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## Navigating Hunter-Gatherer Resilience: Networks and Insularity in the Prehistory of the Ryukyu Islands

### Introduction

Prehistoric Japan was the land of networks par excellence. Networks of pottery, lithics, jade, asphalt and other goods crisscrossed the archipelago and sometimes beyond to Korea, China and Sakhalin (Kobayashi 2004; Kuzmin 2006; Uchiyama and Bausch 2010). The distribution patterns of these artifacts reflect the presence of past social networks. Scholars working on issues of resilience and sustainability have recently argued that social networks are very important for building resilience in social-ecological systems (Tompkins and Adger 2004; Janssen et al. 2006; Hahn et al. 2008). Networks function to transmit information and build trust, which can then serve to promote resilience, although as discussed further below the type of network involved significantly affects its ability in this respect. Some examples of the importance of social networks in building resilience in contemporary societies are described below.

Given this importance of social networks in navigating resilience, what happened to areas where such networks were absent or poorly developed? Was social-ecological resilience in those areas consequently very low? This paper attempts to examine this question through a comparison of two areas of the Ryukyu archipelago in southwest Japan: the Sakishima islands, where prehistoric networks were apparently very poorly developed, and the Okinawa and Amami islands, where such networks were characterized by much higher density and reachability (Figure 1).

The present work derives from our current research focus on the resilience of hunter-gathering societies in prehistoric Japan and on how lessons from those societies may be used to build adaptive capacity in Native societies in Alaska and other northern regions that are particularly vulnerable to global environmental change (Aoyama 2012; Hoover and Hudson n.d.). Global environmental change is already having a disproportionate affect on circumpolar regions and especially on Indigenous hunter-gatherers in the north (Chapin et al. 2004; Nuttall et

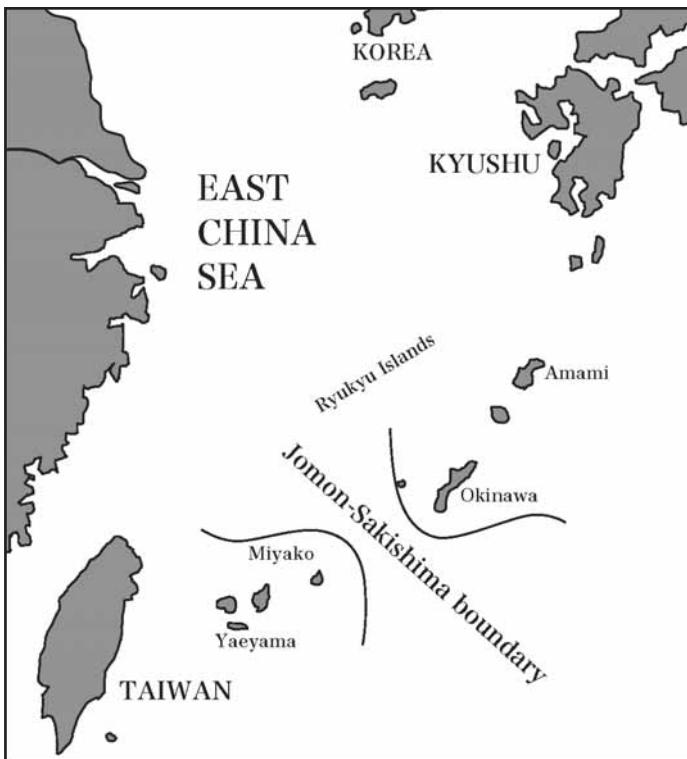


Figure 1.

The Ryukyu Archipelago with the location of the Sakishima islands (Miyako & Yaeyama), the Okinawa and Amami Islands highlighted.

al. 2005). Japan, with its long history of hunter-gathering societies, could provide important comparative material for understanding how circumpolar foragers adapt to climatic and other changes. However, if we are going to use Japan in comparative research on the human dimensions of global environmental change, then we need to consider the range of elements—biogeographical, climatic, historical, social and ideological—that are particular to the adaptive processes by which humans interacted with the environment in the Japanese archipelago. In this paper we provisionally explore the question of insularity and networks. To what extent did the insular nature of the Japanese archipelago in general and the Ryukyu Islands in particular affect the ability of hunter-gatherers to build resilience in the face of social and environmental changes? This question is of relevance to circumpolar areas not just because of potential direct comparisons with the Aleutians and other northern islands, but also because isolation—or what we might term ‘terrestrial insularity’—is a major factor affecting resilience in interior Alaska and other regions.

