverse island characteristics such as biodiversity, local economy, landscape, etc. are analysed, and an elucidation of the proposals of the local actors involved is made based on their own perspectives and knowledge.

The potato pest commonly known as Guatemalan potato moth *(Tecia solanivora)* was reported in the European continent during 2015 in the north of Spain (Galicia) and in 2017 its presence was also declared in the Asturias region affecting in both regions several areas of potato production (Jeger et al., 2018). This small moth (see image 2) has been spreading through several regions during the last 60 years, since it was firstly reported in Central America in 1956 (Villanueva & Saldamando, 2013). During its journey it reached Costa Rica, Panama, Honduras and San Salvador at the beginning of the 1970s. In 1983, it appeared in Venezuela and in 1985 in the north of Colombia expanding to the rest of the country by 1994. In the year 2010 was reported in Mexico (Roblero, Castillo Vera, & Malo, 2011) reaching the Macaronesian region around 1999, concretely in the island of Tenerife (the Canary Islands) (Corral et al., 2017).

Several studies on climate change scenarios predicted the establishment and spread out of this pest across Europe. For instance, Kroschel et al., (2014) developed a global map signifying that "southern Europe, and in particular coastal regions around the Mediterranean and the Atlantic coast of Portugal share an 'Establishment Risk Index' (ERI) (Schaub, Carhuapoma, & Kroschel, 2016) with parts of Central and South America where T. *solanivora* occurs, hence suggesting that parts of the EU provide suitable conditions for the establishment of T. *solanivora*" (Kroschel & Schaub, 2013)".

The following images show the current worldwide distribution of Tecia *solanivora* (figure 8) and its potential spreading into worldwide potato production regions according to model predictions developed by Schaub et al. (2016) (figure 9).

Figure 8. Global distribution of Tecia *solanivora*.

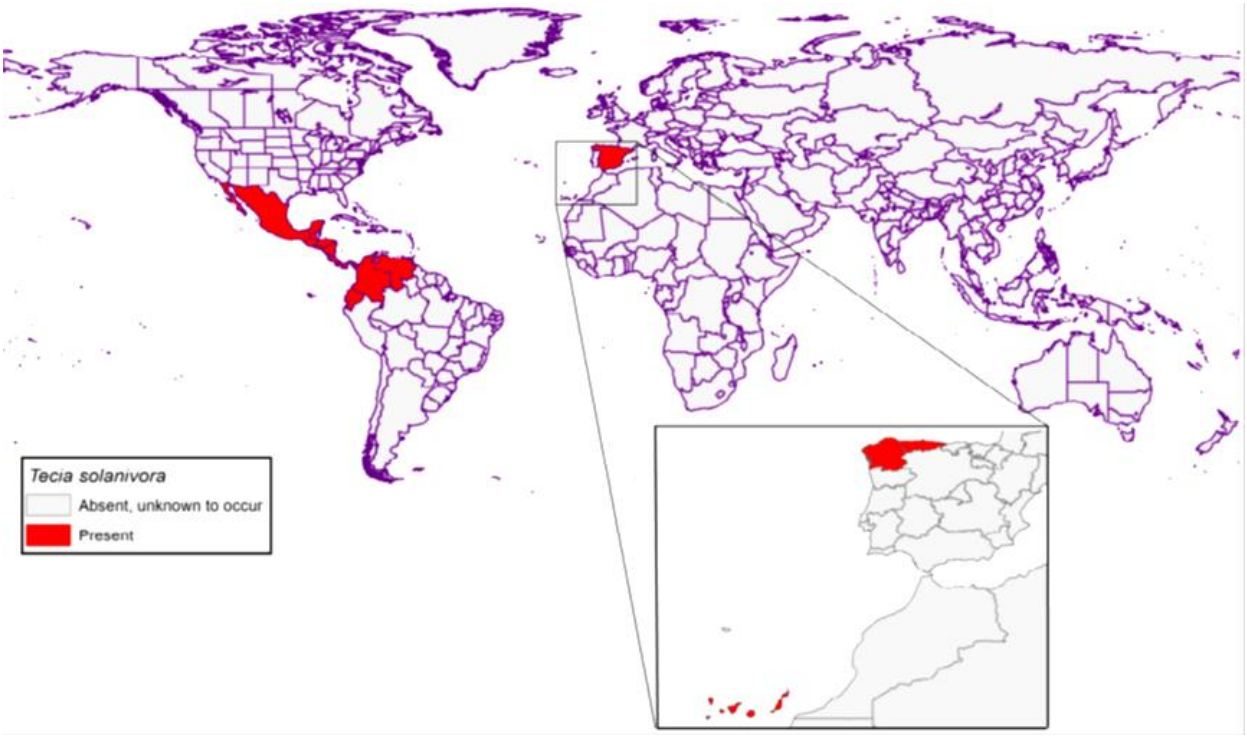
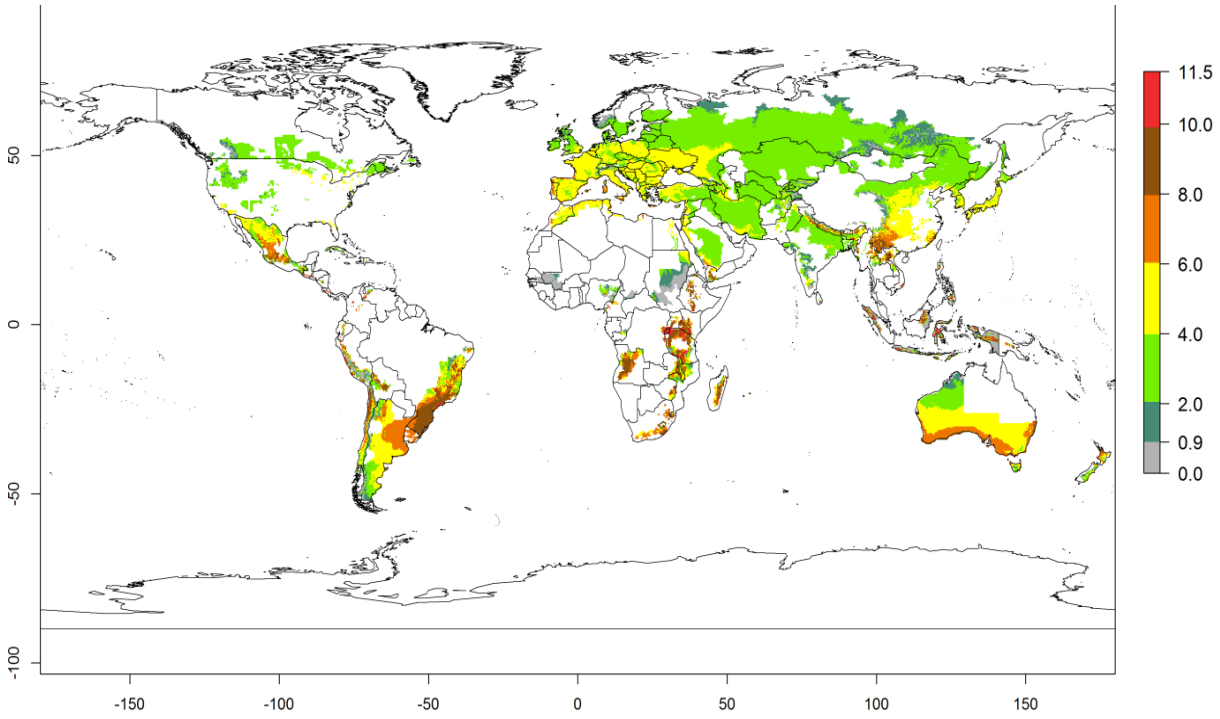


Figure 9. Potential distribution of the Guatemalan potato tuber moth, Tecia solanivora, in potato production regions worldwide according to model predictions.

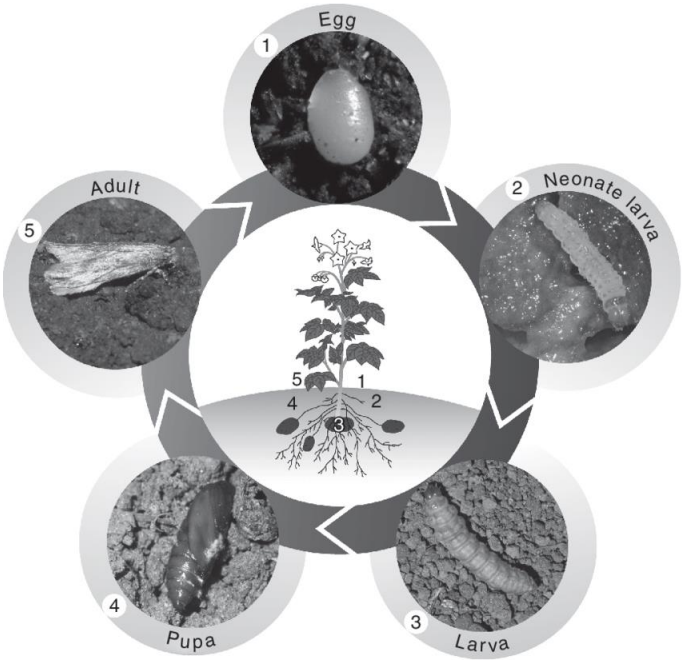


Source: Schaub et al. (2016)

As a consequence, and giving several conditions, such as adverse climate predictions, the boundless spread capacity of the pest, or the inability shown by techno-scientific knowledge to contain it, the complexity involved in this problematic might constitute a huge problem for the potato production in the potential affected areas worldwide.

This species is extremely harmful. The larval stage is the only stage that causes damage to the crop (Image 2). Larvae feed and develop inside potato tubers, excavating galleries and leaving frass inside them, which allows the introduction of bacteria and fungi, damaging the potatoes (Carrillo and Torrado, 2013).

Image 2. . Life cycle of *Tecia* solanivora: 1. Egg; 2. Neonate larva; 3. Larva; 4. Pupa; 5. Adult



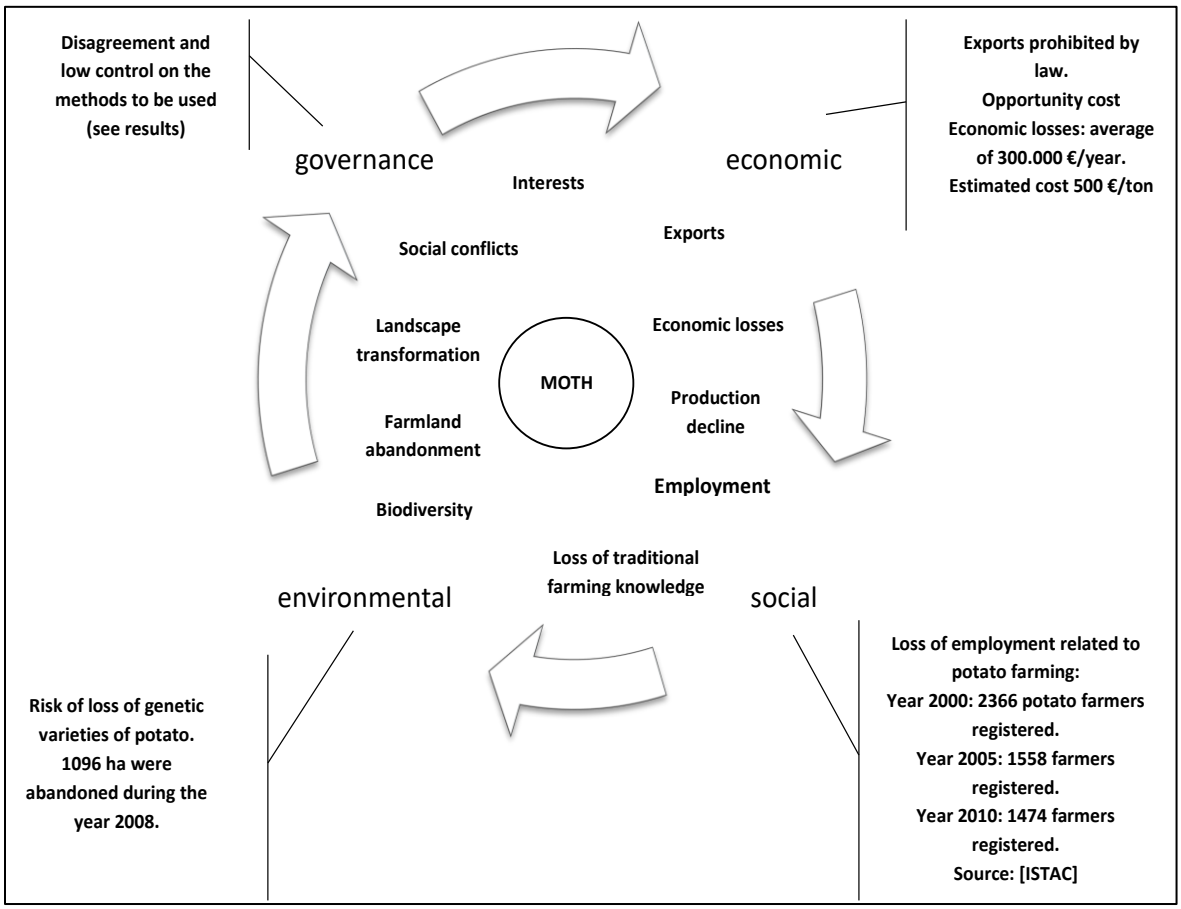
Source: Carrillo and Torrado, 2013

This paper describes how the moth has been unable to be contained, and illustrates a participatory process in which historical decisions taken in the past are assessed by the community.

Results of the analysis

Previous to the participatory processes, the socio-institutional Analysis, which includes literature review and stakeholders analysis, allowed the identification of the relevant impacts caused by the moth on economic, environmental, social and governance dimensions (figure 10).

Figure 10. Complexity of the pest incidence in the island case.



As shown in the figure 10, what seemed to be a *simple* moth implies a complex environmental, cultural, economic and social dynamics, since it affects several interrelated socio-environmental dimensions on the island. The environmental and cultural aspects include the impact on traditional native potato varieties – *Papas Antiguas de Canarias* - which are of great genetic importance since these varieties are unique in the world.

Social and economic dimensions include the loss of employment related to potato farming and the decline of productivity, meanwhile the total agrarian surface of the island dedicated to potato farming has been reduced and land use has changed gradually to a situation of inactivity and abandonment. The 88% of the islander farmers consider T. *solanivora* as their main phytosanitary problem (Falcón and Cubas, 2010) and the cultivation of potato has reduced its surface by approximately 46% in the first five years of appearance of this pest (ISTAC, 2017).

The actors involved in the problematic are immersed in a situation of disagreement about the strategies to fight the pest, and lack of trust and low control about the methods to be used. This situation suggests that the communication channels are not conveniently established among the concerned community.

Pest control strategies applied in the island have been based on the measures applied in other regions affected by *T. solanivora.* Some of the most relevant are the following ones:

- Information campaigns to farmers about the correct use of phytosanitary products.
- Regarding control methods in the field, these are focused on: a) eliminating previous plants, b) sowing pest free seeds, and also avoiding sowing in dry and warm seasons, c) frequent irrigation to avoid cracks and dryness, d) harvesting as soon as possible to avoid egg-laying and removing damaged tubers and burning or burying them in order to break the cycle of the pest.
- As for control under storage, dense meshes have been placed in holes and windows to avoid moths entering, storing at 4–5 °C and monitoring with pheromone traps in every store and weekly trap inspections.
- In order to avoid farmers leaving the potato waste directly in the environment, actions to collect infected tubers for landfill disposal were carried out by authorities. Economic compensation was established by law to farmers per kg of infected potatoes (0.25 €/kg.).
- Finally, a genetic bank to conserve the autochthonous varieties of potato was created.

Those top-down strategies were assessed by the actors involved in the participatory process designed by this study. Those participants expressed their framing perspectives and proposals to face the problematic in forms of recommendations and alternatives of action exposed in table 3.

Table 3. Recommendations extracted from the analysis and proposed by different actors.

Problem to solve - framing	Additional Recommendations	Proposed by
Inconsistent measures application.	Wide farmers' knowledge on agroecosystem.	Farmers
Employment.	Promote intergenerational relay.	Farmers, Rural Development As.
Loss of traditional farming knowledge.	Avoid land abandonment and land use changes	Farmers, Rural Development As.

Non coherent economic expenses. Economic losses. Production decline.	Increase sanitarium control of potatoes' import. Eliminate subsidies and compensations.	All actors ICIA / Farmers
Harmful environmental practices. Loss of Agro-biodiversity. Farmland abandonment and Landscape transformation.	Agroecosystem practices / No phytosanitary products. Shift of crops. Constant field labours. Climate Change adaptation strategies. "The moth will do that".	Farmers / Rural Development As. All actors Farmers / Cabildo / ULL Cabildo / Farmers / Municipality/ULL
Lack of participatory processes. Conflicts and disorganisation.	Maintain technical recommendations and increase control on their application. Promote stakeholders' cooperation and communication. Increase participatory research between science corps and farmers.	All actors Farmers Farmers

As seen, other alternatives arise after the process not only based on techno-scientific strategies but also on social, cultural and economic factors, being more coherent with the complexity of the issue shown on figure 10.

Finally, two main alternatives were proposed by participants to eliminate definitively the plague on the island (table 4):

1. Adjust or modify the crop seedtime. This alternative is focused on breaking the reproduction cycle of the specie and was proposed only by farmers.
2. Establish restrictions to potato farming on the island with the aim of impeding the feeding options of the specie. This alternative has two options: a) according to farmers, establish a moratorium of 4 or 5 months in which the potato farming would be forbidden in the whole island; and b) according to farmers and scientists, restriction of 3 years without potato farming in the whole island.

Table 4. Main proposed alternatives to eliminate the pest.

Alternatives	Proposed by

Adjust the seedtime in order to break the reproduction cycle of the moth.	Farmers
Stablish a moratorium of 4 or 5 months in which the potato farming would be forbidden.	Farmers
Restriction of 3 years without potato farming in the whole island.	Farmers and Scientists (ULL)

According to farmers, these alternatives would definitely eliminate the plague on the island because the larvae's moth feeds only potato tuber, and without food, moth's reproduction is not possible. In contrast, experts allude to the impossibility to end with the pest, and only control and monitoring actions are possible. Those contrasting expectations might contribute differently to the design and development of strategies. Negative expectations regarding the elimination of the pest in the island lead to the establishment of partial strategies based on monitoring the problem and the acceptance of a coexistence situation with the pest.

PARTING THE SEA

Marine and ocean issues are vital for insular communities. But marine scientific studies have enormous difficulties to obtain reliable data, which increases the complexity of the problematique. Fishing communities hold enough knowledge and experience to provide relevant information.

Overfishing *vs.* artisanal fishing, the potentiality of artisanal fishing community to identify, define and solve local problematics (the case of fisher community in the island of Tenerife)

> *Romero Manrique, D., and Corral, S. (2017). Local community-based approach for sustainable management of artisanal fisheries on small islands. Ocean and coastal management, 142, 150-162.*

The second case study addressed in this thesis is also focused on the island of Tenerife, but it relates to a different topic of study: the local insular fishery sector. This case is focused on the ability of local fishermen to both define the problems impeding an efficient local management of fisheries and to produce novel policy actions and strategies.

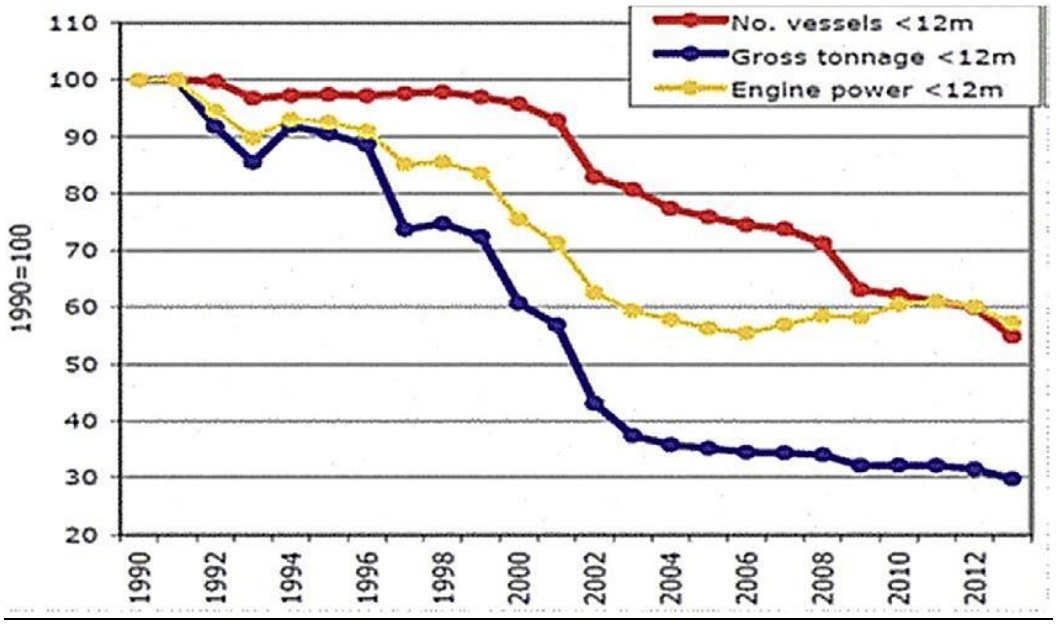
The decrease of marine resources is a very serious problematic and urgent to be tackled worldwide; global marine fisheries are in decline due to several factors such as the collapse of fish stocks caused by the degradation of aquatic ecosystems, overfishing, or deficient fisheries planning and management (Kooiman & Bavinck, 2005). Climate change is likewise a significant issue due to its impacts on marine biodiversity and local socio-economic systems, affecting in a more intense manner fragile ecosystems of insular and remote economies (Connell, 2013).

Additionally, in relation to marine research there is no consensus within the scientific community about the accurateness of the data gathered by the existing methods due to the difficulty of measuring marine stocks (Hilborn, 2012; Ludwig and Walters, 1981) and this implies a high level of uncertainty. In many regions, the lack of systematic scientific data on distribution, fish mortality and recruitment, contributes to elaborate poor

indicator systems about the status of the stock (Caddy, 1998; Rosenberg and Restrepo, 1994; Patterson et al., 2001). Lack of information and data leads to elaboration of partial diagnosis and therefore, to the development of inadequate policies which: a) do not solve the problems, and b) create societal disagreement and conflicts among different actors.

When the information and data available are not enough to support the design of a sustainable strategy, there is a serious risk that decision-making processes and implementation measures will not achieve the expected objectives (Beddington et al., 2007) and lead to depletion of marine local activity (figure 11).

Figure 11. Evolution of the Canarian fishing fleet in terms of number of vessels, gross tonnage and engine power. Vessels less than 12 m long.



Source: Popescu and Ortega, 2013

With these shortcomings, the problematic becomes a complex issue when data to monitor the status of fisheries are needed and also when local fishermen need to plan and manage their own stock. To tackle this situation, this paper presents a qualitative methodological framework grounded on participatory workshops in which the problem-solution tree and the focus groups methodologies were applied. Through the process, the community involved identified the main obstacles impeding a sustainable development of the artisanal fishing sector on the island and proposed a set of alternatives to improve the situation in form of local policy actions.

This paper has been published in Ocean and Coastal Management journal with the title: "Local community-based approach for sustainable management of artisanal fisheries on small islands" (see Annex).

Results of the analysis

Local fishermen, technical staff of the local administration, associations and NGOs, and researchers from the University, composed the fisheries community. Through the participatory processes, the actors were able to identify and agreed on the necessary actions to reduce overexploitation and potentiate artisanal fishing practices through amendments of the regulatory systems, coordination and oversight actions, participatory research and monitoring data, educational practices and dissemination of information.

The main proposals include:

- Establishing seasonal regulations for recreational fishing practices.
- Promoting a participatory dialogue between scientists and recreational communities in order to reach agreements.
- Education, training and information about fisheries disseminated to every agent involved in fishing activities (sea workers, professionals, companies, public body, etc.)
- Developing more effective awareness and control actions.
- Creating marine reserves to protect islander biodiversity.

In order to improve the self-management capacity of local artisanal fisherman organisations, participants proposed the following actions:

- Promotion of a collective vision among the whole fishing sector of the island.
- Joint commercialisation channelled through a united cooperative.
- Development of self-financing models adapted to the characteristics of each *Cofradía*[2].
- Create quality management and innovative guidance for each Cofradía in order to increase their self-capacity.

More specifically, to each concrete problem, strategies to solve them were proposed, as indicated in table 5:

[2] Cofradías are the traditional artisanal fishers organisations in the Canary Islands (see: http://www.gobiernodecanarias.org/agricultura/pesca/temas/entidades_pesqueras/federaciones_cofradias_pescadores) in Spanish.

Table 5. Perceived problems and their respective solution proposals.

Perceived problems	Proposals by Cofradías	Proposals by administration and associations
Fewer fish in the sea /Overexploitation	Illegal fishing control. Limit recreational fishing to holidays. Establish marine protected areas. Establish temporary closures. Diversification by species. Restraints per kilograms on catches and limit number of nets (depending on species). Limit recreational and professional licenses.	Establish Marine Protected Areas. Fisheries management measures (management plan) Establish temporary closures. Increase studies and resources for scientists. Regulations review.
Commercialisation problems	Facilitate direct sales. Staff from Administrations to establish control on traceability and labelling for artisanal products	Adaptation of the European legislation to the Canary Islands with respect to the point of first sale. Develop a collective brand. Studies about the stock of underexploited species
Regulatory system	Regulation review with a consultation period for professional fishers, with emphasis on the revision of the sizes of the species: adaptation to standard size and weight of the Canarian species. Diffusion of policy directives among fishers.	Co-Management strategies and actions. Increase legal support to update the regulations (80 years with no actualisation). Adapt regulations to review studies.
Poor management of Cofradías	Administration support from a technical and legal perspective. Involve local restaurants in commercial chain.	Rationalize the resources of the Cofradias (Unify). Develop innovative projects to diversify the economy (fish-tourism, etc.). - Facilitate the generation of Cofradias own resources.
Low control and oversight	Surveillance: more shifts and equal control of professional and recreational fishers. Increase oversight activities	Establish marine protected areas. Review Underwater Marine Areas regulation. Increase surveillance.
Fishing temporality	The months, in which it is not possible to get out to fish, a minimum compulsory insurance should be paid. Private insurance to cover those months (aided by the Administration). Improve fishing fleet.	Manage private insurance to pay members if they cannot fish. A part of the payment might be subsidized by the authorities. Diversify fishing activity: Tourism?
Recreational and illegal fishing	For recreational fishing: permit only holidays and weekends; prohibit and control aggressive practices. For illegal fishing increase penalties.	Develop monitoring and / or control systems. Co-management strategies. Limited seasons for recreational

	Control of marinas. Establish a register of recreational harvests.	fishing.
Individualism	Develop working groups, workshops and meetings in the island.	Promote cooperatives
Generational relief /Loss traditional knowledge	Facilitate family child / youth employment	-------
Coastal and marine deterioration	Increase information and control on coastal areas. Improve pollutant infrastructures as outfalls, treatment plants, etc. Educational actions to population about plastics and wastes.	Educational campaigns. Volunteer campaigns. Investment by Public Administration to treat sewage and minimize waste. Changing production model of the island (Increase harbours and Marinas)

This work shows the capacity and willingness of the local fishing community to interact and create links with scientists in the search for collaborative solutions in order to move towards sustainable management practices of the fishery sector. For instance, except for tuna species, in the Canary Islands there is a lack of periodicity on assessment about the status of the stocks. After this study, there is now an opportunity to develop scientific data collection processes with the implication of local fishers.

