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Transdisciplinary conceptual modeling of a social-ecological system—A case study application in Terceira Island, Azores

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ABSTRACT

Science and policy integration towards natural resource management is not novel; however it has not always been successful. Partially, this failure is explained by the lack of consideration of different forms of knowledge. In order to incorporate the diversity of knowledge, transdisciplinary has been proposed and, this paper tests conceptual modeling as a tool to promote it. Qualitative modeling is an intermediate step of Systems Approach Framework (SAF) that is a methodology towards the sustainability of social-ecological systems. SAF has been applied in Praia da Vitoria Bay, in the Azores to analyze the future use of wetlands. We promoted a workshop bringing together 18 stakeholders: scientists, managers, private sectors and Non-Governmental Organizations. This paper presents the procedures and discusses the observed interaction between participants, their views and, how the wetlands services were described. Results show that non-scientists found the exercise particularly challenging but with high value due to: the systemic view and, opportunity of sharing viewpoints. The wetlands were mostly described by the direct benefits. The results show that transdisciplinarity can be operationalized and that conceptual modeling is an adequate exercise to achieve it. However, interdisciplinary work and stakeholders' analysis are also necessary because the knowledge gathered is different.

1. Introduction

Science and policy integration within management of natural resources is proclaimed by several scientific fields as well as by regulation (e.g. Directives for Natura 2000: 92/43/EEC directive, Integrated Coastal Zone Management: EC, 1999). This integration is not novel however, previous formats based in a top down approach and in reductionist specialized knowledge have frequently failed in defining sustainable management actions (Berkes, 2003; Ludwig, 2001; Ostrom, 1990). This failure promoted the development of alternative formats based on systems view, knowledge integration and stakeholders' participation (Reed et al., 2009; Tomlinson et al., 2011). Systems Approach Framework (SAF) is one of the procedures recently proposed (Hopkins et al., 2011).

SAF is a step by step process (Fig. 1) towards the assessment of coastal zone systems using the principals of sustainability and systems thinking. Despite the fact that it has been focused solely in coastal systems, the approach can be applied in any social-ecological system. The first step of SAF is the identification of a policy issue (Fig. 1) that is analyzed in detail by an integrated simulation model that presents management alternatives to solve the issue (system formulation and appraisal, Fig. 1). In the end of SAF application, the tool is delivered to stakeholders so that it can be used in a deliberative process towards decision making (system output, Fig. 1).

Along the process there are several intermediate steps and conceptual modeling is one of them. This qualitative model is used in the construction of the simulation model. SAF has been tested in 18 case studies along Europe in a European project called SPICOSA (www.spicosa.eu). So far, the conceptual modeling exercise had been a process performed within the scientific team

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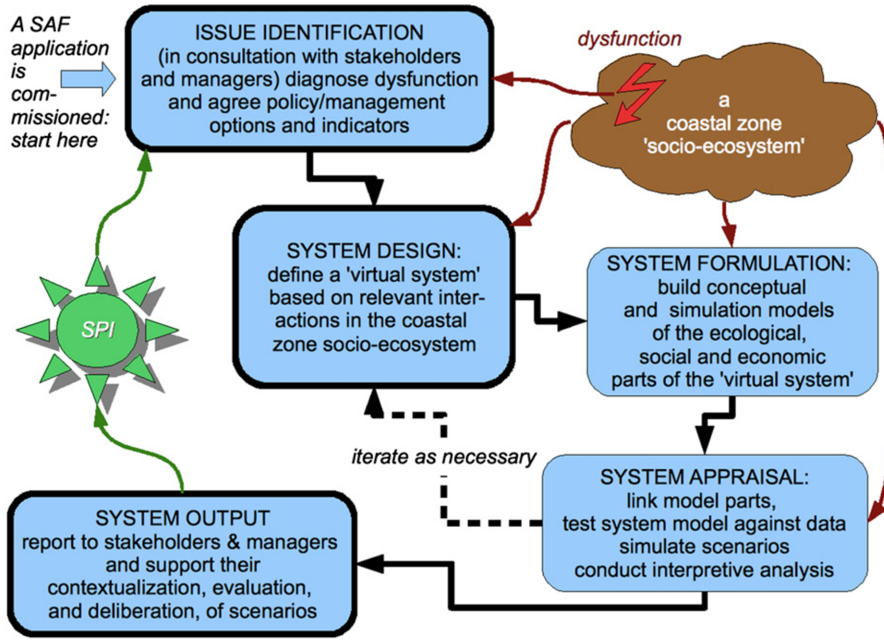

Fig. 1. The steps of SPICOSA's Systems Approach Framework or SAF (from Tett et al., 2011). The issue is a dysfunction in the social-ecological system (including its economy) involving human activity's impact on ecosystem goods and services. The symbol SPI stands for Science–Policy Interface.

(Hopkins et al., 2011) that, by interaction with stakeholders, understands better the system and improves conceptualization.

In 2009, SAF application started in Praia Vitória bay, in Terceira island part of Azores archipelago. In the first year we realized that a relevant issue was the degradation of wetlands (Guimarães et al., 2011), that are habitats that provide several goods and services. Nevertheless, their degradation is a global problem partially explained by the lack of understanding of this habitat value (Dimitrakopoulos et al., 2010; Johnson and Pflugh, 2008; Turner, 1992). In Praia da Vitória bay, the existing wetlands are highly susceptible of disappearing (e.g. conversation into housing, recreational park, industrial structures).