## Networks, Resilience and Small Islands

### What Is Resilience?

Resilience is a key to sustainability (Gunderson and Holling 2002). Resilience can be defined as “The amount of change a system can undergo (its capacity to absorb disturbance) and remain within the same regime—essentially retaining

the same function, structure, and feedbacks” (Walker and Salt 2006: 164). The term ‘resilience’ has been used in psychology since at least the 1930s to refer to the ability of individuals to cope with stress. Current usage of this concept in environmental studies, however, begins with Holling’s (1973) work in forest ecology and following research by the Resilience Alliance (Gunderson et al. 2010). Some archaeological implications of resilience theory are discussed by Redman (2005).

### Insularity and Resilience

Living on small islands is not intrinsically linked with either higher or lower levels of resilience. Most small islands are highly vulnerable ecological systems. To the extent that vulnerabilities in small island social-ecological systems are linked to outside processes, insularity or isolation may be beneficial. Resilience, however, involves the growth of “diverse mechanisms for living with, and learning from, change and unexpected shocks” (Adger et al. 2005: 1036) and too much isolation may harm the ability to build institutions capable of responding to sudden change.

Walker and Salt (2006: 145–148) propose nine factors that promote resilience. Table 1 summarizes how these factors may play out on small islands. This table shows that there is considerable variability in factors potentially affect-

Factors promoting resilience	Relevance for small islands
Diversity (biological, landscape, social, economic)	Biological diversity is usually species-poor and disharmonic*, yet rich in endemic species (Whittaker & Fernández-Palacios 2007: 5). Local micro-environments may increase landscape diversity, but social and economic diversity is variable.
Ecological variability	Can be difficult to maintain on fragile island ecosystems.
Modularity	May be high in archipelagoes
Acknowledging slow variables	Can be difficult when those variables originate outside the island (cf. Rolett and Diamond 2004).
Tight feedbacks	Often tighter than on continental land masses.
Social capital	Highly reliant on population density and networks.
Innovation	Highly reliant on population density and networks.
Overlap in governance	Variable and not necessarily low on small islands (cf. Mitsumata and Murata 2007).
Ecosystem services are valued & assessed	Value of ecosystem services may be clearer on small ‘bounded’ island systems.

Table 1. Some parameters of resilience on small islands. \*Disharmonic means ‘peculiar in taxonomic composition’.

ing small island resilience. In no small part this is due to the great diversity of island environments. While the idea of islands as ‘experimental laboratories’ is often misunderstood simply to mean ‘boundedness’, it is the variety of different types of islands that lends them further power as testing grounds for a range of ecological and cultural processes. Further discussion of these parameters in the context of the Ryukyu Islands can be found below.

### Networks and Resilience

Social networks are thought to be an important factor promoting resilience in contemporary societies. Social networks are listed as “sources of adaptive capacity” in four out of seven Canadian Inuit communities analyzed by Ford et al. (2010: 182). While social welfare policies in modern states typically favor individuals and households, Magdanz et al. (2002) describe the importance of extended-family networks in northwest Alaskan Iñupiaq communities. Social networks are a way to distribute and maintain knowledge, or what Adger et al. (2005) term ‘social memory’. On small islands, larger population densities are associated with greater technological and social complexity (Kline and Boyd 2010) and networks are one way of compensating for low populations. We propose that social networks are important elements in supporting resilience in difficult environments such as small islands. At the same time, however, networks entail costs that may be expensive to maintain and resilience requires an appropriate balance between such costs and benefits.