BREAKING THE ICE

Climate change and other environmental changes are affecting vulnerable territories, such as the Arctic. Scientific methods and observing systems are not able to gather all the information needed to elaborate adaptation strategies. Arctic communities are the oldest environmental knowledge-holders of the planet.

Climate-related displacements of coastal communities in the Arctic: Engaging traditional knowledge in adaptation strategies and policies

> *Romero Manrique, D., Corral, S., and Guimarães Pereira, Â. (2018). Climate-related displacements of coastal communities in the Arctic: Engaging traditional knowledge in adaptation strategies and policies. Environmental Science and Policy, 85, 90-100.*

The environmental impacts due to climate change are causing severe damages to local remote coastal communities in the Arctic region. This paper illustrates how climate-related displacements and subsequent relocation processes are extremely complex issues with multiple causes.

Environmental displacement refers to situations where people are forced to leave their homes or places of habitual residence as a result of a disaster or in order to avoid the impact of an immediate and foreseeable natural hazard (Terminski, 2012).

The Arctic is not a homogeneous region, numerous disperse isolated communities inhabit the whole area and each of them has its own cultural, social, economic or demographic specificities, as well as languages (figure 12).

Figure 12. Demography of indigenous people of the Arctic based on linguistic groups GRID Arendal and Hugo Ahlenius, Nordpil

source: http://www.arcticcentre.org/EN/communications/arcticregion/Arctic-Indigenous-Peoples/Demography)

Although disperse and isolated, these communities share a remarkable capacity to adapt to environmental changes through the use of their "traditional" knowledge (Hovelsrud and Smit, 2010), i.e. knowledge cumulated over generations to monitor the environment and maintain their livelihoods.

Commonly, climate change has been approached mainly by addressing issues of concern through scientific methods (Oreskes, 2004), but top-down strategies have not been able to avoid or prevent the impacts on small communities (Hallegatte et al., 2015; Chan, 2017). Moreover, Arctic traditional knowledge has not been adequately taken into consideration by

the large scientific and policy spheres when developing policies related to climate change.

Results of the analysis

The incorporation of different sources of knowledge in order to develop effective adaptation strategies is being increasingly recognised by international and regional policy institutions, however, traditional knowledge is not completely integrated by all scientific and policy spheres as an equally relevant source of knowledge.

According to the paper´s findings and conclusions, in order to develop more adequate climate adaptation strategies and policies in the region, it is desirable that scientific and policy makers openly recognise the value of and the need for local communities' knowledge of their territory. Its value and usefulness to develop adaptation strategies at local levels has been suggested in numerous studies (Berkes et al., 2000; Green and Raygorodetsky, 2010; Pennesi et al., 2012). To this end, trustful channels between policy-makers and researchers, and the local communities have to be opened, creating specific requirements for legitimate engagement processes of local communities in the design of strategies to oversome environmental and economical change.

In table 6 a summary of possible actions to ensure that traditional knowledge is marshalled into those processes is provided.

Table 6. Main policy and research recommendations extracted from the analysis.

Recommendations	
Foster collaborative engagement of traditional knowledge and science	The opportunity for an effective integration of traditional knowledge into the whole policy design cycle, from policy-shaping to policy-making and implementation, is an asset. Policies might increase their effectiveness and their social value with adequate engagement strategies and a complete recognition of native peoples as active knowledge-holders
Avoid imprecise policies and vague recommendations	Developing specific actions, strategies and recommendations is desirable. Many recommendations made from international organisations and institutions working on Arctic's climate change and traditional knowledge are too general to accomplish any kind of concrete result or effective integration of traditional knowledge into policy-

	making. Well-meaning intentions and vague proposals lead to illusion of progress.
Avoid over-protectionism and paternalism	The perpetuation of an excessively protectionist vision will maintain non adaptive practices, lessening the opportunity to develop more appropriate strategies to the changing realities and, reducing the role of learning through change.
Recognise the value of and legitimate traditional knowledge	Change the approach towards a framework of co-creation of knowledge. The recognition by the scientific community of traditional knowledge as a valid source of reliable data and information could enable cooperation among the scientific and the Arctic communities, leading to knowledge co-creation.

Adequate mobilisation of both traditional and scientific knowledge into policy-making could benefit adaptation and mitigation strategies and policies that effectively support Arctic communities with settling and coping with climate change driven adversities and at the same time ensure good governance of a planetary region that put in jeopardy will affect all regions of the globe with implications not well predicted yet.

6. DISCUSSION

This section discusses the main research questions and objectives of this Thesis through both the outcomes of the case studies and the theoretical and methodological frameworks explored through this work.

In order to facilitate the reading, the structure of the discussion follows the structure of the document, i.e. from the theoretical framing to the empirical results. Hence, in the first place, the theoretical approach in which the thesis is grounded is discussed. Secondly, a reflection about the methodological framework is presented, highlighting its usefulness to achieve the objectives, as well as its limitations found during the implementation process. Lastly, the research questions are explored putting emphasis on more concrete results coming from the case studies.

6.1. The theoretical approach

As described in the introductory section, this thesis focuses on ideas of co-creation, i.e. on bridging different types of knowledge to govern socio-environmental issues in insular and remote communities.

We have hypothesised that the post-normal science framework could be helpful to explore the co-creation ideas as well as make visible the importance of mobilising the relevant knowledge to address complex governance issues. As Funtowicz and Ravetz (2003) pointed out, in complex systems, there can be no single privileged point of view for measurement, analysis and evaluation.

Through this work we examined how insularity is related to adaptability, and we hypothesised that situated experiential knowledge is key to allow insular communities' response to emerging human and ecosystem fragilities. By way of a reminder, this type of knowledge constitutes a cumulative and collective body of knowledge and practices that evolve with the interaction of community members with environmental conditions and adaptive processes to change.

The theoretical framework, suggests the involvement of other ways of knowing into processes of environmental governance; this amounts simply to the engagement of different knowledge-holders, users and other relevant actors into those processes. Funtowicz and Ravetz (1993) called this the *extended peer community* in the Post-Normal Science framing. In line with this, our findings show the value and usefulness of involving insular and remote communities in building the knowledge basis as in the other vast number of academic studies grounded on Post-Normal Science principles[3].

Engaging different actors implies formerly the recognition of different types of knowledge (Brugnach and Ingram, 2012; Bouwen and Taillieu, 2004). Some authors - see e.g. Alberti (1999), and Jiang et al., (2008) - suggested that globalised societies living in urban areas, or severely humanised environments, have lost their capacity to deal with environmental uncertainty due to long-term disconnection from nature. In contrast to this, we assume that non-insular societies have not missed that capacity, but

[3] For instance: Kerr (2005); Jacobson and Stephens (2009); Fung et al., (2001); Hernández-González and Corral (2017); Bremer and Glavovic, (2013); Caims (2012); Curtin, C. (2015).

they have transformed it acquiring other ways of knowing, namely western knowledge systems or western scientific knowledge.

Experiential situated knowledge does not respond to quality processes or epistemological requirements (framings, methods, etc.) of western-scientific knowledge. The epistemological and methodological differences between different types of knowledge reside in that they inform different questions and might provide different perspectives; e.g., Oudwater and Martin (2003) outline the differences between scientific and indigenous/local knowledge when categorising identical soil and land resources. In our case studies in the island of Tenerife, farmers and fishermen provided alternative perspectives to those considered in the official policies, and even different solutions from those that technicians and scientists had provided in the past[4].

In the introductory section of this Thesis, we suggested that the universalisation character of scientific knowledge automatically excludes specific site-based information and knowledges from the policy process. It might be argued from a western-science angle, that the information gathered from local knowledge-holders is site-based and not universal, this being one of the main critics made to alternative forms of knowledge (Kuhn, 2010; Ashwood et al., 2014). The dualistic debate arguing the validity/invalidity of different types of knowledge is, under our standpoint unfruitful since each knowledge system have their own validation means, additionally, this debate is not new (Haraway, 1991; Clark and Murdoch, 1997; Stiglitz, 1999). Agrawal (2014), voices one of the most devastating critiques to technical solution-oriented development policies (techno-scientific-based policies) of the last five decades has been that they ignored the social, political and cultural contexts in which they were implemented.

In this regard, our findings suggest that not all the available knowledge was used to inform policies in the 3 cases. We assume that this situation was due to a lack of systematic approaches to address the complexity of different social and environmental nexuses. Furthermore, as the 3 cases seem to show there has been no room for non-scientific 'evidence' in the decision-making processes; in other words experiential or practical knowledge seems to be considered as invalid. However, what the case studies suggest is that situated experiential knowledges contribute to fill the uncertainties gap in

[4] See section 5: *case studies and results*, and sub-section 6.3. *Research questions*

which policies are implemented. Knowledge-holders provided with specific information that reflects the local context in which the issues evolve, being therefore valuable for framing the problem, finding fit for purpose strategies to address them and enhance local policies; for example recommendable farmers' agricultural practices with regards to soil use; the interchange of seeds across the island, or the structure of local fishing organisations[5].

The Post-Normal framework allowed us to achieve the following outcomes:

- an analysis of the inherent socio-environmental complexity of the case studies;
- the identification of the types of knowledge presented in each space;
- the engagement of the local actors and local knowledge-holders relevant to address the issues of concern;
- the development and identification of novel strategies and alternatives that resonate with the insights provided by the extended peer community;
- assistance to policy-makers to gain a more complex understanding of the issues from a holistic vision, encouraging them to think outside the box;
- a safe space to foster respectful understanding of different matters of concern and of care.

6.2. The methodological framework

The PNS framework is strongly focused with establishing the 'extended peer community', in order to ensure that the relevant knowledge informs the governance process. As we have illustrated throughout the case studies, a PNS approach requires the deployment of participatory methods (Van den Hove, 2000; de Marchi and Ravetz, 2001; Blackstock, 2007). The methodological framework applied in the thesis consisted of a set of different social research methodologies, which were adapted to each case study. In other words, the political, cultural, social and environmental contexts were taken into account to select the methods that would deliver effective outcomes, to our aspiration of designing co-creation processes. On the one hand methodologies need to facilitate a safe space where knowledge-holders can freely share their knowledge, and on the other hand, facilitate the recognition [realisation] of complexity by the participants.

[5] See next section: *What is the pragmatic and tangible usefulness and value of situated and experiential knowledge?*

Gladwin et al., (2002) suggest that participatory methods can be "quick and dirty". In this thesis, we seem to have had quite a different experience, as the participatory processes required a careful and lengthy preparation from planning through to execution in each case.

In this case, the participatory methods have been useful to achieve the co-creation objectives of this thesis. Concretely, the methodological framework applied in the case studies was effective to the extent that they facilitated:

a. A knowledge sharing environment and the direct interaction between the local communities, scientists and policy-makers who collaboratively ensured a respectful, mature and constructive debate to reach compromise solutions.

b. The opportunity of affected actors to express and share their concerns regarding the issues together with other actors.
c. Problem framing, i.e. the exploration of alternative and holistic visions about the problematic as a whole and the identification of the issues and their diverse dimensions (policy, cultural, social, etc.). .
d. The co-creation of different strategies and actions from those reflected in official policies – the case studies findings show that involving local communities in the identification of problems affecting them allow for more fit for purpose options that were not considered on official policies and strategies.

With regards to the application of the methodological approach used in this work, we highlight the following **learnings**:

1. The Socio-Institutional Analysis has been an effective method to map the complexity and find out concealed variables influencing the case studies.

2. The stakeholders, and other actors, analysis and mapping provided an overview of the space in which diverse social actors (individuals and groups) interact within the problematic. Dimensions, such as their influence capacity on decisions, their dissimilar interests and their behaviour were identified in order to search potential points of agreement in further decisions and strategies.

3. The interviews have been useful to collect relevant information that is not easily available in the literature. In-depth interviews are also a swift way to overcome difficult dynamics and practical difficulties of seating at the same

table relevant actors. The information gathered through this technic comes directly from the actors concerned with the issues we studied. The difficulties found during this step were the time it takes to complete the process and reach valid outcomes, so as the planning and scheduling procedure.

4. In this work, it was vitally important to complement and enrich the information gathered through the individual interviews. To this end, the focus groups technic facilitated the sharing of actors' perspectives within a discussion context. The focus groups were implemented in two different ways for the following reasons:

a. Heterogeneous groups in the fishery case study, composed by fishermen, scientists and policy-makers. The objective of carrying out this kind of focus group was the need to establish a debate on different framings of the challenges faced by entire insular fishery, as well as on finding collectively reasoned elements for policy making.
b. Homogeneous group in the potato pest case study, composed only by farmers. This focus group aimed at gathering alternative strategies to address this pest based on the farmers' practices to cope with it. Many farmers of the island are not organised into organisations - as in the case of fishermen; indeed, there are numerous small and anonymous farmers (domestic farmers) who are not included in the commercial channels or cooperatives, but they contribute to spread the pest.

Several limitations have been found during the development of the case studies. These **limitations** are mainly originated by a number of practical difficulties, in particular:

1. The dependency of the implementation of the participatory processes on the willingness and availability of relevant actors can be a shortcoming, which often occurs when there are opposing or hidden interests.
2. The power balance between the actors involved, can also impair the 'safety' of the space, to the extent that the greater the power imbalance, the greater the influence also on the conversations of the most powerful.
3. In the potato tuber moth case study, the number of actors involved was insufficient to obtain sufficiently scalable outcomes; the number of interviews is quite limited and only one focus group is insufficient to address the full magnitude of the issue.

4. In the Arctic region, in-depth interviews were for the moment the sole social research means available to us. Low accessibility (distance, weather seasonality and variations, etc.) and high costs (logistics, economics costs, etc.) make us think that there is a great deal of scope for further study, in particular of social nature. This is a common shortcoming when conducting research in remote spaces. In the case of the Arctic, research activities and field studies are often conducted during the summer time.

While recognising the limitations of our study, we believe that we have largely accomplished the initial objectives of the thesis, contributing to demonstrate the usefulness of the PNS framework and the methodologies to implement it.

6.3. The research questions

The implementation of both the theoretical and the methodological frameworks allows us answering the main research questions of the thesis.

What are the meanings and implications of insularity?

The literature review presented in chapter 2 exploring different conceptualisations of insularity, reveal key insights regarding the geographical and physical characteristics that insular and remote spaces share, namely: meanings

- isolation (Olson and Dinerstein, 2000; McCarthy et al., 2001)
- peripherality (Deidda 2016)
- smallness (Briguglio, 1995; Taglioni, 2011)
- remoteness (Deidda, 2016)
- fragility (Hilker, 2012)
- uniqueness (King, 2002)

Furthermore, the literature review indicates a series of similar historical, social and economic shortcomings within insular communities:

- Social vulnerability and poverty (Conner, 2005; Jodha, 2005; Duncan and Lamborghini, 1994)
- Physical isolation, particularly from larger urban centres (Hugo et al., 1999).
- Health issues (Clark et al., 2002; Charania and Tsuji, 2012)

- Limited transport and telecommunications (Roberts, 2004; Nutley, 2003)
- High costs and difficulties in transportation, construction and the provision of services (Slack et al., 2003)
- Historical migration phenomena (Kramer et al., 2009; Stockdale, 2004)
- Colonisation and nationalism (Bashford, and Strange, 2003; Coates and Powell, 1989)
- Limited availability of natural resources and high costs to exploit (Grose et al., 1998; Paleta et al., 2014; Beal et al., 2016)

In disciplines such as social geography, economics, and regional development studies, the development of the concept of 'insularity' has been rather limited to islands and archipelagos (Steinberg, 2005; Armstrong and Read, 2006; Taglioni, 2011; Sicking, 2014; Deidda, 2016). Nonetheless new approaches to address insularity have been developing; for instance, Drake (2002) has pointed out that understanding insularity requires new frameworks and paradigms; more recently Kazazu (2011) suggests that, island studies require multi- or trans-disciplinary approaches capable to cope with the complexity of these territories.

The case studies implemented through this thesis contribute further to the re-examining insularity, because the case studies seem to suggest it as an evolutionary condition, resulting also from:

1) particular social-cultural practices;
2) a deep situated knowledge about the ecological dynamics;
3) an understanding of uncertainty and coping strategies to deal with it strongly linked to the isolation and remoteness condition.

There are quite similar conditions that influence the development of island and remote communities. Therefore, we suggest that the consideration of both types of spaces under a unique category of analysis, i.e. insularity, can be useful to find strategies to solve issues strongly rooted on different manifestations of isolation.

We recognise that extending the concept of insularity to types of spaces other than islands may lead to conceptual controversies, however, reducing insularity exclusively to spaces surrounded by water, underestimate the influence of other physical boundaries, such as deserts, mountains, or ice.

How to approach socio-environmental complex issues in insular spaces?

The 3 cases suggest that policy-makers are *de facto* distanced from the quotidian challenges of local communities. This, we contend, results into poor policy making to the extent that a) policies are not coherent with the daily needs of the communities they aim to govern, and b) environmental strategies do not take into consideration all the necessary and available knowledge, which create new uncertainties and opens the space for partial actions that do not address the issues and the concerns of the communities.

The farmers and fishermen that participated in our study stressed lack of involvement on the policies design phase, even if they had expressed their willingness to collaborate with policy makers. In the Arctic case, the indigenous groups have been increasingly involved in international forums, as described in the Arctic case study, but this is still insufficient, given the difficulties to work out a useful approach to extend the knowledge basis that informs policies. We suggest the implementation of a PNS approach to this kind of spaces, since, as we have explained before, PNS is about collective understanding of the complexities of the issues as seen from different perspectives. This is why Institutional Analysis, and more specifically Power-Relation Analysis and Institutional arrangement, is needed in order to promote an effective involvement in decision-making processes.

What is the tangible usefulness of bridging different types of knowledge in policy-making?

Over the years, communities develop and adjust their practices through observations and judgment about the resources available *viz. à viz.* the wider conditions that impact on their livelihoods, such as ecological, socio-economic and cultural factors (see e.g. Romig et al., 1995; Smit and Wandel, 2006; Leonard et al., 2013). This is the kind of knowledge gathered through the engagement of relevant actors in the case studies.

The potato pest case

The knowledge about the pest is related to spreading of invasive species in agriculture. Farmer's knowledge to detect and recognise the pests is determinant to avoid infestation and spread into new areas (Dangles, 2010). In our case study, the farmers had learnt through experience to manage the

pest on the field, although their practices were not sufficient to avoid its continuous diffusion.

In this case, the farmer community adopted new strategies – i.e. new knowledge – to fight the pest in the field since they noticed that modifying cultivation methods could minimise the occurrence or intensity of insect pests, as observed in other regions (Gangwar and Prasad, 2005; Dale and Polasky, 2007) - for instance, practices such as changing the crop season and, plough deeper under the soil so the larvae cannot penetrate and reach the emergent seeds; or being able to predict the higher incidence of the pest after a dry season.

The strategies implemented in north-west areas of Spain (Galicia and Asturias) are the same ones implemented previously both in South America and Tenerife, except for the following: the establishment of quarantine areas in which production of potatoes is prohibited, as carried out by the farmers in the case study of Tenerife (see table 7). In the island this option had not been proposed officially as a possible strategy.

Table 7. Proposals made by farmers to end with the pest (potato pest case study).

Alternatives	Proposed by
Adjust the seedtime in order to break the reproduction cycle of the moth.	Farmers
Establish a moratorium of 4 or 5 months in which the potato farming would be forbidden.	Farmers
Restriction of 3 years without potato farming in the whole island.	Farmers and Scientists (ULL)

- Possible follow-up action for local authorities:

Develop a multi-directional dialogue in which the whole farmer community may be involved during both the definition of the problems and the elaboration of strategies. Do not limit the actions only to informing farmers, but allowing them to develop proposals and alternatives.

Artisanal fishery case

The fishermen community demonstrated that they could work closely and collaboratively with both policy-makers and scientists. During the process of identification of problems and solutions, the fishermen demonstrated a holistic vision about the problematics surrounding both the overfishing and the decline of artisanal fishing and, also its causes and potential consequences. One identified cause is the lack of intergenerational transmission of knowledge in the sector, which leads to the loss of traditional fishing knowledge. The fishermen emphasised that this type of knowledge is key to both maintain the artisanal activity and avoid the decline of the ecosystems. This idea is supported by other authors' work with fishermen communities, which, highlight the importance of fishermen' knowledge transmission in marine ecosystems conservation (Berkes et al., 2000; Drew, 2005; Kalikoski and Vasconcellos, 2007).

Marine sciences are characterised by an intrinsic difficulty of gathering reliable data (Pauly et al., 2013). Using the knowledge of fishermen may help with characterising the fish stock structure, variability and abundance, fish distribution and migrations, the behaviour of larval/post larval fish, or changes in habitats variables such as the areas of reproduction of species and its possible changes, the size of the species, the presence of new species or the absence of traditional ones, etc. as numerous scholars uphold (see e.g. Johannes, 1998; Neis et al., 1999; Mackinson, 2001; Saenz–Arroyo et al. 2005; Silvano et al. 2006; Silvano and Valbo-Jørgensen, 2008; Scheer; 2012; Silvano and Begossi, 2012).

- Possible follow-up action for local authorities:

Create observer networks that facilitate the exchange of information between researchers, fisher community and policy-makers. Involve fisher community in the observation and collection of marine and coastal ecological information and data.

In this sense, the local observer networks might serve as applicable examples of the collaborative and prolific use of different kinds of knowledge.

The Arctic case

The case of the Arctic claims that local communities hold centuries validated robust knowledge, useful to develop climate change adaptation and mitigation strategies and policies. Yet the communities' knowledge is systematically undervalued by scientific and policy organisations, as described in the paper (Manrique et al. 2018)[6].

Through the literature review carried out in the Arctic case study, we show that Arctic people can provide invaluable and currently inaccessible environmental knowledge, and also to contribute to scientific assessments and monitoring processes and projects around the following facets:

- Observing and determining the spatial distribution of species or fish behaviour.
- Observing the presence of new species or disappearance of autochthonous.
- Changes in ice layers or ice thickness.
- Land use co-management and planning.
- Use and knowledge about local materials.
- Identify sites for settlements on high ground.
- Mapping areas of cultural significance.
- Observing and documenting coastal pollution.

In combination with remote observing systems, Arctic residents can enhance the quality of environmental knowledge that informs climate change adaptation policies, for instance, in remote areas that do not have temperature records, local knowledge observations may be able to serve as proxy data (Alexander et al., 2010).

- Possible follow-up action for local authorities:

Open spaces to explore how to bridge different epistemologies. This could help researchers with developing scientific research agendas, which address the relevant challenges and matters of concern. For instance, the assessments of climate impacts and environmental changes are widely based on technological observations and models providing very valuable images and identification of environmental change but these technologies have limitations since they cannot provide information in small scales like

[6] See Annex

the traditional observer can do. Therefore, merging these two ways of assessment and monitoring would create a more accurate *image of reality*, allowing the development of effective adaptation and mitigation policies at all levels.

The intrinsic value of experiential situated knowledges

Some traditional practices have contributed to preserve the ecosystems and the biodiversity, in the 3 areas of study. The farmers have contributed to preserve traditional cultivation practices generating a unique landscape whilst preserving genetic varieties; fishermen have maintained artisanal traditional practices avoiding the use of aggressive methods, which contributed to reduce fisheries' impacts on marine and coastal ecosystems; and, in the Arctic region, resident populations still maintain traditional livelihoods in close interdependency with the ecosystems, contributing to preserve the ecological conditions in the region.

This thesis supports the idea that cross-weaving different types of knowledge systems benefit environmental policies and scientific programs that sustain the latter, as the cases listed on table 8 have been suggesting (for instance, Alexander et al., 2010; Berkes et al., 2000; Huntington, 2000; Gagnon and Berteaux, 2009; Menzies, 2006; Manrique et al., 2018).

Table 8. Different adaptation outputs established by scientific knowledge and other initiatives based on traditional knowledge.

Adaptation steps	IPCC examples of adaptation indicators and options (IPCC fifth Assessment Report 2014. Adaptation needs and options, p. 844)	Examples of the use of Traditional Knowledge	Initiatives / Institution / organisation	Region
Vulnerability and risk assessment	Distribution of marine species (IPCC data come, for example, from distribution models). Hazards mapping	Use of local observer networks	SAON Network: Sustaining Arctic Observing Networks	Arctic region
			ELOKA: The Exchange for Local Observations and Knowledge of the Arctic (www.eloka-arctic.org/).	Arctic region
		Bio-cultural Assessments Approach	The Indigenous Peoples Climate Change Assessment (IPCCA) (www.ipcca.info)	Global
		Community-based approach	Climate Vulnerability and Capacity Analysis (CVCA) - CARE Climate **https://careclimatechange.org**	Global

			/	
Actions / measures	Land use management and planning Sea walls and coastal protection structures	Identify sites for settlements on high ground (Mercer et al., 2007) Use of local materials (Hiwasaki et al., 2014)	Participatory three-dimensional 3D (https://www.weadapt.org/) Many Strong Voices (http://www.manystrongvoices.org)	Global
Implementation	Fisheries co-management, for example: controlling overfishing	Identify problems and solutions (Robards et al., 2018; de Lara and Corral, 2017); determining the spatial distribution of species or fish behavior (Raymond-Yakoubian et al., 2017; Roux et al., 2018); mapping areas of cultural significance (Gofman et al., 2011); identify changes in fishing areas (Raymond et al., 2017).	Climate Witness Community Toolkit (WWF GLOBAL) wwf.panda.org/?162722/Climate-Witness-Community-Toolkit	South Pacific
Monitoring	Coastal erosion and/ or coastal ecosystem health (images, satellites, buoys, etc.)	Observing and documenting coastal pollution and/or ice thickness (Davies, 2007).	LEO Network: Local Environmental Observer Network https://www.leonetwork.org Alaska Native Tribal Health Consortium (ANTHC) https://anthc.org/ CLEO Network: Circumpolar Local Environmental Observer (Arctic Council, the Arctic Contaminants Action Program (ACAP) and its Expert Group the Indigenous Peoples' Contaminants Action Program (IPCAP)) https://oaarchive.arctic-council.org/handle/11374/1715	Arctic region

Source: Arctic case study: Manrique et al., 2018

However, the work carried out in thesis strongly sustains that the engagement of local communities in observing and reporting changes of their environment and community, as well as in the development of policies, is necessary at all stages of policy making but primarily in the first steps of policy-making.

