Chapter 22
Claims and Evidence in the Population History of Rapa Nui (Easter Island)

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1 Introduction

For over 100 years, Rapa Nui (Easter Island, Chile) has presented a challenge to researchers seeking to explain how nearly 1000 multi-ton statues carved and transported across this tiny and remote island by a population that, at least at the time of European observation in the eighteenth century, were no more than a few thousand in number. Adding to the mystery is the fact that Rapa Nui is notably barren in terms of natural resources: the island lacks forests, running streams, and large-scale cultivation. For European observers, the island's state at the point of contact presented a stark contrast, a paradox. On the one hand, the island boasts a large number of massive prehistoric statues (*moai*) and monuments (*ahu*), indicating that islanders made incredible investments in labor and organization. On the other hand, the island appeared to lack a large number of people and available resources assumed necessary to produce this magnitude of monumentality. Rapa Nui's remarkable archeological record has, ever since, called out for an explanation.

For some observers, an answer was easily provided by imagining that conditions on the island were far more prosperous in the past. Starting with eighteenth-century visitors, speculative narratives emerged about the impacts islanders had on their environment. Many of these accounts are based on the assumption that the island was once more productive and that some previous event transformed it into its

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current state. Johann Reinhold Forster (1777, cited in Hoare 1981, pp. 475–476), the naturalist who accompanied James Cook on his voyage to Rapa Nui in 1774, reasoned "either a civil or external war, a great mortality, too great luxury, or some other disaster reduced those Islanders to the small number we found them to be of." His son, Georg Forster (*apud* Jakubowska 2014, p. 86), reasoned that a volcanic eruption must have decimated the island; "it is very likely that one of those big, terrible natural disasters suddenly buried a great number of inhabitants." La Pérouse (1807, p. 4), for example, reasoned that the demographic and environmental conditions were due in large part to the "the imprudence of their ancestors" who cut down the island's trees (see also La Pérouse, 1807, p. 26). Some of the accounts are quite fanciful. Macmillan Brown (1924), for example, argued that the island is just a remnant of much greater "civilization" that supported massive populations but later sank beneath the ocean.

Over the past hundred years, visitors and researchers have speculated on the number of people the island may have supported in a previous state. These numbers have varied from estimates as few as 3000 (Meyer and Jablonowski 1901) to speculations as high as 57,500 (Routledge 1919, p. 215; Bahn and Flenley 1992, p. 170). Most of the contemporary numbers for the island's past maximum population size range between 10,000 and 20,000 people (e.g., Bahn and Flenley 1992; Flenley 1993; Diamond 1995, 2005; Puleston et al. 2017). These larger population sizes for Rapa Nui are often taken for granted and treated as fact. Borrowing from Elias (1958), this "population fact" has led to the production of many publications we can generically fit into two titles.

The first paper has the generic title "Mathematical Models of Demographic Collapse on Easter Island" written by a mathematician, economist, or population demographer; individuals who have neither conducted primary research about Rapa Nui nor have an appreciation for the challenges of using information from the archeological record in analyses. This paper tends to cite popular literature, assume chronologies long discarded by archeologists working on the island, and never involve evaluating hypotheses using archeological data. Instead, it uses Rapa Nui as an example of a mathematical model that illustrates why demographic collapse had to have happened, usually via a variant of a Malthusian model. The article invariably assumes the "population fact" and presents the island's demography using "boom and bust"-type graphs common in this kind of work. The graphs boast convincing dates on the x-axis and definitive population sizes on the y-axis, making them appear fully qualified, empirically determined, and validated. The math behind these models is sophisticated and illustrates how population peaks might have occurred if indeed all the assumptions about the island are, in fact, correct. The production of this kind of paper has become somewhat of a cottage industry in disciplines outside of archeology (Brander and Taylor 1998; Dalton and Coats 2000; Erickson and Gowdy 2000; Reuveny and Decker 2000; Pezzey and Anderies 2003; Basener and Ross 2004; Decker and Reuveny 2005; Good and Reuveny 2006; Basener et al. 2008; Bologna and Flores 2008; De la Croix and Dottori 2008; Uehara et al. 2010; Brandt and Merico 2015; Merico 2017; Roman et al. 2017; Basener and Basener 2019).