In this paper we attempt a preliminary analysis of how networks may have affected resilience in two island groups in prehistoric Japan, the Amami and Okinawa islands and the Sakishima islands (Figure 1). While all of these islands are part of the same Ryukyu archipelago, they have quite different histories with long-distance networks appearing to be much more important in Amami and Okinawa than in Sakishima.

### Case Study: Networks and Resilience in the Ryukyu Islands

#### Why the Ryukyu Islands?

The Ryukyu Islands provide a useful case study for this paper because they were colonized on at least two different occasions by Holocene hunter-gatherers, thus giving us the opportunity to compare two rather different adaptive strategies and, thus, the role of insularity in resilience. The Ryukyu Islands are usually divided into three groups: the northern Amami, the central Okinawan, and the southern Sakishima islands. All three of these groups were settled by Pleistocene humans (Nakagawa et al. 2010), but this initial colonization appears not to have survived late Pleistocene sea level rises. In the Holocene, the Ryukyu

archipelago was resettled around 9000 years ago, probably by Jōmon populations from the main islands of Japan, presumably from Kyushu. This Jōmon settlement, however, only expanded as far south as the main island of Okinawa. The Sakishima islands beyond this were settled around 4300 years ago by a quite different group of people(s) who seem to have come from the opposite direction, from somewhere in Southeast Asia. Sites of the Early Prehistoric period in Sakishima have pottery but no evidence of agriculture. Between about 3500 and 2700 years ago there is an apparent hiatus in Sakishima with no evidence of human settlement. The next, Late Prehistoric phase is then characterized by shell adzes and by the absence of pottery. Again there are no artifacts that suggest a relationship with the Jōmon or later cultures of Okinawa and, based on the presence of shell adzes, the Philippines is thought to be a possible source for this culture (Asato 1991). While agriculture was being practiced in the Philippines and elsewhere in Southeast Asia at this time, the Late Prehistoric culture of the Sakishima islands appears to have been based on hunter-gathering.

As noted by Takamiya (2006), the Ryukyu Islands are unusual in world prehistory for having been colonized by hunter-gatherers despite being relatively small, being isolated from nearby continents or large islands, and lacking abundant large sea mammals. A combination of proximity to the mainland and abundance of large sea mammals, in contrast, appears to explain the settlement of the Aleutian and other islands in Alaska. Takamiya (2004, 2006) argues that early foragers in Okinawa experimented with various subsistence strategies before finding a dietary combination of coral reef fish and shellfish and wild plants that was successful in that island environment. While Takamiya's argument is thus that the prehistoric colonization of Okinawa can be explained by (optimal) foraging strategies, the role of networks also requires attention. Despite their geographical isolation, long-range networks seem to have been important in the prehistoric Ryukyu Islands. In the following, we summarize the processes of adaptation by prehistoric hunter-gatherers to the northern/central and to the southern Ryukyu Islands and examine the role of networks in building resilience in these two regions.

### Prehistoric Colonization of the Amami and Okinawa Islands

Several finds of Pleistocene human remains have been made in the Ryukyu Islands (Nakagawa et al. 2010), but no sites are known between about 18,000 and 9000 years ago and it can be concluded that the islands were uninhabited at this time. Sites with pottery appear on Okinawa Island from about 9000 years ago (Takamiya 2006; Pearson *in press*). Since the pioneering work of Torii (1905) it is usually assumed that this new settlement originated in the Jōmon cultures of Japan and the term 'Jōmon period' is often applied to this stage in Okinawa, although the alternative 'Shellmound period' is also common. Recently, Itō (2010) has noted that the earliest ceramic culture in Okinawa and Amami does not possess clear parallels with Jōmon Kyushu and raises the possibility of an alterna-

tive origin outside Japan. Later ceramic sequences, however, are clearly linked with the Jōmon; the ‘Ryukyu Jōmon’ pottery sequence of Amami and Okinawa is not completely identical to Jōmon Kyushu, but the similarities are numerous and clear enough to show that extensive direct contacts occurred between these regions. According to Itō (2000: 4), at least the following seven ceramic types spread from Kyushu to Okinawa: Todoroki, Sobata, Kasuga, Matsuyama, Ichiki, Issō, and Irisa-Kurokawa. Itō (2000: 4) emphasizes that this influence was not just one way: pottery of at least five Okinawan types has been found at sites in southern Kagoshima.

