Rodents of the Sunrise: Mitochondrial DNA Phylogenies of Polynesian *Rattus exulans* and the Settlement of Polynesia

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Introduction

The human colonisation of the Pacific, including Polynesia, has been the subject of research for well over a century. The settlement of the islands of the Polynesian triangle represents one of the last major human migration events, and one which required the crossing of large expanses of water. Over the last 50 years, research in a variety of disciplines including archaeology, human skeletal biology, cultural anthropology, linguistics and genetics has led to a vast increase in our understanding of this important historical problem, yet there still remain a number of unanswered questions.

Archaeological evidence of human occupation of the western Pacific dates from at least 40,000 years before present (BP), with the eastern extreme of this initial presence reaching the Solomon Islands by appoximately 30,000 BP. At about 3500 BP, human settlement expanded beyond this region, eastwards as far as Tonga and Samoa. This process has been associated with the appearence of an archaeological entity referred to as the Lapita Cultural Complex, which has been associated by some with ancestral Polynesian populations and also possibly with the introduction of the Austronesian languages to Remote Oceania. Settlement of Central and East Polynesia began by 1500 BP, concluding with New Zealand approximately 800 BP and the Chatham Islands soon afterwards.

Studies of globin gene variation (Flint *et al.* 1986, Trent *et al.* 1988) and mtDNA lineages of modern Polynesians (Lum *et al.* 1994, Sykes *et al.* 1995) and studies of ancient DNA from Lapita-associated skeletons (Hagelberg and Clegg 1993) indicate that some degree of admixture with Melanesian populations probably occurred as ancestral Polynesians left Southeast Asia and passed through Near Oceania. However, due to the high degree of homogeneity amongst modern Polynesians, analyses of genetic variation have provided little evidence for the sequence of settlement within the Polynesian triangle itself. Yet, the origins of the New Zealand Maori or the Hawaiians, for example, is of great interest not only to prehistorians, but to the indigenous peoples of Polynesia. Here we present a novel approach to the problem of Polynesian settlement and interactions by focusing on genetic variation in *Rattus exulans*, the Pacific rat, an animal that travelled with the ancestral Polynesians on their voyages.

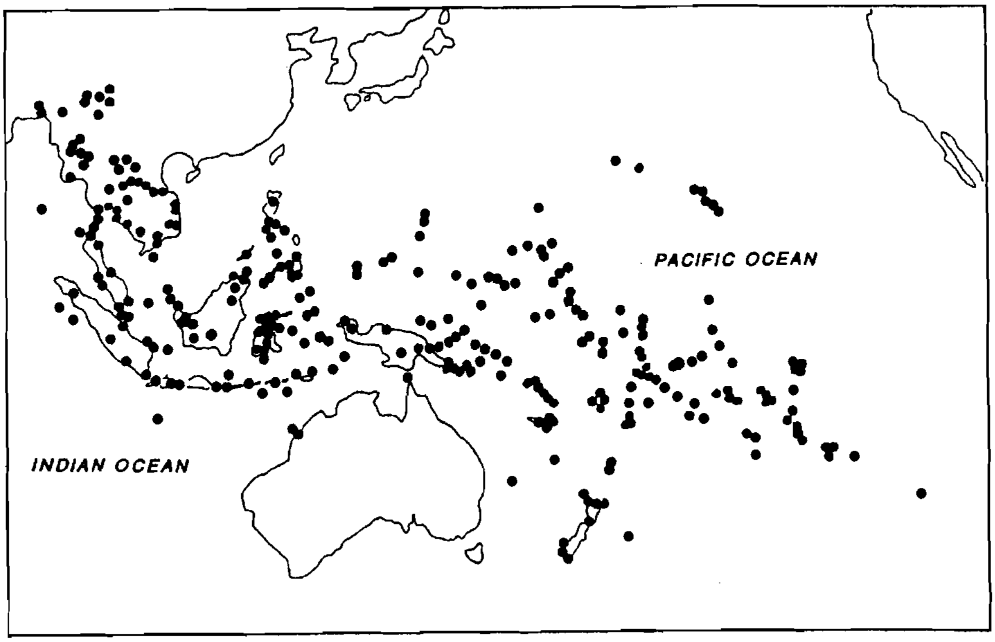


Figure 1
Recorded world distribution of *Rattus exulans* (after Wodzicki and Taylor 1984).

Rattus exulans as a Model

Distribution

R. exulans, also known as the Polynesian or Pacific rat, is said to be the third most widely distributed rat worldwide (Williams 1973). Its distribution (Fig. 1) ranges from the Andaman Islands off the west coast of Southeast Asia, east to Easter Island, and from Hawai'i, the Marianas, the Philippines, Vietnam, Laos, Burma and Eastern Bangladesh, south to Stewart Island in New Zealand (Wodzicki and Taylor 1984). There is no evidence of *R. exulans* on the mainland of Australia, though it has been recorded on two off-shore islands of northern Australia (Taylor and Horner 1973). This distribution includes many «abandoned» islands, such as Henderson and the Kermadecs, which were uninhabited at the time of European arrival in the Pacific, but have clear archaeological evidence of prehistoric human occupation. *R. exulans* is now extinct from Easter Island, and in New Zealand, though found on many small off-shore islands, *R. exulans* is now virtually extinct on the main islands, with the possible exception of small pockets in Fiordland and South Westland on the South Island. It has been suggested that these extinctions are likely the result of competition between *R. exulans* and other rat and mouse species that were introduced after European arrival (Watson 1956, Taylor 1975).