The second paper is typically called something like "Environmental Change Correlates with Collapse on Easter Island" and is written by an anthropologist, ecologist, or palynologist. There are two variants of these kinds of papers. One variant is authored by someone who has a general knowledge of Rapa Nui from a subset of published sources (e.g., Kirch 1984; Ponting 1991; Diamond 1995; Bahn 2015). The articles typically offer no new primary data but instead weave uncritical interpretations of previous publications together to make their case. The second variant views the island from the lens of environmental data, such as the sediment cores taken from one of three sites on the island: Rano Kau, Rano Aroi, or Rano Raraku. The paper then focuses on vegetation changes or climate records to create narratives about environmentally-induced cultural and demographic changes. The paper begins and ends with the overall assumption that the island has undergone population decline or profound cultural changes before the arrival of Europeans and seeks to determine the degree to which environmental factors may have played a role (e.g., Flenley et al. 1991; Pakandam 2009; Stenseth and Voje 2009; Rull et al. 2013, 2018; Rull 2016, 2018, 2020; Lima et al. 2020).

It is not our intention here to explore explanations for why assumed demographic changes might have occurred on the island, whether driven by climate, lack of resources, or some other factor. Rather, we focus on the common assumption held by both types of articles: at some point in the past, Rapa Nui hosted a population that significantly exceeded the small number of people observed at the time of initial European contact in AD 1722. In this paper, we evaluate the many claims that have been made about the pre-contact population sizes and examine the bases for these numbers. We divide these numbers into three categories: those based on speculation, those based on explicit models, and those based on historical observations. We conclude with an evaluation of the current empirical evidence that exists to support pre-contact population numbers.

2 Claims of Pre-Contact Population Sizes

Many of the early writers commented on the likelihood that the past population of Rapa Nui was not much greater than that observed by the earliest visitors. In 1774, John Reinhold Forster (*apud* Jakubowska 2014, p. 80) noted roughly 900 people, but also concluded that the number was since the arrival of Europeans: "therefore I conclude that either the number of inhabitants decreased over fifty years from various thousands to 800 or 900 individuals. Observing the island in 1869, Roussel questions whether the island was ever greatly populated stating (*apud* Lee et al. 2004, p. 46) "I have trouble believing that the population was as high as five or six thousand, as some of the natives insist. The interior of the island has never been settled ... Only the shore was inhabited and the clusters of *maute*, *toromiro,* and *hau* that are scattered about suggest a population of no more than five thousand souls with an average of five or six people per hut."

In one of the first explicit discussions of the island's past population size, Thomson (1889) offers relatively sophisticated comments about the challenges of estimating population based on the archeological record since surface features and artifacts accumulate over time. Although lacking a means of estimating the time-depth, Thomson (1889, p. 460) notes that "the immense amount of work performed by the image-makers and platform builders would indicate the employment of a great many persons, if accomplished within a reasonable limit of time, or the extension over several centuries, if the undertaking was carried out by successive generations." Thomson (1889, p. 460) also considers the possibility that areas of settlement may represent mobile or seasonal occupation: "The ruins … would prove either the presence of numerous inhabitants, or a frequent change of location. The limited area of the 32 square miles of surface available for cultivation precludes the idea of any very dense population, and many reasons might be assigned for a frequent change of habitation." As a result, Thomson readily accepts that the numbers were between 2000–3000 based on information from the Dutch, Spanish, English, and French accounts.

Other early accounts used numbers borrowed from other islands or generalizations made from estimates of what the island's terrain could support. The earliest example of this kind of reasoning is Meyer and Jablonowski (1901, p. 6), who use estimates of 13.7 individuals per square kilometer observed on Tahiti to claim that the island would have had "a population of 3000 people, and one will, in any case, have no room to go beyond this number as the upper limit." Routledge (1919, p. 215) notes that while earlier visitors consistently name just 2000 inhabitants, Percy Edmunds, the ranch manager on the island, suggests Rapa Nui could have supported more: "Mr. Edmunds calculates that about half of the total amount (or some 15,000 acres) could grow bananas and sweet potatoes. Two acres of cultivated ground would be sufficient to supply an ordinary family."

Skottsberg (1920, p. 488), visiting the island at the same time as Routledge, takes a more conservative view of the fertile capacity of the island and argues that "where there is sufficient soil this is of good quality and quite fertile when properly cultivated, and in prehistoric and early historic times extensive plantations existed supporting a population of several thousands." After his visit in the mid-1930s, Métraux (1940) used the land area required to support the island's residents as he observed them to calculate the total carrying capacity of the island. Metraux (1940, p. 22) states that "if 456 natives can live easily on a small portion of the island which is not particularly fertile it may be assumed that eight or nine times that number could have made a comfortable living on the entire island. Formerly fishing was a more important food resource than it is now. I believe that the population of Easter Island a hundred years ago must have been between 3000 and 4000."