Against this background, the extent and nature of contacts between Jōmon Kyushu and Okinawa is a key to understanding the social networks that may have linked these two regions. However, archaeologists working in Okinawa have yet to propose explicit models of such networks, at least for the Jōmon period. The mere presence of shared items of material culture does not necessarily make a network, or at least it does not clarify what sort of network was involved. In continental or large island situations where population levels are low, there will be many cases where hunter-gatherer groups rarely came into contact (cf. Damm 2006 for early Fennoscandia). Where population levels are higher and where competition over resources exists, more complex systems of both hostile and friendly relations may develop, such as those described ethnohistorically for northwest Alaska by Burch (2005). Small islands that are part of archipelagoes are first of all different in that it is usually difficult to *avoid* contact with people on other islands. Rouse (1964) coined the term “passage areas” to refer to close contacts between adjacent areas of islands and Moss (2004: 180) shows how such passage areas served as “the connective tissue of social and historical relationships” in southeast Alaska. Passage areas are also found in the Ryukyus, perhaps most notably in the area between Ishigaki and Iriomote islands in the Sakishima group, but most of the islands of the Okinawa group are arranged in a long string-like archipelago and lack passage area type links.

A major difficulty in modeling early networks in Jōmon period Amami and Okinawa is understanding the role of pottery. While, as noted, there are extensive ceramic parallels between Amami, Okinawa and the Kyushu Jōmon, there are relatively few other exchanged items or cultural links. Some obsidian from Kyushu has been found in Okinawa (Kuzmin 2006) and there are also a few finds of jade (Shinzato 2007). However, the Ryukyu Jōmon has few arrowheads or other hunting tools, few fishing tools, and no clay figurines, phallic stones or other Jōmon ritual artifacts (except for the jade just mentioned) (cf. Itō 2000, 2003). Trading networks centered primarily on shells have been widely discussed for the period following the Jōmon in the Okinawa and Amami islands (e.g., Kinoshita 2003; Shinzato 2003). Kinoshita (2003) argues that trade in cowrie shells may have been conducted between China and Okinawa as early as 2000 BC and suggests that certain types of shell artifacts found in the Okinawa and Amami islands at this time may be related to this trade. Further evidence is needed to test this hypothesis and it is not clear how this cowrie shell trade may have been linked to Jōmon ceramic networks in the islands.

Another potential way of modeling Ryukyu Jōmon networks is through the concept of marital networks. MacDonald and Hewlett (1999) found strong correlations between population density and mating distance for both foraging and horticultural groups. When population levels were low, as they are likely to have been in the Ryukyu archipelago throughout prehistory, islanders would have had to travel further to find marriage partners. Hudson (2004) tested for possible links between population densities and the size of ceramic style (*yōshiki*) zones in the mainland Jōmon (excluding Okinawa) but found no correlation. Similar analyses of smaller pottery type (*keishiki*) zones have yet to be conducted, but Hudson concluded that there is no necessary link between marital networks and Jōmon ceramics.

The distribution of Jōmon ceramic types in Okinawa became more spatially restricted over time and the Late Jōmon phase has the smallest spatial distribution of Ryukyu Jōmon pottery. Takamiya (1997: 34) interprets this as reflecting greater self-sufficiency and reduced need for contact with other regions in the Late Jōmon. However, “the fact that the distribution of local pottery types widens in the Final Jomon may indicate that this self-sufficiency broke down during the Final Jomon” (Takamiya 1997: 236). Takamiya’s research suggests that networks were utilized in prehistoric Okinawa to help buffer food stress. Although further research is required, this interpretation supports the hypothesis that social networks were important in promoting resilience in prehistoric Amami and Okinawa.