At the conceptual modeling step of SAF we decided to move away from previous applications and develop this task in a transdisciplinary setting (Cundill et al., 2005; Klein, 2004). For that, we promoted a conceptual modeling workshop where scientist, stakeholders and decision makers worked together towards the definition of this social-ecological system. Our hypothesis is that SAF will benefit if this task is developed in such a setting. Transdisciplinarity is proclaimed as the way to move forward in an increasing complex world, nevertheless so far no framework or procedure has been proposed (Cundill et al., 2005). We present the results of this empirical exercise and we discuss the benefits and drawbacks of such a transdisciplinary exercise. Explanations concerning the structure of the workshop can be of utility to other potential users; hence we also share what can improve the effectiveness of the exercise. We frame our findings within SAF but we consider them relevant to other approaches. Since we are dealing with the future use of areas today occupied by wetlands, the results also report how this ecosystem goods and services are perceived and described by non-specialists.

The next section provides further theoretical background behind the SAF. After this we present the case study (Section 2) and move into the procedure of the conceptual modeling exercise (Section 3). Results are presented (Section 4) and discussed in Section 5. We finalize by providing some final remarks about the proposed procedure (Section 6).

2. Theoretical outline of System Approach Framework

SAF was been developed taking into account the current best practices of science and policy integration toward nature resource management. Before going into the case study context this section provides a glimpse of the theoretical background of SAF however a proper review is not the scope of this article.

2.1. Science and policy integration

Simply documenting the changes in natural systems, or providing static indicators of environmental conditions, constitutes an insufficient role for science (Hopkins et al., 2011). There is a need to incorporate inputs of social and natural sciences into the science used in policy making (Tett et al., 2011). Furthermore, the traditional reductionist approach does not provide the appropriate scale and a systems view is required (Capra, 1997). Complexity, resilience and non-linearity are characteristic found to be of extreme relevance when trying to understand how natural resources should be managed (Folke, 2006). Finally, top-down approaches are not effective since they lack of agreement for proper application (Reed, 2008). Therefore, people that affect or are affected by a natural resource status (stakeholders) need to be included in the process of science and policy integration,

In SAF the interface between science and policy has been defined has a communication space, a forum in which governance, civil society and science interact. Within SAF, *Science* mobilizes knowledge to explain the dynamics of a selected system and to explore the potential consequences of alternative policy scenarios or management actions; *Stakeholders* deliberate on the basis of their interest and this knowledge; and *Governance* decides in the interest of society as a whole (Hopkins et al., 2011; Tett et al., 2011). In this context, governance is considered to be the steering and ruling of society and the ways in which citizens and groups articulate their interests, mediate their differences, and exercise their legal rights and obligations.

2.2. Social-ecological systems

Nowadays the accumulated knowledge about the dynamics of ecosystems is high however problems in managing natural systems are of different nature (Tett et al., 2011). They arise from human affairs, or more, precisely, from the bad policies which humans use to regulate their use of the ecosystems services and, which are not necessarily helped by the advances in natural science knowledge. With this in mind, the SAF focus is social-ecological systems that include a human component (socio-economic) and the (natural) ecosystem (Tett et al., 2011) with more emphasis on the human part. The interactions of humans and nature are seen in terms of goods and services acquired and pressures exerted. Each part of the system contains a particular form of capital that associates with a particular good.

As SAF, studies of resilience, vulnerability, and adaptability have moved way from analyses focusing either on ecological systems or on social systems towards an holistic conceptualizations and models of socio-ecological systems (Gallopín et al., 1989), social-ecological systems (Berkes and Folke, 1998), or coupled human–environment systems (Turner et al., 2003). In this line of thought Ludwig (2001) stated that the era of management is over and humans need to be seen as they are, included in the ecosystem. Hence, there is an overwhelming consensus that the pursuit of long-term sustainable outcomes should be based on the coupling of human and natural systems (Berkes et al., 2003; Hopkins et al., 2011; Kates and Parris, 2003; Tett et al., 2011; Turner et al., 2003). The management of such a system should aim at finding solutions that are simultaneously ecologically sustainable, economically efficient, and socially equitable. It is still unclear how this sustainability science should look like (Ostrom et al., 2007) nevertheless SAF appears as a tool that can be of great utility to the proper structured of it (Tomlinson et al., 2011).

2.3. Systems thinking and conceptual modeling

Depending on the sectorial perceptions, some problems are considered to be real and existing in the physical environment, while some are deemed to be virtual systems and hence capable of correction by changing people's understanding of an issue (Tett et al., 2011). Most of the times it is difficult to distinguish between the origin of the problem hence, part of the theoretical challenge of SAF was to bring together the hard, thermodynamically based, science of 'General Systems Theory' (Von Bertalanffy, 1968), and the postmodern approach of 'Soft Systems Methodology' (Checkland, 1999). By using both systems thinking SAF is able to provide insights on problems existing in the physical world while also providing tools of reframing issues.

Conceptual models are one tool used in both "Hard" and "Soft" modeling (Fig. 2) and also a step in SAF (Fig. 1). Despite the number of modelers involved in the creation of a model, it can be inflexible and hinder the necessary tradeoffs between conflicting interests (Checkland, 2000; Heemskerk et al., 2003; Reed, 2008; Vennix, 1996; Voinov, 2008). Taking this into account, as well as, the will to test transdisciplinary work, we promoted a conceptual modeling exercise involving scientist, stakeholders and policy makers. Our hypothesis is that such an exercise can provide great benefits because individual conceptualizations would be clearly presented and reframed by the need to develop a common model. Furthermore, our scientific team would have the opportunity to gather relevant information concerning the social-ecological system in analysis. Participatory conceptual modeling is also used within the modeling community that increasingly considers the need of stakeholders' involvement in the development of models. The two most common methods are participatory modeling (Vennix, 1996) and mediated modeling (Van den Belt, 2004). These methods search for a consensus, are based in modeling software's and include an intense collaboration with stakeholders (e.g. several workshops). A more recent approach designated physical–ecological–social systems (PHES) approach offers a similar procedure being the main difference the fact that consensus is not reached (Marin et al., 2008).

