Modeling Variability in Hunter-Gatherer Information Networks: An Archaeological Case Study from the Kuril Islands

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Introduction

It is well known that small scale hunter-gatherer societies use several strategies to buffer resource unpredictability. The primary strategies documented seek to increase information about alternate resource patches and their productivity and to preserve information about rare but particularly severe resource failures and possible strategies for their mitigation. In this paper, we advance a model that simultaneously takes account of differences in the imperative for information sharing at different scales of space and time and factors in the limits and costs of maintaining such information exchange strategies. This model shares similarities with Whallon's (2006) recent "non-utilitarian" model of hunter-gatherer information exchange, while focusing more on mechanisms of transmission and geographical variability.

Our goal is to better understand the structural consequences of adaptation to environments of differing degrees of marginality and levels of constraints on information sharing. Using initial data from archaeological research being conducted in the Kuril Islands of the North Pacific Ocean, we highlight several predictions that can be drawn from this model. This model provides a framework for understanding the evolution of important aspects of hunter-gatherer interaction patterns as well as changes in vulnerability and resilience to socio-ecological variation.

Definitions and Assumptions

Before we can really attempt to model information in human systems, it is helpful to have a working definition of information. We define information as:

a coherent symbolic code of relevance to some topic of interest or concern that can be recorded, supplemented, preserved, transmitted, retrieved, enacted or even forgotten.

This definition has an advantage over others (e.g., knowledge, instruction, data) in that it can apply to a wide range of domains (individual learning, social transmission, signaling, genetics) that we might wish to compare when generalizing about evolutionary processes. It emphasizes the dynamic and contextual nature of information.

We assume that all people monitor environmental variables and that they maintain a degree (but not an infinite degree) of flexibility to adjust their behaviors in locally optimal directions to enhance survival, wellbeing, reproductive success, and other more proximate goals. In this article, we are particularly interested in exploring the limits of adaptive capacity, which will be most identifiable in marginal environments, where failure is most likely. Once we can understand how people succeed and fail at the limits of viability, we can then explore how evolutionary histories can also change the boundaries of marginality, making once marginal environments less so, and in some cases, rendering less marginal environments more so.

In the context of information exchange, it is important to recognize the strategic context of social transmission. In exchange networks, information can be shared or denied. It can be reliably transmitted or falsified, and recipients need to evaluate their degree of trust in information sources. Recognizing a political context of information transmission is important if we want to understand the mechanisms underlying the structures of information networks.

Information acquisition strategies of hunter-gatherer bands

Hunter-gatherers have used a number of different strategies to mitigate environmental unpredictability. These strategies (e.g., mobility, sharing, trade) are usually understood in relation to costs and benefits associated with acquiring resources in spatio-temporally heterogeneous environments. Information flow about changing socio-environmental conditions is critical to thriving in such contexts, and anthropologists have discussed a number of strategies used by hunter-gatherer bands to facilitate this flow. Among others, these include oral traditions, fluid group composition, occasional social aggregation, widespread exchange friendships, and journeying. In this article, we explore these and other potential mechanisms of information acquisition and preservation as they fit into broader geographical and temporal variability.

Information exchange is embedded within and can be facilitated by social gatherings ranging from small opportunistic meetings between two or more individuals or family groups to large megaband aggregations brought together for planned ceremonies, trade fairs, and the harvest of temporarily concentrated resources. Regardless of the scale, periodicity, or regularity of these social gatherings, the result is an expanded pool of <u>potential</u> information about the broader state of the environment and potential mates and partners.

Polly Wiessner's (1982) discussion of the *hxaro* trading partnerships among the !Kung has become the standard model for small scale hunter-gatherer information sharing beyond the microband. In the *hxaro* model, exchange partnerships serve as a pretext and social interaction as a mechanism for the sharing of environmental information. This model is particularly attractive archaeologically because the information sharing networks are highly materialized through the exchange of artifacts.

These strategies of information acquisition emphasize the opportunity for sharing of information across different <u>spatial scales</u>. Other mechanisms have been proposed for the storage of information about environmental variability <u>through time</u>, such as the development and transmission of local and traditional knowledge (LTK).

Local and traditional knowledge as information storage

Local and traditional knowledge (LTK) refers to information that is accumulated, stored and transmitted through 'micro-media' methods (story-telling/ oral history and non-mass replicated forms of literacy such as pictography, journaling and letter writing, when available), about past social and environmental states, cycles, and interventions. LTK is a two dimensional (time and place) form of information storage against which new information is balanced and to which new information is added. Traditional knowledge is the accumulation of information observed and shared about spatio-temporal variations and the suitable strategies for exploiting and mitigating variability. Traditional knowledge can develop information about landscapes beyond the local experience and store knowledge of stable social constellations (neighboring ethnic groups, historical relationships, and so forth). Local knowledge is that part of traditional knowledge that relates individual experiences of local variability to a growing corpus of pooled information held more or less commonly by members of an established group and maintained through a combination of personal experience, instruction, and story telling. Local knowledge is expected to be the most reliable and accurate of information due to its frequent transmission and redundancy with common everyday experience. LTK forms the bedrock of cultural tradition that grows stronger the longer a group lives in a region and the more variability the population experiences (and survives). Oral history is the primary mode of social transmission that preserves LTK, and its fidelity will be based on the population of tradition bearers, the frequency of transmission events, and the consistency of contemporary information relative to the information maintained about past conditions. Colonists to a new environment or survivors of unprecedented environmental and social changes face significant challenges in building relevant knowledge bases about new or significantly altered ecological settings.

Social Network Theory and Relative Vulnerability to Uncertainty

Network theory provides a framework for considering the nature of vulnerability and resilience of information exchange networks (and the people who form them). Assuming comparable capacities of information flow between connected interactors, highly interconnected networks transmit larger amounts of information through multiple pathways allowing for greater redundancy and high system resilience to environmental perturbations experienced locally. By contrast, low density networks with fewer connections have a lower capacity to transmit information and are more vulnerable to similar perturbations, though potentially more insulated from non-local environmental and social impacts. Networks can vary from higher density (resilient to local perturbations) to lower density (vulnerable to local perturbations) structures as a function of geographic variability or changes in underlying characteristics of ecology, demography, technology, economy, and society. This systematic relationship allows us to consider spatial variation and temporal change in efforts to understand the place of information strategies in the adaptations of small scale societies. For examples, the initial success and ultimate failure of the Norse colonies in Greenland turned on relations of evolving social, cultural, and economic networks fit to geographical and climatic factors that increased colonial vulnerability through time (Barlow et al. 1997; Dugmore et al. 2007).