### Prehistoric Colonization of the Sakishima Islands

Unlike Okinawa and Amami, there is no evidence for prehistoric contact between Sakishima and Japan. It is assumed that the prehistoric settlers of Sakishima came from somewhere in Taiwan and/or Southeast Asia. Taiwan, which is only about 111km from the westernmost Sakishima island of Yonaguni, is the closest potential source, but there are no *direct* material culture parallels between Taiwan and Sakishima. While the exact source of the prehistoric Sakishima cultures is still debated, it can be assumed that they originated in the Austronesian speaking peoples of Southeast Asia or Taiwan. A great deal is known about the networks and colonization processes of Austronesian peoples (Bellwood 1995), but Sakishima does not fit easily into any existing models. There is no evidence for farming in the southern Ryukyus at this stage and it does not seem that the Sakishima islands were settled as part of the typical Austronesian process of agricultural expansion. At the same time, there is little evidence that the Sakishima islands were exploited as a source of trade goods. Furthermore, although the usual Austronesian pattern of maritime exploration was upwind (Horridge 1995), the Sakishima islands are downwind from Taiwan and Southeast Asia. Given this usual pattern, it might be expected that the Austronesian settlers of Sakishima would over time have explored *back* upwind to Southeast Asia, but this also does not seem to have occurred with any frequency that is archaeologically visible.

Despite surviving in apparent isolation for as long as a thousand years, the Early Prehistoric culture of Sakishima came to an end by around 3500 years ago. As sites are thereafter absent for about 800 years, it is assumed that the Early Prehistoric people died out or migrated away from the islands. In the mid 1st millennium BC, a new, aceramic culture with shell adzes appears in the Sakishima islands. Based on current radiocarbon dates, this culture was first found on Miyako island and then only later spread to Yaeyama. It is often assumed that this culture represents the arrival of a new group of people in the southern Ryukyus. From the presence of shell adzes made on the hinges of *Tridacna* and other giant clam species, it has been argued that the Philippines are the most likely source of this culture (Asato 1991). The arrival of this culture may have been pure chance or may reflect the presence of more regular (though archaeologically invisible) contacts between Sakishima and the outside world.

In contrast to the Early Prehistoric period, during the Late period there is some evidence of iron and Chinese coins from Sakishima that may be related to trading networks. With one exception to be described below, these finds have so far only been discovered in the Yaeyama islands and not from Miyako. Tang coins have been found at two sites and iron objects from four sites in Yaeyama (Ishigaki City 2009). Kinoshita (2003) has suggested that these artifacts are related to trade in the Great Green Turban shell (*Turbo marmoratus*), which was used for mother-of-pearl inlay in China and Japan. However, the total number of iron and coin finds is so small that Pearson (in press) suggests they may have come from a shipwreck.

Since previous finds of both iron and Chinese coins have been limited to the Yaeyama islands, it is usually assumed that Miyako island remained isolated at this time. However, a new find of iron from the Nagabaka site on Miyako being excavated by the first two authors complicates these assumptions. This iron is an irregularly-shaped lump, 32.14mm long, 26.68mm wide, and 16.55mm thick (Figure 2). The weight is 18g. An X-ray florescence analysis conducted at the Saga Prefecture Industrial Technology Center found that the surface layer of this object contains as much as 76% iron. This piece is not a recognizable artifact. Its irregular surface is similar to reheated iron or even iron slag, but the surface appears polished and shiny unlike other slag or reworked iron objects seen by the authors. This iron was excavated in 2007 from Layer 3 of Trench 1 at Nagabaka. Radiocarbon dates from this layer range from  $2160 \pm 30$  to  $1450 \pm 20$  Cal BP. While we cannot totally discount the possibility that this iron is intrusive, perhaps washed down from (as yet unknown sites) on the cliff above, since iron is present at other Late Prehistoric sites in the Sakishima islands further analyses including chemical sourcing are warranted.

Despite this possible (though apparently small-scale) trade network, the Late Prehistoric culture in Sakishima also seems to have died out by the end of the 1st millennium AD and several centuries prior to the arrival of a new culture in about the 12th century AD. This new culture brought ceramics and agriculture from Okinawa to the north (Pearson in press). Archaeological research in



Figure 2. Iron lump from Miyako Island.