Population estimates jumped considerably following William Mulloy's (1974) publication of "Contemplate the Navel of the World." Grounded in the growing awareness of the earth's limited ecological resources and alarmed by Ehrlich's (1968) book *The Population Bomb* predicting imminent massive global famines, Mulloy's (1974) article frames Rapa Nui's prehistory as an example of the dire consequences of population exceeding carrying capacity. While Mulloy does not specifically cite population figures, this article heralds the first time the concept of "overpopulation" is used in the context of Rapa Nui. He suggests that the growing population, coupled with the limits of the island's resources, resulted in food shortages, precipitating a socio-economic crisis for the islanders.

Following this publication, the literature begins to include a greater emphasis on environmental degradation through deforestation caused by the needs of ever greater numbers of islanders. McCoy (1976, pp. 141–142), for example, rejects the smaller estimates by La Pérouse (1807) and Metraux (1940) and suggests that the island had a maximum population of 7000. His rationale is based on an assumption that much larger numbers than 3000–4000 were required to produce the island's monumental architecture. Based on the comment by Edmunds recorded by Routledge (1919, p. 215) with 15,000 acres of arable land and 2 acres of land sufficient per family, McCoy (1976) argues the island might have had at least 7000 people. McCoy (1979, p. 160) emphasizes the impact that such a large population would have had on such a tiny island: "even if the maximum population was only 4000 to 5000, it is easy to envision the eventuality of near-total deforestation in a relatively short time, assuming that the early forest was indeed a savanna- parkland type formation of scattered trees and shrubs." McCall (1976, p. 45) also posits a population peak that occurred before European arrival, adding that it was in AD 1500 that population increases and decreased rainfall combined to produce famine and the loss of food production capacity.

Stevenson (1984, pp. 172–173) substantially expands on these numbers using ethnohistoric estimates of family size from Hawai'i and the number of residential archeological features identified during field surveys. Based on chronological determinations made using obsidian hydration dates, Stevenson suggests that the population density at ca. AD 1600 was 147 persons per square kilometer. Based on the assumption made by Routledge (1919) that no more than 50% of the island was suitable for cultivation, he then reasons that the population was 8927 in AD 1600 and then 9659 in AD 1800. Stevenson (1984) then reasons that these numbers likely underestimate the population due to denser habitation around Rano Raraku and that individuals also lived in cave habitations. Based on this reasoning, Stevenson (1984, p. 173) posits that the island's peak population was 11,000–12,000 persons.

Ayres (1985) supports these relatively large population numbers. While he rejects Metraux's (1940, p. 151) estimates as being too low, he also rejects his calculations that the maximum population would be between 37,500 and 52,500, numbers he arrives at based on Routledge's (1919) note that the island's 15,000 acres of arable land could support five to seven individuals per household using two acres for each family. Based on general observation of historic population sizes, Ayres (1985, p. 105) concludes that pre-contact populations are "realistically running up to 6–8000 people."

By the mid-1980s, the idea that overpopulation was a major factor in the island's pre-contact history had taken root. In 1984, we see the first emergence of the now-famous "collapse" narrative (Fig. 22.1). Though he offers no specific numbers, Kirch (1984, p. 264) characterizes the island as having a population that "temporarily but brilliantly surpassing its limits - crashed devastatingly." Like

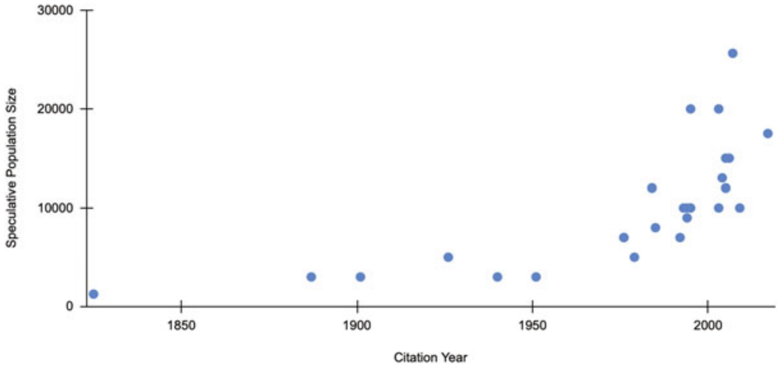

Fig. 22.1 Graphical representation for maximum pre-contact population size claims by citation year

Mulloy, Kirch (1984, p. 274) emphasizes environmental degradation as a major factor in social change in late prehistory and states "Easter Island had reached a state of over-population, which was the proximate cause leading to an ensuing phase of chronic inter-tribal warfare and social disintegration."