7. CONCLUSIONS

This thesis aims to make a conceptual and empirical contribution to the study of insularity and its links to environmental knowledge. In this sense, the study of insularity has been broadened to encompass dimensions, constitutive of the complexity inherent to governing socio-environmental issues, which have been less examined by other authors.

As we have shown, the conditions of isolation, remoteness, peripheralisation and smallness produce compact socio-political and cultural universes and particular modes of social organisation. Hence, according to the complexity of these spaces, we have showed that insularity might be approached as a *space* rather than a *place*, that is, a complex social-environmental space rather than a simple geographical location with geophysical boundaries. Insularity is, therefore, understood here as a living and adaptive social-environmental space, and defined as the 'dynamic and complex interplay between social, cultural and ecological dimensions enclosed by geo-physical limitations or geographical conditions of remoteness and isolation'.

We highlight the importance of insular spaces in environmental policy-making due to the following aspects:

- They constitute a **gauge of ecological changes**, indicators of rapid changes

Insular, remote and isolated socio-environmental spaces can be considered as thermometers of global environmental change, thus deserving special attention. Due to their fragility, ecological changes might impact earlier than other types of regions (Pelling and Uitto, 2001; Gero et al., 2013) and observing and documenting those changes might signify the requirement to develop mitigation and adaptation responses in other regions (Mechler et al., 2018).

- Insular spaces can be considered and approached as **knowledge hotspots**.

The concept of *hotspot* has been applied in geo-biology, from a biodiversity perspective, as *regions with the greatest concentrations of life forms and those at greatest risk of extinction* (Mittermeier et al., 1999) or as areas *that are especially rich in endemic species and particularly threatened by human activities* (Cinncotta et al., 2000).

We propose the extension and application of the hotspot concept to the human-ecological knowledge domain, considering insular spaces as **knowledge hotspots**. As we have pointed out, insular communities hold a robust environmental knowledge that allows them developing adequate adaptive strategies to face environmental changes, additionally, it constitutes a rich source of relevant information to observe and monitor environmental changes and impacts.

Although constituting areas featuring exceptional concentrations and manifestations of situated knowledge, this knowledge is in risk due to several factors that we have considered within this thesis, such as the climate change, the rapid local environmental changes and invasive pests, the intense urbanisation processes, or the lack of involvement of knowledge-holders into environmental policy decisions and strategies.

- The usefulness and value of implementing a **Post-Normal Science Approach**

In our view, the inherent complexity and richness of these spaces, together with the increasing threats they face, can be richly thoroughly examined through of a PNS framework. This framework helped with the comprehension of the wide-ranging issues at stake in each case study, through the inclusion at the very framing stage of each case of the *extended peer insular community.* The development of alternative problem framings and strategies to address them are at the core of the PNS framework.

Our case studies illustrate that, in the face of uncertainty, despite the (often times) difficulties of accommodating different epistemologies and knowledge systems, policy making can only gain on robustness when bridging different types of knowledge at all stages of policy design. In line with this, the engagement of local communities in this thesis has demonstrated its potential to:

- identify and frame the problems in early stages of policy formulation;
- provide different proposals and alternatives as those reproduced on techno-science-based policies;
- evaluate the success and effectiveness of the decisions taken in the past.

7.1. Challenges

7.1.1. Participatory governance challenge

The lack of engagement and expansion of the knowledge basis to formulate quality policies in each case, was a common drawback in all 3 cases. This thesis contributes to illustrate that current policy making needs to overcome institutional barriers to respond with quality to contemporary complex challenges; we suggest that approaches that facilitate trans-disciplinary outcomes at all levels of governance need to be embraced.

Focusing on the 3 case studies we recommend:

- Agricultural pest management and policies should include more widely participatory processes from the earlier stages, taking into account the farmers' knowledge when establishing and developing strategies to face the problem or to prevent it.

- Fishermen' knowledge in the islands does not seem widely recognised as a valid and robust source of knowledge; the discrepancies about fish stocks abundance need to be resolved first between fishermen and marine scientists.

- Arctic indigenous communities are one of the oldest knowledge-holders in the planet; failing to create spaces of engagement in environmental decisions affecting their regions, is not a sign of sound governance; they hold a robust body of knowledge that will improve and complement scientific assessments.

Engagement of communities in policy making requires not only purposeful organised participatory activities but also institutional recognition and readiness to accommodate different perspectives in the policy development. In the case of insularity, collection of different knowledges about the particular insular dynamics seems to be mandatory to ensure quality of outcomes.

Finally, in order to develop fit for purpose policies, it is necessary to mobilise all the available knowledge when identifying, defining and framing a problem. The case studies suggest that the local communities of concern hold robust knowledge about the environmental issues, and should have been involved in the processes of gathering information and proposing solutions.

7.1.2. Interplay of scientific and other types of knowledge challenge

This work does not devalue the importance of scientific knowledge in tackling specific aspects of the issues addressed in the case studies; instead it suggests that it is not a substitute for the existing knowledge resources in each of the situations. Other sources of knowledge cannot be discredited or neglected when informing the rather complex socio-environmental issues addressed through the case studies.

This is not about competing knowledge either: alternative types of knowledge do not constitute rivals against scientific knowledge, they respond to different questions, framings and can be complementary to develop more fit for purpose policies and actions that assist with the agreed and desirable governance of natural resources, including climate change effects.

7.2 Recommendations

Close collaborations with local communities can only be secured if an only if the starting point is respectfulness of their environment, their traditions, as well as, halting any actions that contribute to the degradation of their quality of life.

From the overall analysis of this thesis we can outline some recommendations both for the scientific research and policy-makers:

For scientific research:

- Recognise the value and usefulness of other kinds of knowledge to gather data and information.
- Include knowledge-holders at all stages of the projects and collaborate closely with them on the ground as equals, and if not possible by other means (telephone interviews, online communication tools, interactive maps, etc.).
- Explore the possibilities to carry out scientific projects taking into account different types of knowledge and sources of information when technological tools are not useful at small scales.
- Engage, Communicate, Respect and Value.

For policy-makers:

- Accept those recommendations exposed in the previous point would be a first step. But acceptation and recognition is not

sufficient. Change of mind-sets and attitudes towards local knowledge is necessary in order to develop the following steps.

- Develop and design policies and strategies adapted to the local daily reality of the communities coping with the issues. Policies should not be generalist, they should be adapted to local realities and specific characteristics of local spaces since according to the analysis carried out in this Thesis, the issues evolve in interaction with those local specificities.
- Consider insular spaces as knowledge hot-spots. This implies the recognition of relevant and alternative sources of knowledge, protection of the biodiversity, including agro-biodiversity, the ecosystems, the traditional practices which have coped with environmental changes since centuries, natural and cultural landscapes, etc. all these elements are interconnected and are constitutive of the complex insular system.

7.3. Further research

Taking into account the limitations faced during this research, we suggest that further research actions focus on how to open new channels to expand communication between different "languages", i.e. translation of different ways of understanding the ecological dynamics and changes affecting human communities and societies. This implies to progress in the exploration and development of methodologies capable to cross-weave and bridge different epistemologies and different knowledge-holders into a wider policy framework.

There is scope for partnerships and co-creation of knowledge based on different ways of knowing; yet the models of cooperation are in the making and therefore there is space to explore in participatory ways what partnership models could work. The creation of closer communication channels through a dialogue with each relevant actor would allow the identification of obstacles hindering the development of a more openness policy and research.

Insular communities hold valuable skills to develop resilience strategies and deliver early-warning signs through their knowledge. Thus, in the face of rapid variability, the knowledge of scientists and local communities is needed

to expand capacities and collaborate in the design of questions and solutions.

Would be desirable and beneficial to advance in the possibilities that computational sciences and tools may bring when engaging different people, in different locations, and distanced spaces. For instance, virtual focus groups, online workshops, etc.; these tools might provide spaces to combine different information and data, such as qualitative and quantitative; and the possibilities to translate different visions and make them more comprehensible to divergent knowledge-holders and policy-makers.

Final remark

As Hernández-González and Corral (2017) pointed out, in contexts of scientific uncertainty and social controversy, environmental governance is well beyond action around the technical aspects of a particular issue. During this thesis we have highlighted that techno-scientific framings, knowledge and tools cannot cope with the enormous complexity and uncertainty involved in specific issues in which there are diverse expertise, perspectives and interests. Here comes the necessity to broaden the approaches and include other types of knowledge capable of providing alternatives that technological and scientific tools cannot reach due to their intrinsic limitations. This is more understandable with a concrete example:

Climate change in the Arctic is monitored by the use of technological tools, such as satellite images, aerial photography or sensors, but these tools cannot reach and collect changes at small scales. By the development of local observer networks based on the knowledge of local people, the changes can be detected, documented and monitored. Those two types of observation might be used together in a larger framework to gather more complete data and information.

Post-normal science tells us that the only way out to tackle socio-environmental complexity and uncertainty is what many have described as democratisation of expertise and knowledge. Institutions of science and policy making need to respond with new relationship models between policy, science and society to deal with the governance needs of our times.

ANNEXES

1. JOURNALS METRICS AND INFORMATION

Journal name	ISSN	Journal Metrics	Website
Land Use Policy	0264-8377	• Citescore: 4.22 • Impact Factor: 3.573 • 5-Year Impact Factor: 4.236 • Source Normalized Impact per Paper (SNIP): 1.678 • SCImago Journal Rank (SJR): 1.406	https://www.journals.elsevier.com/land-use-policy
Ocean and Coastal Management	0964-5691	• CiteScore: 3.19 • Impact Factor: 2.595 • 5-Year Impact Factor: 3.043 • Source Normalized Impact per Paper (SNIP): 1.432 • SCImago Journal Rank (SJR): 0.984	https://www.journals.elsevier.com/ocean-and-coastal-management
Environmental science and policy	1462-9011	• CiteScore: 5.58 • Impact Factor: 4.816 • 5-Year Impact Factor: 5.127 • Source Normalized Impact per Paper (SNIP): 2.004 • SCImago Journal Rank (SJR): 1.919	https://www.journals.elsevier.com/environmental-science-and-policy

2. ARTICLES

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Assessing the complexity of the spreading processes of agricultural pests: the case of the Guatemalan potato moth in Tenerife

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A B S T R A C T

Potato pests should be considered complex issues with multiple interrelated causes and impacts. These pests cause serious socioeconomic and environmental damage. Several management approaches based on chemical, physical and cultural control methods (among others) have been traditionally applied to deal with such infestations. However, pests' spreading processes often seem virtually unstoppable. Considering that the potato is the fourth most important crop worldwide, this is a major problem, which needs to be tackled from both a global and local perspective.

This article illustrates a participatory assessment of the social-institutional context of an invasive agricultural pest in an island territory. The case of the Guatemalan potato moth in Tenerife is investigated using socio-institutional analysis and participatory assessment with the aim of developing novel alternatives of action to tackle the spread of this disease. During the process, historical decisions taken in the past are continuously assessed by the relevant stakeholders, thus broadening the scale of analysis and introducing social, economic and ecological variables involved in the pest infestation.

This study might assist other regions suffering from agricultural pests, as well as those at risk of potential infestations, to take more effective decisions based on a macro scale perspective. Such decisions should take into consideration the social-institutional context surrounding other experiences and integrate variables that influence the problem directly or indirectly.

1. Introduction

Potato tuber moths are one of the most important and harmful pests for potato crops worldwide. Currently, the most important ones are *Tecia solanivora* (Povolny, 1973), also known as Guatemalan Potato Moth, and *Phthorimaea operculella* (Zeller, 1873). Both pests have a virtually limitless capacity to spread around the world.

Thus, *Ph. operculella* has become an invasive potato pest globally (Kroschel et al., 2013), since it was first reported in 1855 in Tasmania, New Zealand, and Australia (Berthon, 1855). It is considered the most serious potato pest tropical and subtropical regions (Das, 1995; Sporleder et al., 2004). This pest originated in western South America and its presence is currently reported in more than 90 countries. These days, *Ph. operculella* can be found in tropical and subtropical countries in South, Central, and North America, Africa, Australia, and Asia (Rondon, 2010).

Ph. operculella has produced severe harvest losses in storage potatoes, with losses oscillating between 50% in Yemen and Peru, 86% in Tunisia, Algeria and Turkey, 90% in Kenya, and 100% in India and the Philippines (Alvarez et al., 2005). In Egypt, the potato tuber moth has caused up to 100% loss of potato plants in fields as well as in storage (Ahmed et al., 2013).

By contrast, *T. solanivora* was first reported in 1956 in Guatemala, one hundred years after *Ph. operculella*. At the beginning of the 1970s, it reached Costa Rica, Panama, Honduras and San Salvador. In 1983, it appeared in Venezuela and in 1985 in the north of Colombia expanding to the rest of the country by 1994.

Similarly to *Ph. Operculella*, controlling *T. solanivora* has proven to be very difficult, since the potato trade usually evades most kinds of phytosanitary control (Barragán et al., 2004) and currently, no effective control methods are available to farmers (Carpio et al., 2013). This has enabled the pest to spread across Latin America year after year, reaching the Macaronesian region, more specifically the Canary Islands (Villanueva and Saldamando, 2013).

In June 2001, *T. solanivora* was listed on the alert list of the European and Mediterranean Plant Protection Organization (EPPO) as a

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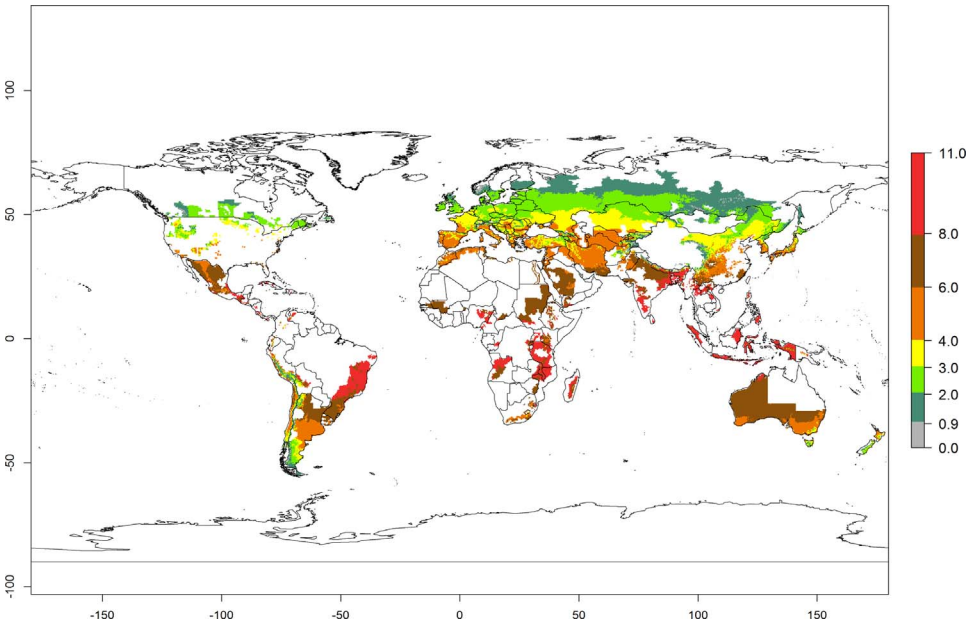

Fig. 1. Potential distribution of the Guatemalan potato tuber moth, Tecia solanivora, in potato production regions worldwide according to model predictions (Schaub et al., 2016).

potential invasive pest for southern Europe (EPPO, 2002). Recently the moth arrived on the European continent (Galicia in the north of Spain) in 2015.

As insects cannot internally regulate their own temperature (Heinrich, 1977; Atkinson, 1994; Pörtner, 2002), their distribution is significantly influenced by changes in external temperature. Climate change projections predict the global spread of *T. solanivora* by the year 2050 (Sporleder et al., 2013; Kroschel et al., 2014) (Fig. 1) resembling the previous process of *Ph. operculella*.

Potato pests should be considered as complex issues with multiple interrelated causes and impacts, as the case presented in this paper as well as others (Pollet et al., 2004). These pests cause serious socio-economic and environmental damage. The Colombian Agricultural Institute (Arias et al., 1996) considers *Tecia solanivora* to be the pest that most affects the economy, as infestation leads to heavy losses. These losses are attributable not only to the deterioration of the appearance of the potato tuber, which reduces its commercial value and farmers' income, but also to the fact that severely affected tubers cannot be used for seed or for human or animal consumption. Thus, if this pest replicates the global colonization process of *Phthorimaea operculella*, there is a serious risk for the food security in the world regarding potato production.

Fig. 2 represents a casual loop of the main dimensions and impacts related to the evolution of potato pests in different case studies (Evans et al., 1992; Fuglie et al., 1993; Arias et al., 1996; Coll et al., 2000; Kroschel and Lacey, 2009; Dangles et al., 2009; Lacey et al., 2010; Soliman et al., 2010; Mazzi and Dorn, 2012; Carrillo and Torrado-León, 2013; Kroschel et al., 2013; Alyokhin et al., 2012; Rebaudo et al., 2014; Rebaudo and Dangles, 2015). These impacts surpass agricultural or economic aspects, and affect environmental, governance and social domains.

Wherever these pests spread, their dispersal ability is extremely high, causing losses averaging between 50 and 100% of production, for instance, in Colombia, farmers reported losses over 50% in 1985, with losses even reaching 100% of total production in Antioquía region in 1993 (Villanueva and Saldamando, 2013).

In all cases, according to Carrillo and Torrado-León (2013), the appearance of *T. solanivora* in new geographical areas has been attributed to the movement of infested tubers. This has resulted in population explosions that have significantly harmed potato production, often devastating potato crops in the invaded areas (Arias et al., 1996; Torres et al., 1997).

Several management approaches have been traditionally applied to deal with both pests (Alyokhin et al., 2012). These methods have been based on chemical control (pesticides); biological control (natural enemies); increasing potato resistance against insect herbivores (genetic resistance); biopesticides (viruses, bacteria, fungi, nematodes); physical control methods (barriers, mounding, mulching, pheromones, etc.); cultural control (such as elimination of cull piles and timing of vine-kill, deep seeding, etc. (Rondon, 2010)) and other non-chemical control (management of biotic and abiotic conditions). However, such top-down and strictly techno-scientific methods have not been able to contain the spread of the pests as the evolution of infected potatoes shows (see for instance Fig. 5).

The spreading process of both pests seems unstoppable. Given the similarities between these tuber moths and considering that conventional control methods have not been able to halt the expansion process of *Ph. operculella* around the world, the dispersion of *Ph. operculella* might be considered as an antecedent of the dispersion of *T. solanivora*. Therefore, it might be expected that *T. solanivora* continues its spread to other regions, not only because of the ineffectiveness of control methods which do not entail the whole complexity, but additionally due to climate change conditions, which are expected to facilitate its spread (Sporleder et al., 2013; Postigo, 2014; Crespo-Pérez et al., 2015).

Considering that the potato is the fourth most important crop worldwide after wheat, rice and maize (FAO, 2009), this is a major problem, which needs to be tackled from a global and local perspective. As mentioned, *Tecia solanivora* seems to be following the spreading path of *Ph. operculella.* It is becoming a major risk and a cause for considerable uncertainty in potato-producing regions that are already affected, and for those where the pests has not yet spread. Such a high degree of risk and uncertainty therefore needs to be addressed through community engagement approaches, in which the different opinions and knowledge of involved actors are integrated and documented in order to find alternative actions and strategies.

The main objective of this study is to prevent *T. solanivora* replicating the worldwide spreading process of *Ph. Operculella;* exploring the complexity in which the moth has evolved and spread in a local case study. To do this, a participatory integrated assessment process has been carried out in an island territory, in which the relevant local stakeholders are identified and involved to evaluate historical policies and decisions taken to deal with *T. solanivora* since the beginning of the problem. As a result of this assessment, participants identified unsuccessful past actions and proposed a set of novel alternatives to deal

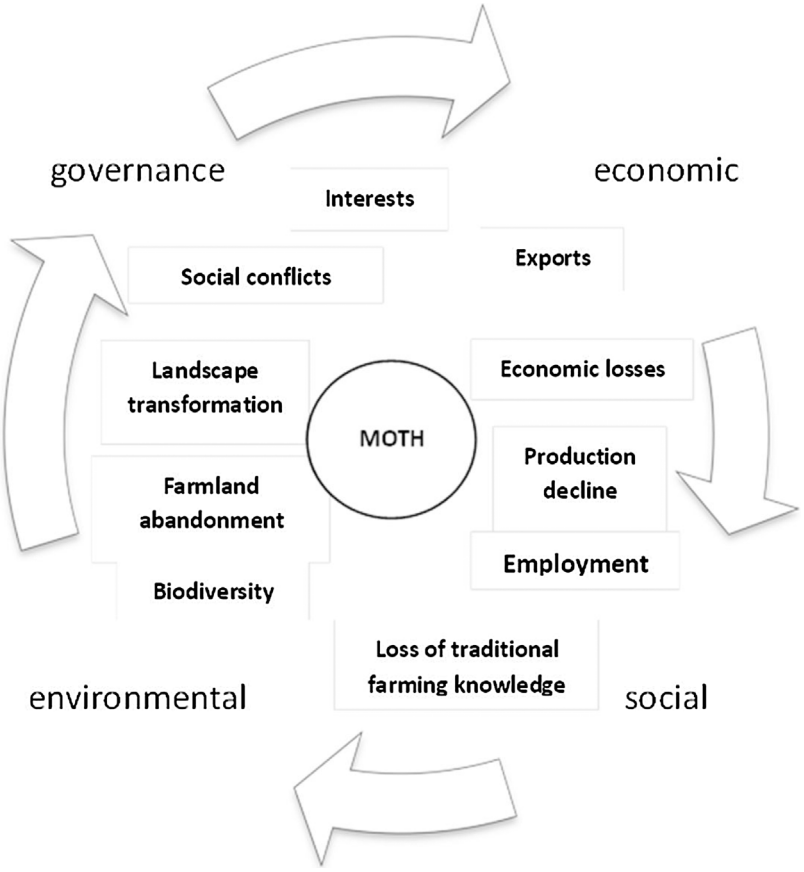

Fig. 2. Main impacts caused by potato pests.

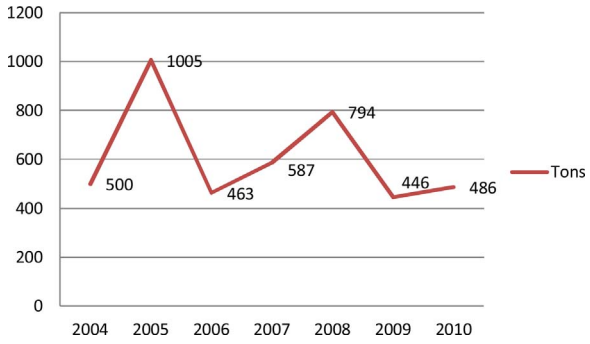

Fig. 5. Tons of infected potatoes (2004–2010).

with the moth.

2. Methodological approach

The methodological approach applied identifies the relevant stakeholders involved in the problematic so that actions and decisions can be taken by them from the beginning. The main aim is to involve these stakeholders in the entire policy assessment process.

To illustrate the interaction between social processes and pest impacts, the proposed methodological framework employs a socio-institutional analysis. Following the works of various authors (Salgado et al., 2009; Corral Quintana, 2004; Corral-Quintana et al., 2016; Hernández González and Corral Quintana, 2016), institutional analyses (Ingram et al., 1984; Ostrom 1990; Ostrom 2005) and social research encompass the examination of regulatory contexts, analysis of national and local press, the study of economic political processes and participant observation (Corral Quintana, 2004). In this context, the methodology allows us to establish a broad framework of the social complexity and to clarify the interactions between the stakeholders dealing with the pest.

In short, the proposed methodology (Fig. 3) is aimed at tackling the problem from a broad perspective, paying particular attention to the social context in which policies and decisions are taken, and the stakeholders involved in the process, as well as their interests and interrelationship (Van Der Sluijs et al., 2008; Pereira and Quintana, 2009). Particularly, the main objectives and steps of this social analysis were the following:

(A) Mapping

i. Contextualises the issue, covering all possible variables, and analyse the social, environmental, economic and governance interrelationships caused by the pest. To do this, social research techniques, such as literature reviews (press, articles, documents, legislation, etc.) were used.

Stakeholder identification and mapping also involves identifying the preferences and interests that cannot be explained and forecast on the basis of a *homo-economicus* rationality, but are conditioned by rules, by the role of institutions, by values and habits, and interactions with other stakeholders (Bacon et al., 2012). The sub-objective is, therefore, about identifying the stakeholders, a static element of the decision-making processes, and identifying the interactions and potential conflicts between them.

This information is useful to establish a detailed view of the issue in order to open a discussion in the following phase.

(B) Participatory Integrated Assessment

ii. Carrying out a round of interviews and focus groups, involving the stakeholders to extract their points of view about the information gathered during the previous phase. The information and data extracted from literature analysis are analyzed by experts and stakeholders during the interview phase. It is an analysis and review of actions taken in the past based on their knowledge and expectations.

