Archaeological spatial modelling
A case study from Beagle Channel (Argentina).

Juan A. Barcelo
Divisió de Prehistoria. Facultat de Lletres. Edifici B
Universitat Autonoma de Barcelona
E-08193 Bellaterra, Spain
E-mail: ilphd@blues.uab.es

Ernesto L. Piana
Centro Austral de Investigaciones Científicas
Av. Malvinas Argentinas s/n
V9410BFD Ushuaia, Tierra del Fuego (Argentina)
E-mail: arqueologia@tierradelfuego.org.ar

Daniel R. Martinioni
Subsecretaría de Planeamiento
Gobierno de Tierra del Fuego
Antártida e Islas del Atlántico Sur
E-mail: danymart@satlink.com

Abstract: Social actions are always performed in locations intrinsically better or worse for some purpose, because of their position relative to another location used for any other action or for the reproduction of the same action. The objective is to analyse how a social action "varies from one location to another". The analysis then pretends to examine if the characteristics in one location have any relationship with those of a neighbouring location. This goal can be made possible through the definition of a general model of spatial dependence. In other words, the main objective of spatial analysis should be the spatial correlation of different social actions: how the spatial distribution of an action has an influence over the spatial distribution of other action(s).

This paper discusses the probabilistic nature of spatial causality. Once it is known whether social actions at neighbouring locations are similar or not, it can be explained why the location of social actions are homogeneous or heterogeneous in the area defined by the performance of that actions. That means that spatial causality can be studied in terms of the "influence" landscape features have over the location of social action or the "influence" the location of social action has on landscape features.

The discussion is presented with the help of an intensive and extended archaeological survey of shell-middens, ranging from 6000 ^{14}C years B.P. from the northern coast of Beagle Channel, Tierra del Fuego (Argentina): "the uttermost part of the world".

Key words: Spatial Archaeology, Settlement Patterns, Hunter-Gatherer, American archaeology, Correspondence Analysis

Hunting, fishing and gathering at the Beagle Channel

The southernmost extremity of the Americas was the last major landmass to be settled by human beings. This area has always been dominated by hunting-fishing-gathering economies. In Tierra de Fuego neither agriculture nor fully-fledged pastoralism ever emerged. However, it would be a mistake to characterise those populations as an "archaic" adaptation to hard environmental conditions (Orquera & Piana 1996; 1999a). The idea of this paper is to show how simple environmental determinism and easy generalisation are misleading.

When the first Europeans arrived, the South American territory southward from 34°S latitudes was inhabited by nomadic hunter-gatherer groups with a subsistence economy whose environmental adaptation patterns differed. Europeans found two fundamentally contrasting socio-economic systems, which can be characterised as the "terrestrial" and "canoe -or- sea nomad" cultures. The terrestrial people focused on the exploitation of terrestrial big mammals -mainly guanaco-, whereas the subsistence of "sea nomad" people was heavily dependent on the consumption of sea mammals, mussels, marine birds, and fish (Estévez & Vila 1995; Orquera 1999a; Orquera & Piana 1999a; Piana *et al.* 2000). When the opportunity presented, however, "sea nomad" populations hunted otters or pursued terrestrial mammals, and terrestrial hunters had access to coastal resources.

Isotopic dates suggest that human populations have been exploiting coastal resources for the last 6200 uncorrected radiocarbon years (Orquera & Piana 1999b). The beginning of such life style was not much older (Orquera & Piana 1988), with

the oldest population covering at least down to the southern coast of Navarino island (Legoupil 1995). With an unknown sort of navigation device, they were capable of sea travelling from the very beginning of their colonisation (Piana 1984; Legoupil 1993; Piana & Orquera 1998), but known data of their presence as far south as Cape Horn is restricted to later moments (Legoupil 1993). Steep relief and tangled unending woodland appear unattractive for human settlement, since they provide few vegetable or animal food-resources. Abundant littoral resources largely counteract that fact: pinnipeds, molluscs, occasional stranded cetaceans, sea birds, fishes, crustaceans, etc. There, abundance, concentration, predictability and the diversification of resources provide enough food to support relatively dense populations with high mobility within small ranges (Orquera & Piana 1999b, Piana et al. 1992).

This paper deals only with the exploitation of coastal resources and spatial properties of human settlement along the northern shore of Beagle Channel. Massive accumulations of shellfish constitute the main archaeological evidence in the area. Within them, remains of many other activities such as other resources processing, fires either for cooking or heat, lithic chipping, bone instrument making, and so on, have always been found (Clemente 1997, Piqué 1999). Fires for cooking and warmth were tended inside the huts and the refuse, primarily the quickly accumulated shells, were tossed outside huts. In this manner the depressions were maintained and served as partial shelter from the wind (Orquera & Piana 1992). Archaeologically, these structures may appear as domes, annular structures, thinner lenses, or a combination of them, containing an inordinate amount of charcoal and humus in comparison with intervening midden consisting mainly of shells and giving way to a hummocky topography (Orquera & Piana 1991).

The spatial nature of social action

Social actions are performed in specific locations because of their position relative to another location used for any other action or a reproduction of the same action. Consequently, actions performed at one location may have some relationship with actions performed at a neighbour location. For instance, when an action is performed *here*, it increases the probability of some posterior action and decreases the probability of some others. Therefore, if the location of action influences, conditions or determines the location of other actions, we can calculate a general model of spatial dependence.