[Fig. 1: here]

A Model

For the purposes of this model, we assume that the environmental perturbations that matter to people scale together in time and space. That is, unpredictable fluctuations in environmental conditions that are locally scaled are also the most frequent and of lowest amplitude. Less frequent but higher amplitude perturbations are also more likely to be manifest over greater areas, thus the rarest anomalies are also the ones that will affect the largest area and will be the hardest to mitigate. At some scale of space and amplitude, no adaptive strategy will be appropriate, and catastrophic change can be expected. This assumption allows us to orient our social networks according to a framework of spatio-temporal variability and unpredictability.

The important derivative of this relationship is that strategies that enable information flow across larger regions and for dealing with increasingly rare and severe perturbations are more costly to maintain.

Individual monitoring of the local environment on a fairly regular basis is relatively inexpensive. It can be accomplished more or less incidentally in the course of daily activities. Observations are made of local surroundings, weather, vegetation, animal behaviors, and the skills and moods of colleagues. Social transmission diffuses information about the physical and social environment reinforcing and qualifying individual observations. Direct observation and social transmission at the local scale is ongoing, allowing for frequent updating and redundancy in information flow (building up local knowledge). These modes of information acquisition are effective for monitoring rapidly changing characteristics of the environment at relatively close spatial and temporal scales. Redundancy allows for an increase in reliability of information and greater confidence in decisions based on that information. Redundancy also encourages honesty in social transmission, since dishonesty is easily disclosed and punished. We call the resulting network an “inter-band information network” (Fig. 2). Inter-band network structures provide high connectivity with low individual opportunity cost.

[Fig. 2: Here]

As distance increases from the area of regular interaction and movement, frequency and redundancy of information flow necessarily deteriorate. Greater degrees of logistical and residential mobility can increase the area under direct observation, though with a modest decrease in the intensity of more local-scale monitoring. In foraging societies where group membership is often relatively fluid, the more socially mobile *individuals* are able to access information over a greater range than others, presumably also facilitating greater social information flow across multiple residential groups or bands.

Multi-band social aggregations for feasts, parties, and trade fairs, provide a mechanism for supra-band information sharing between proximal bands. These aggregations occur most commonly in the course of other activities where patterns of movement intersect or where large resource windfalls draw bands together. Benefits of aggregation, in addition to updating information about neighboring territories, include the maintenance of reproductive networks. Nevertheless, the information that is shared between groups should be more selective than that shared within bands and we can expect a greater degree of effort placed in establishing and maintaining trust.

Overlapping and expanding the scale of aggregations, *hxaro*-like "friendships" are a special kind of supra-band relationship in which individuals (or families) invest significant energetic and material resources in maintaining information and mutual support networks beyond the band level ("supra-band" networks in Fig 2). Compared to wholesale aggregation, these egocentric friendship relationships allow for greater fidelity of information transmission between partners. Multiple ties to partners in different bands increase the diversity of information available, while multiple partners in the same band or close area increase the redundancy of information on particular regions. At greater distances, partnerships become increasingly costly to maintain, requiring more significant tokens to show good faith and trustworthiness. As a result, the costs of exchange partnerships can be measured in the material goods that have to be acquired or produced to fuel the exchange as well as the effort involved in traveling to visit with partners (e.g., function of distance and terrain difficulty). There are real constraints on the number of partners any individual can maintain while also obligated to sustain themselves and their families on a daily basis.

Compared to local networks, supra-band information exchange networks (aggregations and exchange friendships) are moderately connecting, and have reduced content volume and reduced redundancy. Individual opportunity costs are relatively high and fidelity of the information transmitted is reduced due to lower redundancy. Trust is expensive, leading people to invest in more costly-signals of friendship. Likewise, as transaction costs increase with distance and reduced redundancy, the number of partners necessarily declines, further limiting the spatial scale of effective information networks. As a result of these characteristics, supra-band networks will be most effective in providing information about lower frequency environmental variability with relatively gradual onset. Knowing which friends to turn to in an environmental catastrophe depends on knowing where conditions have deteriorated and where they are still favorable, as well as which "friends" are most likely to be "friends in need."

At scales beyond local and supra-band networks, some individuals can establish and maintain networks of information flow with relatively low connectivity, leading to lower volume and lower redundancy in information ("Regional" networks in Fig. 2). The costs of maintaining these far-flung networks can be reduced for the networker through direct subsidies provided by the groups that they visit or by permission of those groups to forage in their territories. The

Australian Aboriginal traditions of Dreamtime pilgrimages and walkabout, for example, give some individuals an opportunity to directly observe and become familiar with landscapes and populations beyond the annual rounds and territorial rights of families, bands and macro-bands. Returning pilgrims bring with them a fresh store of information to share with their families and neighbors about the state of the broader world. The rate at which this information is refreshed would be influenced partially by environmental and demographic circumstances closer to home (local food scarcity, numbers of individuals in appropriate age grades, family dependency on local labor inputs, etc).

Moving desirable goods from one group to another would serve as a particularly attractive proximate justification for acceptance and logistical support during travel away from home and in some conditions would justify the emergence of semi-specialized traders. The networks connected by such traders would be good for maintaining information flow about low frequency and large amplitude variations. Examples of semi-specialized traders – albeit from more complex societies than is the focus here – can be seen for example in Mesoamerica with the Aztec *pochteca* traders. We might expect to see a gradation between 'walkabout' style travelers (forming "informal regional"networks) and specialized traders (forming "specialized regional" networks) based on the capital investments required to travel, with walkabouts and pilgrimages more common across relatively inter-connected social landscapes and where provisioning is not too capital intensive. By contrast, specialized traders might be supported more commonly where social landscapes are punctuated by difficult terrain, where travel is risky and requires specialized technology and specialized knowledge, and where provisioning is costly.

Connections of networks across all of these scales results in the indirect social transmission of information over the greatest spatial scales. All social transmission of information is in some sense "indirect", but we can recognize that non-local information is often acquired in any group through networks of communication flowing through multiple nodes or transmission events along trade and gossip networks. This "indirect hearsay" form of information acquisition permeates social life and is the mechanism largely through which individuals come to understand the larger world and its changing state. Resulting from the linkage of multiple networks of information flow (e.g. partners of partners of partners), indirect hearsay has the greatest geographical reach but the lowest fidelity over distance. Such 'down the line' information exchange is vulnerable to increasingly biased transmission at its joints, those places in network structure where fewer independent pathways exist to carry redundant information.

Temporal and spatial dimensions of variability

The foregoing discussion focuses on social and spatial scales of information acquisition and transmission. To more fully explore the importance of information strategies to people in small scale societies, we need to also consider the temporal scale of environmental variation and how different information strategies might serve to minimize people's exposure to hardship at different scales.