The transdisciplinary conceptual modeling exercise presented here includes some characteristics of all the referred approaches. The main similarity is that during the exercise, participants develop qualitative models towards a quantitative model. The differences start at the objectives, since in our case we want to promote a dialog between scientist and other stakeholders so that knowledge, with significance to all, can be produced. Our intention is not to transfer a scientific knowledge. During the exercise, knowledge coming from non-scientists is treated the same way than that presented by scientists. As in PHES a final consensus model is not achieved and there is a brainstorming activity. While all the referred approaches imply several moments of interaction, our procedure is a one-time event. Furthermore we only develop qualitative models whereas in the other approaches the intention is to reach a participative quantitative model. Our approach is better compared to the

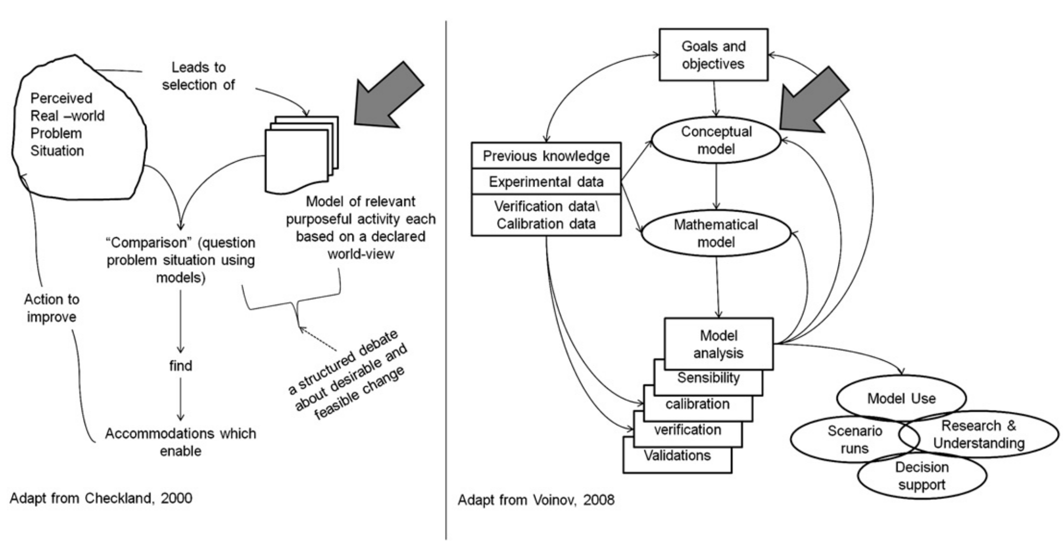

Fig. 2. Modeling process in Soft System Modeling (SSM) and Hard System Modeling (HSM) (adapted from Checkland, 2000; Voinov, 2008). Gray arrows show where conceptual models are used in both approaches.

conceptual modeling described by Heemskerk et al. (2003), despite the fact that we do not use the same symbols and participants include scientist and non-scientist.

3. Praia da Vitória wetlands—the case study

The perceived worth of wetlands has increased rapidly over the past two decades (Dimitrakopoulos et al., 2010; Johnson and Pflugh, 2008). The goods and services provided by wetlands include direct utilization and ecological services that support or protect human activities and properties. Fifteen percent of the value of the world's ecosystem services and natural capital is generated by wetlands (Costanza et al., 1997). However, the entire world experienced severe losses of wetlands (Turner, 1992) and sustainable management of these assets is highly relevant.

The wetlands discussed during the workshop are located in Praia da Vitória bay situated in Terceira Island (38°43′49″N; 27°19′10″W).; one of the nine islands of the Azores archipelago (Fig. 3).

Praia da Vitoria bay was flanked by one of the longest beaches of the Azores (3 km long), which was once fringed by a 300 m-wide dune system (Bannerman and Bannerman, 1966; Morton et al., 1998). The low-lying nature of the shoreline, the protection afforded by former dunes, and the incursion of seawater through porous sediments, resulted in a natural setting for the development of a coastal wetland that, prior to human settlement, was the biggest in the Azores. The wetland and dune system has been altered since 1929 by human settlement (Bannerman and Bannerman, 1966; Morton et al., 1997).

3.1. *Paul da Praia and Belo Jardim—remainders of the natural wetland*

Paul da Praia is the biggest reminder of the natural system (Total area = 40,000 m^2; Figs. 3 and 4) and has been submitted to a restoration project in 2005. Today, the dune system is only observed in a specific area designated Belo Jardim (Fig. 3), that was probably part of an ecological continuum with Paul da Praia (Morton et al., 1998, 1997). Nowadays, the state of degradation of Belo Jardim is high and the natural system is reduced to a *Juncus* community (100 m^2), surrounded by agricultural fields, livestock farms and a diked stream.

The management of these wetlands is an issue hotly debated and there are two main opposite discourses by those who consider the recovery project beneficial, and their opponents that consider it a waste of public funds.

