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Conceptual PHES-system models of the Aysén watershed and fjord (Southern Chile): Testing a brainstorming strategy

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Abstract

The use of brainstorming techniques for the generation of conceptual models, as the basis for the integrated management of physical–ecological–social systems (PHES-systems) is tested and discussed. The methodology is applied in the analysis of the Aysén fjord and watershed (Southern Chilean Coast). Results show that the proposed methods can be adequately used in management scenarios characterized by highly hierarchical, experts/non-experts membership.

Keywords: Conceptual models; Stakeholder's participation; Integrated management; Brainstorming

1. Introduction

The explicit incorporation of *Homo sapiens* as a component (and stakeholder) of earth's ecological systems is an unavoidable result of our influence on almost every corner of our planet. However, classical ecological concepts (e.g. communities, ecosystems) do not allow for the straightforward incorporation of human society and economy (O'Neill, 2001). With this problem in mind we generated the physical–ecological–social system (PHES-system) concept as a way to incorporate constructivist ideas into ecological analysis (Marín and Delgado, 2005). A PHES-system is a spatially explicit ecological system for which limits and components (with the exception of human societies that by definition belong to every PHES-system) depend upon the questions being asked and the people that ask them. The concept falls within moderate or contextual constructivism (Jones, 2002), where diverse worldviews would correspond to different interpretations of a common reality. The role of scientists in this view of nature has been clearly defined by Kay (2001): "In post-normal science, the scientist's role shifts from inferring what will happen ... to providing decision makers and the community with an appreciation of how the future might unfold". However, there may be as many PHES-systems for a given ecosystem (*sensu stricto*) as groups of stakeholders, all of them equally legitimate and even occasionally incompatible (Ludwig, 2001). Furthermore, the integrated management of any ecological system requires that all involved stakeholders reach agreements regarding their components, limits, pressures, states and societal responses. Thus, many strategies have been designed to generate such agreements (Cundill et al., 2005; Theobald and Hobbs, 2002; Heemskerk et al., 2003; Chermack, 2004; Burt and van der Heijden, 2003; Mysiak et al., 2005). The development of conceptual models is one strategy we have employed when dealing with the need to make our ideas explicit to other people (Delgado and Marín, 2001; Marín and Olivares, 1999).

Although conceptual models can be effective communication tools, their development in interdisciplinary environments is difficult due to, in part, language differences among experts (Heemskerk et al., 2003). Furthermore, if the range of stakeholders involved in the creation of the conceptual model is too broad, then the possibility of inhibition of certain groups of people, especially in highly hierarchical settings (e.g. students–professors; land owners–peasants), is highly likely. Thus, we

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felt that a more uncritical environment should be engendered prior to the generation of conceptual models. In such an environment, the focus should be on reducing inhibitions, so that people express their points of view in a more open manner. Nicolson et al. (2002), working to develop heuristics for interdisciplinary modeling, point out that the task of communicating with stakeholders is vastly underrepresented in many scientific projects. The strategy we have developed has been oriented to solve this problem and to go one step beyond. That is, to incorporate stakeholders within the modeling team. This is rather timely, because as pointed out by Freudenberg and Alario (1999): real world decisions involve not only facts but a combination of facts, values and blind spots. Furthermore, the incorporation of stakeholders within the modeling group increases their awareness of the ecological conditions upon which they exist. This contributes to the integrated management of ecological systems. Thus, we need to widen our modeling teams to allow the interaction of experts and non-experts. In what follows we describe an academic exercise designed with the purpose of testing the strategy we have devised to develop conceptual models of a watershed-fjord system in Southern Chile (Aysén). Participants for this exercise belonged to local government organizations related to environmental issues, undergraduate and postgraduate students from environmental curricula and university professors.

2. The ECOManage project

The ECOManage project (Integrated Ecological Coastal Zone Management System; http://www.ecomanage.info), is a research initiative financed by the European Union as part of the Sixth Framework Program. Its main aim is to push the capacity of assisting managers in the integration of knowledge derived from ecological and socio-economic disciplines. The three key aspects of ECOManage are: (1) the consideration that a coastal zone depends not only on local pressures, but also pressures originating in the drainage basin, transported mostly by rivers and by groundwater, (2) that socio-economic activities are the driving forces of those pressures and that their impacts on the ecosystem have feedback on socio-economics, and (3) the impacts depend on physical characteristics of the ecosystem that together with the loads determine its ecological state. Three coastal zones showing conflicting interests between urban, industrial and agricultural pressures and environmental maintenance have been selected for developing the system. The selected areas are: Aysén Fjord in Chile, Bahía Blanca estuary in Argentina and Santos estuary in Brazil. ECOManage is based on the generation of strong interactions with stakeholders, in order to establish study scenarios and to measure the environmental impacts of management decisions. The project is being carried out by a highly diverse group of specialists from ten institutions in six different countries from both Europe and South America. Thus, from the very beginning there has been a clear need to generate innovative participatory methods, both among project partners and between partners and stakeholders.

3. The Aysén fjord in Southern Chile

Chile is a South American nation located in the eastern South Pacific. The country is politically divided in thirteen regions from North to South. The Aysén region is located between 43°38′S and 49°16′S, within the Sub-antarctic domain. Although this region comprises 14.2% of the Chilean territory ($109 \times 10^3\,km^2$), it hosts only a 0.8% of the country's total population with 91 492 inhabitants (INE, 2002). Indeed, in 1907 the population in the area was of only 197 people (Ortega and Brünning, 2000). Most of today's population (80%) lives in two counties (Aysén and Coyhaique) located within the Aysén watershed which drains into the Aysén fjord (Fig. 1). The original population of the area was composed of two ethnic groups: Tehuelches and Alacalufes. These groups are currently nearly extinct in the region, with the exception of a 0.3% of the population that associates themselves to the Alacalufes. Nevertheless, an 8.4% of the population state that they are Mapuches in origin (INE, 2002).