Temporal variability has a generally predictable relationship to spatial variability, such that larger amplitude fluctuations tend to have the largest "footprint", requiring more extensive information networks to mitigate negative fluctuations (Figure 3). Local information networks and direct observation are most effective for dealing with relatively common, low amplitude shifts in resource productivity, diversity, and distribution, as these networks allow for the most frequent updating of information and the greatest flow of information about local conditions and options. Supra-band scale networks such as *hxaro* partnerships would be less effective for dealing with high frequency variability, both because of the reduced frequency of interaction and the higher cost of network maintenance. These networks would instead help to distribute information about decadal scale variability that might require temporary adjustments or even re-organization of populations into new groups at the regional scale. Such adjustments could extend to somewhat broader scales (though often with increased inter-group conflict) by means of information collected through walkabouts, and indirect hearsay over greater distances (facilitated by specialized traders and/or down the line social transmission). In rare cases when perturbations are strong but highly localized, mobility and broader networks should provide a ready mitigation strategy set.

[Figure 3: Here]

The ability to anticipate and deal effectively with high amplitude centennial or longer scale fluctuations is limited to strategies for preserving information about ancient experiences preceding the lifespan of individuals preserved in traditional knowledge (Minc 1986). People are most vulnerable to the longest scale, highest amplitude fluctuations, for which prior experience (if at all) is distant in time and for which relevant information has been transmitted through the greatest number of transmitters (leading to greater opportunity for erosion of accurate content). Millennial scale variability, such as the climate change currently affecting the Earth, approaches or exceeds the capacity of most (if not all) existing cultural information strategies to predict and mitigate effectively. Extreme hardship (as well as unprecedented opportunity), large scale migration, social displacement or demographic expansion, colonization of new regions or local extinctions are all expected outcomes of environmental fluctuations at these longest time scales.

It follows that, all else being equal, vulnerability to environmental fluctuations decreases the longer a group remains in a region and accumulates local and traditional knowledge about the variability affecting them at various spatial and temporal scales. With increased residence time, resiliency should expand from local to more regional scales and from shorter to longer cycles of variability through the accumulation of information.

[Figure 4: Here]

Geography influences the ease with which different information networks can be implemented. Following basic principles of network theory, information networks should be most resilient (providing the greatest information by which people can adapt to environmental change) where the greatest connectivity is maintained at all levels from local to supra-regional scales. Figure 4a shows a resilient social information network with maximum adaptive depth. In this case, people interact frequently and with minimal constraint locally and regionally, with information of supra-regional conditions flowing into and through the network by means of relatively frequent walkabouts and indirect transmission. This network structure would be supported by a relatively continuous social landscape, with few physical or social barriers to interaction and short effective distances between interactors. Figure 4b illustrates a vulnerable social landscape in which interaction is costly at all scales due to low population densities, and where interactions involve high opportunity costs. Following the predictions sketched in Figure 5, people on such a landscape should put the greatest value in maintaining information networks, despite the greater costs involved in doing so up to the point at which such connections are unsustainable.

Predictions

The relationships outlined in the model allow us to consider the ways that changing social, geographic, and environmental conditions should influence the nature and degree of investment hunter-gatherers place in information network strategies. Figure 5 identifies the kinds of information strategies expected to develop under different combinations of environmental predictability and the costliness of maintaining networks at different scales.

[Figure 5: Here]

Political Networks

In situations of high environmental predictability (low uncertainty and variability) and low interaction cost, we expect information networks to be externally focused on socio-political over environmental content. In these cases, because of the predictable nature of the environmental, people should focus their information networking investments/interests in developing social and political relationships.

Insular and Stable Networks

Where there is high environmental predictability but also high interaction costs, we expect networks to be minimal and internally focused. Under these circumstances, investment in the high cost of interacting with and maintaining information network relationships with other groups is not warranted given the predictable nature of the environment.

Fully Integrated Networks

Where environmental predictability is low but interaction costs are also relatively low, we expect egocentric networks with many strong ties to emerge. Because of the relatively low cost of interactions relative to the value of information, people would invest in a diverse range of local and regional networks, maximizing their access to information at all scales and creating a network structure of high interconnectivity and resilience. In other words, a set of nested networks is produced with many strong ties at the supra-band level and informal regional integration (walkabouts, etc.)

Specialist Networks

By contrast, the most vulnerable situation occurs where interaction costs are high but environmental predictability is low. In these cases, fewer people can afford to invest in diverse information strategies and the network should become increasingly specialized with smaller numbers of interactors maintaining fewer strong ties. Others would invest more heavily in more intensive local strategies (such as expanding diet breadth, improved technological efficiency, etc.) to mitigate unpredictability. The resulting network structure would be one of low connectivity and high vulnerability. It is this kind of network that we would expect to be more prone to failure, especially early in the period following initial colonization or after a major social or environmental change.

Through time and under circumstances of relative social and environmental stability, we would expect a successful population to increase their local knowledge and ability to mitigate variability locally, allowing them to become less dependent on extensive networks, but perhaps rendering them more vulnerable to rare perturbations. Increased technological effectiveness can both reduce the costs of communication (e.g., by improving the safety or facility of engaging in communication networks) and increase the predictability of environmental outcomes (e.g., through development of mass harvesting and storage technologies, or better mechanisms for tracking or securing resources). Technological developments, however, also often lead to unintended consequences such as altered system parameters (prey populations, human population densities, etc) and dynamics, in ways that render accumulated knowledge less relevant to future variability.

Predictions for the Kuril Islands

In the Kuril Islands (Fig. 6), two key variables will affect the vulnerability of a population to specific environmental fluctuations. First, is the inherent productivity and variability of the environment in which people live. Second, is the facility through which supra-band networks can be maintained. These variables are largely independent of one another, but both are tied in part to geography, in part to demography, and in part to technology. Given the linear orientation of the Kuril Island chain and the regional differences in ecological diversity that are present, information network strategies should shift dynamically with cycles of island colonization, occupation, and abandonment. In the southern parts of the island chain, settlements would have been able to develop in closer proximity under conditions of greater ecological productivity and diversity, as well as greater availability of suitable settlement locations to support larger population densities. Higher ecological diversity would also have resulted in lower vulnerability to perturbations in any single resource or suite of related resources. Due to the low interaction costs between more closely spaced settlements, these groups would have been externally focused and highly interconnected. However, the more predictable and productive nature of their environment should place an emphasis on networking for socio-political purposes more so than ecological information exchange (**Political Networks**).

The Kuril Islands can be classified as an island environment demonstrating sub-polar climate variations. The most northern latitudes of Kuril Islands may therefore experience greater shifts in the predictability of resources in response to changes in sea ice and temperature than southern latitudes. The affect of low predictability of resources shifts networks structures to the investment of long distance information in order to mitigate unpredictability. The information networks model would suggest many strong ties between individual across long distances assuming interaction costs remain low. In reference to the Kuril Islands, the northern regions are most likely to demonstrate this pattern given the greater unpredictability of northern latitudes and the relative ease of interaction between islands and the mainland of Kamchatka. (**Fully Integrated Networks**).