Ponting (1991) uses the work of McCoy to put forward a Rapa Nui collapse narrative in a popular context in his book "A New Green History of the World." Ponting (1991, p. 5) states that "the population of the island grew steadily from the original small group in the fifth century to about 7000 at its peak in 1550." Bahn and Flenley (1992, see also Bahn 1993, p. 54; Flenley and Bahn 2002, p. 170; Bahn and Flenley 2017, p. 218) utilize the high numbers quoted by others: "most archaeologists who have worked on the island in recent years estimate that the prehistoric population may have reached 6000 to 8000, while some speculate about figures of 10,000 or even 20,000" though they do not share where the 20,000 numbers might have originated. Diamond (1995) simply repeats the arguments made by Ponting, Bahn, and Flenley in his collapse narrative: "an estimate of 7000 people is widely quoted by archeologists, but other estimates range up to 20,000, which does not seem implausible for an island of Easter's area and fertility."

With these publications, a massive pre-contact population decline had become widely accepted as fact. Based on the summaries of others, Cohen (1995, p. 357), for example, provides his summary of the island's history: "the population remained low until about A.D. 1100. Growth then accelerated and the population doubled every century until around 1400. Slower growth continued until at most 6000 to 8000 people occupied the island around 1600. The maximum population may have reached 10,000 people in A.D. 1680." Loret (2003, p. 21) states "the densities of archaeological sites indicate a population greater than 7000; some archaeologists estimate it could have been up to 20,000." Kirksey (2003, p. 196) argues the island had "a native population that once numbered over 10,000." Foot (2004, p. 13) asserts that "the population peaked in mid-century at around 10,000 (+/–3000) people and then suddenly collapsed." Fischer (2005, p. 45) claims "On Easter Island itself, by the early 1700s the peak population of approximately 12,000 that might have been attained in the fourteenth and fifteenth centuries had perhaps shrunk." Pakandam (2009, p. 16) cites population sizes of 7000–10,000 based on claims made by Bahn, Flenley, and Stevenson to support his argument.

While many authors simply assume the large numbers cited by others (e.g., Pakandam 2009, p. 16), some attempt to use aspects of the archeological record to rationalize the values offered. Van Tilburg (1994), for example, made use of unpublished settlement pattern data generated as part of the Easter Island Archeological Survey conducted by Vargas Cassanova and Cristino to justify pre-contact population sizes (Vargas Casanova and Cristino n.d. 1997). Van Tilburg (1994, p. 67) states:

> Métraux recorded nine members per Rapa Nui family. If we multiply the 3244 house foundations known to date by nine, we arrive at the extraordinary population estimate of 29,196. At five family members, we still have a very high figure of 16,220. Many Rapa Nui shelters were recycled and reused, and it is not yet certain how many houses were contemporaneous, specialized, or temporary. A good rule of thumb is to reduce the population estimate by two-thirds. This gives us a figure of 9732 people (at nine per family) or 5406 at five per family. Considering the bulk of the survey evidence and the previous 7000 estimates of McCoy's research, a total population of between 7000 and 9000 people, or a gross density of between 44 and 56 people per square kilometer, is reasonable and in fact, somewhat low by Polynesian standards.

Vargas Cassanova and colleagues (2006, p. 300) follow a similar argument in their claim of more than 15,000 inhabitants, focusing their estimate on assumptions about the maximum agricultural productivity of the island in addition to house counts.

Diamond's (2005) popular book "Collapse" repeats claims by others and rejects the relatively conservative estimates of 6000–8000. Diamond (2005, p. 91) states "it seems to me impossible that the 1864 post-smallpox population of 2000 people represented the residue of a pre-smallpox, pre-kidnapping, pre-other-epidemic, pre-seventeenth-century-crash population of only 6000 to 8000 people. Having seen the evidence for intensive prehistoric agriculture on Easter, I find Claudio's and Edmundo's "high" estimates of 15,000 or more people unsurprising." Likewise, other authors simply assume high numbers based on claims made by others.

