Ethnoarchaeology of hunter-fisher-gatherers societies in the Beagle Channel (Tierra del Fuego): ethnographical sources and social simulation.

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Abstract
Research from the Beagle Channel (Tierra del Fuego) offers a rich ethnographic and historical record produced by the late inclusion of Tierra del Fuego in the industrial world (the Beagle Channel was discovered by R. Fitz-Roy in 1830). This is an interesting frame for using new techniques (social simulation by Agent Based Modelling (ABM)) to generate new hypotheses in archaeology. In this case, the hypothesis is focused on the role of social cooperation in Yámana hunter-fisher-gatherer society.

Resumen
<u>Etnoarqueología de sociedades cazadoras-pescadoras-recolectoras en el canal Beagle (Tierra del Fuego): fuentes etnográficas y simulación social</u>
La investigación etnoarqueológica en el canal Beagle (Tierra del Fuego) ofrece un abundante registro documental etnográfico e histórico producto de su tardía incorporación al mundo industrial (el canal Beagle es descubierto por R. Fitz-Roy en 1830). Este marco posibilita la aplicación de técnicas novedosas (simulación social mediante "agent based modelling" (ABM)) para la generación de hipótesis a contrastar arqueológicamente. En el caso de nuestro proyecto esa hipótesis versa sobre el papel de la cooperación social en la sociedad cazadora-pescadora-recolectora Yámana.

Résumé
<u>Ethnoarchéologie des sociétés de chasseurs-pêcheurs-cueilleurs dans le canal de Beagle (Tierra del Fuego): sources ethnographiques et simulation sociale</u>
La recherche ethnoarchéologique dans le Canal Beagle (Tierra del Fuego) offre un registre riche de documents historiques et ethnographiques come conséquence de son entrée tardive dans le monde industriel (le canal de Beagle est découvert par R. Fitz-Roy en 1830). Ce cadre permet l'application de nouvelles techniques (simulation sociale à l'aide de «modélisation de l'agent sur la base» (ABM)) pour générer des hypothèses à tester dans le registre archéologique. Pour notre projet cette hypothèse concerne le rôle de la coopération sociale dans les chasseur-pêcheur-cueilleurs Yámana.

1. Introduction: Archaeology of contact and invisible survival strategies.

In recent years, different researchers have opened a fruitful field of debate related to active nature of indigenous societies in the process of European colonization of the Americas. A critical revision of different approaches and terminologies was undertaken providing a strong stimulus to theoretical and methodological development (see, for example, Lightfood 1995; Silliman 2005 and 2009; Martindale 2009). As a result, two valuable issues were highlighted in colonialism and cultural encounters research.

Firstly, the agency of indigenous people was put on the agenda of colonialism inquiry (Lightfoot et al., 1998; Martindale 2009). Many of the traditional studies overemphasized the repressive role of the European nations overlooking, at the same time, the creative strategies developed by native societies to face new changing scenarios.

Without downplaying the oppression and the inequalities embedded in the colonization process, the new approaches brought into focus the need to overcome the assumption that considered indigenous societies as simple recipients of new ideas and practices (Silliman 2005; Stein, 2005). The notion of acculturation was deeply questioned since it emphasized the passive role of native societies and provided a static picture of colonial process denying its dynamic nature. In contrast, concepts such us "*entanglement*" (see Martindale 2009), made explicit the decision-making process and the negotiation abilities of the native peoples.

Secondly the recognition of the dynamic and bidirectional effects of colonial encounters led to reject the atomist view of colonialism as an exchange of material objects from European to Native American societies. Several authors clearly showed that the outcomes of these social interactions did not only involve the passive adoption of certain cultural items such as glass or metals; instead of it, it implied a complex set of variables, practices and values performed by individuals in an historical and shifting context (Silliman 2005).

Following these ideas grounded in methodological improvement, we started a project addressed to establish if the development and the hypothetical intensification of cooperative activities were a strategy to strengthen social ties and to make a more profitable and productive use of resources by hunter-gatherer and fishing societies who inhabited the uttermost part of South America to face Colonization. In contrast with what happened in other parts of the American continent, this region had a scarce interest to the objectives of Mercantilist nations at the first phases of the Colonial period, between the XVIIth and the beginning of the XIXth centuries: it was envisioned like a point along a route that communicated the Atlantic and the Pacific Oceans. Consequently, during these times the encounters were discontinuous and sporadic (see below).