The environmental history of the region includes an unfortunate episode where human colonization was accomplished using fire (Ortega and Brünning, 2000). The resulting wildfires—which burned throughout the 1940s—have left a long-lasting mark on the Aysén region. The fires were started intentionally by settlers (and supported by the governmental policies of the time) to clear areas for cattle and sheep. However, they went out of control, burning freely in the summer months and smoldering underground during the winter. This long-term and subterranean burning has affected the soils of the region in terms of organic content as well as chemical and physical properties. In total 1.5 million hectares were burned. This legacy is still affecting the development of the region, since any increase in agribusiness will require external fertilizers.

Table 1 shows the top ten exports of Aysén for three recent years. Eight of these are related to fishing and aquaculture; the remaining two are from the mining and forestry sectors. The main sources of environmental conflicts in the area are related to water quality, both within the watershed and the fjord of Aysén. Salmon farming requires clean waters, which in turn generates restrictions to the industrial development within the watershed. Local fishermen, on the other hand, complain that salmon farmers are located in shallow areas where they used to fish and that their income has decreased in recent years. Furthermore, there are complains from the tourism industry that salmon cages degrade the "pristine scenic beauty" which it sells. All these conflicts are important to solve since a governmental study, conducted as part of the ordination of the Aysén territory (http://www.planregional.cl/portal/), has shown that the economic

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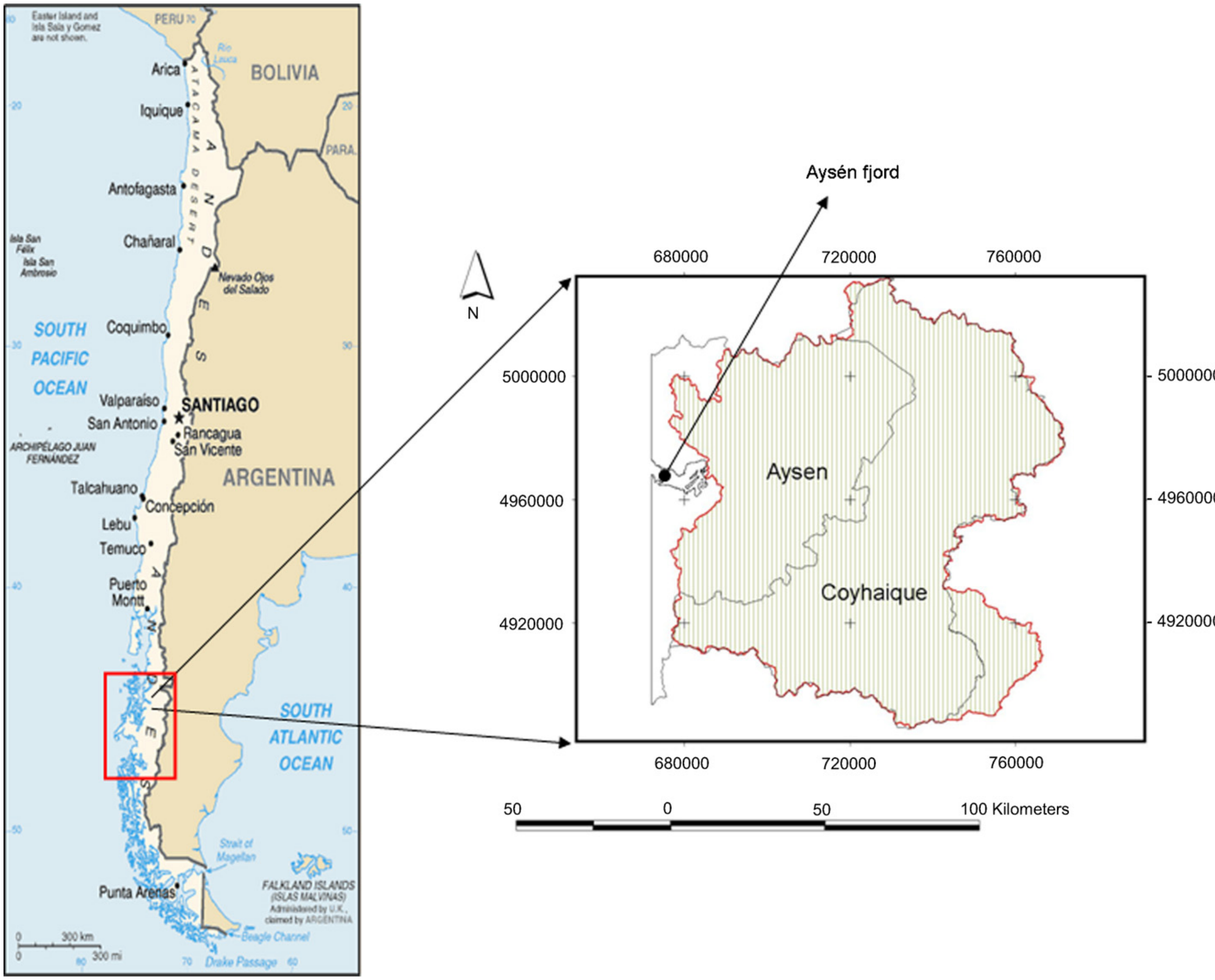

Fig. 1. Geographic location of Aysén fjord and watershed in Chile (South America). The watershed is identified as a red polygon (right graph) subdivided in its two main counties (Aysen and Coyhaique).