As shown in Fig. 22.1, the history of pre-European contact population size claims for Rapa Nui hovered largely between 3–5000 through the 1970s. It was only after the 1970s and the rise of contemporary concerns about global resource degradation and overpopulation that speculation about much larger population sizes began. Once introduced by Mulloy (1974) and McCoy (1976) and supported by claims made by Kirch (1984) and later Diamond (1995), these speculative numbers increase markedly and became the basis for many of the Malthusian narratives about the island's ecological and demographic collapse.

3 A Critical Review of the Evidence

While these population estimates are speculative, they follow several basic algorithms. The first set of estimates (e.g., Mulloy 1974; Kirch 1984, p. 274; Ayres 1985, p. 105; Ponting 1991, p. 5; Bahn and Flenley 1992, 2017, p. 217; Bahn 1993, p. 54; McCall 1994, p. 37; Cohen 1995, p. 357; Diamond 1995, 2005, p. 91; Flenley and Bahn 2002, p. 170; Kirksey 2003, p. 196; Loret 2003, p. 21; Foot 2004, p. 13; Fischer 2005, p. 45; Pakandam 2009, p. 16) is speculative and based on second-hand numbers and/or numbers assumed as “overpopulation.” The reasoning here is circular as it relies on the a priori claim that the historic populations must have been far smaller than those that pre-dated European arrival. These population numbers are most closely associated with the “collapse” narrative.

3.1 *Historic Observations*

Rather than speculate about possible population sizes, we suggest a better starting position is gained by examining the currently available evidence. Among the most relevant are a series of eyewitness accounts recorded by the initial European visitors who observed and described conditions on the island beginning in the eighteenth century. As documented by Boersema (2015; Boersema and Huele 2019, Table 22.1), the earliest European visitors noted no more than 3000 people. In 1722, for example, Behrens (1737, p. 82, *apud* Boersema and Huele 2019, p. 84) notes that “the inhabitants were swimming around in their thousands.” In 1770, Spanish observers (Corney 1903, p. xlv) report that the island’s “natives number about 3000 of both sexes.” In 1786, La Pérouse (1807, p. 26) concludes “the whole population may be estimated at two thousand persons.” While each account may be based on just a sampling of the island, the earliest observations converge on the conclusion of about 2000–3000 people at contact (Boersema and Huele 2019).

3.2 *House Count Estimates*

The second line of evidence might be gained from counts of the number of residential features observed during field surveys (e.g., Thomson 1889, p. 460; Stevenson 1984, pp. 172–173; Van Tilburg 1994, p. 67). In this “house count” method, the number of domestic features identified through field surveys is multiplied by an assumed constant household size to yield a total population size. For Rapa Nui, this has been based on multiplying estimates of family size (e.g., between 5 and 9) by the number of residential units (e.g., Stevenson 1984, pp. 172–173; Van Tilburg 1994, p. 67). While changing intensities of domestic features actively in use can indeed provide a rough measure of demographic change, several issues

Table 22.1 Summary of claims for pre-European contact population sizes

Year	Citation	Number cited
1825	Beechey (1831:12)	1260
1887	Thomson (1889)	2000–3000
1901	Meyer and Jablonowski (1901:6)	3000
1926	Roussel (1926) (A. Atlman, Trans.)	5000
1940	Métraux (1940:22)	3000
1951	Skottsberg (1920:488)	2000–3000
1976	McCoy (1976:141)	7000
1976	McCoy (1976:142)	7000
1979	McCoy (1979:160)	4–5000
1984	Stevenson (1984:172–173)	11,000–12,000
1985	Ayers (1985:105)	7000–8000
1992	Ponting (1991:5)	7000
1993	Bahn and Flenley (1992) Bahn (1993:54) Flenley and Bahn (2002:170) Bahn and Flenley (2017: 218)	>10,000
1994	Van Tilburg (1994:67)	7000–9000
1994	McCall (1994:37)	10,000
1995	Diamond (1995)	20,000
1995	Cohen (1995:357)	10,000
2003	Loret (2003:21)	7000–20,000
2003	Kirksey (2003:196)	>10,000
2004	Foot (2004:13)	10,000+/−3000
2005	Fischer (2005:45)	12,000
2005	Diamond (2005:91)	15,000
2006	Vargas et al. (2006:300–301)	15,000
2007	Rallu (2007:22)	25,650
2009	Pakandam (2009:16)	7000–10,000
2017	Puleston et al. (2017: 10)	3500–17,500