The central Kuril Islands present different challenges in colonization and maintenance of information networks. In this region, where ecological diversity is at its lowest and distances between neighboring populations would have been most costly to maintain, we would expect people living in these remote regions to invest more heavily in maintaining a few, but very strong, network ties to compensate for their local vulnerability. These ties would have been essential early in the colonization phase, before locally sufficient population densities and local knowledge were developed (see Fitzhugh and Kennett, in press). If information networks persist after initial colonization with no reduction in interaction costs, populations may come to depend upon resources accessed via network relationships to the parent populations. In this case, network specialists may assume the role of moving between groups who are inwardly focused on adapting to local environmental conditions (**Specialists Networks**).

Conversely, in the central islands an alternative scenario is that the local population density may have remained low and high interaction costs constant, but environmental predictability increased. This scenario can occur via an expansion in local knowledge and internally oriented investments in localized adaptations (such as diet breadth or technological efficiency). The model suggests that networks may be devalued in terms of maintaining expensive relationships with parent communities, and only a few weak ties should remain (**Insular/Stable Networks**).

The Kuril Islands

The Kuril Islands of the northwest Pacific Ocean provide an interesting case for exploring the adaptive imperative for information sharing at different places and points in time throughout the island chain. The Kuril archipelago is an active volcanic island arc spanning the Okhotsk Sea – Pacific Ocean boundary from northern Japan to southern Kamchatka. The Kuril Islands are comprised of 160 Quaternary terrestrial and 89 submarine volcanoes with thirty-two of the volcanoes known to have erupted in the past 300 years (Ishizuka 2001). Tephra layers present throughout the islands indicate that prehistoric volcanic activity was a regular occurrence.

The Kuril Islands become more geographically isolated towards the center of the island chain, and vary in size from 5 km^2 to 3,200 km^2, with the northern and southern islands generally much larger than those in the central region. In spite of their mid-latitude location, the Kuril Islands experience subpolar conditions in winter due to strong northwesterly winds (Leonov 1990). Sea ice covers up to one-third of the Sea of Okhotsk by the end of the winter season, and typically reaches the southern Kuril Islands from the west. With partial ice-free ocean upwind, heavy snow is common from November to March. Summers are characterized by dense fog and mild southerly winds (Rostov et al. 2001).

[Figure 6: Here]

Marine and anadromous fish, marine mammals and birds are common throughout the Kuril Islands. Sea otter (*Enhydra lutris*), northern fur seal (*Callorhinus ursinus*), and sea lion (*Eumetopias jubatus*) frequent the shores and bays of the islands. As of the mid-20th century (Hacker 1951), few land mammals were present in the Kurils, with most concentrated on the larger islands close to Hokkaido and Kamchatka. Recent biogeographic surveys of the Kuril Islands have found that southern-source land mammals and freshwater fish extend north only to Iturup, while freshwater fish and mollusks from the north have made it south only to Paramushir, rendering the majority of islands in the center of the island chain relatively impoverished in these taxa, and lowest in overall species richness (Pietsch et al. 2003).

The Kuril Islands: Cultural History

Terrestrial Hunter-Gatherers

The earliest archaeological remains in the Kuril archipelago are found at the sites of Yankito and Kuibyshevo (Iturup Island) and Sernovodskoe (Kunashir Island) and date to around 7000 BP (Vasilevsky and Shubina 2006). Archaeological material from the Sernovodskoe show early relationships between the southern Kurils and Hokkaido with large cord-marked ceramics characteristic of the Early and Middle Jomon periods of Japan dating from 16,000 to 2,500 BP (Vasilevsky and Shubina 2006; Habu 2004; Aikens and Higuchi 1982). While little is known about the adaptations of these earliest Kuril occupants, we assume that they lived much as their Jomon cousins in Hokkaido. These early groups lived in small and highly mobile populations subsisting primarily by terrestrial hunting and gathering, which was supplemented by small amounts of fish and shellfish (H.Okada 1998;Y. Okada 2003; Imamura 1996).

Marine Hunter-Gatherers: Epi-Jomon

The inhabitants of the Hokkaido exhibit a shift from terrestrial foraging to an increased reliance on marine mammal hunting (whale, seal, sea lion) between 5000-3000 BP (Niimi 1994). The Late and Epi-Jomon periods are recognized as the first consistent occupation of the islands (Fitzhugh et al. 2002; Niimi 1994; Yamamura and Ushiro 1999). The Epi-Jomon occupation of the Kurils appears to be one of the first and most expansive settlements of the region with large numbers of sites extending north of the Bussol Strait into the more remote central islands. Yamaura (1998) suggests that increased sea mammal hunting may have related to cooler climatic conditions and increased populations of sea mammals in the area around Hokkaido and the Kuril Islands. Increased sea mammal populations along with technological specializations would have improved the overall return rate of sea mammals and favored population expansion.

Marine Hunter-Gatherers: Okhotsk

The Okhotsk culture flourished under a time of significant social and economic change through East Asia (Hudson 2004). The development of the Okhotsk culture is identified as occurring in three distinctive stages (Amano 1979 in Hudson 2004). The first stage identifies the initial expansion from south Sakhalin Island into the islands of the Japanese archipelago including Rishiri, Rebun and northern Hokkaido. This stage is characterized by a heavy reliance on marine resources as well as breeding of pigs (Yamauara 1998). The second stage is identified as eastern movement of Okhotsk culture to the northeastern corner of Hokkaido and into the southern Kuril Islands (Hudson 2004). The Okhotsk culture similar to it Epi-Jomon predecessor expands from the southern islands through the central islands and to the most northernmost Kuril island of Shumshu. Substantial changes to subsistence strategies may have occurred in conjunction with movement into this region based on the need to extract resources over longer periods of winter sea ice. The third stage is identified by high population pressure increasing the separation of regional groups assimilating the eastern Hokkaido Okhotsk with their Satsumon neighbors and pushing the northern Okhotsk groups further into the Kuril Islands. After 800 BP, the Okhotsk culture is replaced on Hokkaido and, perhaps later, on the Kuril Islands by Ainu settlements (Fitzhugh and Dubruil 1999).

Ethnographic Hunter-Gatherers: Ainu

The Ainu presence in the Kuril Islands is first noted in ethnohistorical accounts and identifies distinct cultural and linguistic groups among the Ainu (Kono and Fitzhugh 1999). The Kuril Ainu lived throughout the island chain in relatively large pit house villages as well as smaller seasonal camps (Fitzhugh 1999). Kikuchi (1999) suggests that the Ainu movement from Hokkaido into the Kuril Islands would have likely taken place during the fourteenth or fifteenth centuries AD, these tentative dates seem to coincide with preliminary radio-carbon dates obtained by the Kuril Biocomplexity Project (PI: Ben Fitzhugh). During the early eighteenth century into the nineteenth century the Russian-American Company settled the Kurils with transplanted Alaskan and Siberian sea mammal hunters (Shubin 1994). The Japanese occupation of the Kurils during the twentieth century forcefully displaced a number of Ainu populations and World War II saw the fortification of the islands by the Russian military.