The earliest evidence of *R. exulans* comes from East Timor and is dated to approximately 4000 years BP (Spriggs 1989), but there is much debate regarding the mode of dispersal of *R. exulans* east of Indonesia. The Wallace-Huxley line, which runs between Borneo and Sulawesi, marks a major transition separating a region with one of the richest vertebrate fauna from a region with one of the world's poorest. The trend towards faunal impoverishment continues as one moves eastward out into the Pacific. Twenty-four genera of rodents including 16 species of *Rattus* are indigenous to New Guinea (Roberts 1991). Only three rodent genera and three species of *Rattus*, *R. mordax, R. praetor* and *R. exulans* have been identified from prehistoric sites in New Ireland (Allen *et al.* 1989). What has been referred to as the "Thorne-Green line" (Roberts 1991), delineating Near and Remote Oceania, represents "a major cutoff point in the natural distribution of animal and plant species" (Pawley and Green 1973). Beyond this point, only bats and commensal mammals, including two species of rat *R. praetor* and *R. exulans*, are found. Slightly further east is the "exulans only" line (Roberts 1991). In prehistoric times, only *R. exulans*, and the pig, chicken and dog were found east of the "exulans only" line, which separates Near Oceania, including Santa Cruz and Tikopia from the rest of Remote Oceania (Fig. 2). This type of distribution is typical of one associated with human dispersal. A debate focuses on whether the dispersal, particularly of *R. exulans*, was intentional or accidental in nature. Tate (1935) argued for deliberate transportation due to the widespread nature of dispersal. He also argued that accidental introduction of *R. exulans* would result in an eastwardly decline in the proportion of island groups reached and also in the percentage of islands colonised within any given group. However, there are supporters of accidental introduction (e.g. Atkinson 1986, Anderson 1996), and despite the stronger support for intentional introduction, this can never be totally discounted.

The great swimming capabilities of rats seems to exist in general folk knowledge of rat behaviour. However, the Norway rat, *R. norvegicus*, is the only rat currently found in

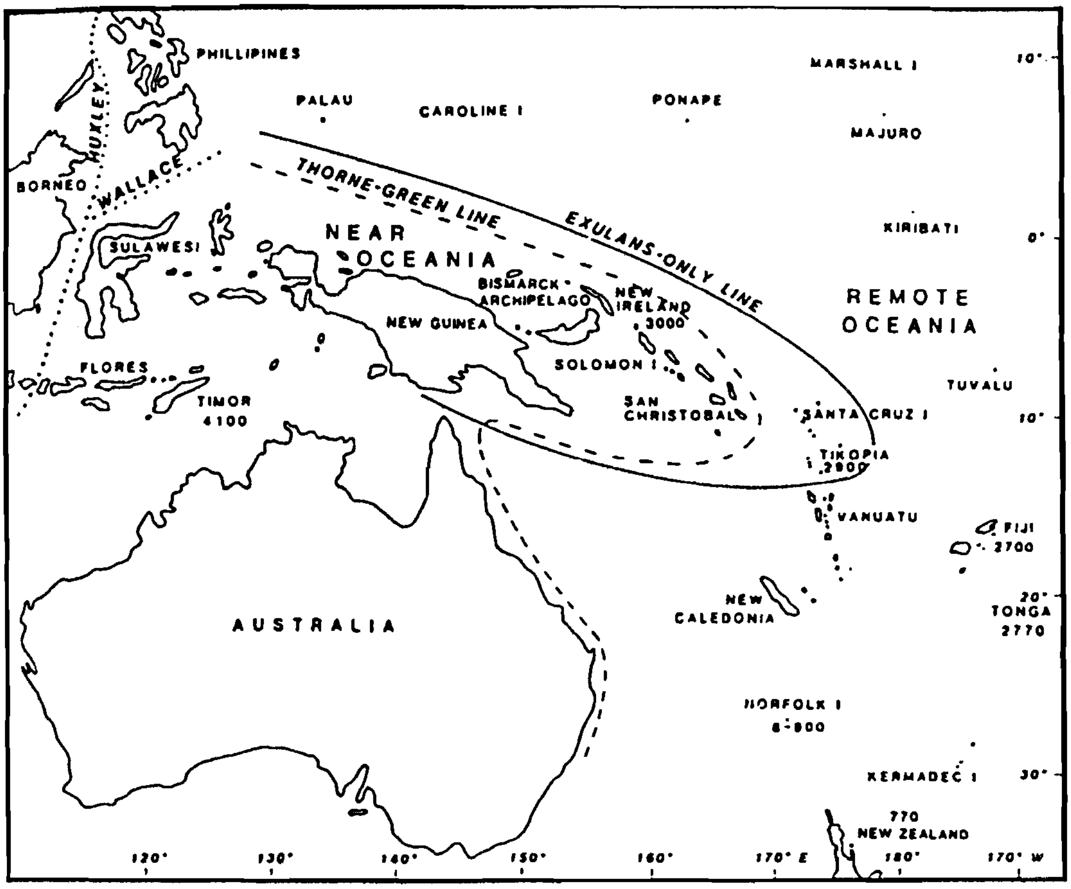


Figure 2
Location of "Thorne-Green and exulans-Only" lines (reprinted from Roberts 1991).