(C) Set of novel proposals

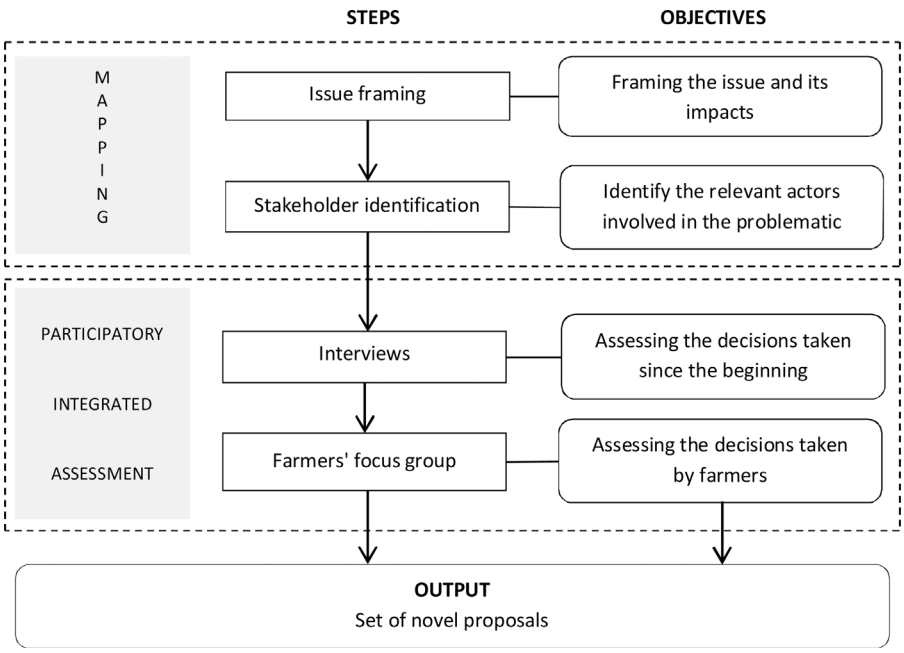

Fig. 3. Methodological framework.

iii. Participants give their own perspectives based on their own knowledge and assisted by the information collected during the mapping phase. Finally, they provide a set of novel proposals and alternatives to deal with the issue, in this case the pest infestation.

2.1. Issue framing: the impacts of *Tecia solanivora* in Tenerife

Potato growing on the island of Tenerife, in the Canary Islands, has an undeniable economic, social, cultural, scenic, historical and environmental significance (Álvarez Rixo, 1868; Álvarez and Gil, 1996; Gil González, 1997; Gil González et al., 2000; Marrero, 1992; Suárez Hernández et al., 2003; Casañas Rivero et al., 2003). It is the third crop in importance in terms of surface area, and the main agrarian activity on the island, especially in the northern area. Potatoes are grown mainly at an altitude of between 500 and 1000 m above sea level on the north of the island. However, they are also grown in the south of the island, and below 1,000 m all over the island.

These crops are linked to the cultural traditions of the island and account for approximately 13% of Tenerife's arable land; in terms of production over 30,000 tons are grown a year. In 2010, it was estimated that potato production in the province of Santa Cruz de Tenerife generated over 13 million Euros a year. It is also an important factor in landscape conservation. In addition, potato consumption in the Canary Islands is high (143 g/person/day) (Casañas Rivero et al., 2003), and they are an important part of the island's food security.

Regarding agrobiodiversity on the island, the potato has great value. Ancient potato varieties are grown in the Canary Islands, which are direct descendants from Peruvian varieties. They are most likely selections, hybrids or variants of those early tubers that were brought to the islands from America and have contributed to a biodiversity that is unique in the world (Ríos et al., 2007; Ríos 2012).Source: Agrocabildo (2016). Note: The arrow indicates the municipality in which the pest first appeared.

In 1999, the presence of a moth, unlike local species, was detected in a specific area of the north of the island of Tenerife. In 2000, it was confirmed to be *Scrobipalpopsis (Tecia) solanivora*, otherwise known as "the Guatemalan potato moth" (Ríos 2012). This pest has spread over almost all the island, and it has not been possible to contain (see Fig. 4).

Following the casual loop diagram discussed earlier (Fig. 2); the different dimensions and impacts interacting in the case of the Guatemalan moth and its effects on potato production in Tenerife are as follows. It has to be mentioned that these dimensions are not independent boxes as they are interrelated with each other.

2.1.1. Environmental dimension

The environmental aspects include the impact on traditional native potato varieties – *Papas Antiguas de Canarias* PDO (Protected Designation of Origin) – that are affected by this pest. This is particularly serious as these genetic varieties are found nowhere else in the world, and the worst-case scenario could mean the disappearance of some or all of these varieties taking into consideration the following context:

Agricultural surface area has been reduced and land use has changed to inactivity, this situation has affected the value of agricultural landscape on the island. Consequently, the surface area devoted to potato cultivation has fallen by approximately 46% in the first five years since the pest's appearance, from an initial 5514 ha in 1989–2,708 in 2004 (ISTAC, 2017a, 2017b). During this period the Guatemalan potato moth, especially in the north of the island, had a considerable impact.

This continuously decreasing trend of land surface devoted to potato growing is caused by low prices, the serious problem caused by the Guatemalan moth and the lack of generational handover. However, 88% of the farmers consider their main phytosanitary problem to be the Guatemalan moth (Falcón and Cubas, 2010).

According to available statistics for Tenerife's landfill sites, between 2007 and 2010 around 500 tons per year of infected potatoes were collected (Fig. 5).

Source: Ríos, 2012.

These data only correspond to the tons of infected potatoes that farmers deposited in the collection containers placed at different locations across the island by the public administration. They do not reflect the real magnitude of the problem, since the data do not take into account the rest of infected potatoes that are discarded directly into the environment. In fact, this large number also has a significant environmental impact on the island's ecosystem, because a substantial quantity of infected potatoes is dumped illegally in the island's ravines. This allows the pest to reproduce freely in the open and re-infect subsequent crops, which means that a much higher quantity of potatoes are affected annually.

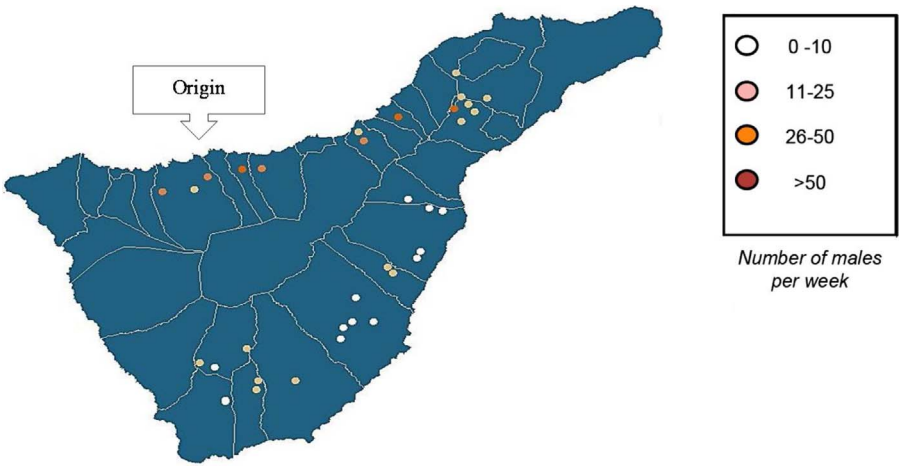

Fig. 4. Territorial distribution of the Guatemalan potato moth on the island of Tenerife and the average weekly number caught using the "pheromone trap" system.

2.1.2. Social and economic dimension

Dealing with all these tons of potatoes implies a considerable cost for local and island authorities in terms of subsidizing farmers, with an average cost of 300,000 €/year, this gives an estimated cost of 250 €/ton (BOC, 2009). Other services that generate expenses are not included in the analysis due to the lack of data, but there are also costs involved in providing collection containers, logistics and transport to the landfill, treatment at destination, etc. are expected.

Source: ISTAC (2016).

As shown in Fig. 6, the decline in potato production on the island is evident and has a correlation with the seasons in which the pest has had the greatest incidence. More than 50% of production has been lost in less than a decade.

This decline in agricultural activity leads to the abandonment of farmland and a change in land use to other economic activities, mainly tourism (Martín Martín, 2005,2000). This process has been accompanied by a reclassification of the land (Martín Martín, 2000).

The social dimension also includes the loss of employment related to potato farming on the island. According to official statistics from the Canarian Government (ISTAC, 2016), in 2000, there were 2366 potato farmers registered in the island; in 2005, the number of registered farmers was 1558; and in 2010 the decline was even more evident with just 1474 farmers.

2.1.3. Governance dimension

Moreover, the negative effects have not only been felt in production and land use, legislation impacts also affect business, since *T. solanivora* is classified as a quarantine organism (EPPO, 2002). This has meant the immobilisation of the island's potato production, banning shipments both between islands and beyond, either to the Spanish mainland or the rest of the world. This is because the larvae persist inside the potato seeds and it is not possible to discriminate a healthy potato from an infested one during the first stages of infection.

The interaction of several stakeholders with divergent interests and different points of view can lead to a chaotic situation in which decisions do not achieve the expected results. For instance, aspects such as disagreement on the strategies to fight the pest, lack of trust and low control over the methods to be used (as shown in following section) are recurrent complications.

Under this complex situation, stakeholder analysis and mapping was carried out to identify the socio-institutional context in which stakeholders interact.

2.2. Stakeholder identification and mapping

As shown in Table 1, four groups were identified according to their geographical level. At local level, there are the potato farmers and municipalities of the producing regions. At an insular level, there are rural associations that work to protect and develop agricultural and rural heritage; economic stakeholders such as cooperatives and exporters; CULTESA is a public biotechnology company dedicated to the production of plants by in vitro multiplication techniques and provides solutions to farmers' production and commercial strategies; CCBAT is the Centre for the Conservation of Agricultural Biodiversity in Tenerife; the University of La Laguna (ULL) as a science stakeholder, and the Cabildo, that is the island's governmental body, with its Agricultural

Fig. 6. Production decline in potatoes (2004–2010).

Table 1
Stakeholders and their geographical level of action.

Local level	Municipalities
	Farmers
Island level	Cabildo (Island Government)
	Rural Associations
	Cooperatives
	CULTESA
	CCBAT
	University of La Laguna (ULL)
Regional level	The Canary Island Government
	Importers
	ICIA
National level	INIA
	Biotechnology Institute of Navarra

Extension Agencies. At regional level, there is the Canarian Government; importers of seeds and potatoes for consumption; and the Canarian Institute for Agricultural Research (ICIA). Finally, at national level, the National Institute for Agricultural Research (INIA) mainly as a research funder and the Biotechnology Institute of Navarra that has collaborated with research projects.

At a national and regional level, INIA (as a part of the Ministry of Agriculture) and the Canarian Government act as regulatory stakeholders, implementing preventive measures to reduce the risk of pest d. These organizations collect information and data about monitoring of the pest, but it is the Cabildo (Island Council) that makes the main effort.

Thus, decisions are made directly by the Cabildo, based on technical and scientific results and information provided by representatives of the business and science sectors, such as cooperatives and rural associations, ICIA, CULTESA, CCBAT, ULL, and by technicians of the Canarian Government and the Agricultural Extension Agencies.

In Fig. 7, stakeholders are positioned according to their capacity to influence decision-making, the territorial scale in which they operate and the degree to which they are affected by the pest. It was elaborated firstly referencing each group in its correspondent territorial scale and secondly, assigning weights based on the information extracted from the literature review and the interviews.

At the local level, farmers are the most affected social group. They are the group that deals directly with the pest as they grow the crops, but have no capacity to directly influence decision-making. Exporters are in a similar position and whose activity is being paralysed by the regulatory system. This group is affected in terms of opportunity costs, since production cannot be shifted to other regions. By contrast, potato importers for household consumption have not been affected by the pest.

Municipalities are affected in terms of loss of employment, changes in land use and rural landscape degradation, but they do not have power enough to influence decisions and their economic limitations determine their possibilities of actions.

At the insular level, the private sector, such as farmers' cooperatives and growers' organizations have suffered a huge economic impact during the years in which the pest caused the greatest losses. As this aspect is relatively unpredictable, they have to deal with the uncertainty every season.

Rural associations work to promote integrated rural development with the purpose of improving the quality of life of farm workers and to empower farming communities through skill development and information initiatives. In this context, the pest has had a medium impact level on their activities, though they are in some cases concerned about this matter. In terms of their influence capacity, these groups might be considered as pressure organizations at higher levels.

The Cabildo (Island Council) is the main stakeholder and is being affected in terms of economic costs aimed at research activities and human resources, waste management costs of infected potatoes, information campaign costs and conflict management efforts, since it has to deal with all the stakeholders that interact within the potato sector.

At a national and international level, research bodies collaborate occasionally with local technical and scientific stakeholders without being directly affected. Finally, there is the legislative body that has a high level of influence but are not affected by the pest since it has not spread to other territories.

3. Integrated participatory assessment process

As a result of the stakeholder analysis, a set of interviews were carried out with six stakeholders from different fields of activity and knowledge during January and May 2015. The experts were selected, according to the following criteria: (a) level of involvement in solving the problem; (b) experience of the problem (personal knowledge, fieldwork); (c) knowledge of the species *Tecia solanivora* and potato cultivation in Tenerife (measured in terms of publications and/or teaching on the subject); and (d) representativeness of a social sector (political-administrative, civil society, science and technology). The identified stakeholders are shown in Table 2.

The purpose of these interviews was to create socially robust knowledge by either filling the gaps in the analysts' understanding or providing a different perspective on the issue. Thisallows experts to reflect on events and offer social stakeholders' the opportunity to voice opinions on the problem (Corral et al., 2015; Hernández-González and Corral, 2017).

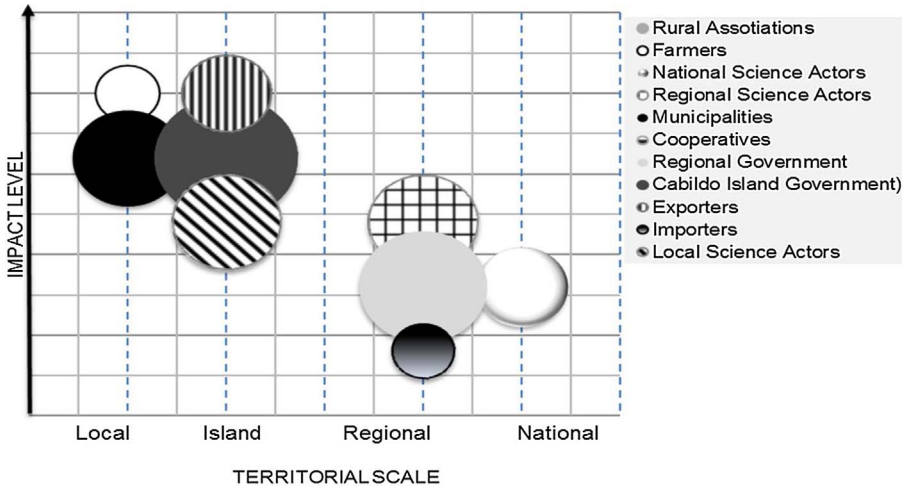

Fig. 7. Stakeholder mapping in terms of impact level, territorial scale and capacity to influence the decision-making process.

Table 2
Stakeholders interviewed.

Experts	Field of Knowledge
A member of a local Rural Development Association	Representative of civil society; knowledge of the potato sector.
A researcher from a regional R & D institution (ICIA[a])	High level of involvement; knowledge of *T. solanivora*; representative of the science sector.
A potato farmer from the north of the island	Fieldwork; representative of the civil society; directly affected.
A researcher from an educational institution (ULL[b])	Knowledge of the species *Tecia solanivora* and potato cultivation in Tenerife; high level of involvement; representative of the science sector.
A technician from the agricultural department of a municipality (Municipality of La Victoria)	Experience of the problem (personal knowledge, fieldwork); knowledge of the species; representative of the political-administrative sector.
A technician from the Agricultural Extension Agency in the north of the island (Cabildo, Island Council)	Experience of the problem (personal knowledge, fieldwork); knowledge of potato cultivation in Tenerife; representative of the political-administrative and science sector.

[a] ICIA: The Canary Islands Institute of Agricultural Research.
[b] ULL: University of La Laguna.

Considering farmers as a wide and heterogeneous group, but with a specific knowledge, a focus group was carried out to extract the views and expectations that they have about the issue. The selection and identification of farmers was based on several criteria: a) interest on protection of historical varieties; b) importers; c) domestic farmers; d) large producers; all of them are affected by the pest. The focus group was attended by twelve potato farmers, with ages between 35 and 84 years old, from several agricultural districts of the north of the island affected by the pest. Specifically, two of them were members of a Rural Association that works at an insular level; one of them is a large local producer and also potato importer at a regional level; two are large vegetables and potatoes entrepreneurs; four of them produce for local market (municipality); and three are domestic farmers interested in conservation of historical genetic varieties.

The session was structured around four main points: a) the existence of the potato moth, its impacts and consequences for participants; b) the relationship between farmers and other stakeholders (Are they listened to in decision-making? Have they participated somehow in a decision process? Do they agree with decisions taken?); c) their expectations about the future; and d) actions and strategies to fight against the infestation.

3.1. Current management strategies implemented

Pest control strategies applied in the island have been based on the measures applied in other regions affected by *T. solanivora*. Some of the most relevant are the following ones:

- Information campaigns to farmers about the correct use of phytosanitary products.
- Regarding control methods in the field, these are focused on: a) eliminating previous plants, b) sowing pest free seeds, and also avoiding sowing in dry and warm seasons, c) frequent irrigation to avoid cracks and dryness, d) harvesting as soon as possible to avoid egg-laying and removing damaged tubers and burning or burying them in order to break the cycle of the pest.
- As for control under storage, dense meshes have been placed in holes and windows to avoid moths entering, storing at 4–5 °C and monitoring with pheromone traps in every store and weekly trap inspections.
- In order to avoid farmers leaving the potato waste directly in the environment, actions to collect infected tubers for landfill disposal were carried out by authorities. Economic compensation was established by law to farmers per kg of infected potatoes (0.25 €/kg.).
- Finally, a genetic bank to conserve the autochthonous varieties of potato was created.

3.2. Participatory assessment of previous management strategies

According to participants, such control strategies did not lead to the expected results, since their application has not been regularly followed by farmers and authorities. According to scientific stakeholders, scientific experiments need time to achieve results, and in many cases it has not been possible to accomplish satisfactory outcomes.

The following five factors were identified by participants as the main obstacles to controlling the pest on the island regarding the measures taken in the last decades: lack of participatory processes to address the issue; harmful environmental practices of soil use; inconsistent application of measures; low control over delivery and transport of persons-seeds-potatoes and finally, non-coherent economic expenses.

3.2.1. Lack of participatory processes

All the impacts discussed do not occur spontaneously, as said before; they are due to the interaction among the different social groups with interests in potato cultivation and production on the island. Thus, their behaviour and interrelationships will largely amplify the effects of the pest. In this sense, research innovations and efforts are not useful if farmers do not trust and follow instructions in an adequate manner.

- Technician O "At the beginning of the problem, during 2002 and 2003, several efforts from technicians of the *Cabildo* (Island Government) were made to involve farmers from affected areas in a process targeted at providing information about the dynamic and behaviour of this new moth. These efforts consisted of periodical meetings and crop visits, but resulted in a progressive loss of interest from farmers, and finally these meetings were abandoned".

There is no exchange of knowledge based on the experience of farmers on the ground, and their experience and knowledge is usually given very little consideration. They form a group that may be considered mere recipients of scientific and institutional information, and this leads to "malpractice" in the field. However, they do have specific and appropriate knowledge that experts should consider to control the pest. In fact, the focus group revealed that farmers have a clear and holistic vision of the problem. Trust and coordination −or the lack of- among the relevant stakeholders interacting at all potato sector levels (production, commercialisation, consumption, etc.) can influence and lead some decisions to positive or negative results.

3.2.2. Harmful environmental practices on the use of soil

Sustainable practices on soil as a management strategy are perceived as being disconnected from the issue at hand. This disconnection is not unique to this case study, for instance, Carrillo and Torrado-León (2013) found that due to the risk of high losses, lack of collaborative management, insufficient extension programs and the involvement of other important pest problems, potato growers tend to rely on the application of chemical pesticides as their only management option. In our case, researchers and technicians coincide:

- Researcher I "The results we have been obtaining have been disseminated in such a way that farmers, agricultural extension agents and cooperative managers can understand them. However, the hardest thing is to make them understand that to provide a solution, time is needed to develop and evaluate tests… Farmers seek a quick solution in

the field because they do not want crop losses."

- Researcher B "Farmers ask for rapid solutions, they do not want to lose their production and cannot wait for the results of scientific methods".

- Technician V "Technicians try to communicate recommendations to farmers, but sometimes, low expectations from farmers on the results and the need to sell their production as best as possible have more bearing on their decision than applying methods correctly".

Therefore, many farmers, when working on their land, do not follow the recommendations and measures prescribed by the authorities to prevent and/or control pests, and those that do are in a minority. This is due, on the one hand, to the lack of effective supervision by the authorities, and on the other hand, to the fact that the farmer loses motivation and interest in carrying out the measures after observing that the pests' effects have not been minimised, since:

- Farmer K "Farmers are not receiving adequate information to enable them to adopt the farm management measures proposed by the *Cabildo* (Island Council) and by other researchers. Farmers do not usually adopt these measures but in no way can they be blamed, because in most cases they are unaware of them. In addition, the lack of financial and technical resources, in many cases, makes them unworkable."

Moreover, the information and research processes have mainly been top-down, this was the opinion of one of the agronomists who was most directly involved in this issue:

- Technician V "This knowledge is presented in talks given by researchers to farmers and to technicians at farmers' offices in the municipalities so that the information can be passed on. However, let me tell you, there are then many 'scientists' among farmers who then decide to commit 'atrocities' in the field."

In this sense, many farmers do not trust the administration and scientists' practices and try to attack the moth with their own strategies. Some of them spray the plants with domestic use detergents; others put bleach in the irrigation water or spray bleach directly to soil.

During the focus group, experienced farmers mentioned that phytosanitary methods applied so far are ineffective and the moth must be fought through agro-ecological practices, though there are many farmers, technicians and politicians who are not aware of this approach and its practices. This leads to the following problem:

3.2.3. Inconsistent application of measures

Potato' trade between farmers from different areas of the island is a tradition, so affected potatoes can move between crops spreading the disease. The capacity of farmers to understand the scientific methods or technical language can be a limitation when applying these methods during the crop seasons in a correct manner.

There have been failings in the handling of affected potatoes by farmers, for example, by leaving them in the land or in nearby areas (ravines, etc.), new crops have been reinfected, thus perpetuating the annual cycle of pest infestation.

Furthermore, there is inconsistent application of recommended control measures on the ground between growing seasons. During some seasons intensive measures are applied and in others there is a full or partial relaxation due to misperceptions about the incidence of the pest. The argument given is that the weather variable in each growing season determines how the measures are applied, i.e., in years of plentiful rainfall the spread of the pest decreases and in dry seasons it increases, but the measures are not implemented due to the perception that the pest will not be affected.

3.2.4. Controlling the movement of persons-seeds-potatoes

Much of the problem has historically had a social origin, in terms of organisation, management and coordination, and the scientific and technical measures serve as a complement to help mitigate the consequences.

- Researcher I "The phytosanitary barriers and controls are not strict enough; there is a large volume of incoming and outgoing people in a tourist area like Tenerife. A simple but real example is the number of students carrying potatoes from the island to the mainland and the rest of Europe for consumption there. In many cases, these potatoes are infested, but look healthy, so much so that even the farmers themselves classify as healthy potatoes ones that are infested".

This perception of incomplete control influences the negative expectations of the experts:

- Technician V "I think this pest will never be eradicated in the Canaries, we will always have to live with it, sometimes more heavily in some years than in others, but we must accept this situation".
- Technician O "The Guatemalan potato moth is the most important problem for the potato sector in terms of crop destruction and economic losses, and nowadays, there are no control methods capable of stopping it".
- Non-coherent economic expenses.

Treating and destroying tons of surplus infested potatoes in landfills produces economic losses for the authorities, as they have to pay farmers per kilogram, as well as the costs of transport, storage, treatment and destruction, and maintenance of the treatment plant. Additionally, it was deduced from the interviews that this was the wrong decision, since appropriate control measures were not taken, as stated by researcher I:

- Researcher I "…On the other hand, no one should obtain financial gain from this pest (the case of payment per kilogram) and instead of paying for the infected potatoes per kilogram, there should be more control and sanctions on the part of the administration."
- Association P "Transportation to the collection containers is done in poor conditions, which helps the pest propagate. A solution has been chosen which disperses specimens in transit to the warehouse."

The following table (Table 3) summarizes the results of the assessment of the specific previous actions carried out by participants during the interviews and the focus group session.

4. New management alternatives

As a result of the collaborative work of participants, a new set of actions to tackle the issue were discussed (Tables 4 and 5). These recommendations and alternatives are intended to manage the pest in a better way to minimise loss of agro-biodiversity, as well as dealing with contradictions among stakeholders and system uncertainties such as climate change.Farmers expressed concern about the pest and a lack of trust in technicians, scientists and institutions, but they revealed a holistic vision of the problem, given that they expressed concerns on environmental, social-economic and institutional aspects. The research team asked them to turn these concerns into proposals. This showed that the most of them placed their trust in agroecological practices as the best way to fight the moth, except for large entrepreneurs and importers, who were not concerned about this topic since these groups consider more appropriate conventional methods in order to increase production levels.

Three main alternatives were proposed by participants (Table 5) to eliminate definitively the infestation on the island.

According to farmers, these alternatives would eliminate definitively the pest on the island because the moths' larvae only feeds on potato tubers, and without food, moth's reproduction is not possible.

5. Conclusions

A participatory policy assessment allows the identification of problems causing a non-desirable situation and in parallel, of novel policy

Table 3
Results of the assessment expressed by participants.