The perceptions and images built up by Western societies of the indigenous people, the socio-economic dynamics developed by the Mercantilist-Capitalist world and the effects of missionary activities have been deeply studied (Orquera & Piana, 1992 and 1999a). It is well-known that the overexploitation of sea lions undertaken by Euroamerican sailors to take advantage of their fur and fat had a strong impact in hunter-gatherer economies. However, the strategies developed by the native societies to deal with the new scenario provided by the colonization are not fully understood yet.

In order to assess if cooperation was an internal mechanism to promote social integrity within a hunter-gatherer-fisher society to face a critical situation fueled by colonialism, we are undertaking a multidimensional ethnoarchaeological approach that includes the interplay of archaeology, ethnography and computer simulation as well as several methodological steps (Briz et al. 2009; Zurro et al., 2010).

The use of ethnographic sources has been a long-standing practice in Contact Archaeology of the Americas. Several authors include this analytical tool within the field of "ethnoarchaeology" (Gould, 1980; David & Kramer, 2001; Briz et al., 2006). Currently, the debate in ethnoarchaeology and archaeology is focused on two problems: the aims and limits of ethnoarchaeology that includes the use, or not, of historical sources as basic element of this research (Estévez & Vila, 1996; Vila et al., 2007; Briz, 2010; Briz & Vietri, 2011) and, secondly, the correct use of analogical reasoning to avoid the danger of direct analogy as an interpretative tool without a proper control of historical contexts (Gándara, 2006). The separation between both methods –the use of "living societies" data or historical data (Harkin, 2010)– is not relevant for the final aims of this research proposal. We consider that ethnoarchaeology is an archaeological method to improve techniques as well as to provide hypotheses to test against the archaeological record (Estévez & Vila, 1996; Gándara, 2006;

Briz, 2010). At the same time, we can obtain a critical revision of the ethnographical and historical documents (Lightfoot, 1995; Estévez & Vila, 1996 & 2006) to assess changes related to the colonial period.

Within our framework, the critical use of ethnohistorical sources is the starting point to accomplish a threefold objective: a) to develop applicable models and methods to understand material culture variability; b) to provide data for building up models for computer simulation; c) to obtain historical information of hunter-gatherer practices to compare with archaeological databases with the aim to detect changes and continuities.

From an archaeological perspective, we intend to identify the anthropic markers of a social aggregation event process in order to unveil the cooperative activities carried out. This approach involves the study of the production-consumption practices developed and their spatial organization (Briz et al., 2009).

The Computer Simulation approach is undertaken to analyze, in a temporal framework, the historical development of cooperation. Computer Simulation is a scientific tool that allows us to investigate different complex systems by means of the construction and implementation of computational models. It was already used in the 40s of the last century in disciplines in which great amounts of calculation were needed, such as Nuclear Physics or Meteorology. After that, the use of computational models and complex systems simulation has spread to the Life Sciences and the study of complex biological systems (Miller & Page 2007) and, finally, to the study of human societies. In Archaeology, even though research programmes employing Computer Simulation are still scarce, its use is currently growing (Lake 2000; Costopoulos & Lake 2010; Kohler & Van der Leeuw 2007). Archaeology benefits from this perspective due to an enhanced understanding of collected data in order to link that record more precisely with the formulated hypotheses/assumptions. It also makes the analysis of the results easier, since computer models allow us to represent extremely complex patterns through the interconnection of simple computer mechanisms. Finally, in some cases, computer simulation can even suggest new avenues for future empirical research by showing that certain models inferred from empirical data –possibly written in natural language– may be underspecified, and by pointing out in which precise way they may be so (thus indicating where there is a need for further empirical research).

Likewise, Archaeology returns a great benefit to Computer Simulation as it is able to generate information about past social processes, ranging from a short temporal rate (e.g. days) to thousands of years (Shennan, 2002). Consequently, the contribution to the analysis of complex systems is considerable. The methodology applied in Computer Simulation is similar to that applied in experimentation: first, there is a selection of a set of assumptions, aimed at solving a concrete question. Such assumptions a) need to be formalized (i.e. written in a formal –unambiguous– language) and b) must be sufficient to shape and unfold a complete dynamic story (i.e. no significant details can be left behind) in order to have a fully operational computer model that can be run. In many cases, such requirements for formalization and for completeness (i.e. everything needed for the computational model to be run must be formally specified) suffice to uncover implicit or vague assumptions that were not made explicit before this process. Thus, the mere effort of trying to design a computer (and therefore formal) model is most often, only by itself, a tremendously useful exercise to increase the clarity and rigor of the scientific endeavor. Once the model is fully specified and implemented, it is run –as a virtual laboratory– as many times as necessary, varying initial conditions to create different scenarios in which to explore the logical implications of the assumptions embedded in the model and the effect of the different parameters on it. The following sections elaborate this argument and illustrate it by sketching a sample simulation model.