the Pacific that swims with any adeptness. Studies conducted on the swimming capabilities of *R. exulans* (Jackson and Strecker 1962; Spenneman and Rapp 1989) have shown that *R. exulans* cannot swim or be dispersed in the ocean. Spenneman and Rapp (1989:398) conclude:

"It seems highly unlikely that rats would voluntarily cross any great distance of water. However, rats were shown to be capable of reaching other islands by drifting if assisted by winds and currents or by sitting on large floating objects. It appears that their survival time allows them to drift in moderate winds for about 1 km. With increased winds they would drift faster, but the increased wave action could cut down survival time. Small floating objects such as a large piece of coconut husk or a coconut frond, however, were quite suitable means of transport not accepted by the rats... in archaeological terms the results of the experiments imply that the dispersal of the various rat species observed in Oceania is predominantly induced by humans."

Jackson and Strecker (1962:63) similarly argued:

"On the basis of these releases it would seem unlikely that rats would voluntarily swim across a river or portion of the lagoon. They can, however, remain afloat and alive in the water for several hours, probably longer, and can survive repeated submergings. That rats accidentally falling into the water may be carried between closely adjacent islands or out to sea is quite possible. Many of them, however, are likely to fall prey to predatory fish. This mode of travel is not likely to have been important in the spread of rats across any sizeable expanse of water."

Rattus exulans *in Polynesia*

Archaeological evidence of *R. exulans* is often vague, recorded only as present/absent and often clumped with bird bones in published accounts. *R. exulans* remains are reported from the earliest sites in the Marquesas (Kirch 1986, B. Rolett pers. comm.), Easter Island (Skjolsvold 1994), New Zealand (Jennings 1979, Holdaway 1996), the Chatham Islands (Sutton 1985), the Kermadecs (Johnson 1995) and Norfolk Island (Specht 1993).

Rattus exulans *in Pacific Languages*

In near Oceania, there are multiple species of rat, though in Karam (PNG highlands) classification, *R. exulans* is specified as *kopyak*, or *kopyak walcogon* (Bulmer and Menzies 1972). There are two words reconstructed for Proto-Austronesian: **tikus*, which is mostly western Indonesian, but the Proto-Micronesian **kit'iki* might be related to it. The word **labaw* is much more widespread, and Eastern Fijian *kalavo* is probably a reflex of it (R. Clark, pers. comm.). The most widespread Oceanic word is **kasupe* or **kusupe*, which occurs in North-Central Vanuatu, Southeast Solomons, Western Fijian, various parts of New Guinea and probably also in South Vanuatu and New Caledonia. Locally in Northern Vanuatu there is another innovative form **karivi* (R. Clark pers. comm.).

Polynesian languages don't have any of the above forms for rat, but have three different forms of their own. In Tongic (Tongan and Niuean), **kumaa* is found; it is also found, probably through borrowing, in East Uvea, Anuta and Rotuman (meaning "baby rat"). There is also a possible cognate in Marquesan (R. Clark, pers. comm.). Throughout the Samoic Outliers, and through borrowing in Gilbertese, is found **kimoa*, which looks rather similar to **kumaa*. The word **kiole* occurs throughout East Polynesian, also in Pukapukan, Samoan, Luangiua, Sikaiana, Rennellese and Tikopia (Biggs). This distribution would justify reconstructing it for Proto-Nuclear Polynesian, but what its relation to **kimoa* might be is hard to say (Clark pers. comm.). A few languages have more than one form. In Samoan *'imoa* and *'iole* are said to be synonyms, along with the Samoan specialty *'isumu.* Likewise in Rennellese, there is no clue as to any difference of meaning between *kimoa* and *kioge*, though the former seems to be the more common form. In Marquesan *kio'e* and *kumakuma* or *kukuma* are used (Clark pers. comm.). In Hawai'i, the word is *'iole*, in Tahitian, *'iore*, and in New Zealand and Cook Island Maori, *kiore.*

Mythology

R. exulans is a major part of mythology and story telling throughout Polynesia and in Melanesia, Micronesian and Malaysia. In Polynesia, the rat is regularly mentioned in the creation myth. This, we suggest, is very strong evidence for the importance of *R. exulans* in Polynesian culture, and shows that the attitude of Polynesians towards rats is positive. This makes it much easier to understand and accept the concept of the rat as an intentional introduction, rather than seeing it solely as a pest and unintentional stowaway.