Decisions/Actions	Assessment	Assessment expressed by:
Information campaigns and publications	Inconsistent	Farmers/rural association
	Phytosanitary products are ineffective	ULL/farmers
	Not effective: the pest has spread to south.	All stakeholders
Collect infected tubers for landfill disposal.	Inconsistent	Farmers/Rural Association
	Many farmers did not participate	
	This information did not reach domestic farmers	
Campaign to conserve local seed potato varieties.	Successful so far, but farmers did not actively participate.	[a]Cabildo
	A genetic bank is created.	[b]ULL
		Farmers
Pheromone traps.	Successful. This method is useful for monitoring.	Cabildo Municipality ULL
	"*Pheromone traps increase the incidence attracting moths to the crops*".	Some farmers
Economic compensation to farmers	Encourages farmers to not apply control methods and recommendations.	All stakeholders
Control methods in the field	Inconsistent. Low control on their applications by authorities.	All stakeholders
Control under storage	Many farmers do not follow instructions properly	All stakeholders
	Information do not reach to farmers	Rural Association
Biological control	Currently testing	ULL
Entomopathogenic fungi and nematodes		Farmers
Uso of Granulovirus		ICIA
Apply a CO_2 atmosphere in storage.	Success in storage	ICIA
		ULL
		Cabildo
Phytosanitary product application.	Not successful.	Farmers
	Ineffective	

[a] Cabildo = Island Council.
[b] ULL = University of La Laguna.

actions constructed from social consensus. The fact that the strategies used on the island have been based on those used in other regions means a review in those regions should also be carried out to improve the efficacy of measures and policies. Given that stakeholders consider some measures as inadequate or ineffective means it is crucial to discuss and update these measures at local level with the local stakeholders to find new strategies adapted to the local reality.

An invasive agricultural pest is not a simple issue. Diagnosis and strategies to tackle it should recognise the inherent systemic and social complexities. This means that not only should technical and environmental variables be considered, but also social, cultural, economic, ecological and political variables surrounding the pest infestation have to be taken into account. Strategies to deal with a new invasive agricultural pest should integrate the relevant stakeholders into the whole production chain given that frequently, these pests spread using human channels, such as during the interchange of seeds between farmers, tourists, or transportation (import and export).

This case study is a clear example of a conflicting situation in the agricultural sector, in which scientific, social and institutional dimensions interact to ultimately elaborate policy actions with implications for pest control planning and management. This study shows that there has been a lack of properly participatory decision-making processes with the involvement of different stakeholders who interact in the crop production dynamic. The inter- and intra-group conflicts are shown to be indeterminate. This situation leads to inefficient management of all aspects related to potato growing and therefore facilitates the territorial propagation of the moth. For this reason, this study does not focus solely on the pest itself, but also on all interrelationships surrounding potato growing, since they ultimately facilitate the spread of the pest. It broadens the scope of traditional analyses of this type of problem, which usually focus on specific pest controls and ignore all the associated socioeconomic and environmental issues.

This study shows that when strategies have failed and a pest

Table 5
Main alternatives to eliminate the pest.

Alternatives	Proposed by
Adjust the seedtime in order to break the reproduction cycle of the moth.	Farmers
Establish a moratorium of 4 or 5 months in which potato farming would be forbidden.	Farmers
Restriction of 3 years without potato farming on the whole island.	Farmers and Scientists (ULL)

Table 4
Recommendations extracted from the analysis and proposed by different stakeholders.

Problem to solve	Additional Recommendations	Proposed by
Inconsistent application of measures.	Wide farmers' knowledge on agroecosystem.	Farmers
Employment.	Promote intergenerational handover.	Farmers, Rural Development Assoc.
Loss of traditional farming knowledge.	Avoid land abandonment and land use changes	Farmers, Rural Development Assoc.
Non-coherent economic expenses.	Increase sanitary controls of potato imports.	All stakeholders
Economic losses.	Eliminate subsidies and compensations.	ICIA/Farmers
Production decline.		
Harmful environmental practices.	Agroecosystem practices/No phytosanitary products.	Farmers/Rural Development As.
Loss of Agro-biodiversity.	Shift of crops.	All stakeholders
Farmland abandonment and Landscape transformation.	Constant field labour.	Farmers/Cabildo/ULL
	Climate Change adaptation strategies. "The moth will do that".	Cabildo/Farmers/Municipality/UL L
Lack of participatory processes.	Maintain technical recommendations (Table 4) and increase control on their application.	All stakeholders
Conflicts and disorganization.	Promote stakeholders' cooperation and communication.	Farmers
	Increase participatory research between scientists and farmers.	Farmers

Table 6
Types and sources of uncertainties.

Type	Source
Social	Conflicts between groups
Environmental	Loss of agro-biodiversity
Environmental	Climate change
Environmental	Local weather for forthcoming seasons of crop (rainfall, drought, high or low temperatures, etc.)
Economic	Crisis, lack of resources.
Geographic	Invasion of South Europe Regions

becomes established in a territory, a co-existence situation is accepted by the stakeholders, leading to social conflicts, frustration and loss of motivation to fight it. Therefore, it is important to develop inclusive and deliberative processes integrating different knowledge and expertise in order to develop novel proposals.

In the current case study, there has been a realisation that public administrations and research bodies have based their actions solely on technical and scientific aspects and have undervalued important factors such as: the role of traditional knowledge in the use of land and agro-ecosystem management, which could have controlled the pest in the field much better; the potato trade between different agricultural areas of the island, a well-known traditional practice; or domestic farmers who are not involved in the productive sector, but to whom the information did not reach, thus allowing the moths to reproduce.

The methodology applied herein allows a broad contextualisation, including a historic perspective and analysing the problem from different stakeholders' points of view and interests. This has led to the identification of several alternatives and actions to complement the current decision-making processes. Opinions and expectations are extracted to integrate different knowledge sources and types of uncertainty into participatory processes that could change the decisions taken so far.

Scientists and farmers declare that applying one of the alternatives arising from the analysis would eliminate the pest from the island, but if taken, this decision would lead to conflicts and social-economic impacts. Taking one of these alternatives implies several consequences, thus, important questions emerge: what are the economic, environmental and social costs of each alternative, and for each actor? Who would take this decision, and in what manner?

Another crucial aspect to understand more clearly the case study and to facilitate better decisions about the moth is the elicitation of related uncertainties. Complex systems give rise to many sources of uncertainty, some of which, such as uncertainty due to random processes or ignorance, may be reduced by introducing more data and further research. For instance, uncontrollable variables such as climate change and economic crises, which involve undetermined impacts that are very difficult to predict, also influence the issues under study; the tons of infested potatoes, especially those that are not under the control or within the field of vision of the groups, represent an uncertainty in terms of non-availability of data and ignorance. They are not managed properly and the quantity of this type of waste being discharged into the environment is not being controlled.

The types and sources of uncertainties shown in Table 6 were found during the analysis.Fundamental, irreducible uncertainty may arise from non-linear processes (e.g. chaotic behaviour) in the process of self-organisation or through determined behaviour on the part of different stakeholders and agents, each with their own goals. Mainly, the uncertainties in our system are linked to factors surrounding the issue in question and correlate with further propagation and low control. Together, uncontrollable variables such as climate change and economic crises, which involve undetermined impacts that are very difficult to predict, also influence the issues under study. Under these circumstances, decision-making processes demand inclusive, transdisciplinary and participatory approaches.

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Local community-based approach for sustainable management of artisanal fisheries on small islands

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ABSTRACT

Socio-economic development of small island fishing communities is greatly dependent on local coastal and marine resources. Illegal fishing and aggressive practices in insular ecosystems lead to over-exploitation and environmental deterioration. Moreover, a lack of scientific data increases uncertainty and prevents adequate monitoring of marine resources. This paper focuses on the integration of a local fishing community into decision-making processes with the aim to potentiate artisanal fishing on the Island of Tenerife (the Canary Islands). The aim is to preserve both the marine ecosystem and promote the socio-economic development of traditional Cofradías (local fisher communities).

A qualitative methodological framework, based on participatory problem-solution trees and focus groups, was implemented to identify the main obstacles impeding the sustainable development of the artisanal fishing sector on the island. Collective proposals with policy implications are also discussed.

The community involved identified four main issues that are causing an unsustainable island fishery: 1) Overexploitation; 2) Poor self-management of Cofradías and commercialisation problems; 3) Fisher individualism and low co-management strategies, and 4) Illegal fishing increase vs. artisanal fishing decline. Results show the required policy enhancements to tackle those issues with, for instance, the creation of marine protected areas, the promotion of a common islander vision, and an increase in participatory research projects between scientists and fishers. Participants also revealed the necessity to adapt existing regulations to local specificity to reduce the gap between policy makers and local community.

1. Introduction

Global marine fisheries are in decline, they began to decrease in the late 1980s (Watson and Pauly, 2001). Across regions, average recruitment capacity has declined at a rate approximately equal to 3% of the historical maximum per decade (Britten et al., 2016) due to environmental changes and chronic overfishing. Three main related causes are maintaining this negative trend (Kooiman and Bavinck, 2005): a) the collapse of fish stocks caused by the degradation of aquatic ecosystems; b) fishing overcapacity, and c) deficient fisheries management.

Climate change is also an important issue due to its impact on biodiversity and local socioeconomic systems. The precise impacts and direction of climate driven change for particular fish stocks and fisheries are uncertain (Allison et al., 2009), but some regions are more vulnerable than others due to the fragility of their ecosystems (Walther et al., 2002; Hoegh-Guldberg et al., 2007) and their low capacity to develop adaptation strategies (Barnett, 2001).

Impacts on island fisheries might be more severe due to the social, economic and environmental vulnerability of these types of territories (Briguglio, 2003). In these regions, factors such as aggressive fishing practices and inadequate fisheries management might increase impacts and contribute to the decline of both marine biodiversity and socio-economic activity (Burke et al., 1994; Marsh et al., 2004; Shepherd et al., 2004).

In the Canary Islands region, there is a lack of systematic scientific data on fish distribution, mortality and recruitment. The absence of reference indicators about the status of stocks constitutes an important source of uncertainty. Moreover, this may lead to incomplete diagnosis and therefore, to the development of inadequate policies, which: a) do not solve the problems, and b) create social disagreement and conflicts among stakeholders.

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According to Santamaría et al. (2014), the information available is not sufficient to support the design of a sustainable strategy for the Canary Islands' artisanal fisheries.

Given this condition of high vulnerability and lack of data, the implementation of actions focused on the integration of different types and sources of knowledge into policy making processes is an asset (Corral-Quintana et al., 2016; Raymond et al., 2010). Additionally, local knowledge can provide valuable qualitative information related to planning and management alternatives (Pereira and Quintana, 2009; Van der Sluijs et al., 2008). In fact, local fisher communities have been handling marine resources for centuries without quantitative data instead using inherited traditional knowledge (Corral et al., 2015; González and Quintana, 2016; Gupta and Singh, 2011; Srivastava, 2010). The usefulness of integrating local knowledge into fisheries planning and management practices or strategies has been highlighted by several scientists during the last few decades (Mackinson and Nottestad, 1998; Davis and Wagner, 2003; Johannes, 1998; Johannes et al., 2000; Olsson& Folke, 2001; Hamilton et al., 2012; Hauzer et al., 2013).

Traditional fishing knowledge on the Canary Islands, as in the rest of Spain, is channelled through traditional fisher groups called *Cofradias.* These relevant social actors maintain artisanal fishing practices, but they have been declining for several years (Castro and Hernández-García, 2012; Chuenpagdee, 2011). There are several reasons for this decline such as the displacement of fishing families from the coast due to the construction of tourism infrastructure, the impossibility of using traditional beaches to land catch and the destruction of fishing grounds due to the establishment of tourist resorts (Pascual, 2004).

The main objective of this paper is to contribute to developing more efficient fishing policies focused on the conservation of artisanal fishing on the island of Tenerife. The paper presents a community-based process designed to generate socially robust knowledge (Gibbons, 1999) with policy implications. Assisting the community to produce robust knowledge that applied to environmental and fishing policies might produce implications to a more sustainable fishing in Tenerife.

The following section describes the study area as well as the framework applied and in section 3, the results are discussed. Finally, section 4 establishes some conclusions and recommendations for further research.

2. Material and methods

2.1. Study area

The Canary Islands archipelago is located in the Northeast Atlantic Ocean, approximately 110 km from the northwest coast of Africa. The archipelago is located in the path of the Canary Current, where deep waters are cold and nutrient-rich and have a key role in stimulating primary productivity. Inhabited by a large number of endemic and migrant species, the Canary Current is a unique ecosystem of global significance, and rich in fishery resources (Popescu and Ortega, 2013). Specifically, Tenerife is the island with the highest number of native flora species of the Canaries (476 spp. = 68% of total) (Francisco-Ortega et al., 2009), and the waters around Tenerife constitute an important habitat for cetaceans (Carrillo et al., 2010).

Fishing activity in Tenerife is coastal artisanal (for small pelagic species, crustaceans, demersals and molluscs), several methods of fishing are used, ranging from artisanal inshore fishing to recreational marine fishing, which includes spear-fishing and angling.

Inshore Canarian fish fauna includes 217 species from 67 families (Dooley et al., 1985). More than 60% of catches include sardine (*Sardina pilchardus*), sardinella (*Sardinella aurita*, *S. maderensis*), anchovy (*Engraulis encrasicolus*), chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus* sp.). Other species include tuna (e.g. *Katsuwonus pelamis*), coastal migratory pelagic fish, hakes (*Merluccius merluccius*, *M. senegalensis*, *M. poli*), a wide range of demersal finfish, cephalopods (*Octopus vulgaris*, *Sepia* sp., *Loligo vulgaris*) and shrimps (*Parapenaeus longirostris*, *Penaeus notialis*) (Popescu and Ortega, 2013).

Fishing activity in the Canary Islands region, and lastly in Tenerife, is regulated under a set of European, national and regional policies and laws. It is a complex regulatory system in which several regulations and competences between administrations are overlapped. The Ministry of Agriculture, Livestock, Fisheries and Waters and the Ministry of Agriculture, Food and Environment controls the exterior national waters and regulates the use of fishing methods, periods, specific areas of closure, target species and capture quotas.

The Canary Island government has the responsibility to regulate fishing management in each island and, in addition, it is responsible for implementing the European Common Fisheries Policy (CFP) in inland waters, aimed to manage fishing fleets and preserve fish stocks. Concretely, this administration is responsible to authorise the undertaking of fishing activities, regulate fishing gear, mark out fishing zones, set exclusion periods and activity timetables, establish authorised species and minimum sizes, and keep an official register of activities. But according to a review of the Canary islands fisheries management plans (Uriarte et al., 2014), there is an incomplete strategy to minimise impacts on Canary Islands' fishery through: *i) limiting fishing effort; ii) limiting catches; iii) limiting the use of some gears in some areas; iv) authorisation of fishing areas; v) implementation of closed fishing areas as marine protected and artificial reefs areas; vi) implementation of authorised and closed fishing areas for harvesting; and vii) limiting the recreational fishing activity in some areas.* The fact that this strategy is not fully developed in the island stresses the importance of involving local groups and other stakeholders, which is the purpose of this research (see Fig. 1).

As an example, the definition of marine reserves on the island of Tenerife has been characterized by the presence of historical conflicts between local groups that have made impossible the establishment of these figures of protection (Rodrigues Henriques, 2013). This has not happened on other islands, as there are marine reserves in La Palma, Lanzarote and El Hierro with positive results for both the ecosystem and the fishing community (Tuya et al., 2006).

Cofradías represent the primary fishing group in the island and all professional fishers are members of Cofradías. There are several differences between them related to economic incomes, work force and fleet capacity. These differences impact on their capacity to access fish stock. Each Cofradía sells their catches at their respective authorized port, where particular consumers buy fish directly while different small companies distribute to restaurants of the island.

The fishing fleet in Tenerife shows a high social and economic dependency on small-scale fishing, but these practices are in decline according to an analysis by the public administration as a consequence of several major factors (PIOT, 2011):

The Canarian artisanal fishing fleet (vessels of less than 12 m long) has been in decline since 1990 (Fig. 2). The number of vessels, the total gross tonnage, and the engine power have been reduced by ca. 60%, with a severe fall since 1990 (Popescu and Ortega, 2013).

Recreational and illegal fishing activities increase pressure on coastal and marine resources, but official statistics are not available. Nevertheless, the number of fines and reports have increased over recent years.

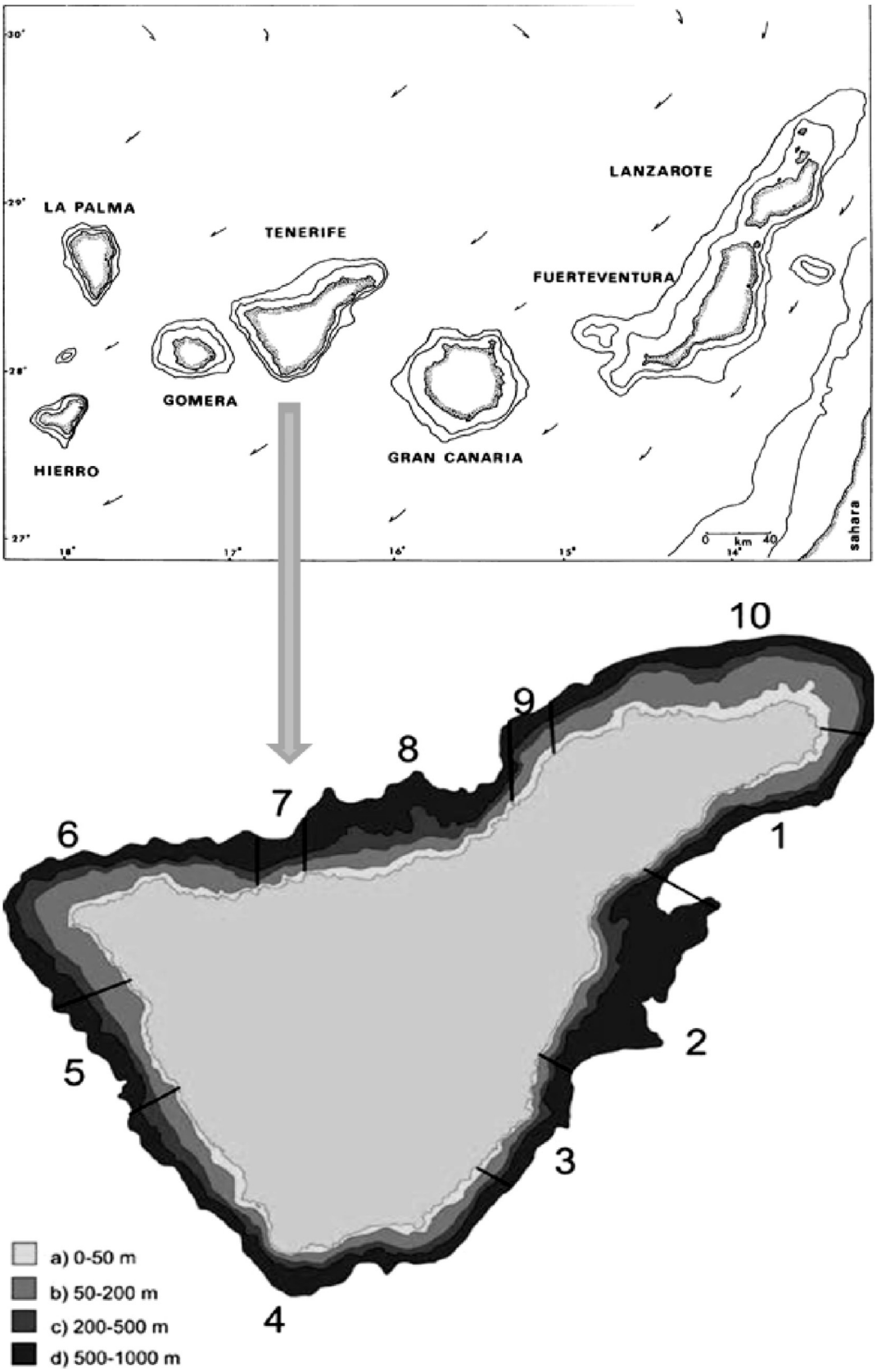

Fig. 1. Map of the Canary Islands (source: Dooley et al., 1985). Below, delimitation of fishing areas of Tenerife island and depth contours.
Source: Santamaría et al., 2014.

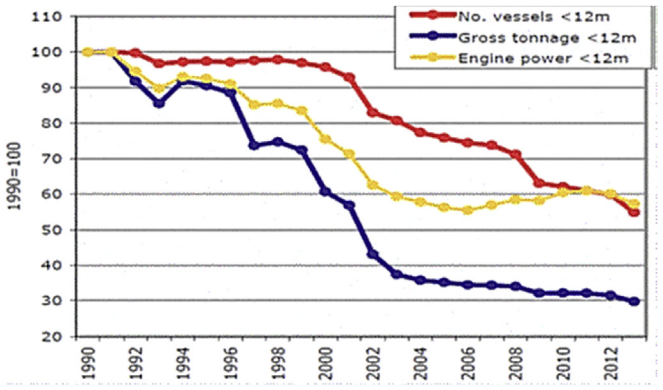

Fig. 2. Evolution of the Canarian fishing fleet in terms of number of vessels, gross tonnage and engine power. Vessels less than 12 m long.
Source: Popescu & Ortega, 2013.

2.2. Methodology

2.2.1. Institutional analysis

A qualitative methodological approach was adopted in order to develop a progressive learning process. It consisted of two phases: (i) initially an institutional analysis based on interviews and document analysis was carried out to frame the current status of fishing in Tenerife and (ii) a stakeholder participatory process based on several participatory techniques (focus group, problem and solution trees), which allowed participants to express their perceptions, establishing a debate, and identifying specific issues and solutions according to their knowledge and experience.

Prior to the implementation of workshops, an institutional analysis was carried out in order to:

a) Evaluate the current status of the fishery.
b) Identify the relevant fisheries' stakeholders as well as their interrelation over the problematic. To do this, an issue framing was established through a round of semi-structured interviews to analyse the opinion and position of each stakeholder and their expectations and willingness to be engaged in advancing project stages. This action was performed through an analysis of the local press, a literature review and official sources from public administrations. The delimitation of the local community was accomplished using the following categorisation:
➢ Groups *substantially dependent* on fishing activity
➢ Groups engaged and/or concerned about coastal and marine conservation (NGOs, associations, etc.)
➢ Public administration at insular level
➢ Public administration at local level: Municipalities with fishing tradition.

Small island territories can provide one advantage when defining the boundaries of local fishing community due to their restricted geo-spatial limits. Nevertheless, this assumption is not that simple, following (Pascual et al., 2005) 'geographical limits are not the main basis of the definition of local coastal communities'. Therefore, social, economic, cultural and political criteria should be taken into account (see Table 1).

With the purpose of identifying the local groups (Table 2), the following definition was used: a "fishing community" is *a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs* (Magnuson-Stevens Fishery Conservation and Management Act, 1996).

Traditional fishing communities in Tenerife are organised into

Table 1
Factors influencing the decline in traditional practices.

Lack of adequate seaport infrastructures.
Poor capacity of Cofradías to commercialise catches.
Progressive loss of employment by the migration of workers to the tourism sector.
European financial aid is being reduced.

Source: PIOT, 2011.

10 Cofradías (see Table 3), these are traditional and historical fishers' organisations in Spain (Fernández, 1999; Bavinck et al., 2015). Cofradías are local non-profit corporations with public rights, which represent the interests of the whole fishing sector by acting "as consultative and cooperative bodies for the administration, undertaking economic, administrative and commercial management tasks" and with the ability to "cooperate in matters of regulating access to the resources and informing on wrongdoing occurring in their territory" (Pascual and Symes, 1999). Thus, Cofradías play a key role within the fishing activity, maintaining social cohesion and representing local economic interests.

Coastal Action Group is a local partnership formed in 2012 with the main aim to channel the European Maritime and *Fisheries Fund* (EMFF) that gives *financial* support to the *EU fisheries* sector. This organization monitors the Strategic Plan and the fishing activity on the island. It is composed of local public administration (Cabildo and municipalities with fishing tradition), local associations and NGOs, and the private sector.

Once stakeholders were identified, they were contacted, via telephone and via e-mail, and formally invited to participate in the following workshops.

2.2.2. Stakeholders' involvement

To give rise to community-based management proposals, three rounds of workshops were carried out in a progressive manner using several participatory techniques (see Fig. 3). Problem-Solution Trees and Focus Group techniques were selected given their facility to be understood and developed by a wide range of participants.

2.2.2.1. Problem-tree workshops: cause-effect analysis. In the first round of workshops, a Problem Tree tool was applied and developed by participants. This method is useful to 'determine the root causes of a main problem' (Snowdon et al., 2008). The first step consists of defining the focal issue to be analysed. Then progressively, participants build up levels of causal factors (represented as roots) and illustrate in a visual manner the issue with its interrelated causes and effects.

To develop problem trees, each group worked separately, on different days, at their respective places of daily activity. Concretely, 10 workshops were carried out with every fisher organisation of the island ($n = 10$); representatives of associations and NGOs were collected in a same workgroup ($n = 2$); finally, local and insular public administrations were placed together in another workgroup ($n = 5$).

Table 4 shows the classification of groups and the number of workshops carried out with each of them.

Due to the huge quantity of problems identified by participants during the workshops (concretely 26) a ranking was established in order to simplify the information. All problems identified in the problem trees were collected on a board and participants were asked to assign a weight to each factor in order to identify the most relevant for them (from 0 = not relevant to the fishery's unsustainability; to 9 = highly relevant) and the arithmetic mean was calculated. The first 10 problems of the ranking were selected to be

Table 2
Stakeholders involved.

Classification	Participant
Groups substantially dependent on fishing activity.	1 Traditional fishing organisations (Cofradías)
Social groups engaged in and/or concerned about coastal and marine conservation.	•Members of Coastal Action Group (GAC): •Ecologist Association BEN-Magec •Canarian Surf Federation
Public administration at insular level.	•Members of Coastal Action Group (GAC): Cabildo (Insular Government)
Public administration at local level: Municipalities	•Members of Coastal Action Group (GAC): • A municipality of the north of the island: Buenavista. • A municipality of the south of the island: Candelaria.

Table 3
Artisanal fishing organisations in Tenerife (Cofradías).

COFRADÍA	MEMBERSHIPS	No. OF BOATS
1. San Andrés	60	60
2. Nuestra señora de la Candelaria	32	22
3. San miguel de Tajao	23	14
4. Nuestra señora de Las Mercedes	159	71
5. Nuestra señora de La Luz	84	39
6. San Roque e Isla Baja	19	12
7. San Marcos	42	23
8. Gran Poder de Dios	30	24
9. Nuestra señora del Carmen (El Pris)	18	26
10. Nuestra señora de La Consolación	12	10
TOTAL	479	301

worked on in a successive step. This action allowed the selection of the most relevant problems for the actors and facilitates the following phase.

2.2.2.2. Solution-tree workshops: problem-solution analysis. In the second round of workshops, the process is similar to the previous step, but in this case the information is structured and turned from negative statements (problems) into positive statements (solutions and objectives).