2. Modeling, formal modeling, and agent-based modeling

In very general terms, one could argue that the ultimate goal of Science is to advance our knowledge about the world we live in. One could also argue that the way we –scientists– try to understand this world (or at least certain aspects of it) is by developing models. A model, understood in this admittedly broad sense, is an abstraction of an observed system that enables us to establish some kind of inference process about how the system works. The process of abstraction starts with a thorough observation of the target system (including, most often, the collection of data), and ends with the design of the model. Building the model requires distilling the essence of the real-world system we try to understand, by purposefully ignoring those aspects of the system that we do not deem fundamental for our aims. Thus, some of the complexity of the target system is deliberately abandoned with the intention of obtaining a simpler representation of it, which will be –ideally– more manageable and comprehensible than the original target (see e.g. Hesse 1963 and Hughes 1997).

Naturally, models understood in this general sense can be of the most diverse kind. In particular, models can be written in natural or formal languages. One approach is not necessarily more adequate than the other, not even for one particular system, since the two alternatives exhibit fundamentally different benefits and limitations.

Models written in a natural language tend to be more descriptive, richer in details and subtleties, and therefore more realistic and faithful to the original target. However, it is this very wealth of niceties, which often makes it difficult to assess the completeness and logical consistency of the set of implicit –and potentially ambiguous– assumptions that underlie the foundations of such non-formal models.

At the other end of the spectrum, we find simple formal models, which have traditionally been written in mathematical languages, most often in the form of sets of equations. These models are certainly more tractable –since they are often built precisely for that purpose– and allow for a formal and rigorous inspection of their logical consistency, and for an exhaustive analysis of their logical implications. However, these mathematical models tend to be less realistic than models written in natural language due to the simplifying assumptions that must be made in order to achieve the longed tractability.

With the advent of computer simulation, a middle avenue seems to have opened up. Computer models can accommodate much of the descriptive richness that is often lost in mathematical models, whilst still keeping their analytical rigor –since they are also written in formal languages. This means that their logical consistency can be easily assessed, and one can use powerful computers to thoroughly explore the logical implications of the assumptions that are embedded into the model. Thus, using computer simulation we have the potential to build models that –to some extent– combine the intuitive appeal of theories written in natural language with the rigor of analytically tractable mathematical modeling (Axelrod, 1997).

Within the realm of computer simulation, there is one approach that has proved to be particularly useful to model social processes where interactions among agents –and between agents and their physical environment– play a crucial role; namely agent-based modeling (Gilbert, 2007). What distinguishes agent-based modeling from other modeling paradigms is the way we construct our abstraction of the observed system (Edmonds, 2000). The idea in agent-based modeling is to establish a direct correspondence between agents in the target system and their representation in the model, and also to establish a more direct correspondence between the interactions among agents in the target system and the interactions among their representations in the model. This is in contrast to other modeling approaches where some entities are represented via average properties or via single representative agents.

So, to be clear, in agent-based modeling entities within the target system are represented explicitly and individually within the model. The boundary of the entities in the target system corresponds to the boundary of their representation in the model, and the interactions between entities in the target system correspond to interactions between their representations in the model (Edmonds, 2000). This modeling approach has the potential to be a step forward towards both realism and rigor, providing a more natural and transparent –yet formal– representation of the target system. Admittedly, however, it is not exempt from disadvantages: models constructed in this way are very often intractable using mathematical analysis so, whilst still formal, the analysis of these computer models cannot be –in general– as exhaustive as the one performed on simpler mathematical models.

Within the context of archaeology, agent-based modeling is particularly appropriate because it allows us to address the following issues in a formal way:

- The importance of heterogeneity among agents (Axtell, 2000). The use of representative agents –which is common in disciplines such as Economics– is particularly inappropriate in archaeology, given the significance of diversity in human societies.
- The crucial role of the specific features of the physical environment under study, of how this environment conditions the social fabric of the societies that live on it, and of how these societies shape the environment back (Epstein and Axtell, 1996).
- The importance of adaptation or innovation, both at the level of individual agents and at the level of social groups as distinct and identifiable units.
- The significance of social networks which are often spatially structured.
- The importance of addressing the bidirectional relationship between the attributes and behaviors of individuals (the “micro” level) and the global properties of social groups (the “macro” level) (Gilbert and Troitzsch, 1999).