Refinements in Culture History: Initial Results of the Kuril Biocomplexity Project (KBP)

KBP teams documented occupations from each of the culture historical phases that are known to have been present in the Kuril Islands. Based on existing radiocarbon dates (Fitzhugh et al. 2002; Zaitseva et al. 1993) and new dates generated by the KBP (Fitzhugh et al. 2007), several dates between 4250 and 2750 BP suggest a small but persistent occupation of the southern Kurils during the Middle to Final Jomon periods of Japan. A single radiocarbon date of 3330 BP from the northern Kuril Island of Shumshu indicates that there was activity in the northern Kurils during this time, though the path to Shumshu Island, either from the Kamchatka peninsula to the north or from the southern Kurils, is still unresolved. The absence of archaeological radiocarbon dates from this period in the central Kuril Islands suggests that the relative geographic isolation or potential resource poverty inhibited substantial occupation of the central Kuril Islands at this time.

A surge of occupation of the Kuril Islands begins in the Epi-Jomon period and is represented by a significant increase in the number of radiocarbon dates for this period and the distribution of Epi-Jomon ceramics through much of the island chain. Diagnostic Epi-Jomon ceramics are common in many archaeological sites from Kunashir to Shiashkotan, and Epi-Jomon pottery is tentatively reported from the northern Kuril Islands of Paramushir and Shumshu (V.O. Shubin, personal communication).

The Okhotsk period occupation of the Kuril Islands is well-represented throughout the island chain, and includes the earliest substantial occupation of the central Kuril Islands.

Okhotsk-type materials are found as far north as the southern tip of Kamchatka (Dikova 1983), and the Okhotsk period presence in the Kuril Islands suggests that these people were prepared to adapt to the environmental and ecological variability they would have experienced across the length of the island chain. Based on KBP radiocarbon dates, the end of the Okhotsk period falls around 700 BP, roughly coeval with the time when Okhotsk populations are replaced by the Ainu on Hokkaido.

Evidence of Ainu period occupations is relatively scarce throughout the Kuril Islands. Ethnohistoric accounts (Krashenenikov 1972) and earlier archaeological research (Baba 1937, 1939; Baba and Oka 1938) have documented Ainu settlements across the length of the island chain, while systematic survey over three field seasons of KBP have found very few Ainu sites relative to the earlier periods. While historical accounts suggest significant Ainu occupations, we are evaluating the possibility that Ainu colonization of the central and northern Kurils occurred late in the Ainu period and may have been less substantial and more mobile than earlier occupations (Fitzhugh et al. 2007).

Testing Model Predictions with Archaeological Data

Ceramic Technology

The Kuril Islands demonstrate a pattern of colonization and abandonment of geographically isolated regions. This dynamic is clearly recognized in the ceramic technology of the islands with three distinct ceramic types: Epi-Jomon, Okhotsk and Ainu. Analysis of ceramic artifacts previously excavated suggests a significant degree of regional variability in functional and stylistic attributes. During the Epi-Jomon period, the island chain maintains strong similarity with Hokkaido ceramics specifically in design motifs (cord-marking) and vessel form. However, nearing the boundary between the southern island region (Northern Urup) and central island region, variation in functional attributes emerges. This variation includes the increased presence of sand as the primary tempering agent on southern islands with more localized patterns of vegetation temper identified in the central to northern regions. A similar pattern is also recognized by Hall et al. (2002) on the island of Rishiri, west of Hokkaido. Hall et al. (2002) suggests pottery from the Epi-Jomon layers as manufactured using local raw materials while maintaining strong ties with morphological and decorative attributes identified on Hokkaido.

The preliminary interpretation of the Kuril ceramics fit well with the predictions of the information networks model. The model suggests that with initial colonization of marginal ecological areas, such as the central and northern islands, strong ties will remain between original and founding populations in order to mitigate ecological unpredictability of the new area. Specifically for ceramic technology, the information network model would suggest after colonization functional and stylistic attributes would show little variation from the parent population. Eventually, after accumulation of localized ecological knowledge, we can expect a shift towards the use of localized materials in functional attributes of the ceramics. This archaeological correlate of the prediction is the regional use of sand and organic tempering agents in the differing regions of the Kurils while maintaining similar stylistic attributes. Building on localized knowledge in the northern and southern regions, ties become weaker moving the network structure towards a specialist network structure with localized investment in raw materials and specialists maintaining few strong ties. Presumably, these specialists may still provide the network ties to maintain similar stylistic attributes over greater scales of space and time. Unfortunately, current data resolution does not permit accurate interpretations of the central island region. Drawing from the information networks model, future research needs to consider that given the severity of geographic or ecological constraints, isolation of certain populations may subject both stylistic and functional ceramic attributes to diverge from those of other regions with the development of more insular/stable networks.

Lithic Technology

Lithic artifacts recovered through KBP excavations include a number of tool types (projectile points, knives, scrapers, and drills) but there are currently no culturally diagnostic tool forms or typologies. Lithic raw materials represented among the tools types and tool production debitage include obsidian, basalt, chalcedony, and a variety of different colors of chert (Fitzhugh et al., 2004). Although lithic artifact assemblages from across the Kuril Islands include tools and flakes made from obsidian, there are no geologic sources of obsidian in the Kuril Islands that are known to have been used prehistorically (Phillips and Speakman in press). Non-local obsidian brought to the central Kuril islands may initially have been the result of migration and colonization events as groups moved through the islands in search of marine resources and/or the expansion of group size.

Based on predictions of the model specific to the initial colonizers of the central islands, we would expect to see evidence of ties maintained to parent communities in the form of non-local obsidian from Hokkaido (assuming a southern origin of colonizing populations) in the earliest levels of excavated sites with obsidian artifacts. We would also expect early lithic assemblages from the central islands to be composed of higher percentages of non-local obsidian relative to other types of locally available lithic raw materials (high-quality basalt, chert, and chalcedony). An information network structure tied to maintaining access to long-distance, non-local obsidian could be classified as a “specialist network”. As groups adapted to and learned more about the lithic resources present in their local area (i.e. lithic resource availability became more predictable), reliance on non-local obsidian should have lessened, and should be evident by a decrease in the presence of non-local obsidian relative to other locally available materials. Information network structure may transition to either the “insular/stable” or “political network” based on the predictability of other ecological resources and population density growth.