In this case, the action we are studying is *settlement*. Humans decide the location of their settlements according to many reasons, but more specifically we make "placement" decisions based on the social strategies for resource management in the area around the settlement. What means a sophisticated effort balance between social needs, available techniques and resources?

Since the human population under study concentrated on the consumption of marine resources, it is to be imagined that settlements were mostly concentrated along the shoreline. The question to be solved is how and in which way did the natural configuration of the coast and coastal landscape, and local availability of resources along the northern shore of Beagle Channel determine human settlement during the last six millennia.

Traditional conceptions about hunting-gathering argue for the axiom that space determines settlement. That is, that settlement is a consequence of the environmental features or spatial properties of resources. In this sense, the distribution of sea nomads occupation of this region (*sensu* Orquera & Piana 1999b) -when no other factors like exposition to stormy open sea limited the constant peopling- coincides with the distribution of austral beech forest. Other than the marine resources, the sea nomad's life style relied heavily on the availability of extensive amounts of firewood and large trees. This explains why the territory of those populations dependent more on maritime resources extended only as far as the distribution of forest permitted (Orquera & Piana 1988). This fact underlines the fundamental role of wood and tree bark for these cultures, of which they used to make items ranging from canoes to buckets (Borrero 1997). Nevertheless, this explanation is only to be put forward when analysing the whole sea nomad regional limits, though it is not useful to analyse causal selection of spots for settlements *within* that region.

"Space" is not a cause, but a material product of social processes acting back on social structures by limiting, constraining, and, in some cases, determining future actions. Human settlements may be tied together by proximity, but the causal mechanism is not physical proximity. The real cause should be explained in terms of the "influence" an action performed at a location has over all locations in the proximity (Barceló & Pallarés 1998) and the future use of the same spot. Thus, social actions are not adapted to the environment, but productive actions (hunting, fishing, gathering) determine the location of residential actions (settlement). The suggestion is that a social action can generate the reproduction of similar actions around it, or it can prevent any other similar action in the same vicinity. In this case, the "visible" characteristics of shell middens increase the probability that new human sites appear in the vicinity of older sites (*cf.* Orquera & Piana 1991; 1992).

Settlement (*stricto sensu*) is not adapted to environmental conditions or resources, but the place where social agents perform actions like shellfish gathering, sea lions or sea birds hunting, and fishing. Human action increases the probability of settlement in the vicinity or at the same spot, while it diminishes the probability of performance of other social actions, for instance, of non-residential nature.

Distance is a much better candidate for a causal mechanism, because it is usually assumed that "everything is related to everything else, but near things are more related than distant things" (Tobler's law). This assumption is based on an intuitive Neighbourhood Principle, which relates the intensity of influences converging to a single location from the spatially neighbouring locations. Therefore, it is no surprise to discover that all shellfish gatherers choose to locate their camps near collecting spots or, at least, process shellfish at the shore and carry only the meat back to the camp. Thus, be it transitory shellfish preparation sites or base camps of shellfish gatherers, both are predicted to be located near the collection point (*cf.*

Waselkov 1982). Shellfish, from the viewpoint of a human predator, are small packages of meat sealed in heavy inedible shells. In terms of energy efficiency, this fact sets definite limits in the distance live molluscs can be transported with simple technologies, beyond which, energy expended in transport will exceed that gained from the food (Orquera 1999b).

The approach here relies on a prior hypothesis of spatial smoothness (see also Barceló & Pallarés 1998), which considers that two neighbouring observations of the similar kind are supposed to have been more likely originated from the same cause than two of such observations lying far apart. Therefore, if spatial variation among settlements were not wholly erratic, it can be said that there is a certain degree of spatial dependence between spatial units. This is the reason why most settlements are concentrated on the shoreline: social work took place where it was most efficient. Herein it is not described how settlement is adapted to the environment, but how some specific social actions are related with other actions, because of their neighbourhood relations.

Instead of "adaptation", the term *attraction* is more suited to the study of social space from a dynamic standpoint. Let's consider all possible locations of human settlement along the shores of Beagle Channel. There are a vast number of possible settlement locations, depending on the places where social action may be performed. If the range of possible locations is so great, why do spatial effects of social actions appear at first glance always regular? Why is so usual to find spatial dependency, if spatial consequences may be so diverse? In this way, Social Activity areas should be considered as spatial attractors. Any social action is performed in space, and as a consequence it produces a social activity area acting as spatial attractor and conditioning the performance of the action and successive actions performed in the neighbourhood.

The observation and statistical measurement of "regularity" in human settlement can be misleading. In archaeological spatial modelling, spatial correlation is commonly used as an evidence of regularity. This paper intends to discuss some usual mistakes connected with the trivial inductive explanation of spatial regularity. Observed regularity is meaningless, if a model of social actions as spatial attractors is not proposed. Anything can be related with anything, and if the proper method is used, it will always produce a measure of regularity. But not every regularity can be explained as a result of social action.