The next section explains the background of the particular question we try to investigate using computer simulation.

3. The Yámana society of Tierra del Fuego: a case study.

Environmental setting

Isla Grande de Tierra del Fuego is located at the 54º Southern hemisphere, and takes part of a labyrinthine group of islands and channels lying between the Atlantic and the Pacific Oceans, the Magallanes Strait at the North and Drake Passage at the South (between Cape Horn and Antarctica).

The climate is highly oceanic and the seasonal without marked variations between summer and winter (Tuhkanen, 1992). Persistent rainfall, low temperatures and regular winds characterize meteorological conditions all year round (Heusser, 1989); while snow is more common during the winter (long moderated mild) than summer (short and cool). The southernmost islands possess a sub Antarctic climate. The geomorphological landscape comprises mountains, meadows and coasts of the different channels modeled by last glaciations effects and postglacial changes (Rabassa et al., 2000). Magellanic subpolar forests covered extended on the south while the steppe on the north (Zurro, 2010).

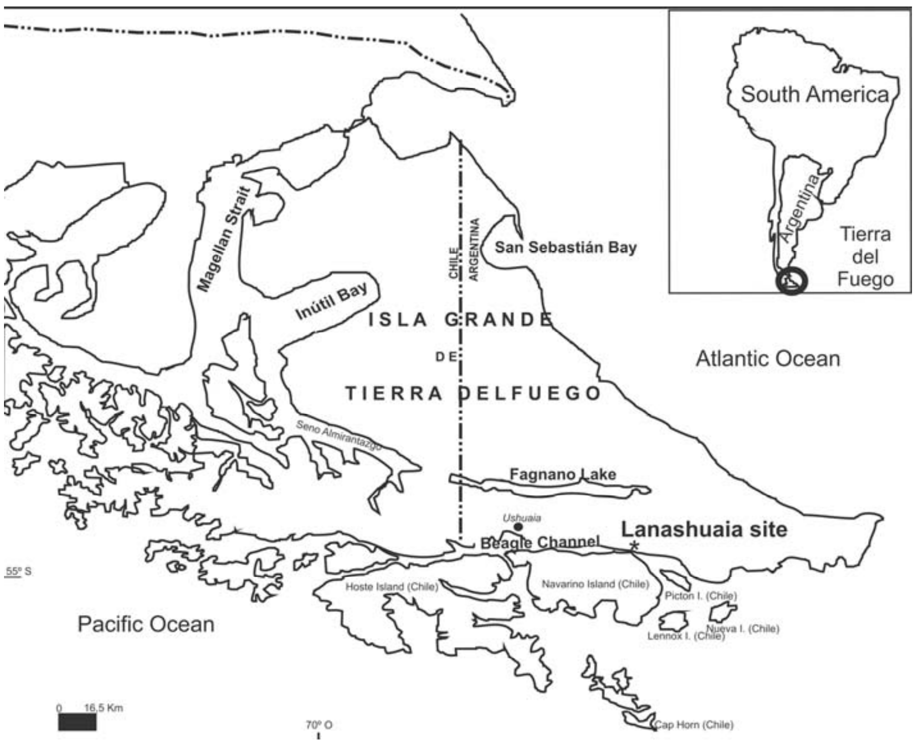

Figure 1: Map of Tierra del Fuego.

The contact period in Tierra del Fuego

From the first moment of the European discovery, Tierra del Fuego was considered a land "out of the world". The latitude, the climatic conditions and the lack of the resources required by the colonist nations did not offer any special interest to European colonization. Starting with the first European visit of Magallanes-Elcano expedition (May, 1520) until the British Empire got interest for its worldwide strategies in the XIXth Century, all the historical references about Tierra del Fuego and its inhabitants were characterized by a negative perception under the perspective of a an aggressive environment (Darwin, 1839; Fitz-Roy, 1839; Emperaire, 1963; Gusinde, 1937; Orquera & Piana, 1995; Estévez & Vila, 1997). Basically, Tierra del Fuego could not offer any interesting resource for the European colonization of America: previously to the Industrial Revolution, it was just considered just as a traffic area between the Atlantic and the Pacific Oceans (Belza, 1974; Fernández, 1990; Ortiz-Troncoso, 1990).

Despite the sporadic visits of different ships or expeditions, the enclosure of Tierra del Fuego in the World-system (Wallerstein, 1979) was effectively developed in the XIXth Century within the frame of the emergence of global empires supported by safe trade routes and intense commercial structures that included the strict control (not only direct control) of strategic sailing points (Briz, 2004). The Beagle Channel was discovered in the first expedition of HMS Beagle on April, 1830 (under the command of R. Fitz-Roy (1839)).