Regarding the rat in New Zealand, Best (1942) writes:

"For the origin of the rat, as explained by the Maori, we must delve far into Maori myth, even unto the time when cultivated food products were first acquired, and the Earth-Mother took an active interest in human affairs. We are told that one Pani, whose full name was Pani-tinaku, was a sister of Tangaroa-i-te-rupetu, who took Taranga to wife and begat the five Maui Brothers of immortal fame. Pani was taken to wife by Rongomaui who introduced the *kumara* or sweet-potato into this world by causing Pani to give birth to that tuber...Now this Pani is said to have given birth to a female being known as Hine-mataiti, who represented, or was the progenitor of, the *kiore* or rat" (1942:419-420).

Henry (1928:415) describes the Tahitian creation myth, in which rats are specifically mentioned. In the period "after the sky was raised" rats are clearly linked with humans, and those things important to humans:

The eyes of Ra'i-tupua looked towards the dwelling place of man, and he saw land was produced; there were gulfs and bays with capes stretching out; there were rivers and friths; there were weeds, flowers, and a variety of food; sugar-cane, bananas, plantains, sweet potatoes, and yams. Dogs and rats were also born, but pigs and fowls had not yet come into being. And there stood the settlement, houses for the people, and a temple to pray in.

In the Tuamotuan account of Tane and Maui, part of the creation mythology, Tane makes his earthly home on a large cliff-bound atoll called Fakarava, which was formerly known as Havaiiki. It is from here that he distributes the languages on earth: "From the rat came the human language; From the grasshopper came the language of birds; Variable sounds was the language of the gods; Whistling was the language of kings" (Henry 1928:352).

Rattus exulans *as a Food Item*

In New Zealand, *kiore* were considered by the Maori to be a valuable food source for which land reserves, or *rahui*, were set aside and claimed by local *iwi*. These reserves, also used for trapping various bird species, such as *keruru* (wood pigeon) and kiwi, were protected, and individuals from other *iwi* required permission from the owners to trap in the area (Haami 1994, Makereti 1938). Traps were set along the trails left by *kiore*, the *ara kiore*, or were placed in favoured feeding grounds such as those where *miro, hinau* or *tawai* fruit drop from the trees (Best 1942:447).

The Maori took these rats by means of setting spring-snares, by which means one man would take many, that is to say the traps of a single person would take many. When many were so taken they would be plucked; when all were plucked then they were cooked and packed in gourd vessels, whereupon they were known as *huahua*, and *huahua kiore* was extremely good; the best kinds of such potted foods were *kiore* [rats] and *koko* [the *tui* bird] (Best 1942:428).

From the Whanganui region, Best (1942) was told:

"Rats were esteemed as being rich and very palatable food, nourishing, one of the foodsuplies [sic] that served to build up vigourous bodies. These rats were cooked as the *weka* bird was, and then packed in kelp-bags and gourd-vessels, preserved in their own fat as *huahua*. From remote times such food has been viewed as fitting sustenance for the most important persons; down the changing generations has this been the case" (1942:435).

There is a large body of ethnographic data pertaining to the eating of *kiore* in New Zealand, and Mangaia in the Southern Cook Islands, but the use of *R. exulans* as a food source elsewhere in Polynesia is not so straightforward, despite the fact that they appear in large numbers in middens throughout Polynesia.

It is said that rats were not eaten in Samoa (Buck 1930:541-542), Mangareva (Buck 1938a:194), or Manihiki and Rakahanga (Buck 1932:83). However, the situation may actually represent adoption of the European attitude towards rats (see Roberts 1994), which undoubtedly was introduced by the missionaries. When asked by foreign ethnographers, many of whom were early missionaries, there might have been a hesitancy to admit to such a "disgusting habit" as eating rats. For example, regarding Easter Island, Metraux (1957) writes:

"The rat is not a domestic animal, but, like the fowls, it was introduced into Easter Island by its first colonists, to whom it was a delicacy. The modern islanders still remember the taste for these rodents displayed by a few old people they knew in the past. They are rather ashamed of it, and the epithet 'rat-eaters', like that of 'cannibals', calls to mind the barbarous age from which they flatter themselves they have escaped" (1957:66-67).

Similarly, Ferndon cites a missionary, Crook, in his discussion of early Marquesan attitudes towards eating rats:

"Young pigs were distributed to various families, probably relatives, for feeding and raising. It was in the feeding of these piglets that Marquesans found a use for the islands' rat population, other than as occasional human famine food. The little animals were caught by hand and hung alive before a fire until dead, after which the were broiled, mashed up, and the flesh mixed with fermented breadfruit and fed to the young pigs" (Ferdon 1993:94).

Regarding the eating of rats in Niue, Loeb (1926:7) writes:

"When Europeans first visited Niue, the only mammal (*manu*) on the island was the rat. The people had neither pigs nor dogs. At present time the native rat (*kuma*) has disappeared, having been driven out by the Norway rat. The natives deny that they ever eat the rat, but they told Smith that their fathers did eat the animal. It is probable that in the olden times the rat was shot with bow and arrow; nowadays it is caught in traps made of a hollowed stick and a snare."