Variability of settlement along the Beagle Channel

Survey at the Beagle Channel and adjacent areas

The *Proyecto Arquelógico Canal Beagle* development lead to the observation and location of more than 500 archaeological shell-middens since 1975, because of the use of different scopes and methodologies along time though, the information gathered is not uniform. Since 1994 European Union Project "Beagle Channel Marine Resources Prior to the Industrial Exploitation (CI1*-CT93-0015)" enabled the systematic record of sites, which made 318 of them to be homogeneously described and compiled in a geo-referenced data base (Martinioni 1998; Piana *et al.* 1998). Data involved here 318 shell-middens-result from an intensive and long term surveying of archaeological sites along a fringe of circa 1 km depth along the northern shore of Beagle Channel, i.e. the southern hill slope of the Andes Fueguinos and the coastal area of the Isla Grande de Tierra del Fuego between roughly 68° 36' W & 66° 45' W latitudes. Under proper conditions, i.e. a valley transverse to the coast, the survey was carried uphill and inland, up to the vegetation limit at circa 700 m above sea level. In special locations, where topographic characteristics were unsuitable for human settlement, e.g. a cliff, the survey was restricted to less than 1 km from modern shore.

Landscape correlations

The goal is to test if all archaeological sites present in the database are in similar landscapes, or if some physical features within those landscapes are spatial attractors for human settlement. The database of the *Proyecto Arqueológico Canal Beagle* includes subsidiary and particular observations and descriptions not relevant for statistical analysis. The information useful for landscape correlations involves the following features:

1. Geographic location, archaeological structures (morphology of the shell-middens accumulations),
2. quantity of observable structures (discriminated by morphology),
3. size of the sites (range of surface units),
4. substratum (geomorphologic features of the site location),
5. back-of-the-site (geomorphologic and topographical characteristics of those parts of the site opposite to the area open to the coast),
6. relationship with moraine deposits,
7. distance to the (modern) shoreline,
8. kind of shore (slope and composition),
9. kind of coast (geomorphologic features),
10. distance to (modern) woods,
11. distance to (modern/ancient) water sources,
12. kind of available (modern/ancient) water sources,
13. wind protection (percentage of total protected area),
14. wind protection (orientation of protected area),
15. kind of protection (only topographic features),
16. height above sea level, chronology (^{14}C available dates).

Since dating was done under a different scope and looking forward recent sites, these data are biased. Nevertheless, the total number of dated sites is low, and presence of layers included in the known range for sea nomads occupation is to be expected. Archaeological sites are mostly grouped along the coastline and appear in large quantities. The distance between two neighbouring sites is usually less than a few hundred meters, with the exception of few non-habitable very steep or wall like coastal segments. There seems to be no difference in density, size or aspect. A preliminary inspection of data would allow concluding:

- the majority of shell-middens are near or very near the actual shoreline (81% of all sites closer than 100 meters),
- related to modern beaches with smooth slope (67%), n near a modern and/or ancient water source (76% of all sites closer than 100 meters), and

- near moraine deposits (69% of all sites closer than 100 meters), which serve as a back-of-the site (56%).
- archaeological sites overlay ancient pebble/cobble beaches (63%).

According to these first results, the main *spatial attractors* for human settlement activities seem to be:
- the location and slope of the modern shoreline,
- a substratum composed of materials from ancient pebble/cobble beaches,
- modern and/or ancient water sources,
- and moraine deposits, seem to be determining human choices.

In contrast, the location of modern woods and the existence or absence of wind protection do not seem to determine human settlement. It is easy to see that those results are contradictory: in which way modern landscape features can be spatial attractors for social actions performed in the past?

It is true that isostatic movements uplifted the landmass resulting in drop of the relative sea level of a maximum of 10 m (*Rabassa* et al. 2000). Consequently, since the general slope is relatively steep, the retreat by coastal elevation, in general, did not affect more than 600 horizontal meters. So that there are several locations within 200 m off the modern shoreline that were always available for settlement. Nevertheless, to pay attention to this fact does not solve the previously stated contradictions.

The contradictory nature of preliminary results is enhanced by the fact that less than 4% of all archaeological sites are attracted *simultaneously* by the most common landscape features. For instance, only 49% of all sites are near (less than 100 meter) the modern shoreline *and* near a water source. Many coastal sites are far from water, and even worst, those sites near the modern shoreline are those that are more distant to modern water sources.

There is however some evidence of two-dimensional correlation between the best candidates for spatial attractors –notably between distance to the modern shoreline, and the location of the site on pebble/cobble ancient beaches. If the shoreline has been since the beginning of human occupation a spatial attractor for human settlement along the Beagle Channel, then we would understand why archaeological sites are simultaneously related with past evidence of shoreline, preserved as the substratum of archaeological sites, and modern ones. The correlation between ancient beaches and the modern shoreline suggests that changes in sea level have not affected the general orientation along the Channel. The majority (82%) of the archaeological sites with pebble/cobble *substrata* (evidence of ancient beaches) are near or very near the modern shoreline. As the sites are less related to the modern coast, they are less related to pebble/cobble ancient beaches.

We have calculated a Multiple Correspondence Analysis to test those hypotheses. We have done the calculations for Multiple Correspondence Analysis using SPSS 10, optimal scaling series of commands. A preliminary solution, using all non-missing data (183 sites), shows that 45% of total variance in the data set is produced by the existence of three outliers. Rock-shelters seem totally different from the rest of the sites, probably because their eccentric relationship with modern shoreline, which is the most dominant variable.