In the case of the southernmost portion of Tierra del Fuego, the first industrial pressure was focused on the exploitation of sea lions by Euroamerican populations. As a consequence, an indirect competition with native populations started since the activities of Euroamerican hunters were basically developed outside of the Fuegian Channels (Orquera & Piana, 1999a). The beginning of missionary activities by the South American Missionary Society was an important inflectional point (the mission in Ushuaia was established in 1869: Gusinde, 1937) and, subsidiarily, in the Falkland Islands (Gusinde, 1937; Chapman et al., 1995; Salerno & Tagliacozzo, 2006). Similarly to other colonization processes, the following step was the exploitation of immediate natural resources by permanent immigratory population, specially farming activities, followed by a gold rush in the period of 1883-1909 (Gusinde, 1937).

Figure 2. The Beagle Channel from the northern coast near *Lanashuaia*, in the Bahía Cambaceres Exterior (Picture: I. Briz).

Finally, in 1884 the city of Ushuaia was founded as a part of the colonizing race between the South among Chilean and Argentinean Republics. The progressive increase of the industrial society presence in that area followed the same trend very similar to other colonization processes: social dislocation epidemics, alcoholism, prostitution, high mortality and social marginality (Chapman et al., 1995; Vega & Grendi, 2002).

This belated colonization produced a “high-resolution” record by ethnography and ethnology: ship’s logs, missionary reports and letters, pictures, draws, and many tools or objects are at present times placed in museums or private collections around the world (Estévez & Vila, 2006; Vietri, 2010). Regarding ethnographical documents, three sources are really relevant: the personal diaries, letters and reports from the missions of the South American Missionary Society (Orquera & Piana, 1999b); the French scientific expedition “Mission Scientifique du Cap Horn” developed between 1882 and 1883 (Hyades & Deniker, 1891) and, finally, the ethnographical research work about native societies carried out by M. Gusinde (1936) in the Magellan-Fuegian area in the 20’s and 30’s of the XXth century.

But, at the same time, a second trait is specially interesting for us: different from the same dynamic of conflict in North America in the same period (the colonization of the Far West by the United States of America: O'Sullivan, 1839), the Fuegian societies (and, specially, the hunter-fisher-gatherer society of the Beagle Channel) had no contact with other farmer societies: the dynamic of conflict was strictly developed between the Capitalist world (in a classical sense) and hunter-gatherer societies. Consequently, any social re-organization or new dynamic was produced as a reaction to the situation of conflict, departing from its own socio-historical resources and innovative dynamics (Estévez et al., 2002).

The Yámana Society.

From the 7000 BP, hunter-fisher-gatherer societies inhabited the Beagle Channel and southern Channels between Cape Horn and the Beagle Channel from the Atlantic to the Pacific Oceans (Orquera et al., 2011). These groups were named Yámana (Gusinde, 1937) or Yaghán (Bridges, 1987) by the XIX century ethnography (Furlong, 1917).

Parker King and Fitz Roy expeditions on board of the HMS Beagle (Fitz-Roy, 1839) were the final point of a period characterized by sporadic contacts between crews and Fuegian hunter-fisher-gatherers that started in January of 1624 (Gusinde, 1937). The society "discovered" in the Fuegian channels in the historical period (XVII-XIX centuries) was portrayed by visitors and first ethnographers as users of a plain technology, focused on the exploitation and management of coastal and marine resources, with a high level of mobility based in nautical technology (Hyades and Deniker, 1891; Gusinde, 1937). The use of canoes established a pattern of subsistence at regional scale based on the consumption of marine mammals (South American fur seal: Arctocephalus australis; Zimmerman, and sea lion, Otaria flavescens; Shaw), shellfish, fishes and stranded whales. At the same time, Yámana people also hunted terrestrial mammals such as guanaco (Lama guanicoe; Müller), coastal birds such as kelp gull (Larus dominicanus; Lichtenstein) and albatross (Diomedea exulans L.) and collected plants and mineral resources from the inland areas (Gusinde, 1937). Because of this, the canoe is the most evident material expression of the essential social unit of production and social reproduction in the Yámana society, which is very close to the familial structure (Gusinde, 1937). The XIX and XX centuries ethnography considered as another principal trait of this society the absence of protective costumes and the extensive use of fire for maintaining body temperature (Fitz-Roy, 1839; Hyades & Deniker, 1891; Gusinde, 1937).