preclude a straightforward reconstruction of past population sizes based on counts of surface domestic features (Drennan et al. 2015, pp. 14–16; Palmisano et al. 2017; Bevan and Crema 2021). The problems with the house counting approach center on determining the equivalence of the unit being counted (Bevan and Crema 2021), whether equivalence in time or equivalence of occupation characteristics (Drennan et al. 2015). For example, researchers have typically assumed a time equivalence for Rapa Nui domestic features in the sense that features found on the surface are contemporaneous. As Thomson (1889, p. 460) was astute in pointing out more than 100 years ago, the challenge with this approach is that it requires robust knowledge about the chronology of occupation.

House count-based demographic estimates for Rapa Nui assume that surveyed domestic features were actively in use at the same time. Mulrooney's (2012, 2013) analyses of the Hanga Hoʻonu region, however, clearly shows this cannot be the case and that structures were in use at different times. Stevenson (1984) attempts to address the chronological issue by sorting residential locations at the scale of *ahu* through time using obsidian hydration dates. It is unclear, though, how these dates relate to the contemporaneous occupation of individual structures. Without a high-resolution radiocarbon chronology directly related to deposit events for a large sample of these features from across the island, it is not possible to ascertain an absolute count of which 'houses' were inhabited at various times in the island's history.

Another unresolved issue is their assumed equivalence in terms of use duration (e.g., Drennan et al. 2015; Crema and Kobayashi 2020). If, for example, some domestic features are in use for a single human generation whereas others substantially more or less, then any demographic estimates based on equivalent duration would be strongly biased. While Bayesian radiocarbon chronologies could be used to estimate the span of domestic feature use (Bronk Ramsey 2009), such studies are largely lacking on Rapa Nui. DiNapoli et al.'s (2020b) Bayesian analyses of *ahu*, however, offer an example of how this work might be productively conducted.

An additional concern is the assumption of an equivalent and constant number of occupants per domestic feature across space and time. In his early twentieth century demographic work, Metraux (1940, pp. 97–98) divided the population of 456 Rapanui by the 50 houses in use to estimate an average of 9 individuals per household, though he notes there is no reason to assume this figure characterizes households in pre-contact times. If the number of house occupants was variable in time (seasonally, annually, decadally) and space, then an increase in one domestic feature is not directly proportional to a unit increase in population (see Bevan and Crema 2021). Lacking a fine-grained chronology of domestic features and assuming their equivalence in several domains, most previous house count estimates for Rapa Nui, therefore, remain questionable.

4 Resource-Based Estimates

The third line of evidence used to estimate population numbers considers what the island *could support* given potential agricultural productivity (e.g., Meyer and Jablonowski 1901, p. 6; Routledge 1919; Skottsberg 1920, p. 488; Métraux 1940, p. 22; McCoy 1976, pp. 141–142, 1979, p. 160; Vargas Casanova et al. 2006, pp. 300–301; Rallu 2007). While researchers acknowledge that historic population numbers were reduced due to disease, slave raiding, and other atrocities that took place after the arrival of Europeans (Fischer 2005), this approach typically uses productivity values extrapolated from observed settlement patterns for the island. The challenge in using productivity values is that the argument is based on generalizations about the amount of land used by a group of families at some point in a particular place. Some of the estimates (e.g., Bahn and Flenley 1992; Bahn 1993; Flenley and Bahn 2002) are particularly questionable as they largely rest on speculation by Routledge

(1919) that 15,000 acres of land could be put into use for agriculture in an equivalent fashion.

Additionally, there is an implicit assumption in population estimates based on resource abundance: that the actualized population size is a simple function of the absolute productivity of the land at any point in time. Even Malthus (1890) argued that reproduction is not determined solely by resource abundance. As Wood (1994, pp. 37–47, 1998, p. 104) notes, family size is driven by a host of factors that include risk tolerance, cultural traditions, rates of pregnancy loss, rates of maturation, and so on. While Malthus argued that populations tend to grow when food is abundant, the population size reached is not necessarily the maximum possible. The *possibility* of large populations does not mean that these populations were necessarily the case. In the case of the pre-contact history for Rapa Nui, only the assumption that the island must have been more greatly populated at one time, a proposition first raised in 1774, drives the conclusion that the numbers must have been greater. If we remove that assumption, it is no longer *necessary* to posit that the population was much greater than observed at European contact.