Deleting the 3 most notorious outliers, the results are slightly different, showing a greater variability between sites. A three dimensional Correspondence Analysis solution only accounts for the 32% of total variance explained (eigen values: 0.365, 0.332 and 0.275). This gives strong support to the absence of explainable spatial regularity.

Regularity accounts only for a third of total variation:
- sites far from the modern shoreline are inside the modern forest, very near to moraine deposits, and located on organic substratum areas, and very much protected from winds.
- sites far from modern woods, and far from moraine deposits, and located on ancient pebble/cobble beaches.

It is very interesting to show that those sites, which are well protected from the wind, seem to be in similar geomorphologic areas, that is, wind protection is only possible in some specific conditions, and not everywhere along the coast.

Those sites, which are not *on* the beach, not *inside* the woods or which are not immediate to moraine deposits seem also very similar between them. This observed regularity suggests that there is only one cause of exceptional location.

The Second Dimension discriminates between three types of back-of-the site features: depression, smooth or plain and abrupt, and associates sites on smooth or plain modern beaches with sites on substratum defined by the presence of materials from pebble/cobble ancient beaches.

Finally, the Third Dimension differentiates sites on abrupt shores and half protected to the wind from sites on sandy beaches and mostly open to the winds. That means that wind protection is a cause of settlement location only in a few cases. In general, discrimination measures suggest that the variables SUBSTRATUM, DISTANCE TO THE SHORELINE, RELATION TO WOODS, and WIND PROTECTION are the most influent to explain spatial variability. If we calculate the Correspondence Analysis using only these variables, we obtain a much more adjusted solution, which accounts for 54% of the total variance explained (eigenvalues = 0.622 and 0.458).

Figure 4 (*a* and *b*) graph shows an increasing difference from sites on pebble/cobble ancient beaches (E) or on stony ancient beaches (D). Sites on those locations are not in the woods (O: very far, N: far, M near), and are mostly open to the winds (P). Sites on ancient sandy beaches (C) are associated to half protected from wind sites (Q) and sites very near the shoreline (G). Sites a bit farther from the shoreline (H) are predominantly on moraine deposits, very near the woods, but not inside them, and are well protected from wind (R). Finally, the most opposite category to the first one are sites on organic substratum (A), in the woods (K), completely protected from wind (S), and far from the shoreline (I: far, J: very far). The fact that there is a non negligible correlation between ancient pebble/cobble beaches and proximity to modern shoreline suggests that measured variation cannot be explained in chronological terms.

The results suggest that the main spatial attractors are the modern shoreline and the modern wood. The first one *attracts* settlement, the second one prevents settlement. The relationship between both attractors is, however, characteristically non-linear (Figure 5).

These results are misleading, because human groups are not avoiding woods. Statistical results show that woods are also settled (28% of total sample). Along the northern coast of Beagle Channel, forests arrive to the shoreline only in few occasions. Austral beeches need organic soils to grow, a certain pH and stable substratum for their superficial roots. These characteristics are not fulfilled by soils on ancient beaches pebble/cobble substratum. Elsewhere the woods can arrive to the beach, *e.g.* where moraine deposits are near the shore. In those cases, coastal lines become rocky and steep, which makes social action performance much more difficult, and human settlement avoids them. Consequently, if human action is produced inside the woods, then it should be mostly performed in woods which are relatively far from the shore, with organic substratum, and related to moraines.

51% of archaeological sites inside woods are *also* near the modern shoreline. Only a 9% of sites are inside woods *and* far from the modern shoreline. Those far sites seem very different from the rest of the sample.

The possibilities for wind protection do not appear as a spatial attractor. Only 25% of the total sample is well protected from wind. The strong positive correlation between wind protection and proximity to the shoreline, suggests that modern shoreline is the most influential spatial attractor, and only within its attraction basin, the most protected locations attract human settlement.

Smooth modern beaches act as a spatial attractor, however, we cannot say that, within the beaches, abrupt ones appear as negative attractors, because 26% of sites appear with this feature. Correspondence Analysis has not discovered any significative correlation with this fact.

Archaeological correlations

The most characteristic archaeological site along the northern shore of the Beagle Channel is the shell-midden, constituted by the accumulation of a big quantity of mussels and other molluscs shells, discarded tools, charcoal, stone sherds, mammal and bird bones, etc. (Orquera & Piana 1991; 1999b: 23, Estévez & Vila 1995). Given the results of the intensive survey, the most frequent morphology is the ring-shaped mound (more than 50%). It is also interesting to remark the existence of sites composed of "isolated structures" (33,2%) and sites characterised by the presence of "grouped structures" (66.8%). Correlating the morphology and topology of observable archaeological sites, the majority of cases can be divided in two kinds:

- Ring-shaped grouped mounds (40%)
- Bell-shaped isolated mounds (11 %)

The quantity of isolated ring shaped mounds is very low (9%), as it is the quantity of grouped bell-shaped ones (4.5%). Size differences between isolated and grouped structures confirm this point: largest sites are always composed of many grouped ring-shaped or bell-shaped mounds, whereas, the smallest sites are usually non-ring isolated structures.