As pointed out by Tate (1935), given the widespread distribution of *R. exulans* throughout Polynesia, it is unlikely that the rat was introduced solely unintentionally.

Evidence suggests that it was initially introduced as part of the ancestral Polynesian colonisation package as a food source. The practice of eating rats may have disappeared in some areas prior to the arrival of the Europeans, for example in Aitutaki (Allen 1992). However, for most of Polynesia, it is more likely that rat eating continued until European arrival, and the introduction of European negative attitudes towards rats. In addition to being a food source, the Polynesian rat was also an important component in the mythology and everyday life of Polynesian people. It had spiritual significance and was not seen solely as an undesirable in traditional society. Unfortunately, the recording of rat remains from archaeological sites is generally only as present/absent, and is not clearly defined as it is in Allen (1992). Until the importance of *R. exulans* in prehistoric Polynesian society is recognised, *R. exulans* remains will continue to be overlooked and undervalued in terms of their role in understanding Polynesian prehistory.

R. exulans as a model
What does it mean for human movement?

The goal of this study is to use *R. exulans* as a model of human movement in prehistoric Polynesia. There are a number of possible scenarios regarding the transport of *R. exulans* which in turn would affect the interpretation of the identified relationships.

Mode of dispersal of R. exulans

Arrival with humans

A) Intentional: Biogeography suggests intentional introduction (Tate 1935). This does not exclude additional unintentional introduction, but explains the ubiquitous distribution. The ethnographic and archaeological evidence strongly suggests the reason why introduction was intentional - *R. exulans* was a food source.

B) Unintentional: If unintentional introduction due to stowaways is the only means of dispersal, then in order for rats to be present, in the earliest archaeological layers on all islands that show evidence of Polynesian settlement, there must have been an extremely high level of contact throughout all of Polynesia and the Pacific during and immediately after colonisation. This is unlikely.

Arrival without humans

This mode of dispersal is highly unlikely given the poor swimming capabilities of R. exulans. Rafting is unlikely across any major water gaps. The evolutionary history of rodents in the Pacific allows rejection of Langdon's (1995:77) suggestion that "over hundreds of thousands of years - perhaps millions - the rat...succeeded in getting from one island to another without any human aid at all." Though there is no way of disproving the possibility of rats travelling successfully in canoes without humans (Sharp 1957, Anderson 1996), it is highly unlikely that this could have been more than a freak occurrence, let alone a major mode of long distance dispersal. The theory of human drift voyaging in Polynesia has been rejected as the primary mode of dispersal (Levison *et al.* 1973) and this critique would also apply to rat drift voyaging. Such extreme interpretations should only be considered when all other more logical explanations are lacking.

We conclude that the evidence supports intentional introduction, but does not allow rejection of the possibility of additional unintentional introduction. Therefore, we can interpret mtDNA phylogenies of *R. exulans* as a marker of human movement. This may represent:

Human colonisation

MtDNA phylogenies of Polynesians rats will model human colonisation if there is isolation of *R. exulans* after introduction. This can be due to:

A) isolation of humans after initial settlement.

B) rats establishing populations only after initial introduction from a colonising canoe. This could be the result of i) rats travelling only on colonising canoes, and not subsequent canoes, or ii) later rat introductions not successfully establishing themselves.

Attempted human colonisation/exploration

It is possible that human populations do not successfully establish after the initial discovery or attempted colonisation of a given island, but introduced rats (either intentionally or unintentionally introduced) do establish viable populations. This may be apparent in the archaeological record, if rats appear much earlier than evidence of human occupation (see Holdaway 1996 for discussion of the possibility of this in New Zealand)

Colonisation and contact

If we accept that rats were introduced intentionally during colonisation, but also may have travelled as stowaways, then mtDNA phylogenies of *R. exulans* will represent colonisation and contact. Again, it is necessary for later introduced females to mate and rear young successfully.

All of the above

It follows, therefore that a phylogenetic analysis of populations of *Rattus exulans* provides an ideal and complementary model for tracing episodes of human movement.

Methods

R. exulans samples were collected, using basic snap-type rat traps, from Samoa, Fiji, the southern Cook Islands, the Society Islands, the Marquesas, the Hawaiian Islands, the Kermadecs, New Zealand and the Chatham Islands. Heart and liver tissues were removed and total DNA extracted using standard phenol chloroform methods (Sambrook *et al.* 1989).