The objective of this phase is to develop a problem-solution relationship analysis through a solution tree tool. Table 5 shows the classification of groups and the number of workshops carried out with each of them.

The problems resulting from the previous ranking were worked out in workshops. In order to simplify the process, the participants were grouped into three working groups and each of them carried out two workshops: I) Representatives of fisher organisations from the north of the island (n = 5); II) Representatives of fisher organisations from the south of the island (n = 5); III) Representatives of insular and local public administrations were put together with associations (n = 7).

2.2.2.3. Focus group workshops: generating policy options. Contrary to previous steps, this phase is carried out in two heterogeneous focus groups to develop a more interdisciplinary discussion, with every group having at least one representative of each social group of the previous workshops. Each focus group was composed of representatives of traditional fisher organisations (n = 5), representatives of associations and NGOs (n = 1), and representatives of public administrations (n = 2). In this step, technical experts in local fisheries' management (n = 1/focus group) and scientists (n = 1/focus group) were engaged. These experts and scientists are researchers from the local university.

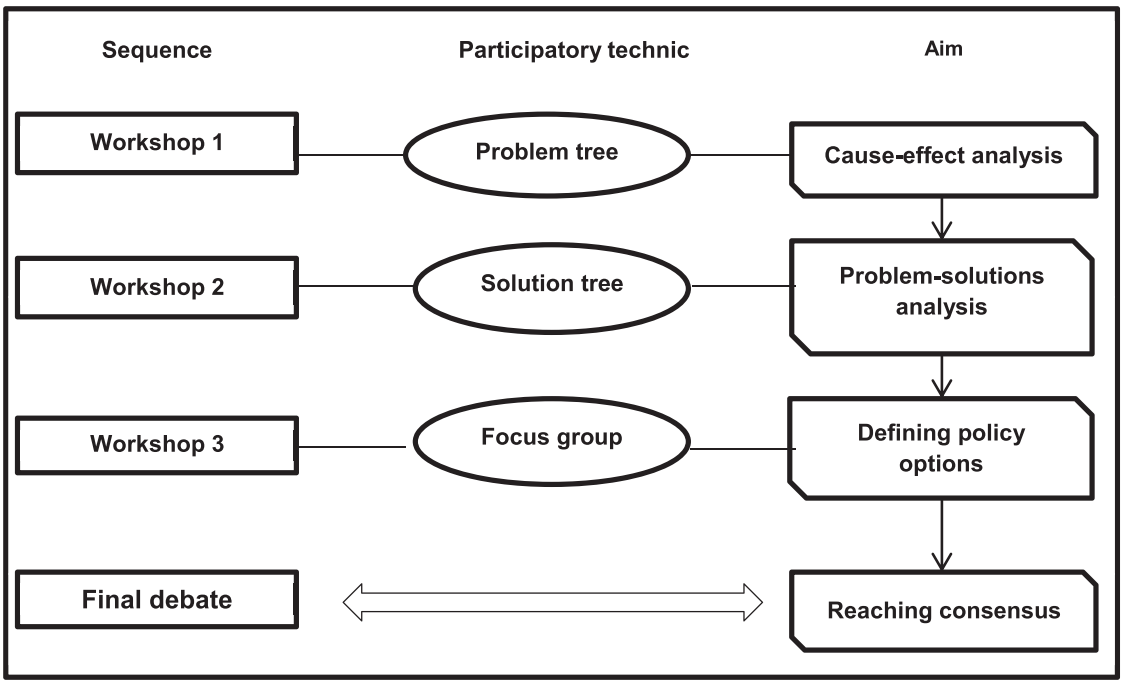

Fig. 3. Methodological framework.

Table 4
Participants involved in problem tree workshops.

Social group	Number of workshops	Number of participants
Cofradías of Tenerife	10 (1 per cofradía)	100 (10 per workshop)
Associations and NGOs	1	2
Public administrations (Island Government ("Cabildo") and municipalities)	1	5
Total	12	107

Table 5
Participants involved in Solution tree workshops.

One representative of	Number of workshops	Number of participants
Cofradías of the north of the island	2	5
Cofradías of the south of the island	2	5
Public administrations (Island Government ("Cabildo") and municipalities)	2	7
Associations and NGOs		
Total	6	17

Outcomes extracted from Problem and Solution Trees workshops were explained and collectively discussed. Focus group A analysed the *overexploitation* in Tenerife and the *poor self-management of Cofradías and commercialisation problems;* and focus group B worked on *Individualism vs. co-management* and *illegal increase vs. artisanal fishing decline* (Table 6).

Finally, the outputs of the working groups were discussed in common and collected on a board.

3. Results and discussion

This section describes and analyses the outcomes extracted from the three phases of workshops in a consecutive manner, from the initial identification of problems to the final generation of policy options.

3.1. Problem tree workshops: identifying problems

Problem tree workshops revealed participants' perception on interrelated variables affecting their capacity to reach a sustainable activity.

As an example, Fig. 4 shows one of the problem trees developed with a cofradía from the north of the island (*Nuestra Señora de la Consolación)* during first round of workshops. Causes and effects related to the focal problem (in box) are illustrated; lower levels of the focal problem represent identified causes/problems which lead to effects at higher levels.

According to this Cofradía, aspects such as deficient control strategies on illegal and aggressive fishing practices, illegal fishers are those who are neither professional nor recreational but take a large amount of marine and coastal resources illegally. The lack of marine reserves and the poor economic capacity of the Cofradías lead to overexploitation and unsustainability of the fishery. This negative situation affects the environmental resilience capacity; produces individualistic behaviour of many fishers and anarchy in the sector thus damaging local economies. For instance, there are fishers who sell part of their catches to restaurants or particular consumers outside of the regulated and controlled commercialisation chains. This condition can distort the monitoring of the stock.

Table 6
Categories of problems, number of workshops and participants.

Categories of problems	Focus groups	Number of participants
I. Over-exploitation.	A	9
II. Poor self-management of Cofradías and commercialisation problems.		
III. Individualism vs. co-management.	B	9
IV. Illegal increase vs. artisanal fishing decline		
Total	2	18

Summarising the results from the problem trees, according to the Cofradías, several social economic drawbacks impede a sustainable fishery development on the island. The main factors identified were: the absence of an awareness of belonging to an islander fishing community; a lack of communication among local stakeholders; poor capacity and knowledge of organisational management; overfishing due to the poor knowledge of Cofradías of fish stocks (Cofradías require scientific data about fish stock through collaborative processes and exchange of information among actors) and illegal fishing.

Concretely, fishers feel that fish stock is clearly in decline given that they have to spend more hours at sea to catch a sufficient amount of fish. Competition from illegal and recreational fishers also hinders a direct sale of the product to local restaurants. Moreover, fishers have a low capacity and knowledge to develop a correct self-management of their organisations. They feel that these factors are not correctly tackled by regulations because these regulations are not adapted to the fishers' daily reality. Additionally, there is not an islander consciousness among the fisher community and this situation leads to individualism and disorganisation of the sector.

Associations and NGOs highlight the lack of environmental education directed at the local population and tourists about Canarian marine biodiversity, overfishing, the marine pollution produced by dumping of waste at sea and impact of coastal infrastructures, and the absence of marine protected areas in Tenerife. These factors affect coastal and marine ecosystem since monitoring and control processes over local resources are deficient.

According to public administrations, the lack of financial resources hampers the implementation of adequate strategies. There is also an overlap of regulations and competences among different administrations (European, national, Canarian, and insular) that creates a complex situation of political conflicts and dispersion of responsibilities. Additionally, this group affirms that external regulations are not adapted to the Canarian reality.

The main issues as expressed by each participant during this phase are summarised in Table 7.

Each group has a different point of view regarding the problems affecting the fishery. As seen, Cofradías demand more active actions to help them economically and more participation in decision making processes; Associations and NGOs stress the importance of the environmental education directed at the local population and tourists in order to reduce marine pollution; and the public administration feel overwhelmed because of the intricate regulatory system. A common issue expressed by all participants is the absence of marine protected areas on the island.

The resulting ranking of factors influencing the focal issue is shown in Fig. 5. This step allows the selection of the most relevant problems for actors and facilitates the evolution of the following phase. The ranking was based on a scale from 0 (less important) to 9 (crucial issue).

According to Fig. 5, the most relevant problems for participants are: *"fewer fish in the sea/overexploitation"*, this suggests deficient scientific monitoring and a lack of data on species distribution, fishing mortality and recruitment, and thus, an overfishing

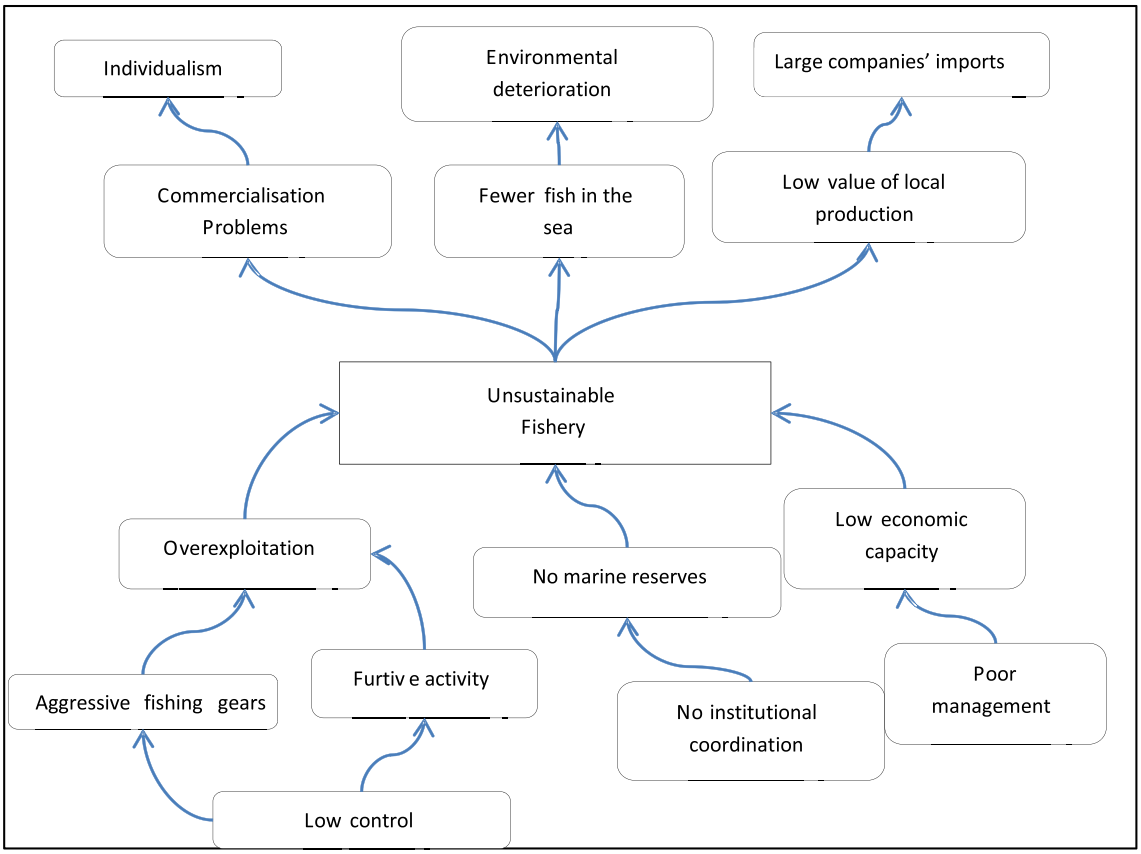

Fig. 4. Causes and effects of an unsustainable fishery as a problem tree output according to Cofradía Nuestra Señora de la Consolación.

situation; *"Difficulties in direct commercialisation"* are related to the low knowledge and capacity of organisational management of these groups; *"Regulatory system is not coherent to reality"* states that policy-making processes are distanced from the quotidian problematic of local groups. This is an important matter in this case study since it reveals that policies are not being coherent with a) the daily issues of local groups, consequently the Cofradías have difficulties to act in accordance with them, and b) environmental conservation strategies do not assemble data in their entirety.

3.2. Solution tree workshops: identifying solutions

As an example, the following figures (5)–(7) illustrate Solution Tree outcomes developed by participants during the analysis of the Overexploitation factor. The figures show the solutions that each group puts forward to tackle overexploitation and avoid fishery unsustainability.

Cofradías from the south of the island (Fig. 6) put emphasis on several factors such as: coastal surveillance actions on illegal fishing; control of quotas for professional fishers; increases in restrictions on the number of fish licences awarded to recreational fishing, as well as the limitation of their activity to weekends. This group considers the establishment of marine reserves in the south of the island as extremely important.

Northern Cofradías (Fig. 7) highlight the urgency to establish protected areas in the north of the island as well as the necessity to develop more intensive actions of surveillance and control over illegal and recreational fishing in order to avoid over-exploitation.

Fig. 8 shows the Solution Tree according to public authorities. Several factors influence the focal problem (overexploitation), which leads to the existence of an unsustainable fishery on the island. In this case, authorities and associations declared that the existence of marine reserves would contribute to coastal and marine ecosystem conservation and facilitate the reproduction cycle of species; this aspect needs to be strengthened by participatory research activities and by increasing funds to marine research on the island. An intensification of surveillance and control action is also mandatory to preserve both the ecosystem and the fisheries artisanal sector.

Summarising, all proposals extracted from the workshops are shown in Table 8. Groups coincide in several actions required to solve the perceived problems.

3.3. Focus groups workshops: generating policy options

The following four topics were the most relevant issues to be discussed:

I. Overexploitation.
II. Poor self-management of Cofradías and commercialisation problems.
III. Individualism vs. co-management.
IV. Illegal fishing increase vs. Artisanal fishing decline.

Regarding the overexploitation issue, the groups stated their concern about the lack of or incomplete scientific data and demand more scientific activities using participatory research and observation methods, taking into consideration the potentiality of sea workers to provide knowledge to scientific community. In relation to this, public institutions also stated that it was necessary to increase financial resources to scientists and research bodies to improve monitoring processes and widen knowledge of fish stocks

Table 7
Main problems expressed by each participant during Problem-trees workshops.

Participant	Main problems identified
Cofradías	• Lack of a collective vision (as a whole) from fishers. • Lack of communication and coordination among local stakeholders. • Poor knowledge of organisational management. • Difficulties in commercialisation • Illegal fishing • Regulations are not adapted to their daily reality • No marine reserves • Loss of traditional knowledge • Poor knowledge or access to fish stock data • Low control • Lack of infrastructures • Age of fishing fleet • Economic problems • Lack of generational relief • Poor capacity to influence decisions – no involvement or consultation • Fishing temporality
Associations and NGOs	• Lack of environmental education • Overfishing • Marine and coastal pollution • Lack of marine protected areas in the island • No oversight over illegal fishers • Lack of scientific data and monitoring
Public Administrations	• Lack of financial resources. • Overlapping of European, national and regional regulations and competences. • External regulations are not adapted to the Canarian reality • Lack of marine protected areas

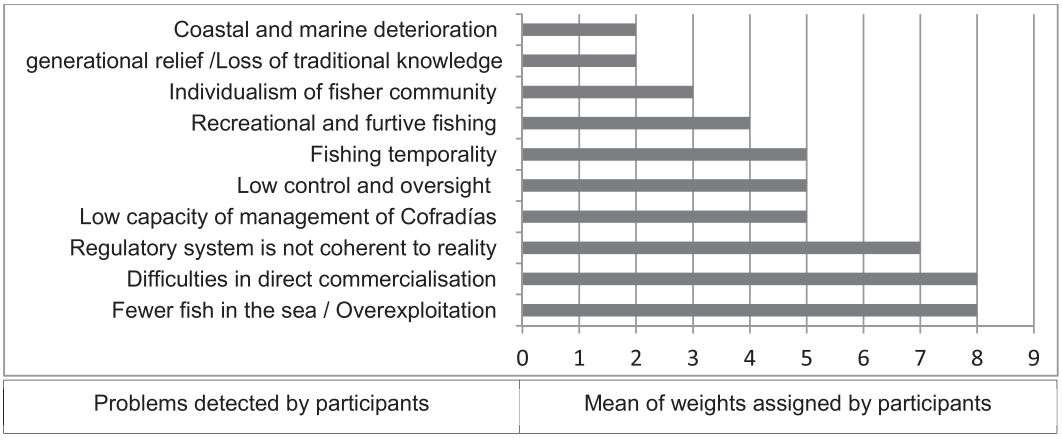

Fig. 5. Ranking of problems affecting sustainable artisanal fishing, according to answers given by participants.

and the local marine ecosystem.

To avoid and/or control overfishing, several recommendations emerged related to regulatory systems, coordination and oversight actions, participatory research and monitoring data, educational practices and diffusion of information such as:

- Establishing seasonal regulations for recreational fishing practices.
- Promoting a participatory dialogue between scientists and recreational communities in order to reach agreements.
- Education, training and information about fisheries disseminated to every agent involved in fishing activities (sea workers, professionals, companies, public body, etc.)
- Developing more effective awareness and control actions.
- Creating marine reserves to protect islander biodiversity.

In order to improve the self-management capacity of Cofradías and solve commercialisation problems, Cofradías stated the need to widen their knowledge and capacity to manage their own organisations. To do this, self-financing models and innovative approaches to commercial management were considered as indispensable factors to reinforce these organisations and maintain their economic viability.

Cofradías feel isolated and demand a more collaborative and coordinated behaviour among the whole sector of the island. This should not only involve developing communication and information channels among actors, but also establishing joint commercialisation as a cooperative, which guarantees the socio-economic competitiveness of their organisations.

Concretely, participants stressed the following aspects:

- Promotion of a collective vision among the whole fishing sector of the island.
- Joint commercialisation channelled through a united cooperative.

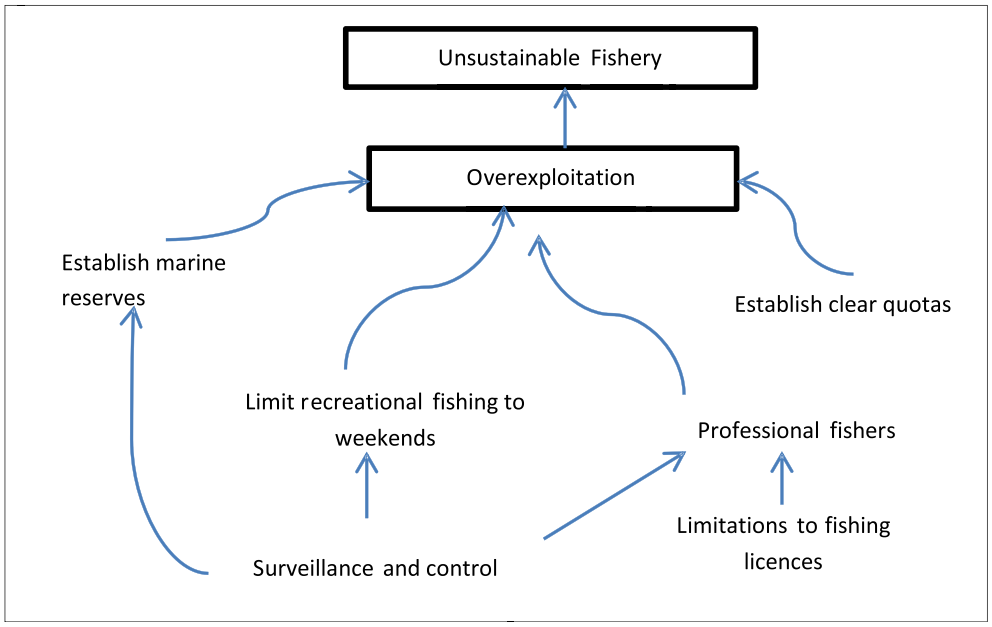

Fig. 6. Solution Tree developed by southern cofradías.

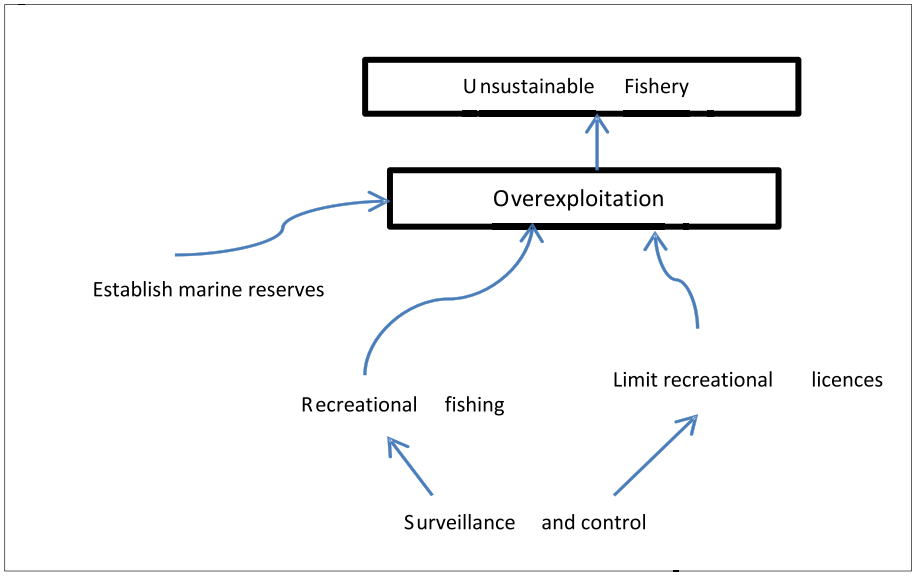

Fig. 7. Solution Tree developed by northern Cofradías.

- Development of self-financing models adapted to the characteristics of each Cofradía.
- Establishment of quality management and innovative guides and processes.

Regarding the individualistic behaviour of fishers vs. co-management, all participants agreed that the ineffective implementation of policies was related to the anarchy and individualistic behaviour of actors, predominantly fishers. To avoid this, more participatory processes were requested with the objective of improving the collective vision of the fishery as an island issue in which each group is responsible.

Fishers do not have a feeling of belonging to an island fishing community, instead each Cofradía works independently on their respective fishing area and market with a lack of communication among them. Moreover, recreational and illegal groups stress the fish stocks have low levels of control. This circumstance reminds us of the classic *tragedy of the commons* (Hardin, 2009), since it is a complex situation in which several groups (professionals, illegal and recreational fishers) are extracting marine resources from delimited, but not protected, fishing areas. Additionally, external factors such as marine pollution from ships, mass tourism, big infrastructures, etc. are damaging marine and coastal ecosystem, in an island fishery with deficiencies in control, scientific, and monitoring data.

Specifically, according to participants, it is necessary to promote a collective vision among the fishing sector facilitating meetings and highlighting benefits of collaborative actions on the island. Fisher empowerment combined with shared responsibility can lead to effective management practices and this can help to establish a

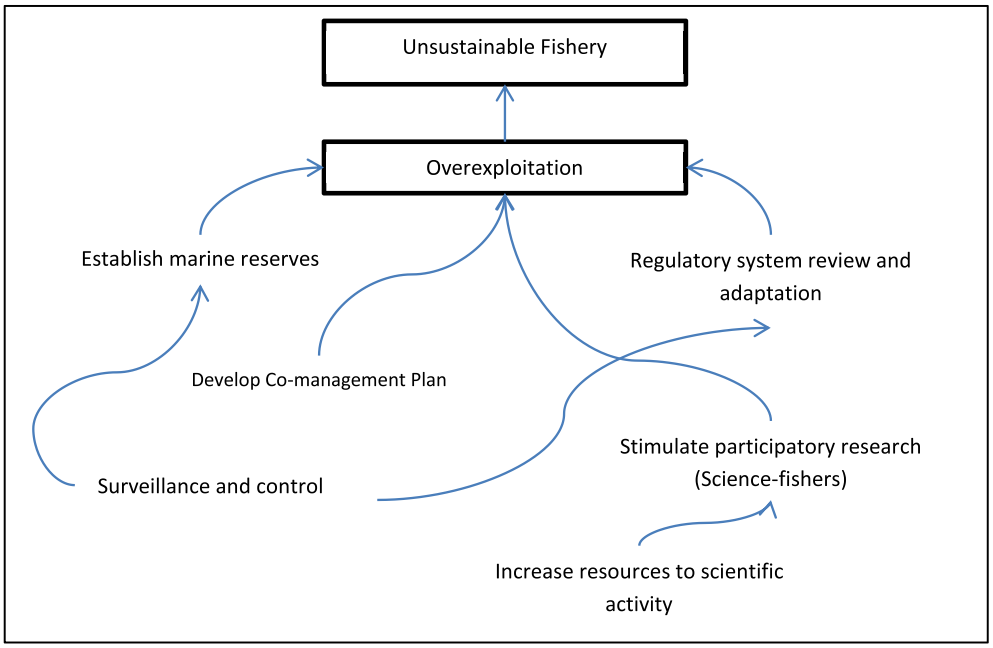

Fig. 8. Solution tree focused on Overexploitation problem by public administrations and associations.

Table 8
Perceived problems and their respective solution proposals.