Sakishima is less advanced than in Okinawa and Amami and we still lack sufficient basic data to help us understand why the Late Prehistoric cultural adaptation also proved unsustainable. The existence and nature of the shell trade network posited for the Late Prehistoric period by Kinoshita is crucial here. If this shell trade was not present at this time, the continued absence of long-distance social networks may explain the vulnerability of the Late Prehistoric societies to social collapse. Alternatively, even if this trade was present it may have involved networks that were socially exploitative or brought epidemic disease to the Sakishima islands, thus reducing resilience. To answer this question we need more information on the type of network concerned.

## Discussion and Conclusions

### Summary of Hypothesis

This paper has presented a preliminary analysis of the role of social networks in promoting resilience in the prehistoric Ryukyu Islands. It was found that such networks appear to have been poorly developed in the Sakishima islands of the southern Ryukyus. Two distinct prehistoric cultures settled these islands for many hundreds of years before eventually disappearing from the archaeological record. While we still have a great deal to learn about the adaptational strategies employed by these cultures, it can be hypothesized that limited social networks was one factor behind their vulnerability.

North of Sakishima, the central Okinawan and northern Amami islands of the Ryukyu archipelago were characterized by extensive networks of ceramic exchange that linked these islands with the Jōmon cultures of mainland Japan. As far as can be reconstructed from the archaeological record, these networks were primarily based on ceramics but in reality pottery is unlikely to have been the most important element. Marriage partners, information, and/or trade items such as cowrie shells may have been the main objectives of these networks but further research is required to clarify this. Whatever the exact nature of the Ryukyu Jōmon networks in Okinawa and Amami, it can be hypothesized that the presence of these networks helped sustain resilience in these islands in pre-history. Although both Takamiya (1997, 2004) and Itō (2010) have noted the existence of cyclical increases and decreases in population, the Ryukyu Jōmon cultures of Okinawa and Amami do not seem to have become extinct like the prehistoric cultures of Sakishima. As discussed in the next section, a large tsunami around 3400 years ago may have played a role in the disappearance of the Early Prehistoric culture in Sakishima, but this tsunami is unlikely to have killed all the inhabitants of the islands and networks would have played a crucial role in the ability of the survivors to overcome the disaster (cf. Adger et al. 2005).

### Other Parameters of Resilience

The hypothesis proposed here that social networks were an important factor in promoting resilience in the Ryukyu Islands requires further testing against a range of other potential factors that may have contributed to the differences noted between the southern and the central/northern islands. These factors include changes in the environment and resource availability, resource exploitation technologies, settlement patterns, and social organization. The problem of how the type of network(s) may have impacted resilience will be discussed in the following section.

As noted above, the Ryukyu Islands were occupied by at least two very different prehistoric cultures. These cultures can be assumed to have possessed quite different identities (Hudson 2012). Despite these differences, however, there are also striking similarities between the subsistence adaptations of the prehistoric cultures of the Ryukyus. As argued by Takamiya (1997, 2006), the ability to exploit coral reef resources was a central factor in the Holocene settlement of the archipelago. Studies of faunal remains have shown that remarkably similar fish and shellfish resources were utilized at sites across a range of locations and time periods in both the southern and the central and northern Ryukyus (Kurozumi 2011; Toizumi 2011; see also Pearson *in press*). Commonly exploited shellfish were giant clams (*Tridacna* sp. and *Hippopus hippopus*), *Turbo argystostomus*, *Tectus niloticus*, *Conidae*, *Strombus luhuanus*, and *Atactodea striata* (Kurozumi 2011). Toizumi's extensive work on fish remains from the Ryukyus has found that three types of reef fish (parrot fish, wrasses and emperor fish) dominate almost all assemblages. In addition to fish and shellfish, wild pigs were also hunted throughout the Ryukyus. At one level, these patterns reflect

the availability of similar resources along the archipelago. In the southern Ryukyus, Kurozumi (2011: 95) notes that similar shellfish species were exploited, not just for the approximately 1000 years of the Early Prehistoric period, but also in the Late period which began after a hiatus of almost a millennium. Kurozumi goes on to make the important point that the presence and absence of ceramics in the Early and Late periods respectively, does not seem to have affected shellfish prey choice.