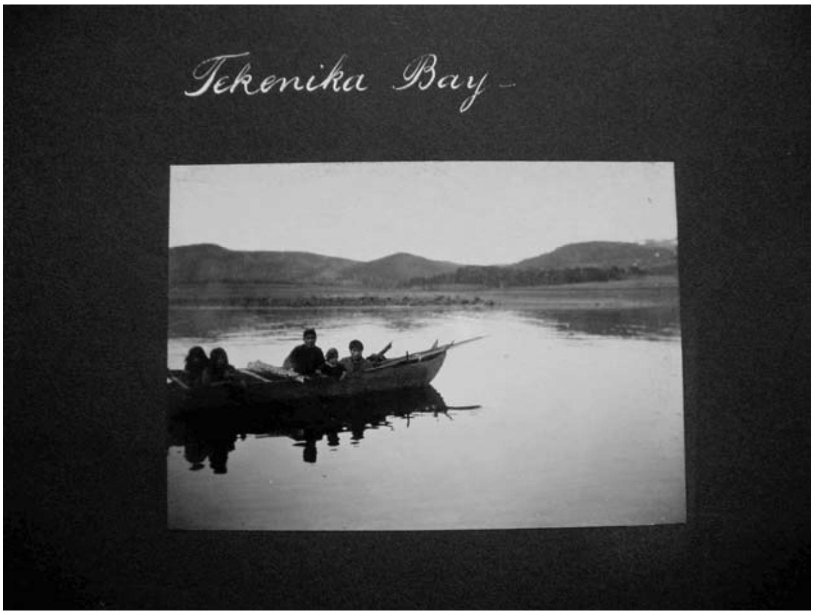

Figure 3: Yámana people into a canoe in Tekenika (Hoste Island), in the XIXth century (Courtesy of South American Missionary Society).

Regarding social organization, Yámana society has been traditionally considered egalitarian not only within the essential social units (family/canoe) but also in relation to other people as other hunter-gatherer societies (Darwin, 1839; Gusinde, 1937; Orquera y Piana, 1999). Some works addressed the social relations on this society consider, using computational techniques, that dissymmetric relations among women and men cannot be considered egalitarian (Barceló et al., 1994). In any case, many ethnographical sources indicate the relevance of social cooperation and, at last, of the solidarity between different people without familial relationships: some of the works could be, or must be, developed under conditions of cooperation between adults (e.g. building canoes (Hyades & Deniker, 1891; Gusinde, 1937), hunting guanacos (Bridges, 1878; Orquera & Piana, 1999b: 142) or hunting birds (Fitz-Roy, 1839; Hyades & Deniker, 1891). The most relevant aspect of this social dynamic is showed in the case of the duty of food sharing: many ethnographical sources indicate specific and emphatic rules about that (Hyades & Deniker, 1891; Gusinde, 1937; Orquera & Piana, 1999b: 194-196), with special incidence of that in initiation ceremonies of young people, called *Ciejaus* (Gusinde, 1937).

The most clear example of this social dynamic is produced in the case of a cetacean stranded or massive fishes stranding (called *iacasi*: Bridges, 1987) on the coast.

In the first case, a big quantity of food and raw materials were available. Following different ethnographical sources and missionary records, when someone discovered the cetacean or the *iacasi*, he/she made smoke signals to communicate this availability of food and materials to people located at long distance (Gusinde, 1937). This level of social cooperation was strongly consolidated: even people without the possibility to move to the place of the stranding, and located at a long distance, received portions of the whale (Bridges, 1872, quoted by Orquera & Piana, 1999b: 196).

This availability of food and raw material offered exceptional conditions for a social aggregation episode where common labor, social networks and ritual ceremonies were developed (Gusinde, 1937). In any case, in spite of traditional visions of ethnology (Gusinde, 1937) supporting a vision of "common life" of Yámana people closest to isolated canoes with sporadic episodes of aggregation, we consider, following some notes of the missionary T. Bridges (MS) that aggregation episodes were more recurrent than that.

Figure 4. Stranded whale in July 2012, Peninsula of Ushuaia (Courtesy of Dr. Luciana Ricciardelli).

This ethnohistorical case offers a promising frame of research for an agent based modeling simulation experiment aimed at understanding maintenance of social cooperation. Our experiment attempts to discover the evolution of social cooperation in a case of a cetacean stranding and, at the same time, the attitudes that were performed in relation to solidarity and disaffection (Santos et al., 2012).