Table 1
Ten principal export products of the Aysén region between 1999 and 2001 (in millions of Dollars FOB)

Product	1999	2000	2001
Frozen Pacific Salmon	48.1	36.1	24.9
Frozen Trout	20.2	10.5	11.2
Frozen Chilean Hake	10.6	11.7	10.1
Zinc minerales	9.3	14.1	8.8
Frozen trout (fillet)	3.5	4.8	6.9
Salmon (fillet and other cuts)	3.4	12.5	5.3
Milled lumber	8.4	10	5.1
Frozen salmon fillets	0.6	1.7	4.5
Fresh Slalmon	2.2	4.8	3.7
Other fish fillets	3.6	3.3	3.7
Total 10 principal products	109.9	109.5	84.2
% of regional total	67.51	69.35	68.96

Source: Alvear, 2003.

sectors with the highest projections for future development within the region are (in decreasing order): (1) salmon farming, (2) tourism, and (3) agribusiness and forestry. An example of the growth of the salmon farming is shown in Fig. 2, which corresponds to an accumulative time series of salmon farming sites within Aysén fjord. The resulting curve can be adjusted to an exponential growth with an $r^2 = 0.94$. Regarding tourism, the number of tourists per year has grown linearly from 4×10^4 during 1990 to nearly 1×10^5 in the year 2000. On top of those trends, the regional government has marketed the slogan "Aysén reserve of life" (e.g. http://www.inviertaenaysen.cl). Interestingly, this slogan has evolved to mean different things for different people. For the government and its institutions in charge of promoting the national productive development (e.g. CORFO, http://www.corfo.cl), the slogan means promoting the idea of bringing foreign

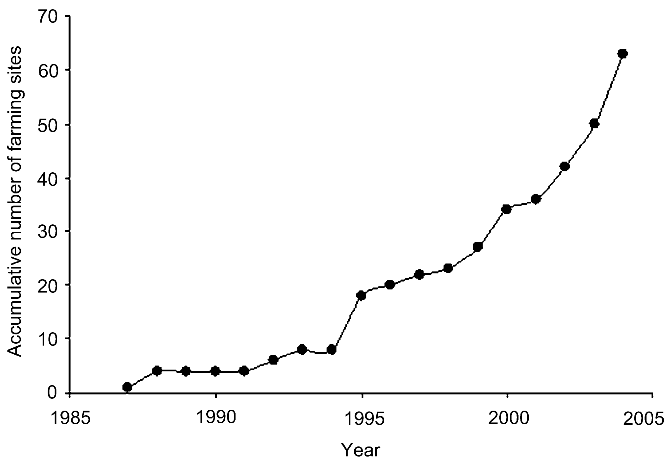

Fig. 2. Time series of the growth of salmon farms within Aysén fjord (Data source: Chilean Government).

capitals to a region where most of its GDP is related to the food industry. On the other hand, for non-governmental organizations (e.g. http://www.aisenreservadevida.cl), the slogan means supporting investment that uses raw materials and local labor in a sustainable way (Hartmann, 2003). Thus, it became clear to us that given the complexity of the environmental issues, and the conflicting visions that different groups of stakeholders have upon the development of Aysén, we should generate integrative conceptual models. These models could then be used as guides for the implementation of numerical models, to analyze the different development scenarios for the Aysén region and their potential environmental consequences.

4. A brainstorming method for conceptual modeling

Fig. 3 shows a flow diagram of the main steps we have followed to generate conceptual models in interdisciplinary, hierarchical, experts/non-experts settings. The basis of the method is the use of brainstorming techniques. Although the interested reader may find many books on the subject, we would recommend two Internet sites that ended up being very useful in designing our sessions.[1] Since there is more than one way to define brainstorming, we have compiled some of the main ideas in Table 2. The process is initiated by sending questions to the potential participants of the modeling session. In our specific case, all questions were related to the quality of water of both Aysén watershed and fjord and they are shown in Table 3. The development of these questions was based on: (a) analysis of current private and state development projects which may have an impact on the PHES-systems, (b) current environmental legislation, and (c) the state of the ecological systems. Although workshop conveners may restrict themselves to the use of the submitted questions during the brainstorming session, their main aim is to provide participants with a global idea of the reason why they have been invited.

In a brainstorming session, narrators play a very specific role: recording all statements of participants without making comments or including extra material. Furthermore, in our case an extra requirement was to have working knowledge of Stella, the iconographic modeling software we used to generate the conceptual models. Thus, during the workshop narrators recorded all statements on large paper sheets attached to the walls of the meeting room and later translated those statements into Stella-coded conceptual models.

[1] 〈http://www.brainstorming.co.uk; http://www.jpb.com/creative/brainstorming.php〉

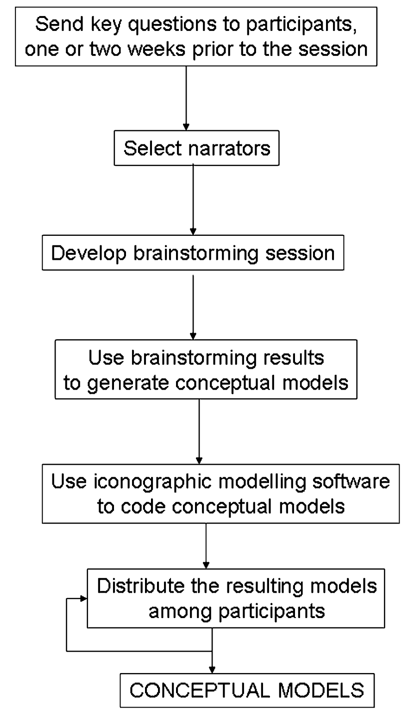

Fig. 3. Sequential steps for the generation of conceptual PHES-system models using brainstorming techniques.