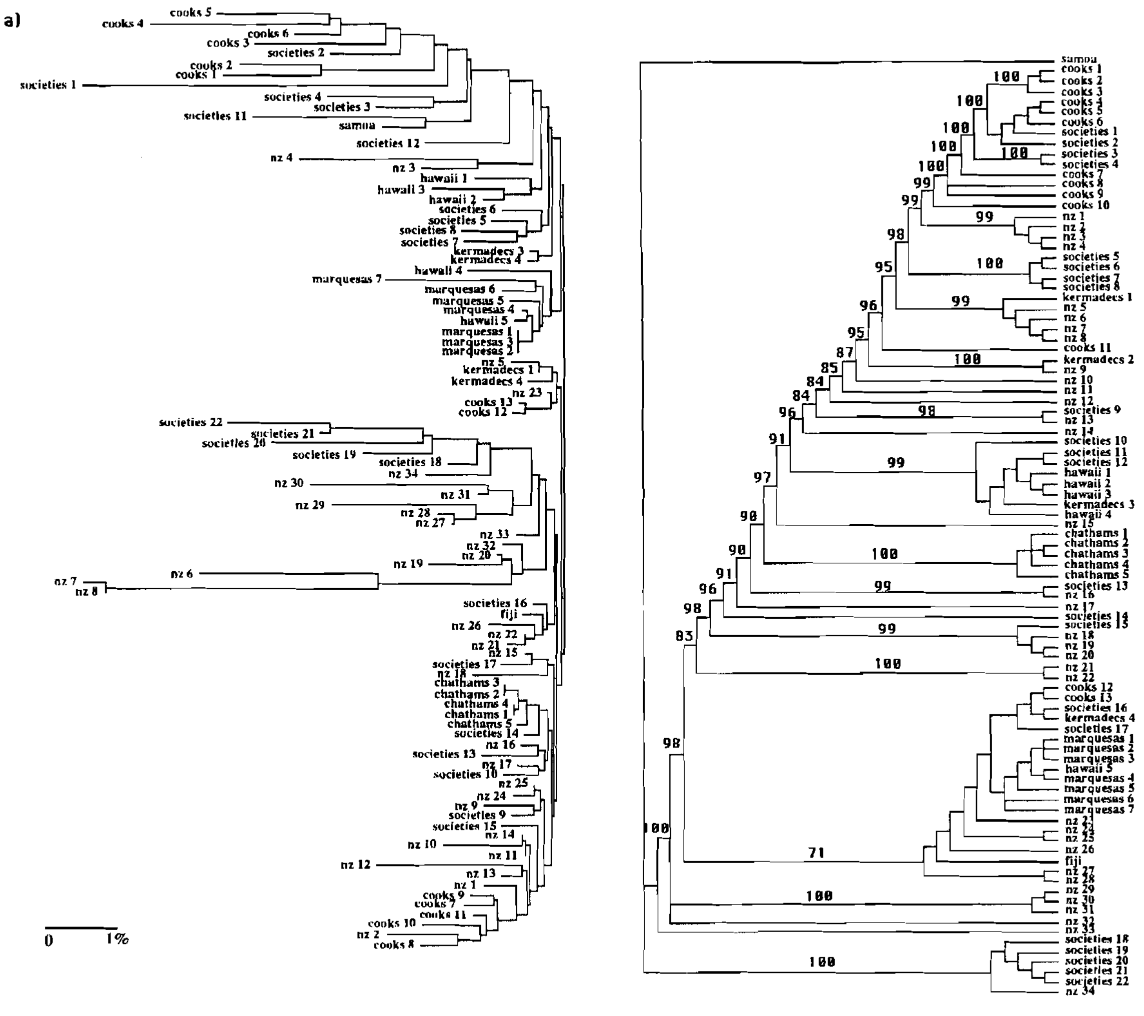
A total of 438 base pairs (bp) of DNA sequence (L-strand 5' - 3') from the mtDNA genome of 132 individuals was obtained using the Polymerase Chain Reaction (PCR) as described in Matisoo-Smith (1994). These sequences were aligned using the GCG programme pileup (Genetics Computer Group 1994) and then later corrected by eye. From the total 132 mtDNA sequences, there were 93 unique sequences which were then subjected to phylogenetic analyses. All duplicated sequences came from animals from identical locations.

The maximum parsimony algorithm in PAUP version 3.1.1 (Swofford 1993) was used to conduct character state analyses. Five hundred initial trees were constructed using the heuristic search method, with random addition of sequences. Using the tree bisection reconnection procedure (TBR), branches were rearranged using all 500 initial trees, and all minimal trees were saved (with a limit of 500 minimal trees). A 50% majority rules consensus tree was generated.

Distance analyses were performed using MEGA version 1.01 (Kumar *et al.* 1993). Kimura two-parameter, Jukes-Cantor and Gamma distance matrices were generated using the pairwise deletion option. Phylogenies were constructed using the Neighbor Joining method (Saitou and Nei 1987) and bootstrap values were generated for 5000 replications. All three methods produced virtually identical trees. Bootstrap values were, on the whole, low (below 50%),but this is not unusual for intraspecific studies, where the level of genetic variation is low.