Notwithstanding these broad similarities in prey choice, Okinawan archaeologist Hiroto Takamiya has proposed significant changes in resource exploitation patterns in the prehistory of the central and northern Ryukyus (relevant analyses for the southern Ryukyus have yet to be conducted). Takamiya's main argument is that population-resource imbalance developed during the Final Jōmon phase due to a "collapse" in coral reef fish (Takamiya 2003). Based on archaeological evidence for more substantial and permanent dwellings and the presence of at least one cemetery site, he proposes that increased sedentism was one adaptation to this crisis. This explanation does not necessarily rule out the role of networks, however, since, as noted above, pottery networks became wider in the Final Jōmon and Takamiya (1997) argues this may also have been an adaptation to food stress.

Direct evidence relating to prehistoric climate change is rare in the Ryukyu Islands (see Pearson in press for a review). Although paleoenvironmental data from neighboring regions such as Japan and China show that major climatic shifts did occur, we have no evidence for differential impacts *within* the Ryukyu archipelago. At present, therefore, climatic changes cannot be considered as factors contributing to different patterns of resilience and vulnerability within the prehistoric Ryukyus. Natural disasters may, however, have played a significant role in this respect. Historical evidence, such as that from the 1771 Meiya tsunami, shows that very large tsunami occasionally affect the Ryukyus, especially the Sakishima islands (Kawana 2011). Research by Kawana and colleagues has concluded that such large tsunami hit the southern Ryukyus around 500, 1000, 2000, 2400 and 3400 years ago (Kawana 2009 and references therein). Kawana (2009: 45) raises the possibility that the last of these tsunami may have played a part in the collapse of the Early Prehistoric phase in Sakishima.

Finally, we can briefly consider the variables listed in Table 1 in terms of their possible effects on prehistoric resilience in the Ryukyus. While it must be stressed that some of the following points are almost impossible to reconstruct from archaeology alone and others require empirical testing, it is nevertheless possible to make some preliminary comments.

- (1) Diversity: biological diversity in the Ryukyus was higher in the Pleistocene (when many of the islands were connected by land bridges) but became reduced in the Holocene. The Ryukyus follow the general pattern for small islands noted in Table 1 in that they are disharmonic with many rare species and yet possess few native terrestrial mammals (the largest island of Okinawa, for example, has only seven mammal species compared to over 100 for mainland Japan)

(Takamiya 1997: 23–24). Humans adapted to this reduced diversity by specializing in coral reef resources. This reef adaptation developed independently on at least two occasions.

(2) Ecological variability: although the ability of prehistoric hunter-gatherers to control and reduce ecological variability may have been relatively limited, there is no doubt that foragers could have significant impacts on the ecosystems of the territories in which they lived (Williams and Hunn 1982; Harkin and Lewis 2007; Rick and Erlandson 2008). However, empirical evidence for such impacts from the Ryukyus is rare. The main exception is Takamiya's hypothesis that Late Jōmon over-exploitation caused a "collapse" in coral reef resources in the central Ryukyus in the Final Jōmon has been discussed above.

(3) Modularity: as noted in Table 1, archipelagoes of small islands tend to be high in modularity and the Ryukyus were no exception. Modularity can, however, be reduced by over-connected networks (Walker and Salt 2006: 146). Further research might be able to analyze long-term changes in modularity in the Ryukyus using archaeological data.

(4) Acknowledging slow variables: difficult to examine from the archaeological record.

(5) Tight feedbacks: although it can be hypothesized that feedbacks are typically tighter on small islands than continental land masses, we currently lack specific examples from the prehistoric Ryukyus.

(6) Social capital: since networks are an important element of social capital, this paper has argued that this factor was an important element in building resilience in the prehistoric Ryukyus.