This relationship is statistically significant using the chi-squared test, and ordinal correlation tests –Sommers *d* and Kendall *t*- give figures around 0.60 for the relationship between isolation and size. Given that size is the result of accumulation of discarded material, it is easy to understand that the more complex the site (more mounds), the more surface it occupies. Highly probable, the largest sites are also those were material has been accumulated for a longer period of time as a result of a high amount of resettlements at the same place independently of the settlers number. Very few sites with thin shell-midden accumulations covering a relatively large area, as Lanashuaia (cf. Piana *et al.* 2000), may have been produced by a large number of occupants along a short period. It is important to realise that isolated mounds show clear evidences of reoccupation, as it is the case for the more complex structures made of a great number of middens. The possibilities of reoccupation do not explain the size or complexity of an archaeological site.

The shape of the site structures seems to be irrelevant for a spatial model of landscape use. Using chi-square, Cramer V and ordinal correlation measures, we have determined only a significative relationship with DISTANCE TO THE WOOD: bell-shaped mounds are mostly *in* the woods, while ring-shaped are *near*, not always *in*. We have calculated a Categorical Regression or Regression with Optimal Scaling (Meulmann & Heiser 1999) to analyse the properties of this relationship. The idea is to consider the predictive ability of WOOD on the shape of sites. R^2 is quite low (0.090) because the intensity of relationship is also very low. As distance to wood increases, predicted shape increases, and that means, that the location of ring-shaped structures is more probable far from the wood, than inside or near it. We should remember that, although present, this non-linear relationship accounts for a very low quantity of total variance. That means that not all sites inside woods can be described as isolated bell-shaped mounds.

We have also studied the relationship between isolated and grouped structures and landscape characteristics. Again, we have used chi-square tests, Cramer V and ordinal correlations. We have obtained significant values in the case of SUBSTRATUM (Cramer V= 0.413) and DISTANCE TO MORAINE DEPOSITS (Cramer V= 0.331). In the first case, isolated structures may appear in any kind of substratum (organic, pebble/cobble, stony, sandy), but grouped structures tend to be concentrated on pebble/cobble ancient beaches. In the second case, grouped structures tend to appear far from moraine deposits, while it is difficult to discover isolated structures far from them.

The intensity of relationship is relatively high ($R^2 = 0.301$), explaining 30% of total variance.

The number of ring-shaped structures increases as the prediction of substratum (from organic to pebble/cobble ancient beaches) decreases. The same relationship is also possible for bell-shaped mounds, although the relationship is smaller; it explains only 8% of accumulated variance.

Given that distance to moraine deposits seems to be related with substratum (organic substratum is positively correlated with moraine deposits and therefore those sites are near moraines), we obtain good relationship also with this variable (10% of total variance). Since some sites composed of isolated mounds tend to appear with organic substratum, there is a higher probability that isolated structures appear near the moraine deposits, than grouped structures.

The linear correlation between morphology/topology and distance to the coast is negative. This fact can be explained in terms that only isolated mounds appear far from the modern shoreline. Grouped mounds are *attracted* significatively by the modern shore-line.

If we consider now the surface of surveyed sites as dependent variable, there is a significant relationship with:

- SUBSTRATUM: small sites tend to overlay organic soils, while large sites overlay substratum defined by the presence of pebble/cobble as evidence of ancient beaches.
- DISTANCE TO THE COAST: 18.8% of small sites are far from the modern shoreline –200 m or more- while only 7.2 % of large sites are that far from the shoreline.
- DISTANCE TO THE WOODS: small sites may appear *inside* the woods, while large sites are usually not in the woods.
- AVAILABLE WATER SOURCES: However, largest sites are not always concentrated where the most significant (or permanent) water sources are

Using Categorical Regression, we observe that SUBSTRATUM explains 23% of total variance, AVAILABLE WATER SOURCES explains 16 %, DISTANCE TO THE SHORELINE explains 11% and DISTANCE TO THE WOOD 10%. Pratt's measure of relative importance (Meulmann & Heiser 1999) gives the same results.

Again, WIND PROTECTION is neither a spatial attractor, nor in the positive, nor in the negative sense. ABRUPT MODERN BEACHES may be considered as a negative spatial attractor in the case of the largest and the most complex mounds, but 23% of grouped structures appear in those areas. The WOOD is also a negative spatial attractor for grouped structures. We have seen why the formation of organic substratum is exclusive of wooded areas. The recurrence of organic substratum with small sites inside woods is then a spurious correlation of the geomorphologic characteristic of wood areas.

Chronological variability

Several ^{14}C dates indicate that a life-style based on a high dependence on littoral resources took place in the region of the Magellan-Fueguian channels and islands from some 6500 uncorrected radiocarbon years to the 19th century AD (Orquera & Piana 1988; Piana *et al.* 1992). From the data available, it can be assumed that the occupation of the northern border of Beagle Channel throughout the period was rather stable (Orquera & Piana 1999b, and references therein; Estévez *et al.* 2001). Support for this hypothesis comes from the fact that ancient pebble/cobble beaches act as spatial attractor in the same way as the modern shoreline. That means that the shoreline has been the main spatial attractor all along the period.