Obsidian source analysis conducted on a small sample of the overall obsidian lithic assemblage collected in the Kuril Islands demonstrated that obsidian from volcanic sources on Hokkaido and Kamchatka were widely used for stone tool production in the Kuril Islands (Phillips and Speakman, in press). Using a sub-sample of obsidian lithic artifacts collected from 18 archaeological sites on eight islands, 131 obsidian flakes were analyzed with X-ray fluorescence (XRF) to determine their source provenance. A total of 49 obsidian flakes from four different Hokkaido sources were found almost exclusively on the southern Kuril islands of Kunashir, Iturup, and Urup. Hokkaido obsidian was utilized on Urup island from at least 2540 – 880 BP, indicating long-term access to Hokkaido sources from the southern Kurils. Only three flakes from Hokkaido sources were found in the central islands north of the Bussol Strait, the widest strait between islands in the Kuril chain and a recognized biogeographic barrier between the southern and the central and northern islands (Pietsch et al. 2003). All of the 79 flakes from five different obsidian sources on the Kamchatka peninsula were found in the central and northern parts of the island chain, none were found in the southern Kuril Islands south of the Bussol Strait. Obsidian artifacts from Kamchatka sources were recovered from Shiashkotan island from contexts dated between 1470 – 750 BP, indicating access to Kamchatka sources from the central Kurils for more than 700 years.

Given the geographic proximity of the southern Kuril islands and northern Kuril islands to Hokkaido and Kamchatka obsidian sources respectively, the extension of obsidian trade or transport networks from local source areas to adjacent islands could be expected. Lithic assemblages from these areas should show a more even distribution of obsidian relative to other types of lithic raw materials through time. Information networks may be classified as political since minimal obsidian resource information exchange is required, and attention should be focused on political and social developments in areas of higher population density in the southern and northern Kurils As groups of people from Hokkaido and the southern Kuril islands persisted into the central and northern islands, they may have found it too costly in terms of time, energy, and risk to maintain access to Hokkaido obsidian sources across the Bussol Strait. Securing access to obsidian sources in Kamchatka would have provided a less costly alternative to Hokkaido obsidian and fostered social connections to the northern mainland. Although networks related to the access and trade of obsidian from sources in Kamchatka are less well known, inhabitants of the central and northern Kurils used Kamchatka obsidian extensively. With a growth in population density in the central Kurils, the development of a down-the-line obsidian procurement system from Kamchatka into the central islands could have facilitated a locally integrated information network composed of many shorter, tighter local ties, and only connected outside of the larger region indirectly via the down-the-line relationships.

Future Research

While the analysis of archaeological materials recovered during the KBP is currently ongoing, initial results indicate the model outlined in this paper provides a useful framework for developing testable hypotheses about the dynamic nature of information networks in the Kuril Islands. Kuril ceramic and lithic assemblages represent just two forms of evidence for material network interaction and exchange that can be considered evidence of information network interaction and exchange. The information network model can be used to explore the functional and stylistic changes that are detected in Kuril ceramics as ties between parent populations and colonizing groups weaken in the face of increased localized knowledge in newly colonized areas. Obsidian provenance studies in the region can use the information network model to explain the changes in obsidian source access and utilization as a function of changing network structure and focus. Ceramic analyses can use this model to predict variability and evolution of technological and stylistic characteristics as they relate to the connectedness between more and less insular groups.

The information network model may also be useful in addressing the issue of the de-population and abandonment of the central Kurils at various points in the occupation history of the island chain. The nature and status of information networks in the central Kurils may have allowed people to retreat from the center of the chain in the face of long-term ecological unpredictability or in the aftermath of a large catastrophic event, or perhaps were a factor in the potential extinction of local groups that had no safety-net to turn to in times of loss.

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FIGURE CAPTIONS

Figure 1: Adaptive strategies for mitigating environmental unpredictability

Figure 2: Organization of information networks operating at different spatial scales.

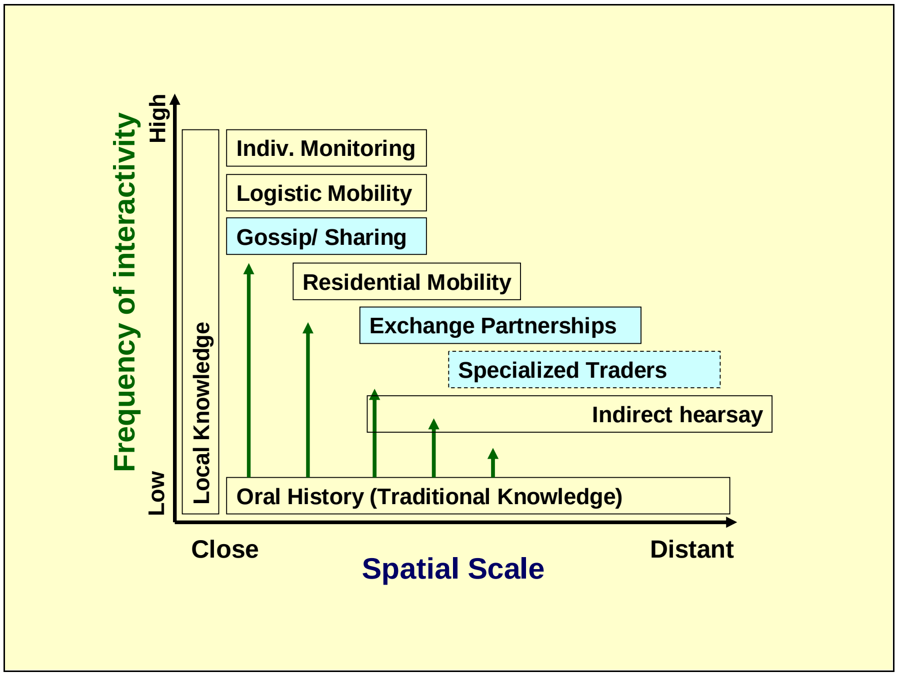
Figure 3: Environmental variability at different time scales, showing the inverse relationship between frequency and amplitude and the information networks most effective for different scales of temporal variability. (a.) Monthly global temperature anomalies in the Lower Troposphere from 1978 to 2008 (UAH 2008); (b.) Mann et al.'s (1999) Northern Hemisphere multi-proxy paleo-temperature reconstruction ("Hockey Stick" model) of millennial climate change.

Figure 4: Extremes in network connectedness: A. highly connected "resilient" landscape in which multiple channels of information flow occur from local to supra-regional scales; B. minimally connected "vulnerable" landscape in which connections are severely limited and tenuous beyond local scales. In these diagrams, clusters of circles represent co-residential groups or "bands".

Figure 5: Information Networks expected for different combinations of environmental predictability and costs of information network maintenance.