(7) Innovation: this is a factor which can be quite easily approached through archaeology. Comparing the two cultural zones of the prehistoric Ryukyus, we can say that innovation was far more widespread in the central/northern than in the southern zone.

(8) Overlap in governance: also difficult to approach from the archaeological record, but it can be hypothesized that rigid, top-down governance structures would have been unusual in the hunter-gatherer societies of the prehistoric Ryukyus. As noted in Table 1, small islands can sometimes develop quite complex systems of land tenure and governance, but in the Ryukyus these evolved in the historic era after agriculture was introduced.

(9) Ecosystem services valued and assessed: difficult to examine from the archaeological record.

We can conclude with the general observation that the fact that the whole of the Ryukyu archipelago was not colonized by the same culture in prehistory can be assumed to have increased the resilience of the islands as a whole.

### Network Types

Networks affect the resilience of social-ecological systems either by providing barriers to the spread of disturbance (stabilizing feedback) or conversely by facilitating the wider spread of that disturbance (amplifying feedback). A central problem with respect to such networks is thus how to balance the dispersal of resources and information throughout systems while limiting the consequent spread of disturbance (Webb and Bodin 2008). This paper has so far only considered social networks, but if we use the concept of coupled social-ecological systems then we have to consider how networks affect links between both social and ecological systems. Janssen et al. (2006) propose three types of social-ecological networks: (1) ecosystems that are connected by people through flows of information or materials, (2) ecosystem networks that are disconnected and fragmented by the actions of people, and (3) artificial ecological networks created by people, such as irrigation systems.

Small islands constitute a special case with respect to Janssen et al.'s types. Since islands are necessarily separated by water, ecological connections are usually less extensive than in contiguous land areas. The spread of ecological links through human activity (whether deliberate or inadvertent) can thus have profound effects on ecosystems, although insularity makes the complete integration of island ecosystems almost impossible. In the prehistoric Ryukyus, we know that dogs and probably wild pigs were transported between islands.

The presence of two different cultural zones in the Ryukyus might theoretically have led to Janssen's et al.'s type (2) fragmented network whereby different cultural traditions differentially affected the ecosystems of the southern and the central/northern Ryukyus respectively. Some such impacts no doubt existed, but at present we have no direct evidence. The larger prehistoric population estimated for the central and northern Ryukyus may have impacted the ecosystems of those islands more than in the southern Ryukyus with their apparently relatively lower population densities.

Type (3) artificial ecological networks created by people became widespread in the Ryukyus with the spread of agriculture and consequent major transformations in land-use in the medieval Gusuku era (cf. Yamamoto 2008: 2–4). It is not clear that such ecological networks existed in the Ryukyus in the prehistoric period. A potential candidate here might be irrigation systems associated with taro cultivation. Several archaeologists have suggested the possibility of taro cultivation in both the southern and the central/northern Ryukyus. This remains a possibility, but there is no direct botanical evidence or indirect evidence of associated large increases in population in the prehistoric Ryukyus.

## Final Comments

Despite the gaps in our knowledge of the archaeology of the Ryukyu Islands and the preliminary nature of the analysis attempted here, it has been demonstrated that these islands can provide a useful testing ground for theories relating to resilience and vulnerability to social-ecological change. While the prehistory of the Ryukyu Islands is very distinctive in many respects, including the early settlement of small islands by hunter-gatherers, it can provide useful points of reference for current work on resilience, relating, for example, to the role of isolation not just on small islands but also in interior Alaska. The analysis here has not attempted to reconstruct network architecture for the prehistoric Ryukyus. The detailed research conducted by Japanese scholars such as Itō (2000) means that such reconstructions would be possible for ceramic exchange networks in the central and northern islands and some network reconstructions have been attempted by Shinzato (2003) for the protohistoric era. Although the reconstruction of internal network architecture is a prerequisite to more detailed analyses, here we have relied on a broader overview of network scale and diversity. Further research is required but our analysis supports the importance of social networks in promoting resilience in hunter-gatherer societies.

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