3.2. *Cabo da Praia—artificial wetland*

Similar discussions of the previous case have been intensified since the appearance of an artificial wetland in 1983 designated Cabo da Praia (Total area = 150,000 m^2; Fig. 3). The wetland is an old overexploited quarry. The quarry was dug too deep and today is inundated at each rising tide (Morton et al., 1997). Over the years, the Cabo da Praia Quarry has been filled with fine sediments and colonized by vegetation and several species of zoo benthos that promoted the concentration of several species of birds. Today, Cabo da Praia is one of the most famous places in the Azores to observe occasional and rare birds (Guimarães et al., 2012).

4. Conceptual modeling workshop

The springboard of the conceptual modeling workshop was: Wetlands along Praia da Vitória Bay—definition of the social-ecological system.

The structure of the workshop was previously tested in the academic environment and the necessary adjustments were made to assure the clarity of the exercise and sufficient allocation of time for each step. The final structure is describe in Fig. 5 and will be further detailed.

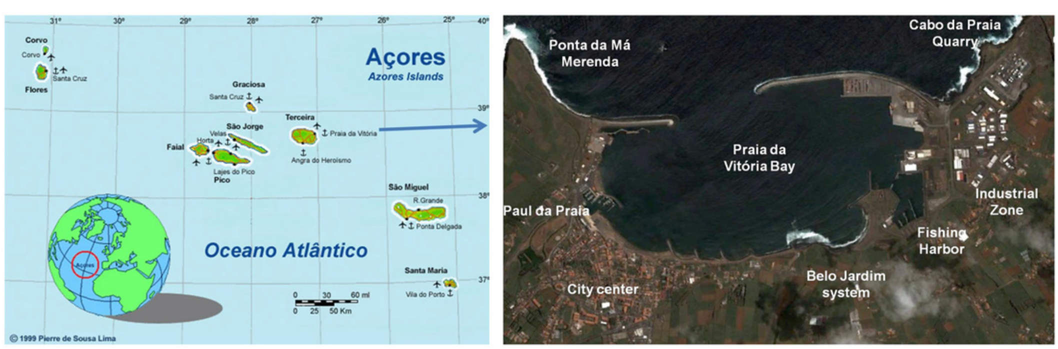

Fig. 3. Azores and Terceira island location, followed by a satellite image of Praia da Vitória Bay with indication of the main elements. (*Source*: Lima, 1999 and Google Earth).

Fig. 4. Old photographs of Praia da Vitória Bay. (*Source* from left to right: Estrela d'Alva magazine 1916, date and origin unknown, date and origin unknown).

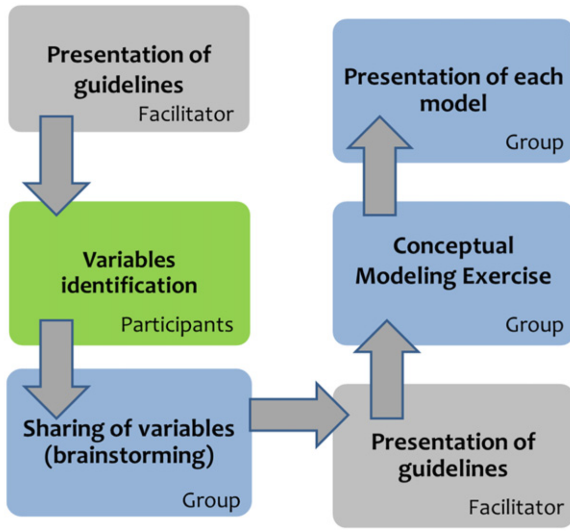

Fig. 5. Structure of the conceptual modeling exercise. It is a step-by-step process that includes individual tasks (green), in groups (blue) and guidelines provided by the facilitator (gray). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Table 1
Participants in the workshop.

Institution	Stakeholder category	Stake related to the policy issue
History Museum	Public—Governmental	Promoter of the recovery project of Paúl da Praia. Defender of cultural heritage.
Azorean Biodiversity Group		Research in biodiversity issues.
Municipality		Management of the area.
Tourism Office		Promotion of the tourism sector.
Mathematics Research		User of the area but with no practical stake, just curiosity due to the modeling component
National Guard		Control of illegal activities in the area, like garbage deposition.
Port Activity		Development of industrial activities.
Climate, Weather and Changes		Research on the area.
Ecoteca		Environmental education.
Industrial sector	Semi-private	Development of industrial activities.
Praia em Movimento		Promotion of the tourism sector in the municipality.
Nature guide	Private	Potential of nature guided tours.
Nautical Activities		Promoter of recreational activities.
Surf Association of Terceira	Public—Non Governmental	User of the zone with stake related to the possible construction of new infrastructures.
Gê-Questa NGO		Environmental education and environmental protection actions.

Thirty stakeholders were invited to participate and more than half of them did (60%). All stakeholders that could not attend the workshop justified their absence with other reasons rather than lack of interest. Table 1 provides information on the stakeholders involved, including their interest in the policy issue. The composition of groups was set before the workshop and participants were distributed in order to assure heterogeneity in background, interests and perspectives. Each group included one researcher and, although all participants were university graduates, the remaining elements were not professionally engaged in research. The workshop took place in December 2010 and lasted 3 h 30 min. The venue was organized in a way that participants sat in a semi-circular arrangement (Fig. 6) to provide better conditions for discussion while focusing attention on the facilitator whenever needed, and also to allow work within groups. The research team included one facilitator, one reporter element and a third one helping with practical issues. Common facilitation techniques (Hogan, 2002) were used to encourage open and frank discussions.

The workshop started with a presentation of the program, the overall goal and the guidelines for the first task (Fig. 5). The first task was an individual reflection about the variables which best described the system. Variables were written down on cards of different colors. Each color represented a component of the system: ecological (green), socioeconomic (gray), cultural (orange) and governance (blue). This way, participants were motivated to reflect about all components of the system. The individual reflection took about 15 min and, during this time, participants were silently identifying variables and choosing the adequate color.