Table 2
Brainstorming definitions

Brainstorming is:
• a conference technique by which a group attempts to find a solution for a specific problem by amassing all the ideas spontaneously by its members
• a process designed to obtain the maximum number of ideas relating to a specific area of interest
• a technique that maximizes the ability to generate new ideas
• where a group of people put social inhibitions and rules aside with the aim of generating new ideas and solutions
• a time dedicated to generating a large number of ideas regardless of their initial worth
• a part of problem solving which involves the creation of new ideas by suspending judgment
• the creation of an optimal state of mind for generating new ideas
• the free association of different ideas to form new ideas and concepts

Extracted from: http://www.brainstorming.co.uk.

Table 3
Extracts from the document submitted (2 weeks in advance) to the participants of the conceptual modeling workshop

Workshop objective: To develop a conceptual model of Aysén watershed and fjord related to nutrients, water quality and potential anthropogenic effects.

Questions used to drive the initial discussion:
1. Forests and prairies of Aysén watershed: What are the components of the nutrient cycle?
2. What are the potential effects of dam construction on watershed nutrient cycling?
3. What are the effects of fish hatcheries on the water quality of Aysén fjord?
4. What is the carrying capacity of Aysén fjord with respect to the development of salmon faming, and what are the system components?
5. Tourism and watershed water quality: do we need additional sewage water treatment?
6. What is the effect of cattle ranching on the water quality and nutrient dynamics of Aysén watershed and fjord?

Methodology: Participative modeling by means of iconographic modeling software, preceded by brainstorming session.

Table 4
Rules of brainstorming

- Postpone and withhold judgment of ideas
- Concentrate on quantity rather than quality
- Encourage the building upon ideas put forward by others participants
- Every person and every idea has equal worth

Extracted and modified from: http://www.brainstorming.co.uk/tutorials/brainstormingrules.html.

There are several ways to develop a brainstorming session, most of which are fully described in the web pages cited above. Among the alternatives (unstructured or free flow, silence-written, structured or in circle), we chose the later. Our main reason was related to the fact that the invited group was new to this type of session and any other format could have inhibited the participation of some of the members (in the case of unstructured format) or prevent the building of ideas based on other member's comments (in the case of silence format). At the beginning of the session a brief introduction to the issues to be discussed was presented by the convener with special attention to brainstorming rules (Table 4). The brainstorming session lasted for two and a half hours with a half an hour break in between to allow exchange of ideas among participants.

As stated in the introduction, we wanted to test our methodology in a highly hierarchical, interdisciplinary environment. Thus, we invited university professors, graduate students (experts) and undergraduate students and government officials (non-experts). A total of 15 people participated in the workshop plus the convener and the two narrators. Fields of expertise ranged from physical and chemical oceanography, resource management, limnology to eco-social studies.

After the main brainstorming session, participants were encouraged to join one of two groups for the development of the conceptual models: (1) a watershed modeling group and (2) a fjord modeling group. Each group was assisted by a narrator with a laptop computer having a copy of the software Stella Research. Groups were then instructed to use the results from the brainstorming part of the workshop in the building of the models, plus other insights arising during model generation. After the workshop, narrators were in charge of the quality control of the resulting models and of sending them to all participants for their final comments.

5. Results

5.1. Brainstorming results

Results from the brainstorming sessions were recorded both on sheets of paper and on tape; both were kept for future reference. For the purposes of this article, we have condensed results related to the questions posed to participants (and shown in Table 3). Results are expressed in terms of the PHES-system components that should be considered and the processes that affect them. Furthermore, processes have been divided according to their dominant spatial scale, in three categories: (a) large scale (above watershed or fjord), (b) system scale (watershed or fjord) and (c) small scale (below watershed or fjord).

Table 5 shows the components and processes related to the nutrient cycles at the Aysén watershed (Question 1, Table 3). The discussion and analysis of the participants showed that erosion, rain patterns and re-forestation seem to be the most relevant issues in regard to nutrients cycling and transporting within the Aysén watershed. Aysen′s regional government has re-forestation plans, including incentives for de-forested areas. However, within the brainstorming session, there was consensus among participants that current conditions, including areas burned in the last century which are now grasslands, should be used as the reference or starting point for both management plans and for simulating future scenarios. The reason for this, however, varied among participants including: (1) re-forestation with native species (e.g. ecosystem restoration) is complex and hard to implement in the short run and (2) there are plans for cattle expansion within the watershed which requires grasslands and not forests. Ideas about re-forestation were diverse including:

1. Promoting research on the best species for the different eco-regions within the watershed, especially native species.
2. Search for funds for this research activity, including CO_2 trade market.

Table 5
Components and processes involved in nutrient cycling in the Aysén watershed

Components
Forest-prairie subsystem
- Forests
- Sediments
- Soils
- Lakes
- Rivers
- Atmosphere
- Fauna within forests
- Fauna within the aquatic subsystem
- Aysén fjord
- Permanent and semi-permanent wetlands
- Cattle biomass
- Pine plantations

Urban subsystem
- Sewage water and liquid industrial residues
- Fish processing plants
- Agriculture subsystems
- Chacabuco port
- Salmon hatcheries

Processes
Large scale
- Inter-decadal climatic variability
- Volcanism
- Inter-annual variation in precipitation

Watershed scale
- Removal of large wood debris from pastures to augment beef production
- Deforestation of native forests for firewood production
- Governmental incentives for re-forestation
- Urban emissions (atmospheric and liquid)
- Forest management plans
- Erosion
- Agriculture management plan

Small scale
- Urban activities
- Mining
- Land use changes

Table 6
Components and processes related to the carrying capacity of salmon farming in Aysén fjord Aysén

Components
- Salmon
- Nutrients in the water column
- Nutrients in the sediments
- Nutrients in other organisms (biodiversity)

Processes
Large scale
- Oceanic circulation
- Precipitation variability

Fjord scale
- Estuarine circulation (2 or 3 layers)
- River fluxes
- Governmental coastal zone management plans

Small scale
- Urban activity
- Salmon excretion
- Food losses from salmon cages

3. Educating the population to utilize pine trees as firewood instead of the native species currently being used.
4. Concentrate re-forestation in areas where erosion problems are more acute.