Results and Discussion

The relationships identified through the phylogenetic analyses of mtDNA variation in the Polynesian rat suggest the following: with regards to the specific issues of origins, the phylogenetic results, specifically Figure 3, suggest first, that the Samoan *R. exulans* sample is most closely related to Society Island samples. This *may* be interpreted as ini-



I Figure 3

a) Neighbor Joining, and b) Parsimony phylogenetic trees for 93 unique *R. exulans* mtDNA control region sequences of 438 base pairs (bp) in length.

tial settlement of East Polynesia occurring in the Society Islands. However, the fact that there is only a single sample from Samoa severely limits the strength of excluding any other island as the point of initial settlement. A more likely scenario, which is not inconsistent with either tree but is directed by archaeological evidence, is settlement from West Polynesia (Samoa) to a region encompassing the Society and Southern Cook

Islands. This region, which may have included the Austral Islands, may have encompassed a broad interaction sphere which appears to be the likely source of all identified East Polynesian *R. exulans* mtDNA lineages.

Second, mtDNA lineages of Hawaiian *R. exulans* are related to both Societies and Marquesan lineages. Linguistically and archaeologically, Hawai'i may be derived from the Marquesas, but there are also clear links between Hawai'i and the Society Islands. While these results appear to represent dual introduction of *R. exulans* from both the Marquesas and the Societies, this study is unable to discern whether this represents more than one effective human colonisation, or later interisland contact as archaeological evidence suggests (Cachola-Abad 1993).

Third, New Zealand *R. exulans* populations are clearly derived from both Cook Island and Society Island populations, which parallels the strong indications of archaeology and language. Again, the dual settlement interpretation suggests particular models of colonisation of New Zealand which may include colonisation and later contact from a large "homeland region".

In terms of the theoretical issue of homelands, as discussed above, the results suggest that a region encompassing the Southern Cook Islands and the Society Islands is the likely source of all identified *R. exulans* mtDNA lineages in East Polynesia. In addition, these data show monophyly of the Marquesan samples. This result may indicate greater isolation of the Marquesas, and therefore they may be assigned a more minor role in the "homeland region". However, due to the fact that the samples represent only a single island within the archipelago, this may be the result of sampling error.

The Chatham Islands and the Kermadec Islands are two small island groups equidistant from New Zealand, yet in terms of latitudinal location are very different. The contrasting patterns of mtDNA variation in *R. exulans* from these two locations suggests two very different population histories. The Kermadec samples show a high degree of genetic variation, while the Chathams are monophyletic. This may reflect a contrast between an intermediary or "stepping stone" group and an island group which was quite isolated, and only settled once. These results clearly relate to the issues of process of settlement and contact.

As with all mtDNA phylogenies, there has to be a compromise between the number of samples that are required to reliably represent the population in question with both costs and feasibility of sample collection and the limitations of phylogenetic analysis. Therefore, we must state that mtDNA phylogenies are only inclusive and *not* exclusive. In other words, any mtDNA phylogeny present represents a descendent of a founding female, yet there may be, and most likely are, some founding mtDNA lineages not represented. This can be due to both lineage extinction and sampling error.

Patterns of prehistoric colonisation and contact revealed through analysis of *R. exulans* mtDNA are summarised in Figure 4.

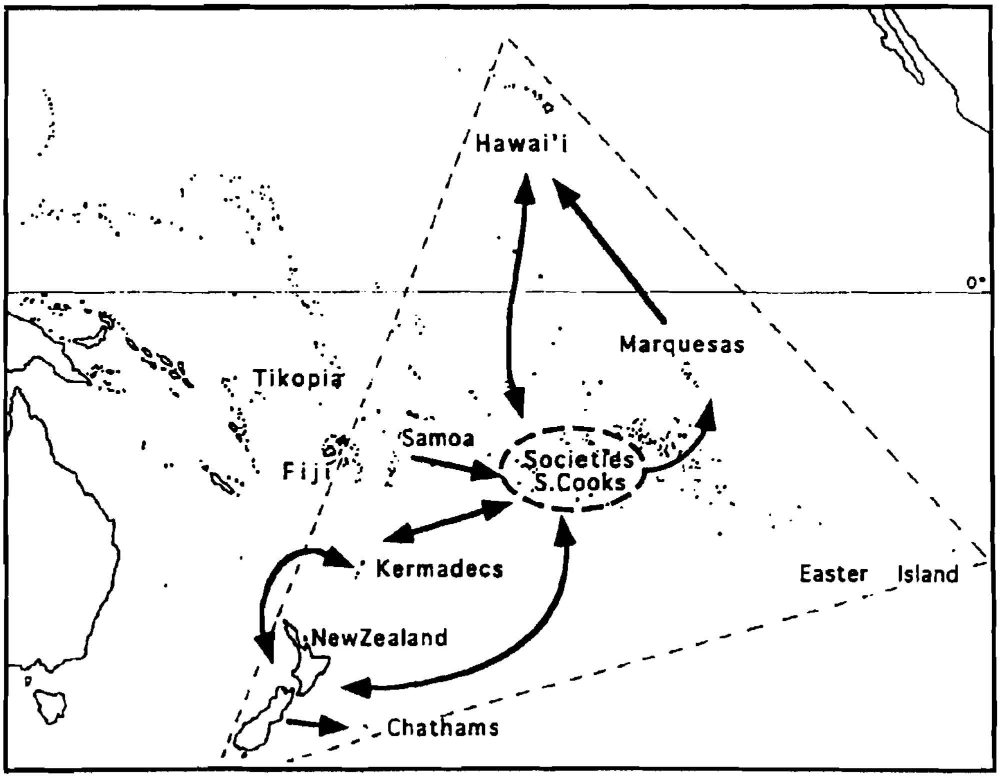


Figure 4
Likely patterns of colonisation and contact based on interpretations of *R. exulans* mtDNA phylogenies.