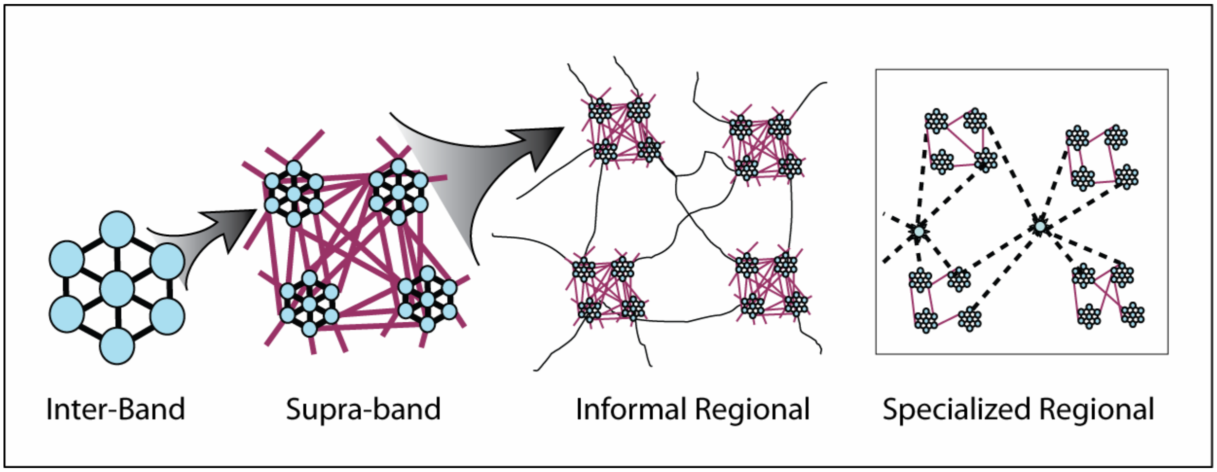
Figure 6: Map of the Kuril Islands.

Figure 1:



Frequency of interactivity
High
Low
Local Knowledge
Indiv. Monitoring
Logistic Mobility
Gossip/ Sharing
Residential Mobility
Exchange Partnerships
Specialized Traders
Indirect hearsay
Oral History (Traditional Knowledge)
Close
Distant
Spatial Scale

Figure 2:



Inter-Band
Supra-band
Informal Regional
Specialized Regional

Figure 3:

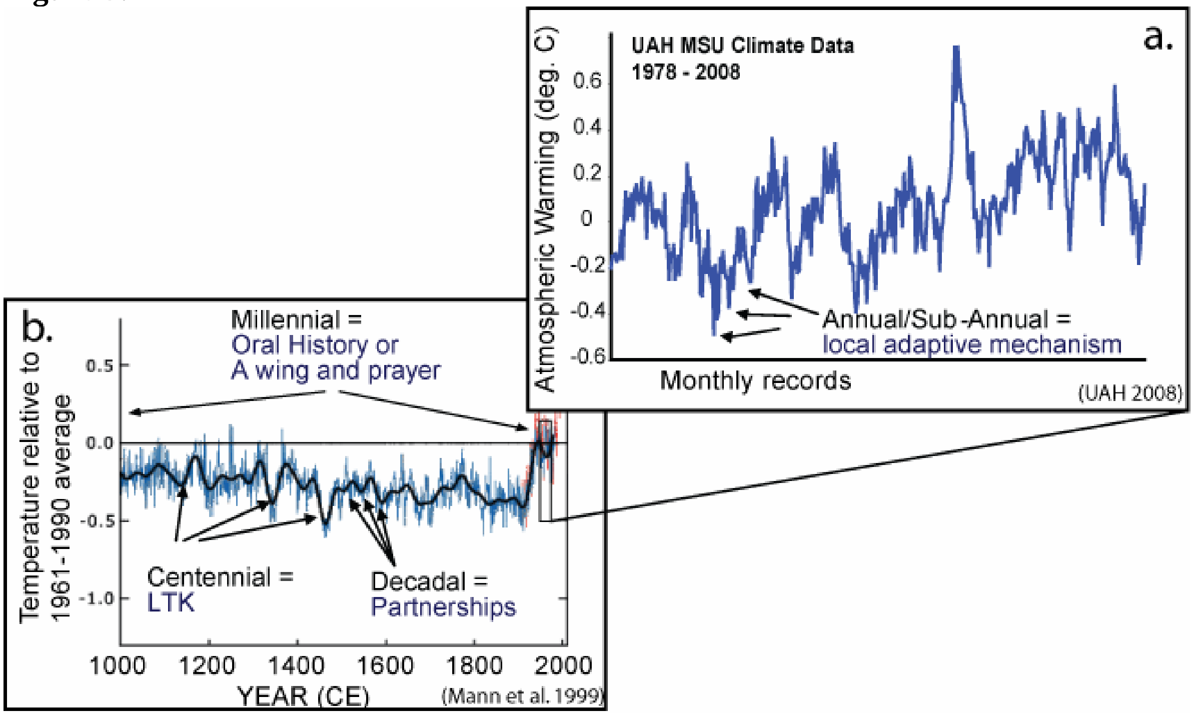

a.
UAH MSU Climate Data
1978 - 2008
Atmospheric Warming (deg. C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Annual/Sub-Annual =
local adaptive mechanism
Monthly records
(UAH 2008)
b.
Temperature relative to 1961-1990 average
0.5
0.0
-0.5
-1.0
Millennial =
Oral History or
A wing and prayer
Centennial =
LTK
Decadal =
Partnerships
1000
1200
1400
1600
1800
2000
YEAR (CE)
(Mann et al. 1999)

Figure 4:

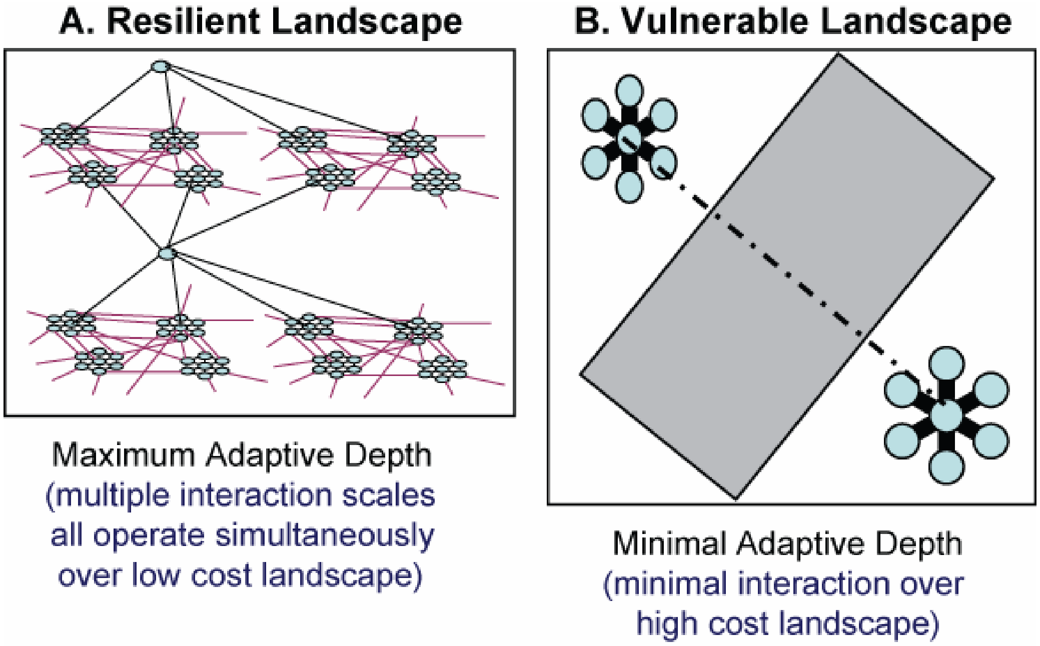

A. Resilient Landscape
Maximum Adaptive Depth
(multiple interaction scales
all operate simultaneously
over low cost landscape)
B. Vulnerable Landscape
Minimal Adaptive Depth
(minimal interaction over
high cost landscape)