Regarding dams and nutrient dynamics (Question 2, Table 3), the key issue seems to be the retention of nutrients given the oligotrophic characteristics of the watershed. Participants proposed that the building of dams may generate a great deal of sediment retention. This retention, in turn, would affect particulate matter in the water system (lotic–lentic transformation). Furthermore, the riparian subsystem may be affected producing changes in nutrient transport from forest soils to the river. Finally, concern was expressed regarding potential hydrological change including the thermal regime, and inundation pulses in the event of emergency water evacuation from hydroelectric plants. It is important to note that at the moment, the Aysén region is a key geographic area for hydroelectric development in Chile.[2]

On the issue of fish hatcheries within the watershed (Question 3, Table 3) two components were identified (fish food and fecal material) and one process (excretion) as dominant. Although there are today only 14 hatcheries, the salmon market has established that their number should grow up to 110 within the next 5 or 10 years. These hatcheries not only use river water, but drill wells with a pumping rate of nearly $200\,\mathrm{l\,s^{-1}}$. However, some participants suggested that loosing fish food from hatcheries is not a problem (current losses are nearly 5–7% by mass), since this represent a cost that companies intend to decrease. Finally, concern was expressed over the fact that other components of the fish diet (zinc, antibiotics) are currently not regulated and that may represent a problem in the future.

Table 6 shows the processes and components related to the carrying capacity of the Aysén fjord in relation to salmon farming (Question 4, Table 3). The results of the brainstorming processes were perhaps clearer in relation to this as compared with other issues. While one group of people emphasized mostly physical phenomena (e.g. water circulation) the other insisted in the potential effects that escaped of salmons may have in the biological subsystem (e.g. biodiversity).

Regarding the potential problem of tourism and water quality (Question 5, Table 3), there was consensus that current capacities for water treatment within the watershed are adequate to deal with the flow of tourists through the area. However, some participants expressed concern about garbage disposal during high season for tourism in the summer when the watershed's population closes to doubles.

[2] 〈http://www.sociedadcivil.cl/nuevodiario/sitio/informaciones/noticia.asp?Id = 6936〉

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Table 7
Components and processes related to the effects of cattle ranching on the water quality of Aysén watershed and fjord.

Components
- Forests
- Fertilizers
- Organic matter
- Rain (volatile compounds)
- Forage
- Animal excretion

Processes
Large scale
- Economic development (governmental incentives)
- Free trade agreements

Watershade scale
- Artificial fertilization
- Changes in ranching regime (extensive–intensive)

Small scale
- Cleaning of dead trunks (large woody debris)
- Cattle excretion

Finally, participants discussed the potential effects of cattle ranching on water quality (Question 6, Table 3). Ranching is still local; however, there are plans to industrialize it and to make it a substantial part of the region's economy. Table 7 shows the processes and components related to cattle ranching. The analysis of the records of the brainstorming session showed that participants gave considerable importance to a before/after analysis of water quality as related to industrial cattle ranching. The main reason is that it is highly likely that some fertilization will be required during the industrial phase, given the low nutrient levels in the area.

The exercise of conducting a brainstorming session prior to the generation of conceptual models produced the anticipated results: all involved participants contributed ideas to the models. The flow of thoughts was indeed very rich with many ideas not being anticipated by the people running the session. Furthermore, many of the processes and components that later became part of the models (see below) were suggested by one or two of the participants, in