4. The Simulation Model

To illustrate the potential usefulness of computer simulation in the field of archaeology, this section presents the main features of a simple computer model that has been specifically designed to assist researchers in exploring social cooperation and competition among the *Yámana* People. The model –named WWHW (acronym for **W**ave **W**hen **H**ale **W**hale)– is a spatially-explicit agent-based model in the sense that *Yámana* families are individually represented in the model, and their physical environment is also explicitly represented using a two-dimensional grid (see figure below).

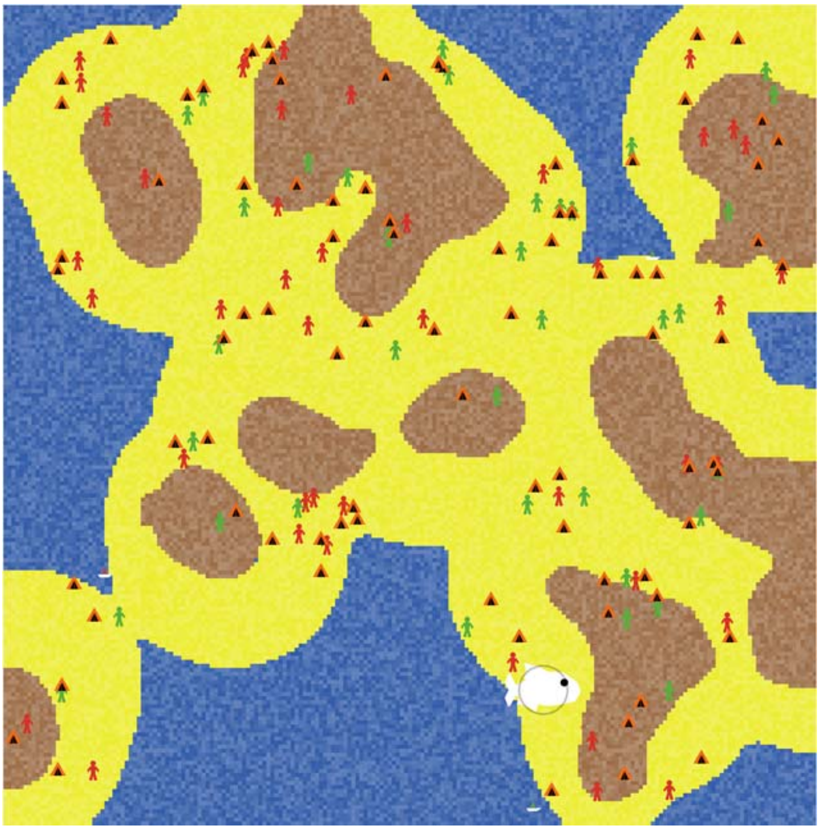

Fig. 5. Snapshot of WWHW. Blue patches represent the sea, yellow patches represent beaches, and brown patches represent elevated land. Beached whales, which are colored in white, may be seen by nearby families, who may decide to make a public call for the whale or not. Families are represented by human figures; green figures represent cooperative families, whilst red figures represent non-cooperative families.

Families in the model move around the coastal environment, either by foot –when they walk over the land surface– or by canoe –when they travel by sea. The mobility of the families is not necessarily the same when they travel by foot as when they paddle on the sea, a feature of the model that allows for the exploration of the impact of geography on the evolution of the society.

From time to time, a whale beaches on land, and canoes which are nearby are able to see it. The range of vision of the families is a parameter in the model. Once a family has seen a beached whale, they will travel towards it, and decide whether to make a public call to let other families know about the exceptional amount of resources just found or not. Cooperatives families always make beached whales public, whilst non-cooperative families do not. The range of the signal made when a cooperative family makes a beached whale public is also a parameter of the model.

When several families gather around a beached whale, they all gain social capital. Thus, the decision whether to make a beached whale public is not trivial. If a family uncovers a whale, they will not be able to get as much meat from the whale as they could if they hid their discovery; on the other hand, if a family launches the public signal, they will benefit from knowledge sharing with more peers and increase their social capital more than if they had not called others. How much a particular family increases their social capital depends on how many other families there are in the gathering, and may also depend on the family's past actions via their reputation. Cooperative families enjoy a higher reputation, and this implies that they increase their social capital at the gatherings at a greater rate than non-cooperative families. Thus, the reasoning above (which is admittedly somewhat simplistic (there are subtleties uncovered by the computer model which qualify these arguments) seems to suggest that non-cooperative families will tend to accumulate more meat, whilst cooperative families will tend to build up more social capital. The relative importance of meat versus social capital is another parameter of the model, which is used to reduce these two variables into one single measure of performance –or fitness. Finally, the model includes an imitation process by which the least fit families tend to copy the behavior (i.e. either cooperative or non-cooperative) of those families that are doing better.