After these individual exercise, participants shared the variables identified using a brainstorming technique (Hogan, 2002; Marin et al., 2008; Osborn, 1963).

For each variable participants were asked to provide an explanation and after the facilitator placed it on the central board (Figs. 5 and 6). Once variable *A* was identified by participant A; the exercise was repeated by the next participant. All participants had a chance to share the variables previously identified and the exercise was only concluded when there was no more new variables. During this task no discussion was allowed.

After the brainstorming, another presentation provided the guidelines for building the conceptual model (Fig. 5). This presentation included explanations of how to build the conceptual model and examples (Fig. 7). Explanations included the definition of processes between variables that should be represented by an arrow with a verbal identification of it (e.g. produces, impacts, increases). The following hour was devoted to the conceptual modeling process (Fig. 6). This occurred within predefined groups that had an individual board were the model was drawn.

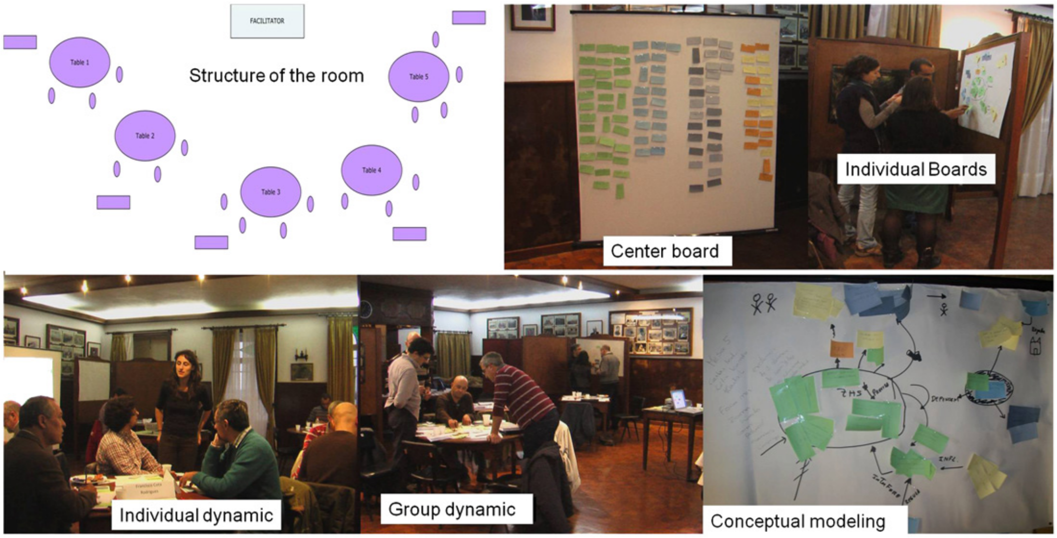

Fig. 6. Structure of the room and workshop dynamic (personal pictures).

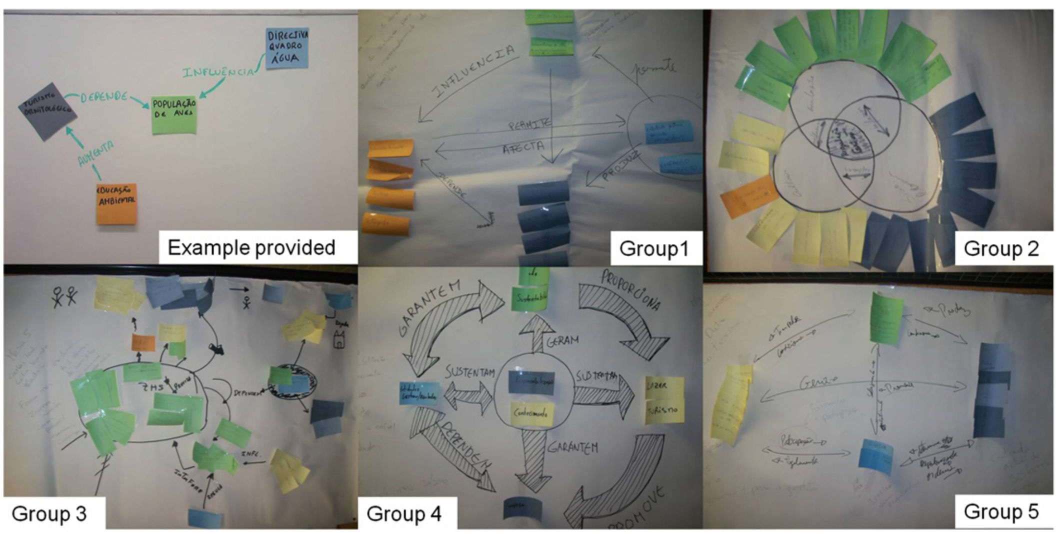

Fig. 7. Example given during the presentation concerning the conceptual modeling and process identification. Aspect of the conceptual models developed during the workshop.

Participants could go to the central board to review the variables previously identified. When all groups finalized the process of model building, a selected spokesperson presented it (Fig. 7). Discussion followed each presentation and continued after all models had been presented. This stage took about 1 h 30 min. Finally, the participants were asked to reply to an individual questionnaire. The goal of this questionnaire was to evaluate the workshop as well as the approach used. Most questions included a structured component using the *likert scale* and an unstructured component where participants could justify their choice.