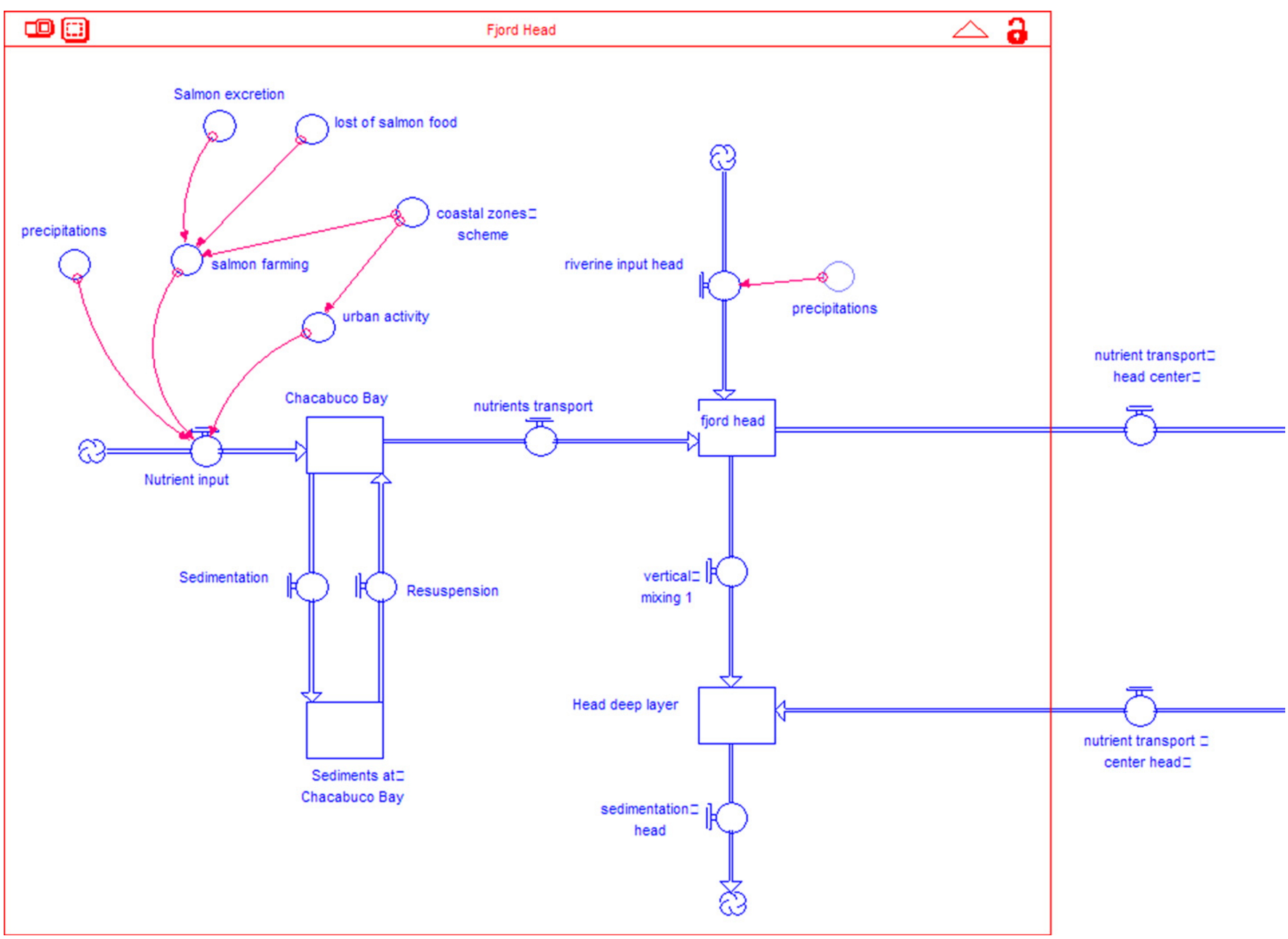

Fig. 4. Stella-coded conceptual PHES-system model for Aysén fjord. The symbols show the relationships, developed during the brainstorming session, between the components and processes related to nutrient cycling and the carrying capacity of salmon farming of the fjord.

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many cases belonging to the lower hierarchies within the meeting. This indeed was the main intention of the method and results were highly satisfactory.

5.2. Conceptual, Stella coded, models of the watershed and fjord of Aysén

All the material from the brainstorming sessions was used in the generation of Stella coded conceptual models. The models very clearly show the relationships between components and processes, a result of the interaction between participants with different areas of expertise. Here we show some portions of both models. The complete set can be found on the Internet (http://ecosistemas.uchile.cl), or can be requested from the authors.

The model for Aysén fjord considers three subsystems (fjord head, fjord center, fjord mouth) all of them divided in two layers (surface and deep layer). The main difference between subsystems is the input of oceanic water at the mouth of the fjord and the input of river water at the head of the fjord. All subsystems are connected through nutrient transport. Fig. 4 shows the components and processes for the fjord head subsystem relating to nutrient loads. Although most of the processes are related to fjord circulation, participants felt that two human-induced processes should be carefully studied: (a) the management and zonation of the coastal areas, since it affects the location and quantity of salmon cages and (b) urban activity (e.g. waste management). The interaction of the fjord system with the watershed has been parameterized as terrestrial nutrient input and riverine nutrient input. The main result of this submodel is that it is possible, to a certain extent, to generate numerical models of the potential effects of salmon cages on the water quality of the fjord based on physical processes only. However, unless the political subsystem is specifically incorporated, the model's potential as a predictive (socially accepted) tool is rather questionable. For example, the process described as "coastal zone scheme" in Fig. 4 incorporates the possibility of modifying the location of salmon cages within Chacabuco Bay. This in turn will have profound effects on the conflicts among salmon farmers and local fishermen.

Unlike the fjord, the proposed watershed model was somewhat more complex (in terms of subsystems and the components within each one of them). Fig. 5 shows the watershed subsystems and the main interconnecting fluxes. The most important fluxes identified are related to the management of forests and prairies. An example of one of the subsystems is shown in Fig. 6. These results reveal the importance of implementing models that incorporate both physical–biological parameters and variables and socio-political variables. Furthermore, many of the components