Research done provided 54 ^{14}C dates from the surveyed sites. Nevertheless, the data cannot describe precisely the temporal evolution of human settlement in the area, because in most cases, only the most recent layers have been dated. Sites with modern dates hide the existence of older layers at the same location. Results of this study can thus be confusing, because the number of old sites is biased.

In general, it is hard to see any temporal variation on spatial effects of human actions along the Beagle Channel. Modern sites have characteristics similar to those known of older times, although it seems possible to suggest some differences between the oldest and the most modern sites. Correspondence Analysis shows that the most modern sites are similar among them, what is not true for the rest of the sample. We have segmented the results of preliminary Multiple Correspondence Analysis using two chronological filters. Figure 7a shows in green colour the placement of old sites (older than 2000 ^{14}C years BP) in a graph of factorial scores, and the Figure 7b shows in green colour the placement of the most modern sites (after 500 ^{14}C years BP). In Figure 7b, modern sites appear much more concentrated in the margins of the distribution. It is important to remember that this particular factorial representation accounts for 50% of total variance.

Very old sites tend to be smaller and more isolated than the most modern. Spatial attractors as Wind Protection and Location on Smooth Slopes determine the location of human settlement as soon as the sites begin to grow in size and complexity, and better areas (beaches with smooth slopes) are being settled.

Abrupt beaches were occupied only at the end of the period. This might be related with the formation of new coastal features -related to abrupt beaches- that became available for settlement as a result of the previously mentioned land uplift with the consequent shoreline retreat. Meanwhile old by-shore locations were progressively farther away from the shoreline. This leads us to consider a very close relationship between coeval settlement and shoreline position. Some of the old sites were on that moment abrupt beaches as it is the case of Mischiuen I, presently under study (Piana unpublished data). Of course, it could also be related to a supposed higher demography in the later times.

It is to be expected that, when foreign colonisation began to interfere with the indigenous social and economic organisation, *i.e.* greeting sedentarism and teaching incipient agriculture and cattle breeding, variables for settlement site selection changed because of changes in social activities. This expectation is based in ethnohistorical information (*cf.* Orquera & Piana 1999a), though, it was not carried out extensively until the last decades of the 19th century, when the social activities of the first Anglican Mission at Ushuaia (1867-1886), the city of Ushuaia (1884), the two first ranches of the Beagle Channel, namely Harberton (1886) and Puerto Remolino (1898), were social attractors for the remaining aborigines. Up to that moment, the majority of the Yamana maintained the basis of their settlement pattern as shown in the only two archaeological sites studied from this period (Estévez & Vila 1995; Orquera 1999a; Orquera *et al.* 1993; Piana et al. 2000).

Conclusions

Along the Beagle Channel, the shoreline has been the main spatial attractor for human settlement for the last 6000 ^{14}C years. Nevertheless, it should be remembered that *space* is not a cause of spatial variability. If geomorphologic features are correlated with the location of human settlement, it is because of spurious correlation: they are features of coastal areas. It is human work made on the coast, that attracts human settlement. The production unit and the residence unit are indistinguishable among the hunter-fisher-gatherer groups studied. Consequently, it can be concluded that people lived where they worked. For instance, a compact resource such as a large mussel bed at a shoal may circumscribe the choice of suitable nearby campsite locations. On the other hand, a dispersed resource such as an extensive rocky shoreline with gastropods can be profitably exploited from a number of points. In the first case, the few preferred camp sites are liable to be frequently reoccupied as long as shellfish may be gathered. As for the latter, campsite selection is arbitrary, not related to the mollusc resource while the other factors remain constant, so the same spot will seldom be reoccupied (*cf.* Waselkov 1982).

From a regional standpoint, staple survival resources for the sea nomads at the Beagle Channel were evenly-spaced distributed within a range of half a day mobility, be it in canoe or walking. This favours human dispersion in the smallest viable social units, evenly spaced in tight proximity to each other and with high mobility within small ranges. Of course, the coastal environment is not homogenous; local differences in landscape morphology are related to differential costs of access to the diverse resources (Piana *et al.* 1992, Orquera & Piana 1999b). This fact explains local diversity of settlement locations among archaeological sites.

Archaeological correlations show also the ambivalent nature of the modern shoreline as spatial attractor. All kinds of sites are near the modern shoreline, but not all. Some human actions were performed far from it, and those locations seem archaeologically different from the others: they are smaller and topologically less complex. Only isolated mounds appear far from the modern shoreline. Grouped and largest mounds are *attracted* significatively by the modern shoreline or by the evidences of the ancient shoreline (pebble/cobble substratum). Settlement inside woods is not avoided, but forest resources do not attract human settlement in the same way as coastal resources. It should be remembered that although most of the sites are near or very near the shoreline, the same sites are also *near* the woods (although most of them not *inside* them). In general, it can be said that the location of ring-shaped structures is more probable far from the wood, than inside or near it.

Hypothetically, it can be concluded that the areas far from the coast were occupied with less intensity than the beaches.

Social space forms an integrated part of social strategies for subsistence and/or social processes, because such strategies and processes inherently involve a spatial (and temporal) dimension. We think that the place of *human work* and *settlement* is the cause of the reproduction of both generic actions *at the same place*. Consequently, the spatial structure of social activities is not constant, neither static. It is dynamic because it is socially *caused,* and simultaneously it *determines* society. Social space is not absolute, but relational. It depends on the underlying network of social actions, which are the interrelationships between objects, objects and individuals, individuals and individuals, individuals and activities.