Perceived problem	Proposals by Cofradías	Proposals by administration and associations
Fewer fish in the sea /Overexploitation	- Illegal fishing control. - Limit recreational fishing to holidays. - Establish marine protected areas. - Establish temporary closures. - Diversification by species. - Restraints per kilograms on catches and limit number of nets (depending on species). - Limit recreational and professional licenses.	- Establish Marine Protected Areas. - Fisheries management measures (management plan) - Establish temporary closures. - Increase studies and resources for scientists. - Regulations review.
Commercialisation problems	- Facilitate direct sales. - Staff from Administrations to establish control on traceability and labelling for artisanal products.	- Adaptation of the European legislation to the Canary Islands with respect to the point of first sale. - Develop a collective brand. - Studies about the stock of underexploited species.
Regulatory system	- Regulation review with a consultation period for professional fishers, with emphasis on the revision of the sizes of the species: adaptation to standard size and weight of the Canarian species. - Diffusion of policy directives among fishers.	- Co-Management strategies and actions. - Increase legal support to update the regulations (80 years with no actualization). - Adapt regulations to review studies.
Poor management of Cofradías	- Administration support from a technical and legal perspective. - Involve local restaurants in commercial chain.	- Rationalize the resources of the Cofradias (Unify). - Develop innovative projects to diversify the economy (fish-tourism, etc.). - Facilitate the generation of Cofradias own resources.
Low control and oversight	- Surveillance: more shifts and equal control of professional and recreational fishers. - Increase oversight activities.	- Establish marine protected areas. - Review Underwater Marine Areas regulation. - Increase surveillance.
Fishing temporality	- The months, in which it is not possible to get out to fish, a minimum compulsory insurance should be paid. Private insurance to cover those months (aided by the Administration). - Improve fishing fleet.	- Manage private insurance to pay members if they cannot fish. A part of the payment might be subsidized by the authorities. - Diversify fishing activity: Tourism?
Recreational and illegal fishing	- For recreational fishing: permit only holidays and weekends; prohibit and control aggressive practices. - For illegal fishing increase penalties. - Control of marinas. - Establish a register of recreational harvests.	- Develop monitoring and / or control systems. - Co-management strategies. - Limited seasons for recreational fishing.
Individualism	- Develop working groups, workshops and meetings in the island.	- Promote cooperatives
Generational relief /Loss traditional knowledge	- Facilitate family child / youth employment.	- ———
Coastal and marine deterioration	- Increase information and control on coastal areas. - Improve pollutant infrastructures as outfalls, treatment plants, etc. - Educational actions to population about plastics and wastes.	- Educational campaigns. - Volunteer campaigns. - Investment by Public Administration to treat sewage and minimize waste. - Changing production model of the island (Increase harbours and Marinas)

unique organisation that channels their needs, composed of all the artisanal Cofradías of the island. This organisation would develop marketing actions for artisanal products of the island, educational training for fishers about business management, sharing costs, or act as a pressure organisation to be involved into advanced political decision-making processes.

Summarising, to tackle individualistic behaviour is necessary to act as a network:

- Creating a joint organisation of artisanal fishing producers.
- Making informative social meetings, organised by the Coastal Action Group, in which several topics would be discussed, for instance, the status of the ecosystem and the stock, information about european financial aids for Cofradías, commercialisation options and marketing for artisanal products and elaborate policy proposals from local groups.
- Strengthen the vision of fishers as members of the island's fishery.

These actions would reduce the isolation of many fishermen by encouraging their inclusion in a group with expectations of improvement.

With regard to illegal fishing increases vs. artisanal fishing decline issue, debate was centred on several issues.

One of the major problems expressed by actors during the process is the existence of a market for illegal fishing that leads to overfishing and *illegal, unreported and unregulated* fishing (IUU) (Bray, 2001). To tackle this situation actors propose the creation and coordination of coastal oversight groups in collaboration with the official coastal and marine guard as one of the actions. Moreover, there should be special attention paid to educational and social information processes aimed at:

- Creating a consumer ecological consciousness
- Developing a common brand that represents artisanal fishing products from the island.

There are relevant proposals and policy options on which every group agrees, mainly, those related to the control of recreational and illegal fishing on the island. Control of illegal and recreational fishing is required to be done not only by increasing surveillance actions, but also by limiting licences, establishing restricted seasons to fish, constraining recreational fishing to holidays, and increasing penalties.

Specific key actions in order to fight illegal fishing include:

- Education, training, information, campaigns, etc. focused on recreational community and consumers developed by Cabildo and associations.
- Cofradías propose the creation of oversight groups in order to identify and control illegal fishing. These groups would be composed and organised by fishers in close contact with marine guard.
- Create and develop a brand for artisanal fishing that identifies restaurants which buy fish directly to Cofradías. This is a marketing action aimed to increase conscience and consume of artisanal products in the island. Cabildo and Cofradías would be the promoters of this action.

The public administration, mainly the insular government, as underlined during the different focus groups, is the institution responsible to develop and implement these actions in close collaboration with associations and fishers.

Participants highlighted the importance of traditional practices and revealed concern about the loss of traditional knowledge on the island. To avoid this, traditional groups proposed an increase in the assistance from the public administration to facilitate the access of youth to employment and support local fishers to generate their own resources. This might be achieved through improvement of fishing fleet, maintaining its artisanal character, and facilitating fishers' access to technology.

The methodological approach applied in this paper allows the identification of common issues affecting the local community and the measures needed to solve them, enriching the collective vision of local actors. For instance, participants identified the importance of creating marine protected areas as a way to protect marine and coastal ecosystem and strengthen the socio-economic conditions of artisanal fishing sector. It is known that marine reserves play a key role in supporting fisheries and biodiversity conservation (Roberts et al., 2001; Jentoft et al., 2007). In fact, marine protected areas in other Canary Islands confirm these benefits (Tuya et al., 2006). Nevertheless, in the case of Tenerife, there have been historical social constraints which have impeded the implementation of this conservation strategy, mainly due to social conflicts (Rodrigues Henriques, 2013).

The participatory process has shown the capacity and willingness of the local fishing community to interact and create links with scientists to search for collaborative solutions to move toward a sustainable management of the fishery. For instance, except for tuna species, in the Canary Islands there is a lack of periodicity on assessment about the status of the stocks. After this study, there is now an opportunity to develop scientific data collection processes with the implication of local fishers.

4. Conclusions

The integrated approach applied allowed the participants to identify and deal with the causes (problems) and effects (solutions) of unsustainability issues, and elaborate proposals to solve the problematic from their own point of view. The inclusionary exercises have facilitated the interaction between the local fishing community and public authorities as a teamwork in order to carry out a constructive debate and reach compromise solutions, thus reducing the risk of the uncertainty related to policy implementation. The members of the Cofradías feel isolated from the current decision-making dynamic on the island, and this process has facilitated a responsible involvement of this group into planning and management practices.

Results show the obstacles and factors that impede the preservation of artisanal fishing in Tenerife as well as a set of communally agreed proposals in order to potentiate artisanal practices and preserve marine ecosystem. These alternative proposals emerged from the local community, thus, they are based on the agreement of several local groups according to their own point of view and interests.

An intensive review of the current regulations is crucial to adapt them to local daily reality and reduce the gap between policy makers and artisanal fishers, since this gap reveals deficiencies in policy making processes and outcomes.

A simplification and unification of patterns of commercialisation is required on the island. A unique cooperative of artisanal producers should be created, which establishes actions such as contacts with consumers, reduces costs of transport, searches for funding, or marketing actions to promote the consumption of artisanal products on the island.

During the participatory process, the creation of two marine reserves on the island has been an important demand by each group involved. This reveals that there are not currently social conflicts in developing marine protection policies. Thus, there is an opportunity to finally create these areas in Tenerife.

The lack of data on fish stocks and marine pollution notably hinder any technical and scientific monitoring of the evolution of the marine environment and the overexploitation rates on the island. For this reason, the integration of the local community into planning processes is essential since it constitutes a source of relevant information and knowledge. Additionally, an increase in financial support for scientists and research projects might improve monitoring processes and widen knowledge of island's ecosystem.

Engaging local actors, as fishers, in island fishery planning and management processes might reinforce their communitarian vision and facilitate collaborative actions in advance, such as the exchange of information about organisational management of Cofradias; scientists-fishers collaboration; or environmental educational actions. An organised and collaborative fishing activity on the island might also contribute to improving the marine ecosystem, since it allows scientific monitoring of both biodiversity dynamics and the state of marine resources. These actions have been poorly carried out in the Canary Islands, which stresses the importance of studies like this one.

Participatory processes aimed at integrating local communities into planning strategies generate several benefits: more socially robust decisions and policies; a qualitative improvement of fishery strategies and concrete actions based on the direct experience of the fishing community. Each of these factors, combined with technical and adequate scientific monitoring of fisheries, can contribute to the long-term sustainability of island fisheries.

Although several factors were identified and discussed collaboratively, other factors affect marine ecosystem, such as harbours infrastructures, uncontrolled invasive species, pollution from ships and dumping wastes at sea, etc. The interaction among these factors needs to be studied in advance from a complex vision and integrating participatory processes with more emphasis.

In short, the main recommendations that have arisen from this analysis to advance and improve fisheries management involve reducing the gap between policy makers and local community and widening the interaction between stakeholders to allow a more certain application of policies in the medium and long term. Finally, it should be noted that policymakers managing incomplete information is one of the primary reasons for ineffective policies.

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Climate-related displacements of coastal communities in the Arctic: Engaging traditional knowledge in adaptation strategies and policies

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ABSTRACT

Climate change impacts lead to alterations in migration patterns and the displacement of exposed native communities and peoples in the Arctic region, forcing them to leave their homes and traditional ways of life as a result of rapid local ecological changes. This paper illustrates climate-related displacements and subsequent relocation as extremely complex processes, and proposes traditional knowledge as a relevant source of knowledge both at local level and policy making spheres.

The main conclusions are that the representation of indigenous peoples in international governance structures does not guarantee that traditional knowledge is entirely engaged in evidence-based policy making and that traditional knowledge is not always valued as an equal source of knowledge by some relevant scientific bodies. In this context, changing the approach towards a knowledge-systems-based framework would contribute to the development of more concrete policies and strategies for adaptation of Arctic native communities.

1. Introduction

While global consciousness of the effects of climate change is increasing within the general public, the impacts on small communities at the local level remain less well known. Among these impacts, the displacement phenomenon is one of the consequences of rapid ecological changes. This paper analyses studies of the vulnerability of traditional coastal communities under risk of displacement in the Arctic region. It aims at identifying opportunities and pathways to engage local native communities in policy-making processes, and assessing the potential of traditional knowledge to mitigate those impacts.

The Arctic region is not homogeneous; there is a large variety of cultural, historical, and economic backgrounds among the groups and local communities (Koivurova et al., 2008), and although natural and human environments in the region have their own specificity, they share a common circumstance: a potential vulnerability condition, but also a significant resilience capacity. The effects of climate change threaten biodiversity, local economies, and social and cultural systems of the region, posing serious challenges to their sustainability.

Throughout human history, migration and displacement have been recurrent phenomena and have periodically occurred around the globe due to several factors (Kelman and Næss, 2013), such as colonisation (Armstrong, 1978), conflicts (Park, 1928; Wood, 1994; Ibáñez and Vélez, 2008; Czaika and Kis-Katos, 2009), sovereignty claims (Dauvergne, 2004), and development projects (Stanley, 2004; Vandergeest et al., 2010; Penz et al., 2011), among others. Migration refers to the geographical movement of people in order to improve quality of life (Benson and O'reilly, 2009; Castles et al., 2013), while displacement has been defined in varying ways. Displacement is forced, involuntary, and highly adverse to affected peoples (Cernea, 2003), including physical, economic, and social exclusion (Cernea, 2005). Other authors consider displacement a phenomenon conceptually and morally distinct from the loss of economic or resource use rights (Agrawal and Redford, 2007); But as Mascia and Claus (2009) point out, in order to understand the full empirical and ethical dimensions of the displacement phenomenon, it is critical to consider the disempowerment of peoples and groups who lose rights and the empowered ones who gain rights. In practical terms, when severe impacts to individuals and communitites' lives are inevitable and irreversible, affected communities are forced to abandon their homes and ways of life.

According to Terminski (2012, p. 39) it is fair to distinguish the general category of *environmental migrants* from the more specific and subordinate category of environmentally displaced people. Environmental migrants are "persons making a short-lived, cyclical, or longer-

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term change of residence, of a voluntary or forced character, due to specific environmental factors". Environmentally induced displacement is applied to "persons compelled to spontaneous, short-lived, cyclical, or longer-term changes of residence due to rapid or gradually-worsening changes in environmental dynamics critical to their subsistence, which may be of either a short-term or irreversible character".

These definitions provide a general framing of the causes of climate-related migration and displacements. They seem to suggest that whilst environmental changes may lead to important impacts on local communities, forcing them to abandon their homes, displacement phenomena are also influenced by governance and social issues related to policy and decision-making processes. In the reminding of this paper, we will first examine climate related displacements in Arctic as depicted in literature, the engagement of communities potential to address those displacements, and the level of integration of traditional knowledge into scientific and policy processes; finally, based on this literature review, we offer a set of recommendations and proposals which encourage the value of this body of knowledge.

2. Climate-related displacements in the Arctic

Environmental hazards and chronic environmental degradation due to climate change are potential sources of displacement and migration (Swain, 1996; Raleigh et al., 2008), particularly in territories of high social and ecological vulnerability, such as island territories (Kelman, 2018) and remote regions, including the Arctic.

2.1. Impacts on small coastal communities

The impacts of climate change on Arctic coastal zones could have potentially both positive or negative effects (see Table 1). For instance, the reduction of sea ice thickness might facilitate access to marine resources, as well as, increase coastal erosion affecting stability of infrastructures and cultural heritage sites (Couture et al., 2002). In fact, the alteration of terrestrial and marine ecosystems may imply changes in marine resource availability, and since scientific assessment methods for data collection in fisheries science are not fully certain, there is a high level of uncertainty in, among other areas, further stock assessment actions.

Effects of climate change include socio-environmental impacts such as the increase of risks on food security due to uncertain changes in species distribution and availability; impacts on infrastructure, including schools, hospitals, various types of buildings and structures; and facilities, such as roads, railways, airports, pipelines, harbours, power stations, and power, water, and sewage lines (ACIA, 2005). Residents of many Arctic communities commonly drink untreated water directly from a variety of natural sources, including lakes, streams, and rivers in summer, and from lake ice, icebergs, snow, and multi-year sea ice in winter (Nickels et al., 2005; Martin et al., 2007; Daley et al., 2015).

These environmental changes have impacts on the social system. In other regions, displacement and loss of access to common natural resources are closely associated with social disarticulation, landlessness, loss of identity, increased morbidity and mortality, and marginalisation (Cernea and Schmidt-Soltau, 2003).

For instance, the loss of permafrost due to climate warming has already caused impacts in ecosystems and communities through collapse of roads and buildings as the ground becomes unstable (Schaefer et al., 2012). Millions of people live in the permafrost area, including in three large cities built on continuous permafrost (see Fig. 1). These cities would most likely transition to the discontinuous permafrost zone with 2 °C of warming (Chadburn et al., 2017), putting their infrastructure at risk of collapse in the coming decades as the ground becomes weaker.

When these impacts are highly intense and irreversible, relocation becomes a critical consequence and a vital decision for affected local communities. Relocation has been defined by Bronen (2010) as a process whereby livelihoods, housing, and public infrastructure are reconstructed in another location and may be the best adaptation response for communities whose current locations become uninhabitable or vulnerable to future climate-induced threats. Therefore, changes in the ecological system seriously affect the sustainability of these communities inducing displacements (Ferris, 2013), and if these impacts are not correctly mitigated, complex processes of relocating entire communities might become a reality in many Arctic coastal areas.

2.2. Relocation events: an overview of the case of Alaska native villages

According to Petz (2015), planned relocation occurred in the context of three types of situations:

I In anticipation of disasters, environmental change, and/or the effects of climate change;
II As a response to disasters, environmental change, and/or the effects of climate change; and
III As a consequence of measures related to climate change adaptation or disaster risk reduction measures.

Including islands, Alaska has 33,904 miles of shoreline; from these, approximately 6600 miles – 19.5% of the total coastline area – and many low-lying areas along the state's rivers are subject to severe flooding and erosion. Most of Alaska's native villages are located on the coast or on riverbanks. In 2003, the US Government Accountability Office (GAO) reported that flooding and erosion affects 184 out of 213, or 86.4 percent, of Alaska native villages to some extent (GAO, 2003).

Rising temperatures in recent years have led to widespread thawing of permafrost, causing village shorelines and riverbanks to slump and erode, threatening homes and infrastructure. Rising temperatures also affect the thickness, extent, and duration of sea ice that forms along the western and northern coasts. The loss of sea ice leaves shorelines more vulnerable to waves and storm surges and, coupled with the thawing permafrost along the coasts, accelerates the erosion threatening the villages. In addition, the loss of sea ice changes the habitat and accessibility of many of the marine mammals that Alaska natives depend upon for subsistence (Mittal, 2009).

The US Government Accountability Office reported that 31 communities were severely threatened by flooding and erosion, and 12 of them were identified as "at imminent risk" (GAO, 2003) and decided to relocate – in part or entirely – or to explore relocation options (Fig. 2). The villages of Kivalina, Newtok, Shaktoolik, and Shishmaref face the most imminent threat (GAO, 2003; Bronen, 2008). In these cases, survival in and of the settlements is unlikely, and residents have begun to actively seeking the opportunity to relocate (GAO, 2009).

According to Mittal (2009), limited progress has been made on relocating the 12 villages severely threatened by flooding and erosion since only one, Newtok, has made significant progress. For several of these communities, there is limited comprehensive information about climate-related threats to community habitability and the options to prevent community displacement (Ferris, 2013).

Relocation is a complex issue since it implies several impacts, different actors, and high levels of uncertainty. Forced relocation and inadequate governance mechanisms and budgets to address climate change and support adaptation strategies may cause loss of community and culture, health impacts, and economic decline (Maldonado et al., 2013). While these communities are weighing relocation options, the environmental impacts continue putting in risk their livelihoods.

Following the report made by the US Government Accountability Office (GAO, 2009), relocation efforts have not achieved the expected results due to several complications. For instance, the economic cost estimates for relocating Kivalina range from $100 million to over $400 million (GAO, 2003), and governance deficiencies are highlighted by the difficulty in reaching consensus to relocate when exploring options

Table 1
A summary of main sources of environmental changes and impacts that could lead to displacements of Arctic coastal communities.

Environmental changes	Governance areas	Potentially negative impacts	Potentially positive impacts
Invasive Species (Hellmann et al., 2008; Rahel and Olden, 2008).	Food security	Decrease of marine resources in some areas.	Increase of marine resources (productivity) available to humans; more productive fisheries in some regions.
Changes in the distribution and migration patterns of fish stocks (Tynan and DeMaster, 1997; Hollowed et al., 2013).		Providing food from other sources may be costlier.	
Increase of invasive species: new species moving into the Arctic and competing with native species (Hassol, 2004, Callaghan et al., 2004).			
Permafrost (Brown et al., 1997; Lawrence et al., 2008; Rowland et al., 2010).			
Ocean acidification (Riedel, 2014).			
Wave action and storm surges due to reduced sea-ice extent and sea-level rise. Ongoing or accelerated coastal-erosion trends are likely to lead to further relocations of coastal communities in the Arctic (Hassol, 2004; ACIA, 2005; Burkett, 2012).			
Changes in river ice conditions, run-off, flow regimes, and water levels can impede access to important fishing areas and increase travel hazards (Fox, 2002; Huntington et al., 2005; Prno et al., 2011).			
Despite increased annual precipitation, a net summer drying effect is occurring due to decreased seasonal precipitation, increased temperatures, thawing permafrost and increased evapotranspiration (Evengard et al., 2011).	Water security	Water quantity: reductions in water levels affect drinking water availability.	X
Shifting seasonal transitions, altering precipitation regimes, reducing snow and ice cover, and increasing exposure to solar radiation (Medeiros et al., 2016).		Water quality: contamination.	
Changes in precipitation chemistry such as decreasing pH can rapidly affect surface water chemistry (Peters and Meybeck, 2000).		Access to water: pressures on freshwater supply.	
Changes in air temperature (Chapman and Walsh, 1993; Thompson and Wallace, 1998; Przybylak, 2000; Polyakov et al., 2003).	Energy security	Inadequate or inefficient energy use at local levels.	Reduction in the demand for heating energy.
Land changes due to erosion, earthquakes, etc. (Parry, 2007; Mars and Houseknecht, 2007).	Land Rights	Loss of sovereignty. Land tenure and access rights. Loss of autonomy, political oppression, and bureaucratic control (Kirmayer et al., 2011)	X
Ice melting (Berkes and Jolly, 2002; Henshaw, 2009; Laidler et al., 2009; Ferris, 2013).	Mobility	Loss of traditional navigation routes.	Opening of new routes (transport, tourism, etc.)
Landuse changes derived from reductions in the extent of sea ice and permafrost, increased coastal erosion (Parry, 2007) or coastal land loss and thermokarst lake expansion and drainage (Mars and Houseknecht, 2007).	Social and Cultural	Social disarticulation, landlessness, loss of identity, increased morbidity and mortality, and marginalisation.	Cultural adaptation to make use of newly-introduced species may occur in some areas.
Sea-ice extent is very likely to be reduced and the animals they now hunt are likely to decline in numbers, making them less accessible, or they may even disappear from some regions (ACIA, 2005).		Population stress.	
		Loss of traditional knowledge. Disrupt or even destroy traditional hunting culture. Loss of cultural practices. Language loss. Cultural heritage loss. Access to traditional food species reduced.	
Changes in ambient temperatures (Parkinson and Butler, 2005).	Health	Increases in zoonotic diseases and injury rates.	The incidence of hypothermia and associated morbidity and mortality may decrease (Parkinson and Berner, 2009).
Temperature and humidity influence the distribution and density of many arthropod vectors (Parkinson and Butler, 2005).		The consequences of shifting to a more Western diet are likely to include increased incidence of diabetes, obesity, and cardiovascular diseases. Incidence of vector borne diseases.	
Risk of floods, mudflows, slides, and avalanches (ACIA, 2005).	Infra-structure security	Change in the maintenance conditions of many structures, especially for those designed without consideration of potential climate change.	X
Coastal erosion (Radosavljevic et al., 2016).		Materials deterioration.	
Ultraviolet (UV) radiation adversely affects many materials used in construction and other outdoor applications (Corell, 2013).		Problems associated with water-retaining dams include seepage, frost heave (in areas of seasonal frost), settlement, slope stability, slope protection, and construction methods.	
Permafrost degradation (Nelson et al., 2002; Chadburn et al., 2017).			

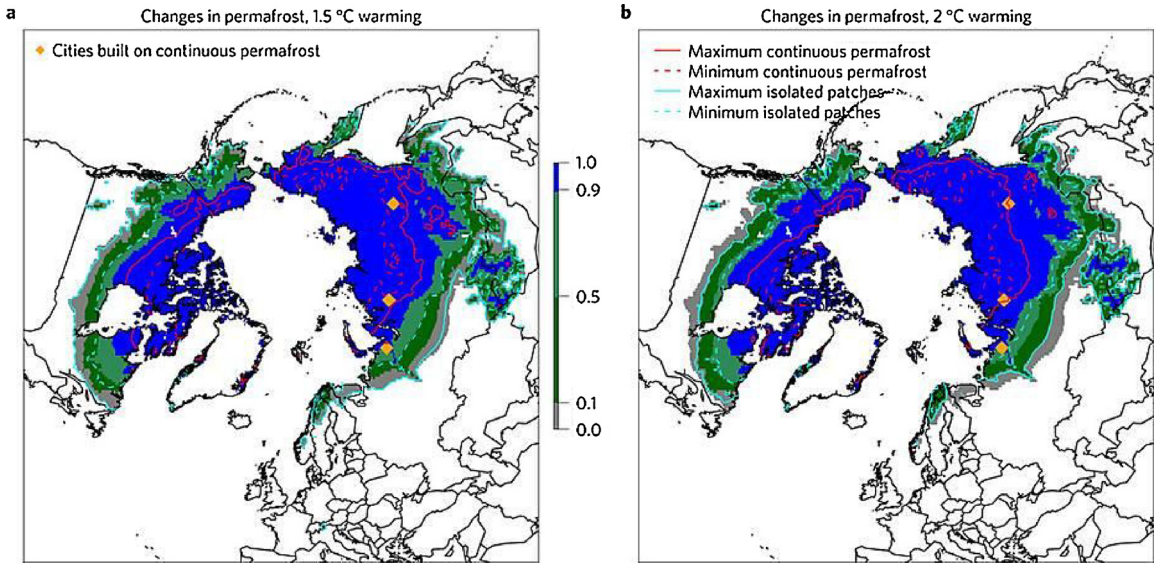

Fig. 1. Changes in spatial patterns of permafrost under future stabilisation scenarios. source: (Chadburn et al., 2017).

for Alaska native villages. None of the decisions to relocate has been unanimous in the selection and identification of alternative locations, with communities diverging on preferred solutions, or preferring to remain in place.

The lack of a lead entity has become an impediment to villages' relocation efforts (Mittal, 2009; Shearer, 2012), suggesting that governance structures and engagement actions have failed. The case of Kivalina is a clear example (Martin, 2012). The Kivalina Relocation Master Plan was released in 2006 by the U.S. Army Corps of Engineers (USACE, 2006), determining that the preferred location site for the community: Kiniktuuraq, was unsuitable and vulnerable to flooding and erosion. The ACE proposed an alternative site, which was rejected by citizens on the basis of the high economic costs and the difficulties to continue with their subsistence activities, and traditional and cultural practices. Kivalina had asked that a third party steped in to reassess the alternatives in the Relocation Master Plan; the Climate Change Sub-Cabinet's Immediate Action Workgroup proposed that a state agency be the lead in this process (GAO, 2009; Gregg, 2010). As Mittal

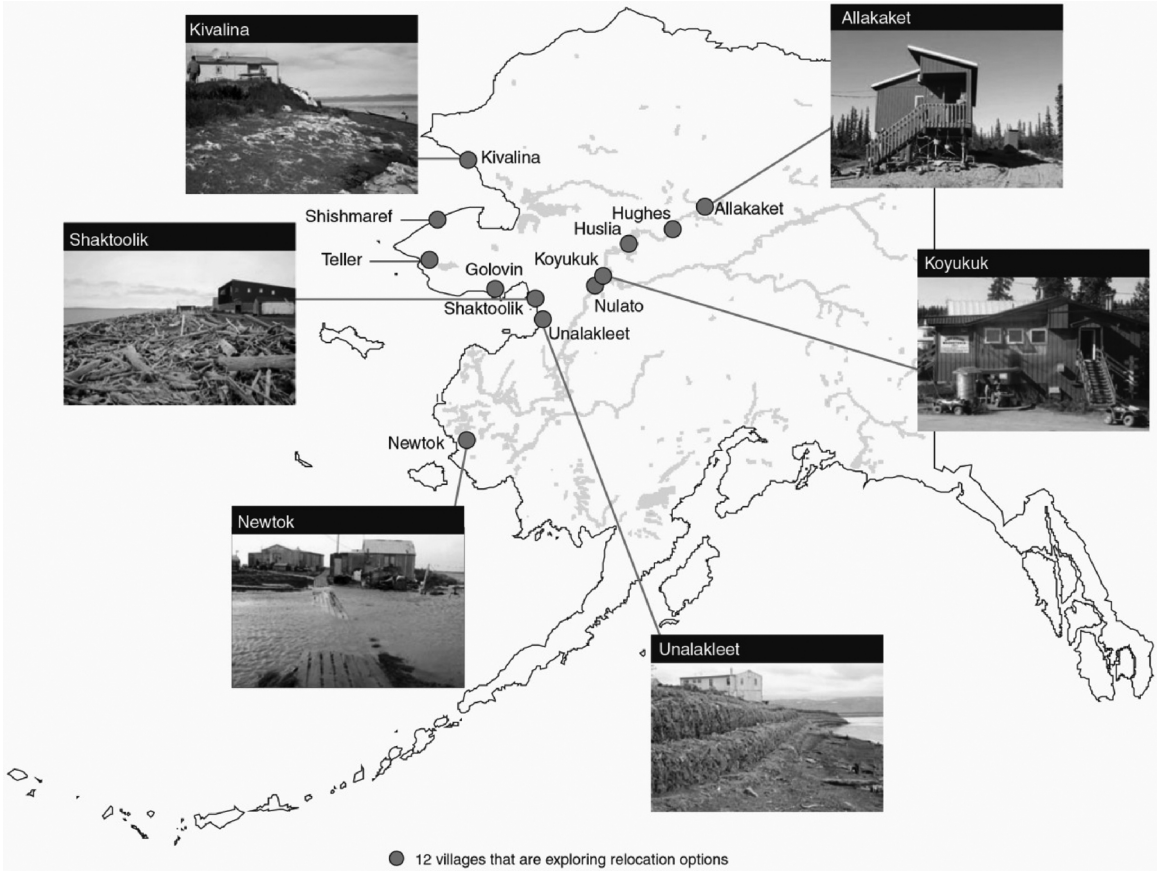

Fig. 2. Location of 12 Alaska Native Villages affected by flooding and erosion. Source: GAO, 2003.