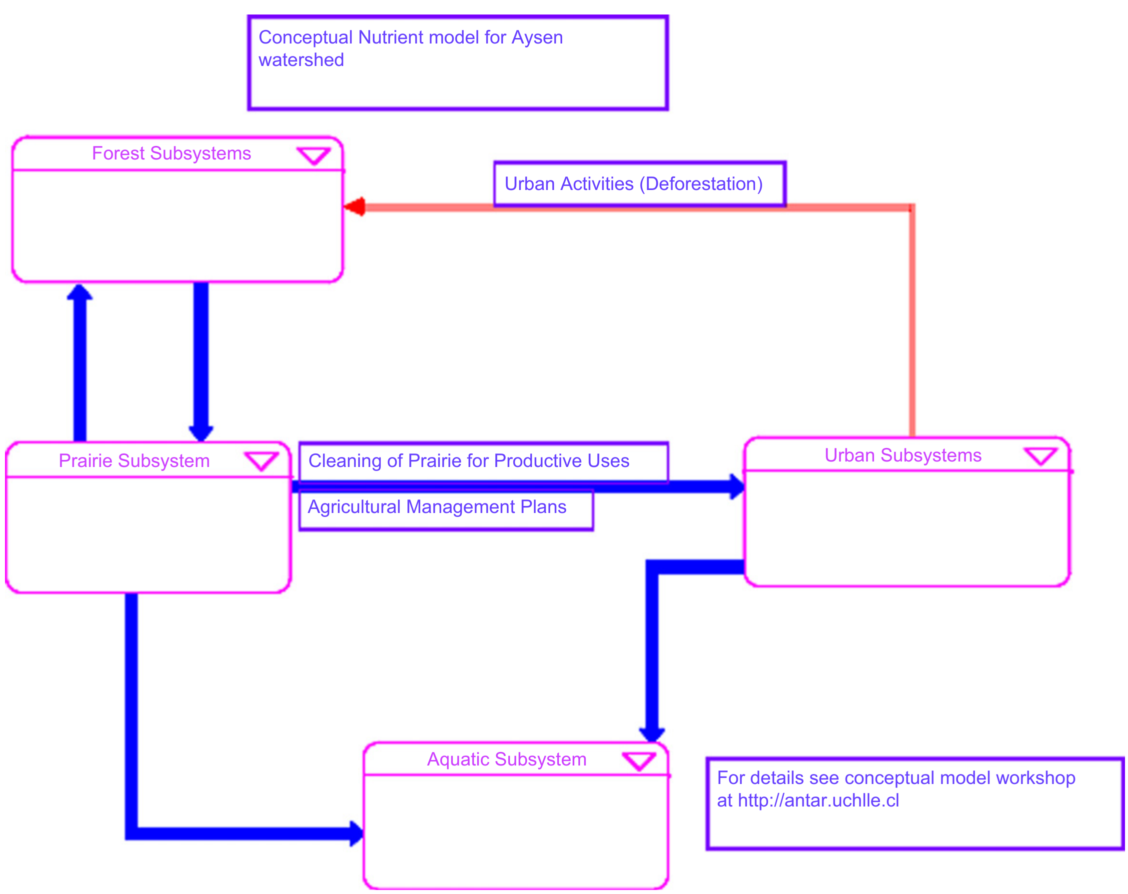

Fig. 5. General conceptual nutrient cycling model of Aysen watershed.

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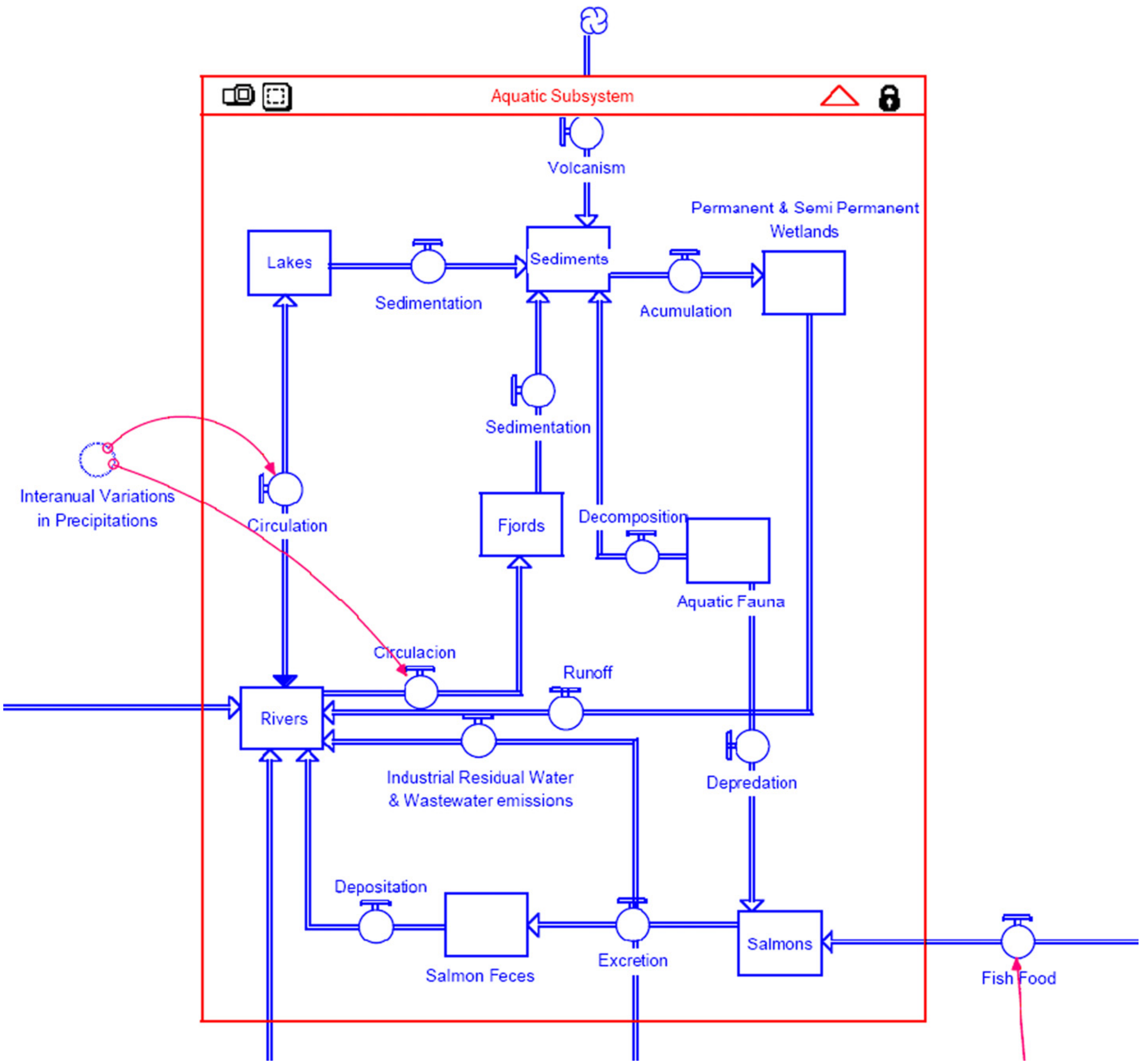

Fig. 6. Stella-coded conceptual PHES-system model of nutrient cycling within the aquatic subsystem of Aysen watershed.

for this submodel were proposed by individuals within the brainstorming session. Thus, the model represents an integration of their PHES-systems.