4.1. Post workshop—confrontation of conceptual models

From the workshop we obtained 5 conceptual models of the social-ecological system that were compared and summarized in a final conceptual model. The final conceptual model was organized using insights of several systems thinking approaches (Ballé-Béganton et al., 2010; Checkland, 2000; Mongruel et al., 2011; Tett et al., 2011). The final model was divided in three layers which are governance, resources and their uses and provides information about what will be the actions of the future development of SAF. The model has been developed using Cmap software (http://cmap.ihmc.us/).

5. Results and interpretation

5.1. During the workshop

As result of the brainstorming exercise, 97 cards were filled and placed on the center board (Fig. 7). At the beginning of the exercise, the concept of variable and the limitation of one word per card were established. However participants did not fully respect the rule and around 30% of the cards include more than one variable, as well as, processes.

Although participants had been asked to define variables that characterized the current status of the system, in some cases, variables represented perspectives about the future of the wetlands. Therefore at the end of the first task of the workshop we obtained information about variables (e.g. employment), processes (e.g. deposition of sand) and future views (e.g. promotion of bird watching activity).

The ecological component included the highest number of cards (Fig. 8). Nevertheless, the cards content shows that some of them were actually representative of the socio-economic component (e.g. light pollution, bathing water quality). In the socio-economic component, the well-established human activities were identified (marine transportation, industrial production, agriculture) as well as, others with less visible economic expression (e.g. bird watching, surf, photography). Most of the narratives included in the cultural component described the values that should be promoted among residents (e.g. valorization of the wetlands). In the governance component, entities with management competences were identified as well as the European Directives that promote sustainable development and environmental conservation. In this component, participants also presented perspectives of how management towards the recovery and maintenance of the wetlands should be done.

All groups reached the final goal (Fig. 7) and finished the group conceptual model. Again none of the participant groups strictly followed the guidelines that were provided; some variables were assembled in bigger groups and some processes were not fully identified (e.g. arrows without verbal identification of the process).

During the modeling exercise, the facilitator did not interfere but solely observed the interactions among participants. The modeling exercise required someone to draw the conceptual model. This person was automatically defined as the spokesperson of the group while presenting the final result. Differences between participants regarding the time spent to build their arguments were observed. The possibility of choosing cards from the central board allowed time for participants to increase their argumentation capacity within the group. Groups with participants from the industrial sector and from NGOs had had the most difficult discussion due to the almost opposite views of the system. However, this tension diminished along the exercise and the conceptual model was built by the group. The observed easing of tension can be explained by the possibility of including in the same model the benefits and cost of industrial activities and also the more "environmental friendly" activities. Furthermore, participants were able to better explain how they related to each other by including feedback loops between variables.

The interaction of the scientists with the other participants also provided important insights. In the workshop, 80% of the scientists are dedicated to natural sciences and, for that reason; we expected a detailed and technical description of the system. However the ecological variables and processes chosen by the specialist were not technically specific. The lack of a technical discourse can be explained by the worry of scientists in not to use a vocabulary that could alienate the non-specialists. One of the groups had difficulty in reaching consensus; this was not due to conflicting interest but due to differences in perceiving the exercise. One of the scientists is specialized in numerical modeling and tried to lead the exercise in this direction. At the end the conceptual model presented was the simplest and focused more on the ethical principle of sustainable management rather than on the actual social-ecological system. Leadership of one participant over the rest of the group was also observed. The leading person is a scientist and the oldest participant of the group, inducing a passive attitude in the rest of the group. Nevertheless, when asked, participants considered that everyone had a chance to include his/her perspective in the selection of the variables. From these results, it appears that participants took as true the information provided by scientists and seldom are willing to discuss them. In general the capacity of systems thinking by scientist was greater, as well as their argumentation ability.

Before the end of the workshop all but one participant replied to the questionnaire (Fig. 9). Most participants considered the approach innovative mainly because of the chance to share ideas about the study area. This denotes the scarcity of public participation and interactions between stakeholders and also shows the utility of the workshop towards the social learning process (definition used in Reed, 2008). Some stakeholders referred to the link between science and empirical knowledge as a good result of the workshop as well as the possibility of having demonstrated their opinion to others. Although most participants were previously concerned with the amount of time spent in the workshop, some subsequently indicated that a longer workshop would be appreciated.

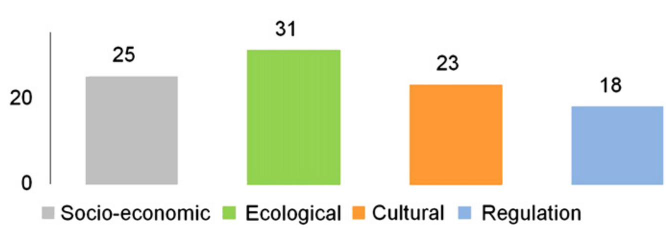

Fig. 8. Quantitative results of the brainstorming activity.