Table 2
Overview of international actors and initiatives working with indigenous peoples and traditional knowledge.

International Institution / organisation	Some references to Traditional Knowledge
United Nations Framework Convention on Climate Change (UNFCCC) - Report of the Indigenous Peoples' Global Summit on Climate Change	To enable Indigenous peoples from all regions of the globe to exchange their knowledge and experience in adapting to the impacts of climate change, and to develop key messages and recommendations: http://www.un.org/ga/president/63/letters/globalsummitoncc.pdf
Arctic Council	Six organisations representing Arctic indigenous peoples have status as Permanent Participants: The Aleut International Association, the Arctic Athabaskan Council, the Gwich'In Council International, the Inuit Circumpolar Council, RAIPON (the Russian Association of Indigenous Peoples of the North), and the Saami Council: http://www.arctic-council.org/index.php/en/ Protection of the Arctic Marine Environment (PAME) Working Group: https://pame.is/index.php/projects/resource-exploration-and-development/mema Arctic Council archive on Indigenous engagement: https://oaarchive.arctic-council.org/browse?value=Indigenous+People&type=subject
The Arctic Circle	Science and Traditional Knowledge forums http://www.arcticcircle.org/assemblies/2016/program-news/news/indigenous-arctic-global-dialogue
UNESCO	Multimedia modules with interdisciplinary complex of indigenous knowledge related to mitigation and adaptation to environmental changes: https://iite.unesco.org/courses/climate_change/en/index.html
Inter-institutional cooperation	Arctic Monitoring and Assessment Programme (AMAP) in collaboration with the Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) working group, and the International Arctic Science Committee (IASC). ACIA - Arctic Climate Impact Assessment: http://www.amap.no/arctic-climate-impact-assessment-acia Many Strong Voices Program develops research, assessment, networking facilitation, support to regions and communities, communication and outreach, and action on climate change mitigation: http://www.manystrongvoices.org/about.aspx?id=5159
IPCC – Working Group II (Impacts, Adaptation, and Vulnerability)	Assessment Reports, Special reports, methodology reports, technical papers and supporting material of the state of knowledge on Climate Change. https://www.ipcc.ch/report/ar5/wg2/
European Commission	EUNETMAR, a study on Arctic lay and traditional knowledge: (https://webgate.ec.europa.eu/maritimeforum/en/node/3569 The Northern Periphery and Arctic 2014–2020 Programme establish actions to protect, promote and develop cultural and natural heritage: http://www.interreg-npa.eu/ The Strategic Assessment of Development of the Arctic: Assessment Conducted for the European Union, recommends to give a voice to Arctic communities in policy developments that may affect them (chapter 9): http://www.arcticinfo.eu/en/

(2009,p.42) states, the expectations were not optimistic:

> "even in the cases where the imminent flooding or erosion threat is clear, the efforts of federal and state programs to provide assistance, thus far, have resulted in little progress toward relocation. Collaborating together, the federal government and the state government have an opportunity to address these threats in a thoughtful, reasonable, and environmentally sound manner. As time passes without significant progress being made on these village relocations, the potential for disaster increases, as does the ultimate cost of moving the villages out of harm's way."

The case of Alaska native villages shows the enormous complexity of climate-related displacements leading to further relocation processes and decision-making. In the absence of effective participatory channels previously established, the decisions become controversial. Meanwhile, increasing coastal storms and erosion, thawing permafrost, and other climate-related impacts, continue to threaten the future of these communities. Regarding the situations in which relocations occur (Petz, 2015), engagement and integration of traditional knowledge could be extremely useful in anticipation of environmental change and the effects of climate change.

3. Engagement potentials and integration of traditional knowledge into policy-making

Climate impacts and displacements have several implications for local native communities and their livelihoods; thus, there is a progressive and increasing recognition of the importance of traditional knowledge in international policy (Berkes et al. 2006; Abele, 2007; Turnhout et al. 2012). At the international level, the "Agenda of the Twenty First Century," adopted in 1992 by the participants of the World Summit in Rio de Janeiro, recognised the importance of traditional knowledge of indigenous populations (Assembly, 1992). More recently, the need to engage native communities in decision-making processes and the recognition of traditional knowledge was established in the Anchorage Declaration (2009) within the United Nations Framework Convention for Climate Change.

Traditional knowledge is an invaluable way of knowing and essential to the economic and cultural persistence of native peoples (Arrow, 1996; Purcell, 1998; Vinyeta and Lynn, 2013). It has been conceptualised as a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (Berkes, 1993, Gadgil et al., 1993, Berkes et al., 1995).

Many fields of study and authors recognise traditional knowledge vital to the adaptation and resilience capacity of local peoples when facing new environmental conditions (Inglis, 1993; Berkes, 2004; Folke, 2004; Berkes and Turner, 2006; Ruiz-Mallén and Corbera, 2013; Pulsifer et al. 2014; Muir, 2015); its integration into policy-making has generated an intense public debate for several decades (Abele, 1997). Thornton and Scheer (2012) address the usefulness of local traditional knowledge to improve understanding of marine systems and foster adaptive management as they change. Regarding the Alaskan case study shown above, Alaskan natives have experienced accumulative effects of climate change. Erosion and flooding put communities at risk in their traditional homelands: changing ecosystems affect food security, the health of traditional plant and animal species used for food and traditional ways of life; changing snow, ocean, river, and lake ice conditions make travel more difficult and dangerous; and drier, hotter summers contribute to health problems due to smoke from increased occurrence and size of wildfires (Markon et al., 2012).

Arctic peoples have moved through the land, navigated the sea, and crossed the ice, using knowledge of routes passed down through generations, allowing them hunting and fishing in the relevant seasons (see http://paninuittrails.org/index.html). For instance, peoples living in

northern Greenland's Thule district, the northernmost inhabited area in the world, have traditionally moved through the territory for fishing and hunting. Mobility has been central to identity, but now fog and changing weather are affecting sledding patterns (Hastrup and Skrydstrup, 2013).

International law has recognised the essential nature of aboriginal consultation and participation and policy strategies supporting traditional knowledge. Specifically, indigenous representatives have suggested several proposals focused on the recognition of the relevance of traditional knowledge in developing strategies to address climate change and safeguarding the effective participation in formulating, implementing, and monitoring activities, mitigation, and adaptation relating to impacts of climate change, among others (Anchorage Declaration, 2009). The engagement of native peoples in governance processes is essential to ensure that they are not marginalised at the local level. The importance of recognising traditional knowledge as a relevant source of knowledge for adaptation has been increasingly reflected in programs and projects by the main international governance bodies working on Arctic and climate change policies (Table 2).

The UNESCO Conference on "Climate Change and Arctic Sustainable Development: Scientific, Social, Cultural, and Educational Challenges" (2009) recommended promoting traditional knowledge of indigenous peoples of the Arctic since these communities are capable of developing adaptation strategies responsive to environmental changes. In addition, the Arctic Council has promoted the use and integration of traditional and local knowledge into their projects and activities, published numerous recommendations for the integration of traditional and local knowledge, recognising the complementarity of science and traditional knowledge to generate new knowledge and inform decision making and policy development.

Although Arctic peoples representation has been recognised by the relevant policy institutions and organisations, the use of traditional knowledge as a valuable source of knowledge has not been universally accepted by relevant scientific bodies. The Intergovernmental Panel on Climate Change (IPCC) is generally recognised by the scientific community and policy-makers as one of the most authoritative policy-relevant bodies on climate change science. This institution has made important progresses on identifying and establishing a wide collection of mitigation and adaptation options to contrast climate change impacts. However, it has been noted that in general the level of adaptation has been inadequate for a reduction in vulnerability to future climate change (Mimura et al., 2015). According to several authors and researchers, the IPCC maintains a partial approach to native traditional peoples and knowledge; for instance, according to Huntington (2011), although the IPCC includes a discussion related to traditional knowledge in its sections on Africa and Polar regions, the consideration of this topic for other parts of the world is poor. Additionally, the methods for gathering data and information are still based on western scientific knowledge. In a similar way, Ford et al. (2012) state that the Working Group II of the IPCC recognises the importance of traditional knowledge in adaptation and resilience, but it does not integrate this knowledge into assessments processes. A preliminary analysis, carried out by Pachauri et al., (2014), of traditional knowledge and related issues in the 5th Assessment Report of the IPCC reveal important gaps and illustrate that, despite the considerable progress since the previous report, much more remains to be done. Ford et al. (2006) concluded that the coverage of native issues is general in scope and limited in length, there is little critical engagement with indigenous knowledge systems, and the historical and contextual complexities of indigenous experiences are largely overlooked.

Table 3 shows some of the most common IPCC adaptation options assigned to each step of the adaptation planning process in marine and coastal areas. The table shows how the IPCC adaptation options might be complemented or supported by other alternatives derived from the use of traditional knowledge. In the case of the first step, *vulnerability and risk assessment*, different approaches are presented in order to show diverse valid possibilities to integrate traditional knowledge into this step; in the successive stages (*actions/measures; implementation; monitoring*) concrete examples are provided.

According to Thornton and Scheer (2012), whereas traditional knowledge is recognised as an alternative source of environmental information, when gaps in scientific knowledge or data exist, it is most likely undervalued. Furthermore, discrepancies between scientific data and local observations have been identified, for instance, on indicators related to sea ice extent and sea ice thickness (Baztan et al., 2017). Nevertheless, collaborative initiatives shown in Table 3, such as the LEO, SAON and CLEO Networks; the development of integrated approaches, such as the IPCCA or the implementation of toolkits,[1] as well as, many others, are making strong contributions in gathering and sharing information about climate and drivers of environmental change among the local communities. This is important because the lack of information and data might lead to conflicts about land use and resources exploitation due to disregard of relevant local variables in planning and development of activities. Gofman and Smith, (2011) state that identifying and mapping areas of cultural significance is crucial for preventing possible future conflicts between coastal communities and marine-based industries, which are expected to increase activities in the Arctic. There are many examples around the world where traditional knowledge is key to maintain livelihoods. For example, in Indonesia, the Sasi community has been managing fishing activity for decades using their own ecological knowledge resulting in a stable regulation system of the different species in different coastal villages (Utomo, 2010). According to Roux et al., (2018) local observations using traditional knowledge are very useful sources to provide and collect information at coastal areas, to assess cumulative effects of multiple stressors (Mantyka-Pringle et al., 2017), or to serve as 'proxy data' measuring temperatures in remote areas (Alexander et al., 2011). Thus, the combination of observation technologies with local and traditional knowledge is not a speculative suggestion since new "observation systems" that include indigenous and local knowledge have been already implemented, for instance, using GPS technologies that capture real time observations of local users (Gearheard et al., 2011; Galginaitis, 2013; Kumpula et al., 2012). Traditional knowledge is not only about the information collected but also about the methods and ways of relating to what needs to be known. The relationships of Arctic communities with their environment determine what needs to be known and eventually who shall act on that knowledge.

4. Lessons learned, challenges and recommendations

Traditional knowledge is co-produced with the interaction of the communities with the ecological conditions in order to develop effective situated adaptation strategies. In other words, traditional knowledge cannot exist independently of the place and the communities that build it. It refers to the purposeful understanding of the local ecological system and has evolved over decades and generations due to systematic observations of complex issues, such as the dynamics of sea tides and currents, the use of local materials, weather and climatology, and local biodiversity and its behaviour, among others. Since this kind of knowledge is linked to complex local ecological conditions, each native community owns its specific traditional knowledge. Contrasting to this point, the IPCC adaptation approach entails an integration of different technological tools, such as modelling systems and GIS techniques, for instance, remote-sensing and global positioning systems. Technological observation systems and models are tools with an important value to monitoring and assessing the environmental changes occurring in the Arctic region, but the information and data gathered through these

[1] A toolkit provides methodological options and practical examples to support communities on the implementation of Local Assessments. See http://ipcca.info/toolkit-en-ipcca-methodological-toolkit.

Table 3
Different adaptation outputs established by scientific knowledge and other initiatives based on traditional knowledge.

Adaptation steps	IPCC examples of adaptation indicators and options (IPCC fifth Assessment Report 2014. Adaptation needs and options, p. 844))	Examples of the use of Traditional Knowledge	Initiatives / Institution / organisation	Region
Vulnerability and risk assessment	Distribution of marine species (IPCC data come, for example, from distribution models).	Use of local observer networks	SAON Network: Sustaining Arctic Observing Networks	Arctic region
			ELOKA: The Exchange for Local Observations and Knowledge of the Arctic (www.eloka-arctic.org/).	Arctic region
	Hazards mapping	Bio-cultural Assessments Approach	The Indigenous Peoples Climate Change Assessment (IPCCA) (www.ipcca.info)	Global
		Community-based approach	Climate Vulnerability and Capacity Analysis (CVCA) - CARE Climate https://careclimatechange.org/	Global
Actions / measures	Land use management and planning	Identify sites for settlements on high ground (Mercer et al., 2007)	Participatory three-dimensional 3D (https://www.weadapt.org/)	Global
	Sea walls and coastal protection structures	Use of local materials (Hiwasaki et al., 2014)	Many Strong Voices (http://www.manystrongvoices.org)	
Implementation	Fisheries co-management, for example: controlling overfishing	Identify problems and solutions (Robards et al., 2018; De Lara and Corral, 2017); determining the spatial distribution of species or fish behaviour (Raymond-Yakoubian et al., 2017; Roux et al., 2018); mapping areas of cultural significance (Gofman and Smith, 2011); identify changes in fishing areas (Raymond-Yakoubian et al., 2017).	Climate Witness Community Toolkit (WWF GLOBAL) wwf.panda.org/?162722/Climate-Witness-Community-Toolkit	South Pacific
Monitoring	Coastal erosion and/ or coastal ecosystem health (images, satellites, buoys, etc.)	Observing and documenting coastal pollution and/or ice thickness (Davies, 2007).	LEO Network: Local Environmental Observer Network https://www.leonetwork.org Alaska Native Tribal Health Consortium (ANTHC) https://anthc.org/ CLEO Network: Circumpolar Local Environmental Observer (Arctic Council, the Arctic Contaminants Action Program (ACAP) and its Expert Group the Indigenous Peoples' Contaminants Action Program (IPCAP)) https://oaarchive.arctic-council.org/handle/11374/1715	Arctic region

technologies have significant uncertainties and shortages (National Research Council, 2006). Marine resources planning and management is an emblematic case; while there is a lack of scientific information and data about species distribution and their biotic interactions (Bellard et al., 2012; Zarnetske et al., 2012) traditional knowledge holders have proven their capacity to provide information on aspects such as fish stock structure, variability and abundance, fish distribution and migrations, the behaviour of larval/post larval fish, or changes in habitats (Johannes and Neis, 2007; Christiansen et al., 2014; Baldwin et al., 2018).

Adequate traditional knowledge engagement into science and policy-making could benefit adaptation and mitigation strategies and policies to support Arctic communities with settling and coping with climate change driven adversities. Below, we summarise possible actions to ensure that traditional knowledge is marshalled into those processes:

- Foster collaborative engagement of traditional knowledge and science

Increasing indigenous representation at the international level and in forums is a historical advancement with regards to community engagement in decision-making processes, but it does not seem sufficient to integrate traditional knowledge into effective science activities and policy outcomes. In general, there is an increasing recognition of traditional knowledge by policy-makers and scientists, but it is necessary to encourage its uses in order to steer useful policies related to potential Arctic climate-induced displacements. The opportunity for an effective integration of traditional knowledge into the whole policy design cycle, from policy-shaping to policy-making and implementation, is an asset.

Policies might increase their effectiveness and their social value with adequate engagement strategies and a complete recognition of native peoples as active knowledge-holders, before displacements of vulnerable communities and relocations occur. Thus, it is desirable that in order to avoid a situation of knowledge monopoly on the establishment of climate policy advice (Tol, 2011). To this end, policy-makers should visit and learn from Arctic peoples on the Arctic peoples' terms. Relying on top-down, large-scale processes such as the IPCC and UNFCCC without understanding their mandates and the resulting limitations, or accepting information from a single source, and not recognising diversity within published science amounts to bad practice (Kelman, 2010; Kelman, 2017). What policy-makers often receive as scientific advice is a selection of scientific results, which constitute the basis for climate policy decisions (Vasileiadou et al., 2011). In order to breakdown this limited cycle, the development of more participatory and inclusive policy-making strategies opens the path to be closer to the reality where traditional knowledge develops and is used; nevertheless, participatory processes require primarily an open and honest recognition by scientists and by policy-makers of the diversity of knowledge systems, as well as establishing safe and honest sharing spaces (Hernández-González and Corral, 2017).

The main challenge would be to develop a novel framework that integrates and supports both traditional knowledge and scientific knowledge systems opening new channels for knowledge-based policy making. This means, the establishment of effective and closer collaborations on the ground with native communities accepting several difficulties, such as costs or language barriers, which could undermine opportunities for shared learning (Armitage et al., 2011).

- Recognise the value of traditional knowledge and change the approach towards a framework of co-creation of knowledge.

A recognition by the scientific community of traditional knowledge as a valid source of reliable data and information could enable cooperation among the scientific and the Arctic communities, leading to knowledge co-creation. Thus, it is necessary to enable the conditions in which actors co-learn in interaction with uncertainty and environmental change, or "learn to be adaptive" (Armitage et al., 2011) through knowledge co-creation processes.

As Armitage et al., (2011) define, adaptive capacity as the ability of an individual or a community to cope with, prepare for, and/or adapt to disturbance and uncertain social-ecological conditions. Environmental problems are complex because the routes of their causal chain are intricate interactions between biological, physical, and social systems (Lemos and Morehouse, 2005; Corral et al., 2017). As seen in the case of Alaska native villages, relocation processes are very complex; hence, these kinds of decisions should not be driven only by conventional science reports. Through knowing (1) the meaningful economic, cultural, institutional, legal, and social costs; (2) the different actors involved; and (3) the inherent social and economical uncertainties of climate-related displacements, a change of approach is possible, i.e. one that is connected to concrete in the ground situations.

The presence of representatives of indigenous peoples at international forums facilitate the expression of the interests, matters of concern and of care of each indigenous group, but does not guarantee the integration of traditional knowledge into policy-making; following Ferris (2013), it is not enough for indigenous groups to produce declarations and reports that are primarily read by other indigenous groups and human rights advocates.

Regarding the institutional context, the majority of Arctic-oriented institutions and organisations recognise the importance of traditional knowledge in science-based policy-making. For instance, the Arctic Council emphasises the need to foster relationships among governments, indigenous peoples, organisations, and other parties through partnerships and effective communication, and the need for traditional knowledge to be incorporated from the outset of a project or activity and used together with scientific results and analysis (Secretariat, 2017). Nevertheless, further work needs to be done, and the pledge for a more consensus-based and inclusive approach by the IPCC is growing in importance among the research community (UNESCO, 2009; Beck, 2011; Beck, 2012). As Silke Beck et al., (2014) uphold, "in contrast to the IPCC, the IPBES (*Intergovernmental Platform on Biodiversity and Ecosystem Services)* accords greater value to regional and local scales, this refers not only to the scale of assessments but also to the inclusion of local and indigenous knowledge". Along the same line, Alexander et al. (2011) emphasised that indigenous knowledge narratives are marginally included in IPCC or other global assessments of climate change. Other authors, such as Smith and Sharp (2012) provide evidence on this narrative when assessing the levels of inclusion of traditional knowledge by institutions such as the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, the Intergovernmental Panel on Climate Change's Fourth Assessment Report (AR4), and the Arctic Climate Impact Assessment (ACIA) concluding that there is no reference to this kind of knowledge in either the UNFCCC or the Kyoto Protocol, while the inclusion in the AR4 is marginal, being the ACIA the most inclusive document. Other authors state that indigenous issues, including their knowledge, have been underrepresented in the way of work and approach to climate change by the IPCC (Ford et al., 2016; Alexander et al., 2011) since this organisation maintains a knowledge monopoly (Tol, 2011).

- Avoid imprecise policies and vague recommendations

Developing specific actions, strategies and recommendations is desirable. As seen in Section 3, many recommendations made from international organisations and institutions working on Arctic's climate change and traditional knowledge are too general to accomplish any kind of concrete result or effective integration of traditional knowledge into policy-making. Well-meaning intentions and vague proposals lead to illusion of progress.

Traditional knowledge is a viable source for co-creation of knowledge. Therefore, the channels and paths to integrate it into policy-

making processes should be explored and concretised, just as the channels for conventional scientific knowledge are established. To this end, local peoples should be considered as great allies to analyse and monitor ecological dynamics of the region, such as detecting changes and impacts, as well as, giving assistance to identifying research priorities and policy agendas. According to Markon et al., 2012, local observers apply traditional knowledge to identify whether an occurrence is unusual or significant; in this sense, local observers provide invaluable surveillance for change. International Arctic institutions already have the capacity to provide resources to achieve the following objectives: to integrate traditional knowledge into risk assessment processes and projects; to carry out participatory environmental impact assessments at local level taking into consideration the knowledge of native peoples about ecological conditions and how these are changing; to implement projects related to resources availability assessments; to assess fish stocks, as well as, selection and identification of fishing areas; data gathering; establishing the best criteria to designated environmental protected areas, etc.

- Avoid over-protectionism and paternalism

In order to overcome these challenges it is necessary to change mind-sets, deconstruct myths and develop a critical view since there are many dominant attitudes towards climate change, potentially linked migration, and climate change related knowledge (Beck, 2012; Kelman, 2014). Many of those are based on myths which propagate despite lack of evidence; e.g. 'that millions of climate refugees will descend on us in hordes'; 'that polar bears and/or ice represent the Arctic' (Kelman, 2018); or 'that the IPCC represents the best of scientific knowledge' (Kelman et al., 2016). We need to continually evaluate, and critically reflect about the dominant attitudes, in order to cut through the rhetoric to the real evidence, to the scientifically published viewpoints (even if divergent from the mainstream), and to what the peoples know and seek, not what prominent climate change scientists claim on their behalf (Kelman, 2017).

Developing a critical view requires the avoidance of an over-protectionist vision of traditional knowledge. In this sense, culture and knowledge, by definition, are dynamic and must adjust to any changes around them (Mercer et al., 2009; Krüger et al., 2015). Thus, the continuation of an excessively protectionist vision will maintain non adaptive practices, lessening the opportunity to develop more appropriate strategies to the changing realities and, reducing the role of learning through change.

5. Final remarks

Community engagement actions should be directed to develop adaptation strategies and avoid the exposed potentially negative impacts so as to benefit from the potentially positive impacts while the situation is still manageable. This paper illustrates how climate-related displacements and subsequent relocation are extremely complex processes derived from multi-related causes. In complexity, the integration of different sources of knowledge in order to develop effective adaptation strategies is being increasingly relevant for international, regional, and local actors. However, traditional knowledge is not completely integrated by all scientific and policy spheres as an equally relevant source of knowledge. Indeed, climate change adaptation policies are often grounded in conventional scientific knowledge, but the perspectives, observations, and adaptation strategies from indigenous groups and communities, which have historically dealt with ecological changes, are not entirely integrated (if not mostly disregarded) into scientific assessments, reports, and conventional policy-making channels. The robust knowledge of Arctic native peoples and cultures is essential to creating consistent strategies and effective policies that reflect the historical and daily reality of life in the Arctic. In order to achieve this, a closer collaboration on the ground of all actors would be necessarily positive, since involving indigenous groups at international forums of discussion is not sufficient. Inherent to traditional knowledge are individual and collective relationships to the territory, different needs and concerns, which imply ways of knowing that correspond to particular expectations about what needs to be known and who should something about that knowledge. We suggest that normalised mainstream scientific assessments and measurements (incl. used methods) may not necessarily capture those needs and therefore be unfit for purpose. Like with traditional knowledge, scientific measurements and assessments equally determine what needs to be known and to a certain degree who is entitled to act on those outcomes.

Hence, we suggest that scientists, technical experts, and policy-makers establish and use closer cooperation channels with local native communities. These channels could be developed through, e.g. collaborative networks, observer networks, citizen science initiatives, and projects based on traditional knowledge, since these kinds of actions would allow on the one hand, a direct connection and collaboration between Arctic peoples and scientific organisations and actors; and on the other hand, it would allow the elaboration of more concrete strategies and policies.

Having identified the sources of environmental impacts at the local level, which potentially cause displacements, the institutions should facilitate and support the establishment and development of local observer networks. These local observers can use their traditional knowledge by monitoring environmental changes through a systematic documentation of their observations in close collaboration with scientific organisations, such as the IPCC and other actors. Since representation of indigenous groups in forums and institutions does not necessarily imply the integration of traditional knowledge, it would be beneficial for indigenous representatives to connect to the initiatives and results of these local observer networks to inform their international activity and help in the formulation of regional, national, and international policies.

Without these types of effort, climate displacements and subsequent relocations could increase in the future, leading to significant effects such as the loss of knowledge and practices, which entail a significant value for human environmental adaptation.

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