The generation of agreed conceptual models for the ecological systems of concern represents a powerful tool in their integrated management. The brainstorming technique used in this exercise effectively showed that it is possible to gather a rather heterogeneous and highly hierarchical group of people and to foster their interaction. The end results are conceptual models that can be used as the basis for both research and modeling and for integrated management.

6. Conclusion

In an article published in 2001, Ludwig (2001) has stated that "The management era is over". The main meaning of this assertion is that it is not possible to keep solving complex environmental problems using the sole advice of experts. Somehow, stakeholders have to become involved, not only in receiving advice, but in every aspect of the integrated management of ecological systems. However, despite the participation rhetoric that may be found in many articles, there are not many innovative proposals on how to incorporate stakeholders in integrated management

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from the beginning. In this paper we have shown the testing of a method, founded on the use of brainstorming techniques, to generate conceptual models that may serve as the basis of management. Heemskerk et al. (2003) had already proposed that conceptual models are promising tools for communicating among disciplines. We have moved the idea one step further and proposed that they can be used as tools for reaching the consensus necessary for the integrated management of ecological systems. Our results show that using brainstorming techniques as the first step of modeling allows for the interaction of people within highly hierarchical settings. The emphasis on withholding judgment of ideas makes this a rather promising methodology, especially when dealing with complex issues where different stakeholders (belonging to different segments of society, represented in this case by professors and students) have to reach agreements. If integrated management requires the participation of all stakeholders, then we have to generate the conditions for a peaceful exchange of ideas. This is rather timely, especially in Latin America where more than 90% of the regional economy is based upon the exploitation of natural resources (Marín and Delgado, 2005).

Our analysis of Aysén fjord and watershed showed us that contrary to our initial perception, people do not think or plan to recover the forests once burned during last century, and they do not have problems incorporating political components within a natural scientist's conceptual model. Basically, we as scientists are the ones requiring a shift of perception from a technocratic view of the world to a post-normal perspective. What do we loose? As clearly stated by Lee (1993), we loose our power quota; our position as the only people that understands ecological systems, their dynamics, future behavior and responses to human manipulation. What do we gain? a re-enchantment among non-scientists about the role that scientific knowledge may have in their day-to-day life and the integration of local knowledge into mainstream management science.

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References

Burt, G., van der Heijden, K., 2003. First steps: towards purposeful activities in scenatio thinking and future studies. Futures 35, 1011–1026.

Chermack, Th., 2004. Improving decision-making with scenario planning. Futures 36, 295–309.

Cundill, G.N.R., Fabricius, C., Marti, N., 2005. Foghorns to the future: using knowledge and transdisciplinarity to navigate complex systems. Ecology and Society 10 (2), 8 [online] URL: 〈http://www.ecologyandsociety.org/vol10/iss2/art8/〉.

Delgado, L., Marín, V., 2001. Bahía Mejillones: un ecosistema para conservar. Chile Acuícola 4, 23–26.

Freudenberg, W.R., Alario, M., 1999. What ecologists can learn from nuclear scientists. Ecosystems 2, 286–291.

Hartmann, P., 2003. Medio ambiente, comunidades, ecosistemas y salud humana y el caso del megaproyecto Alumysa en Aisén, Patagonia Chilena. URL 〈http://www.aisenreservadevida.cl〉 (last accessed: 10 November 2006).

Heemskerk, M., Wilson, K., Pavao-Zuckerman, M., 2003. Conceptual models as tools for communication across disciplines. Conservation Ecology 7 (3), 8 [online] URL: 〈http://www.consecol.org/vol7/iss3/art8〉.

INE, 2002. Instituto Nacional de Estadísticas. National Population Census 2002 [CD-ROM], Santiago, Chile.

Jones, S., 2002. Social constructionism and the environment: through the quagmire. Global Environmental Change 12, 247–251.

Kay, J., 2001. Ecosystems, science and sustainability. In: Ulgiati, S., Brown, M.T., Giampietro, M., Herendeen, R., Mayumi, K. (Eds.), Proceedings of the International Workshop: Advances in Energy Studies: Exploring Supplies, Constraints and Strategies. Porto Venere, Italy, pp. 319–328.

Lee, K., 1993. Compass and Gyroscope. Integrating Science and Politics for the Environment. Island Press, Washington, DC.

Ludwig, D., 2001. The era of management is over. Ecosystems 4, 758–764.

Marín, V., Delgado, L., 2005. El manejo ecosistémico de los recursos marinos vivos: Un desafío eco-social. In: Figueroa, E. (Ed.), Biodiversidad Marina: Valoración, usos y perspectivas. ¿Hacia dónde va Chile? Editorial Universitaria, Santiago, pp. 555–570.

Marín, V., Olivares, G., 1999. Estacionalidad de la productividad primaria en Bahía Mejillones del Sur: una aproximación proceso-funcional. Revista Chilena de Historia Natural 72, 629–641.

Mysiak, J., Giupponi, C., Rosato, P., 2005. Towards the development of s decision support system for water resource management. Environmental Modelling and Software 20, 203–214.

Nicolson, C.R., Starfield, A.M., Kofinas, G.P., Kuse, J.A., 2002. Ten heuristics for interdisciplinary modeling projects. Ecosystems 5, 376–384.

O'Neill, R., 2001. Is it time to bury the ecosystem concept? (With full military honours, of course!). Ecology 82, 3275–3284.

Ortega, H., Brünning, A., 2000. Aisén. Panorama histórico y cultural. XI Región. 2004. 〈http://www.aisenpanorama.cl/libro.htm〉.

Theobald, D.M., Hobbs, N.T., 2002. A framework for evaluating land use planning alternatives: protecting biodiversity on private land. Conservation Ecology 6 (1), 5 [online] URL: 〈http://www.consecol.org/vol6/iss1/art5〉.