5.2. After the workshop

From the five conceptual modes obtained a final one was produced (Fig. 10). In the final conceptual model the public institutions are treated as one entity and include a "take action" arrow that implies the need for clarification of individual competences in defining the future of these wetlands. In the above section we explained how management of the wetlands was discussed between

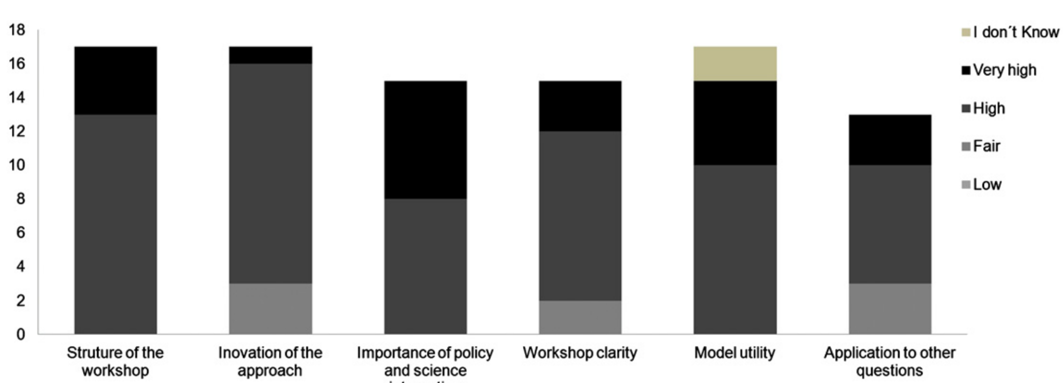

Fig. 9. Indicators obtained by the final individual questionnaire.

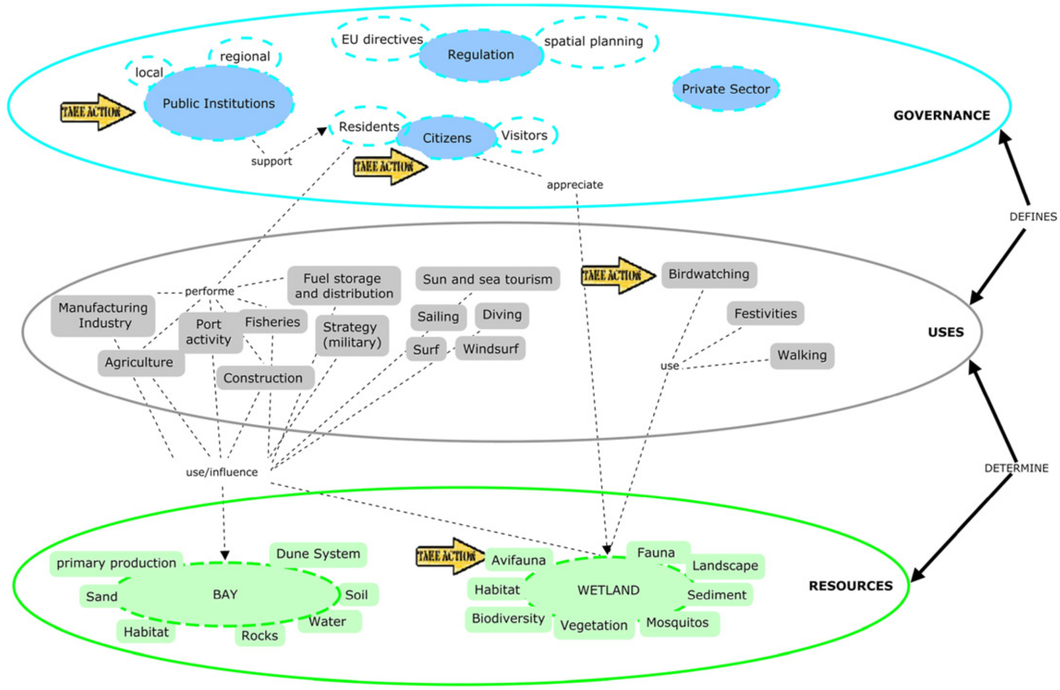

Fig. 10. Final conceptual model and identification of action define.

participants and this highlights the lack of clarity concerning management competences. Within the governance layer, it was also recognized that citizens -mainly residents- do not recognize the importance of the wetlands that are associated with places of garbage disposal, bad smells and proliferation of insects. Since any management action needs public support to be successful, another important action should be the promotion of better understanding of the wetlands ecosystems goods and services (Dimitrakopoulos et al., 2010; Johnson and Pflugh, 2008; Turner, 1992). We highlighted this need by adding another "take action" arrow. Most of the resource uses in the bay were identified. An activity worth highlighting is the bird watching because questions about the economic relevance of this activity were pointed out and opinions diverged. Some of the participants considered bird watching to be an important touristic activity while others questioned whether it, actually, has any economic impact. Bird watching is therefore highlighted with a "take action" arrow, as a sub-component of the system that requires a closer look.

An arrow of "take action" is also identified in the resource level since the habitat is being influence by the dynamics of the above layer and, in case the decision favors conservation of the wetlands, management actions need to be defined.

6. Discussion

6.1. The cognitive effort and willingness to participate

The conceptual modeling workshop was structured first considering the wellbeing of participants and only after our scientific goals. It might seem an odd list of priorities nevertheless we need to understand the context where a participatory process is promoted so that the best methodological choices are made. Lack of interest and fatigue are increasingly referred as problem of the participatory approach that some use to highlight the limitation of this trend (Reed, 2008; Reed et al., 2009). However these symptoms are a result of processes badly structured that demand excessive cognitive effort or that induce expectations not achieved (Reed, 2008; Reed et al., 2009). The fact that the workshop was an on-time event, lasting 3 h, without the use of any electronic equipment were decisions made taking into account the lack of familiarity of the participants with modeling, some suspicion about SAF results, time and resource limitation. The first question of participants while invited to the workshop was: "How long does it last?". This lack of willing to participate is even higher at the managers' level due to the busy agendas and lack of institutionalization of participatory processes that imply an effort not professionally recognized.

The participatory or collaborative modeling exercise can be of extreme importance to SAF nevertheless the methodological decisions need to take into account the trade-off between complexity, clarity of the procedures, expected results and motivation of stakeholders. More demanding and fruitful approaches can be implemented after participants confirm the benefits of such processes. The methodological decisions we made were successful since despite the proclaimed time limitation by participants, most of them expressed interest in future sessions and willingness for longer workshops (Fig. 9 and qualitative responds in the questionnaire).