The spatial model presented in this paper is obviously too simplistic to be considered a model of spatial causality. Nevertheless, our application shows some very important aspects of archaeological spatial modelling:

- The use of only landscape features to define the model parameters is misleading, because most of those features show different degrees of latent correlation, and prevent the detection of the real spatial attractors.
- Archaeological surveying tends to use modern landscape features (observable) instead of past evidences (non observable). This fact leads to affirm the causal nature of modern features on ancient elements.

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Figures

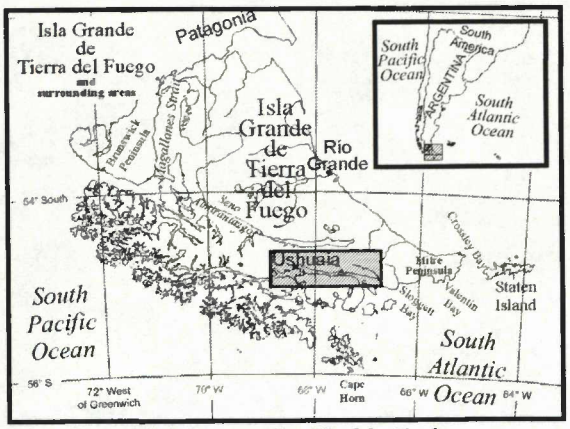

Figure 1. Tierra del Fuego: The World's End