These results are generally consistent with patterns predicted by voyaging simulations (Irwin 1992) and with the Continuous Contact model of Polynesian prehistory (Irwin 1981, 1989, 1990, Kirch 1986). More specifically, these results support the rejection of a number of key points in the Orthodox model (Emory 1963, Emory and Sinoto 1964, Sinoto 1966) of Polynesian settlement - namely the primacy of the Marquesas as the East Polynesian homeland, and the general concept of isolation during Polynesian colonisation. It appears that isolation is most extreme in the case of the settlement of the Chatham Islands. Consistent with Rolett's (1993) hypothesis, the results presented here suggest that the Marquesas may be considered a marginal group, with less contact than is found within the rest of Central East Polynesia.

There are a number of questions that cannot be addressed through a study of mtDNA variation in *R. exulans*. Exact chronology cannot be addressed, but sequential chronology is suggested, when the interpretations are directed by archaeological evidence.

The results of this research suggest a number of directions for future research. Clearly more samples from extant populations from West Polynesia and Melanesia need to be collected. In particular, samples from Tonga, Samoa, Fiji and New Caledonia. Samples from further west would also be valuable, including Vanuatu, the Solomon Islands, coastal Papua New Guinea and even into Island Southeast Asia. Collections from Micronesian populations and from the Polynesian Outliers could provide very interesting results which would help address issues of colonisation and contact between these populations and those of the Polynesian Triangle.

This study highlights the potential value of studying genetic variation of commensals, and opens the door to further studies of other commensal animals and plants. Pigs and dogs were also transported by humans into Remote Oceania. Although analyses of these animals would have added complications (given the fact that they were often traded), with careful interpretations, results would be valuable for addressing a number of questions in addition to colonisation. Genetic analyses of commensal plants is also an area for future research. The phylogenetic relationships of the *kumara* (sweet potato) would provide evidence of influence from the east, which undoubtedly occurred in Polynesia, but cannot be addressed by studying *R. exulans*. Lepofsky *et al.* (1992) have provided evidence of a hybrid coconut. If the DNA sequences of wild and cultivated species of coconut could be identified, this too could provide evidence of human aided dispersal patterns. Other Polynesian commensal plants like taro and paper mulberry could also be subjects of similar studies (P. Matthews pers. comm.), as could snail species which are transported within commensal plants.

One of the most interesting off-shoots of this research project is the potential for mtDNA analysis of archaeological skeletal remains of *R. exulans*. This allows for analysis and inclusion of populations from islands where *R. exulans* are now extinct, such as, Easter Island, Niue, and the North Island and most of the South Island of New Zealand. Analysis of DNA from dated archaeological sites will also allow for chronological control which is not possible in analyses of extant populations. This research is currently underway (see Allen *et al.* 1996).

Analysis of ancient DNA from human populations in the Pacific (Hagelberg and Clegg 1993) has lead some to question long held opinions on the connection between Lapita populations and ancestral Polynesians. Limited sample sizes of human skeletal remains from Lapita sites present a problem in confirming a pattern similar to that reported by Hagelberg and Clegg. Their results showed that Lapita skeletons (total sample size of eight) did not possess the 9 bp mtDNA deletion found at nearly 100% frequency in modern Polynesians. *R. exulans* remains are abundant in Lapita sites, and unlike their human counterparts, *R. exulans* are a different species from the original rodent inhabitants in Near Oceania, and therefore not subject to admixture. Ancient DNA studies of commensals also reduces the risk of undetected contamination by human DNA from the archaeologist or laboratory technician, a problem that plagues ancient DNA studies of human skeletal material.

Analysis of ancient DNA is the best method available to address the question of dispersal of the Polynesian dog (Allen *et al.* 1996). Again, the Polynesian dog is the same species, *Canis familiaris*, as the later introduced European breed. Interbreeding is thought to have been extensive enough to eliminate any known populations of descendants of the Polynesian dog. Once mtDNA from archaeological samples is available, then the question of extant or remnant populations can truly be addressed.

Given the current political and ethical issues of dealing with archaeological human remains and human subjects, the potential for studies of commensal plants and animals makes them extremely attractive to biological anthropologists. It should be noted, however, that in many cases the same political and ethical issues apply. Research involving issues of population origins and prehistoric relationships is often of great cultural significance, therefore, consultation and when possible, collaboration with indigenous communities is still essential, valuable and highly recommended.

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