6.2. The outcomes of the workshop

The use of boxes for what could never "fit" in a box, due to complexity and collateral linkages, can be consider an oversimplification and limitation of the exercise. However, the richness of the workshop is not only on what has been translated in the conceptual models but also in the data gathered during the brainstorming and discussions. In that sense, the work of the researcher after the workshop must necessarily embrace the incorporation of the information included in the models and the discourses during the exercise. The final model (Fig. 10) includes five arrows that indicate the system components where further analysis is required ("take action"). This identification was possible by the analysis of the final conceptual models in the context of the interaction between participants (e.g. tensions between industry and environmentally friendly activities), argumentation used (e.g. bird watching has economy value to the city) and unclear discourses (e.g. management responsibilities of the wetlands).

6.3. Wetlands ecosystem goods and services

One of the main outcomes of the workshop was the clear interest in understanding the economic benefits that the wetlands provide to local population (Fig. 8 and qualitative data). In the context of ecosystems goods and services and total economic value concept (Boyle and Bishop, 1985), debate mostly focused the use value of the wetlands provided by the recreational service. Non Use Values (e.g. regulations and supporting services) were only vaguely mentioned. During the workshop some of the services of the ecosystem (intermediate or final) were discussed (e.g. water quality, food for birds) but the main topic of debate was the benefits (e.g. nature photography, bird watching and environmental education). Further work is needed to understand the economic impact of the current human activities in Praia da Vitoria wetlands and also to estimate the value of an increase in the environmental quality.

The effort to determine the "value" of ecosystem services is considered by some as defeated since those that use these services have their own way of handling and bargaining them (Sagoff, 2011). In the present work, the need to find market based indicators arose from the stakeholders in order to demonstrate the importance of the existing wetlands. Although our work does not support the conclusion of Sagoff (2011), we also agree that stakeholders have particular ways for deliberation and decision. Nevertheless, Praia da Vitória case study is a good example of how tradeoffs made in the past diminished productivity in the future and, this is where science-policy integration needs to find its role.

6.4. Transdisciplinary: benefits and limitations

A transdisciplinary approach is useful for scientists to develop functional links with society (Cundill et al., 2005; Sagoff, 2011). Heemskerk et al. (2003) explains how conceptual modeling in interdisciplinary settings can be a tool for communication across several disciplines. We agree with this conclusion and, broadened the conclusion to the transdisciplinary arena. The results of this workshop show that discussions among scientists and scientists with other stakeholders are different. In Heemskerk et al. (2003), discussion was focused on the definition of concepts between scientific disciplines (e.g. opinions and values). What our results show is that, in a transdisciplinary setting, the discussion is focused on the sharing of perspectives, existing issues and possible solutions. Researchers in this transdisciplinary setting adapt their speech and avoid getting into detail, which is a very important adjustment to enhance a true dialog (Klein, 2004). On the other hand, non-academic stakeholders assume a passive attitude when faced with the argument of scientists. Therefore a workshop towards conceptual modeling restricted to researcher is complementary so that more specialized discussions can occur. The same applies to workshops restricted to other stakeholders since we are unable to conclude if discussion would be different in the absence of scientist.

According to Klein (2004) transdisciplinarity is simultaneously an attitude and a form of action. Many public authorities are eager to engage on experiments, demonstrations, and pilot projects in the name of transdisciplinary, sustainability, and of proximity to the local community (Klein, 2004). In the present work, the positive appreciation of the workshop by stakeholders (Fig. 9) indicates that there is a will to engage in collective search of ways to use the common natural resources. Nonetheless, we do not consider that transdisciplinarity replaces interdisciplinary or stakeholder analysis. All these interactions pose different challenges and provide relevant results toward science and policy integration within SAF and other tools.

7. Conclusions

The experience which was earned through the participatory exercise certainly will increase the efficiency of future process. The structure used in the workshop has been successful and can be applied within SAF or other tool. Or empirical results suggest that the guidelines provided by the facilitator are an essential part of the exercise and should be repeated in different ways (e.g. verbally, using images and/or videos). In future exercises it is important to constantly highlight that:

1. Participants should allocate a concept to each card,
2. Each arrow linking the model items should explicitly identify the process,
3. Each variable needs to be connected to another one by an explicit process.

   Nevertheless, it is also important to take into account the tradeoff between the guidelines and participants willingness to be involved in the exercise. Too many rules, may discourage participation and decrease the information flow.

Other modeling tools that promote stakeholders participation can be of high importance within SAF; however, participatory approaches need to prove its utility first and only after propose sessions that are more cognitive and time consuming. Although the goal of the workshop was the description of the current system, the information obtained surpassed the expectations. During the 3-h workshop the participants produced 5 conceptual models that not only described the current situation but also provided information about future views of the system.

Conceptual modeling has proved to be an efficient tool to communicate in a transdisciplinary setting. Using a conceptual modeling exercise gives participants a sense of heading towards a common goal promoting at the same time a systemic and constructive discussion. We found that the process of model building is, in itself, a valuable step towards science-policy and society integration. The need to promote communication and understanding among stakeholders underlines the necessity to promote a gradual learning process. Everyone with an interest for a certain policy issue needs to understand the system in its various components so that a deliberation process can occur and tradeoffs defined. Finally, going forward with a SAF application in Praia da Vitória Bay, we are still to conclude about what has more impact and importance, the final product (i.e. the simulation model) or the process itself (i.e. the moments of transdisciplinary work).

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