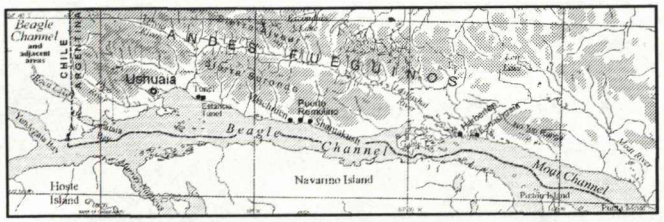

Figure 2. Area of Study

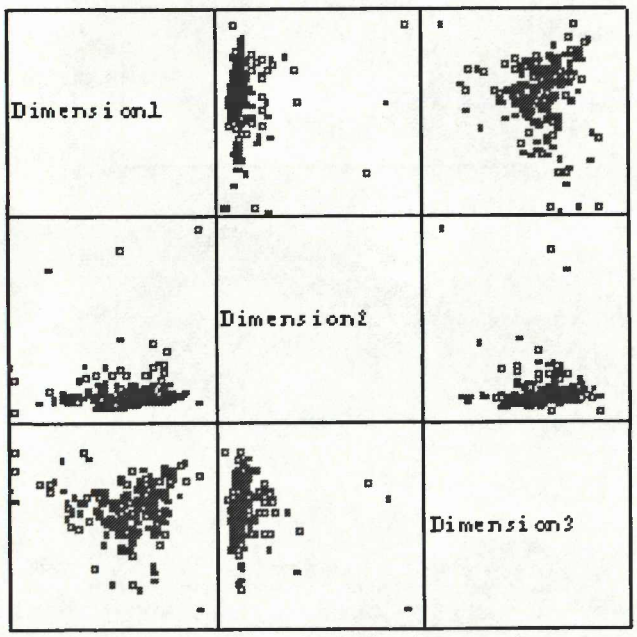

Figure 3. Correspondence Analysis without outliers. Individual Scores

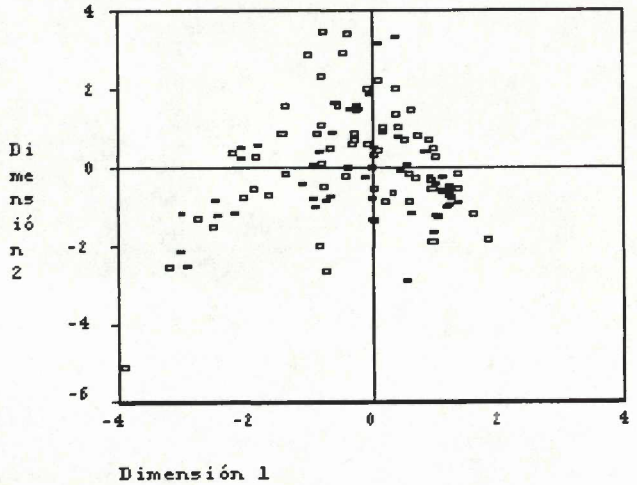

Figure 4a. Correspondence Analysis of selected variables. Individual Scores

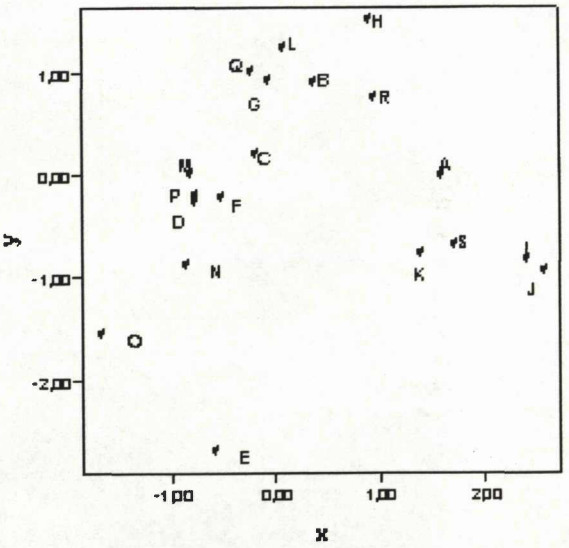

Figure 4b. Correspondence Analysis of selected variables. Variable Plotting

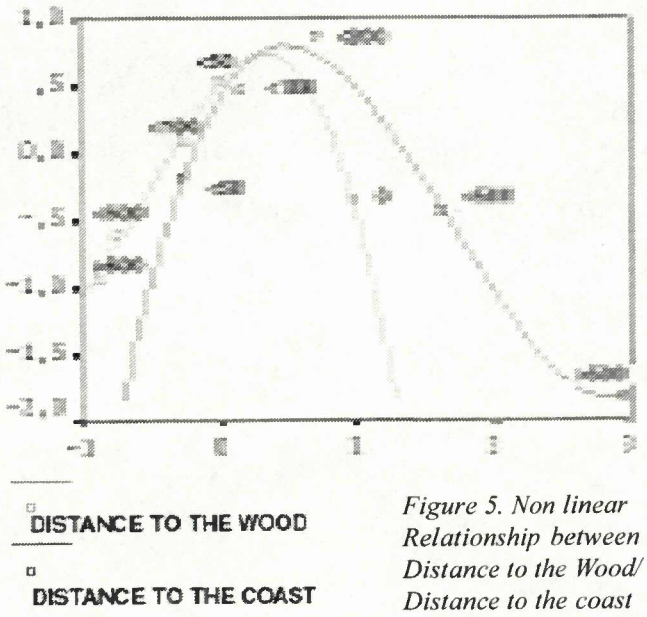

Figure 5. Non linear Relationship between Distance to the Wood/ Distance to the coast

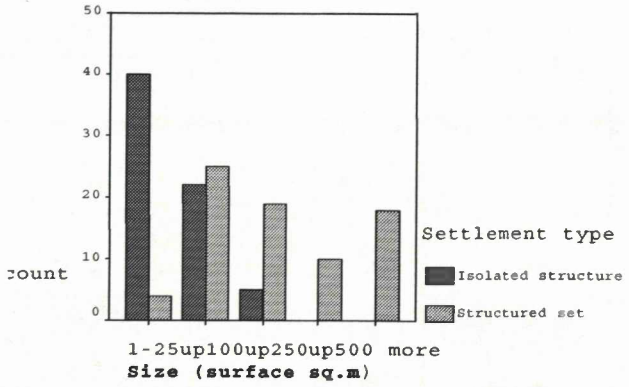

Figure 6. Relationship between shape, topology and size.

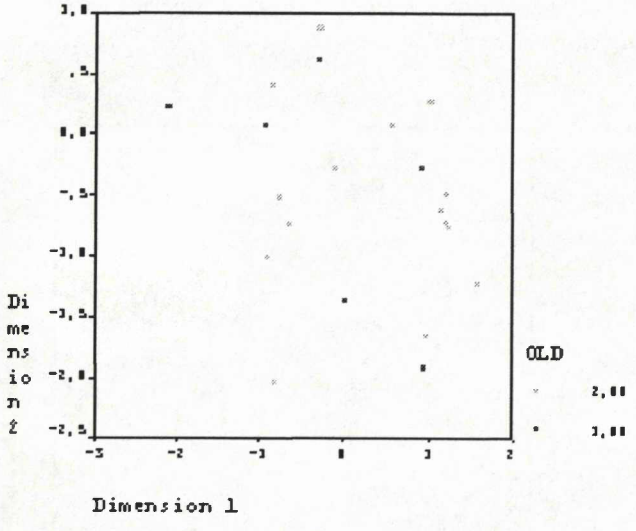

Figure 7a

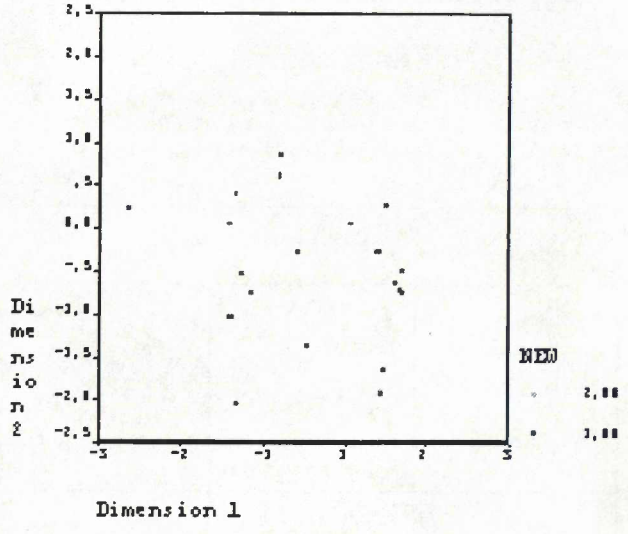

Figure 7b

Figure 7. Correspondence Analysis with chronological information