Thus, once the model is parameterised, it can be used to explore whether certain conditions lead to cooperative societies or not. Importantly, we believe that the computer model is best used as a "*tool-to-think-with*", i.e. it is not meant to provide precise quantitative predictions, but to assist us in understanding the reasons why the *Yámana* People cooperated and called each other when they found extraordinary accumulations of resources under different circumstances. At the end of the day, the model is just a set of various assumptions that we scientists have implemented, and which are so intricately interweaved that we are unable to envisage their logical implications. Thus, the computer becomes a tremendously useful inference tool that enables us to explore the logical consequences of our hypotheses and, in this way, assists us in distilling the role played by different factors (e.g. scarcity and variability of resources, geography of the environment, vision of social units, reputation, etc.) in promoting or hindering the emergence of aggregation events in the *Yámana* society.

5.-Conclusions

Our experience using computer simulation in Archaeological research is proving certainly fruitful for a number of reasons. For a start, designing the computer model forces oneself to distil the very essence of the arguments needed to deal with the archaeological question at hand –abstracting from the details that are not deemed strictly necessary for the case–, and to do it in a logically consistent and unambiguous manner. Furthermore, the model must also be complete in order to be run, i.e. the design must include sufficient detail to provide a complete story; in other words, there can be no loose ends in the logical reasoning used to build the model. Once the model is designed and implemented, it can be usefully employed to explore the logical implications of the hypotheses embedded in it –and the impact of various factors– with much greater confidence, rigor and speed than we would have to do it if we did not have computers. Importantly, this computational exploration often reveals the importance of assumptions that were deemed insignificant at the beginning of the modelling process, an observation that has the potential to turn into valuable knowledge to guide further empirical research. To be clear, in most cases there are many possible computer models (i.e. sets of formal assumptions) which comply with the initial requirements derived from the empirical research, in the sense that they seem equally valid instantiations of the conceptual model that the archaeologists have in mind. In other words, these models only differ in details that are considered irrelevant for the archaeological question to be solved. An issue that occurs with surprising frequency appears when such apparently equally valid models produce significantly different results. The conclusion to draw in such cases is clear: there are assumptions in those models which were considered irrelevant and are actually crucial.

Consequently, there is a need to investigate which of such competing assumptions is more appropriate to consider, a question that can only be informed by empirical research. Thus, it is clear that there is a lot to be gained by using empirical research and computer simulation together, and the synergies are particularly evident in empirical fields with little tradition in the use of formal models, such as Archaeology.

One of the most common critics to Archaeology is the absence of relevant knowledge about social dynamics and relationship in the past. Some of this absence of effective explanation about human past is produced by the strong relationship, even nowadays, with the chronocultural and classifying perspective. From our point of view, the use of ethnoarchaeological way in combination of ABM simulation, can offer a strong frame for proposing new hypotheses and perspectives to explore the social dynamics in hunter-gatherer societies.

The use of this type of new exploratory tools can lead our archaeological research to development of new methods and techniques focused on specific results which could be ultimately confront with the archaeological record.

In the case of contact studies and the strategies developed by Yámana people to deal with the new scenario set up by the colonization process, simulation models allow us to trace a very proactive scene: the diversity of social innovations in hunter-gatherer societies in a dynamic contact context. Specifically, we attempt to disentangle if the increase/decrease of cooperation practices in a critical situation has been a key element to explain the historic trajectories of those societies. Thus the traditional vision of the passive role of colonized societies can be challenged.

Acknowledgments

We would like to thank the following funding bodies for their support:

-Ministerio de Economía y Competitividad de España. Project: “Social and environmental transitions: Simulating the past to understand human behaviour (SimulPast) **(**CSD2010-

00034)” and “Marcadores Arqueológicos de Relaciones Sociales: etnoarqueología de cazadores-recolectores en el Canal Beagle (HAR2009-06996)”.
-Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina. Project: “Procesos de agregación social entre las sociedades cazadoras-recolectoras del canal Beagle: nuevas metodologías de análisis (PIP0706)”.
-The Wenner-Gren Foundation for Anthropological Research. Project: “Social aggregation: a Yamana Society’s short-term episode to Analyse Social Interaction.”

The authors specially appreciate the help and cooperation offered by Dr. Natalie P. Goodall and the Bridges-Goodall family, who offered us the opportunity to access the personal documents and diaries of Rv. T. Bridges.

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