Figure 5:

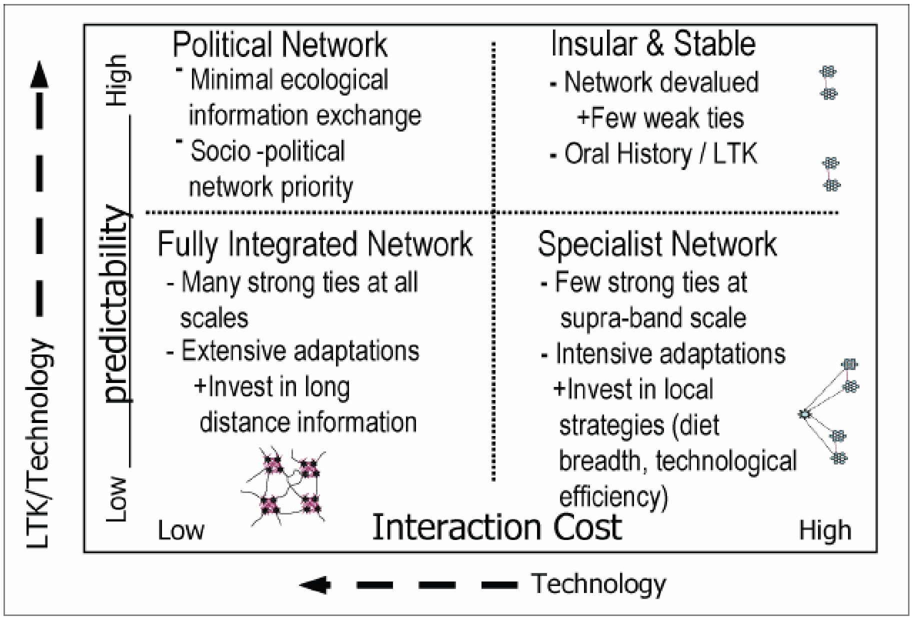
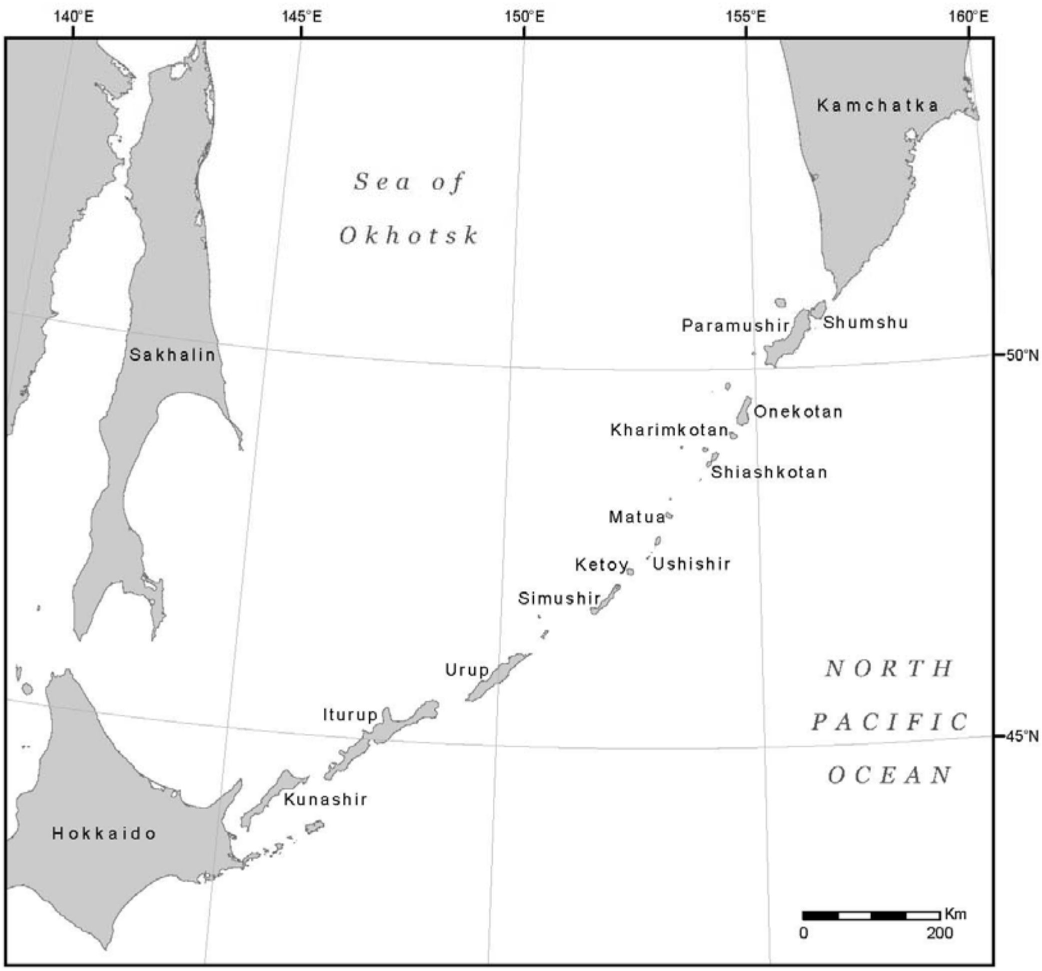

Political Network
- Minimal ecological information exchange
- Socio -political network priority
Insular & Stable
- Network devalued
+Few weak ties
- Oral History / LTK
Fully Integrated Network
- Many strong ties at all scales
- Extensive adaptations
+Invest in long distance information
Specialist Network
- Few strong ties at supra-band scale
- Intensive adaptations
+Invest in local strategies (diet breadth, technological efficiency)
High
predictability
Low
Low
Interaction Cost
High
LTK/Technology
Technology

Figure 6:


140°E
145°E
150°E
155°E
160°E
50°N
45°N
Sea of
Okhotsk
Kamchatka
Sakhalin
Paramushir
Shumshu
Onekotan
Kharimkotan
Shiashkotan
Matua
Ketoy
Ushishir
Simushir
Urup
Iturup
Kunashir
Hokkaido
NORTH
PACIFIC
OCEAN
Km
0
200