In a recent paper, Puleston et al. (2017) built a series of sophisticated food-limited demography simulations that combined ecological and demographic models with different agricultural productivity estimates to derive a range of estimates for potential peak population sizes on Rapa Nui. The outcomes of these simulations are strongly affected by varying the amount of bioavailable nitrogen (N) that could support crop growth. Because empirical estimates of N are limited for the island, Puleston et al. (2017) modeled contrasting scenarios, a "high-N" parameterization that resulted in mean maximum populations of ca. 17,500, and a "low-N" parameterization that resulted in mean populations of ca. 3500. While this modeling represents one of the most sophisticated attempts to estimate pre-contact population sizes, it lacks consideration of the effects of decadal-scale variability as well as sufficient N measurements to calibrate the model. As a result, there is no clear rationale why the high-N scenario should be preferred over the low-N versions (Lipo et al. 2018). One key piece of data that can be used for calibration, however, is the estimates of the first European visitors in the eighteenth century, who consistently note populations of ca. 3000 (Boersema and Huele 2019), indicating that Puleston et al.'s (2017) low-N estimate is most consistent with the available archeological and historical data (Lipo et al. 2018) and likely "is a better representation of pre-contact Rapa Nui than is the high-nitrogen scenario" (Puleston et al. 2018, p. 2).

4.1 Analyses of Summed Probability Distributions

Another approach has been to avoid estimating absolute pre-contact population numbers and instead examine the evidence for relative changes. Several studies have attempted to evaluate whether the pre-contact population was once much larger using summed probability distributions (SPDs) of radiometric dates (Mulrooney 2013; Stevenson et al. 2015; Lima et al. 2020). SPDs are a widely used method for examining relative change in past activity and are frequently used as a proxy for relative changes in population size (Crema and Bevan 2021). In a pioneering study for Rapa Nui archeology, Mulrooney (2013) compiled a dataset of all available radiocarbon dates from the island and used the most secure dates from settlement contexts to construct SPDs. Mulrooney (2013) then compared the empirical Rapa Nui SPD to a series of ad hoc curves for both population continuity and collapse ca. 1680 AD, a commonly claimed collapse date. Mulrooney's (2013) results did not show evidence of a pre-contact decline in the empirical SPD curve. In a similar analysis, Stevenson et al. (2015) conducted SPD analyses of obsidian hydration dates from settlement sites, finding no strong support for an overall major pre-contact decline in human activity. While their results did suggest potential spatial differences in land-use patterns over time, they concluded that "this temporal reconstruction of land-use history associated with food production argues against the notion of an island-wide precontact collapse as a useful explanatory concept for Rapa Nui" (Stevenson et al. 2015, p. 1029). Vargas et al. (2006, Figs. 6.1 and 6.2) also show temporal frequency plots of obsidian hydration dates that do not support the notion of pre-contact collapse (see also Stevenson and Williams 2018; Hunt and Lipo 2016). Moreover, Bayesian analyses of the chronology of *ahu* construction also show continuity in monument construction over time (DiNapoli et al. 2020b), contrary to previous collapse narratives (see DiNapoli et al. 2020a for a recent review).

In contrast to these previous studies, Lima et al. (2020) recently presented SPD analyses which they argue demonstrate a pre-contact population collapse for Rapa Nui. Their analysis is based on radiocarbon dates from settlement and ceremonial contexts coded as Class 1 and 2 by Mulrooney (2013), from which they constructed an SPD that appeared to have a large spike and decline after ca. 1450 AD. Lima et al. (2020) then fit four growth models directly to the SPD, including a simple logistic model with no assumption of collapse, and three additional models where carrying capacity can be reduced by deforestation, climate change, or a combination of these effects. They then compare the fit of these models and conclude that "Population analysis of the prehistoric Rapa Nui time series suggests that long-term climatic variability (e.g. SOI) and palm tree cover are proxies of the island's carrying capacity. A simple model appears to describe the dynamics of the human population in Rapa Nui quite well and can explain the increasing trend as well as population decline episodes that impacted during several generations, which we think can be defined as demographic collapses" (Lima et al. 2020, p. 7). These conclusions, however, are not valid for three important reasons: (1) selection of samples to include in the analysis; (2) normalizing the ^{14}C dates during calibration, and (3) directly fitting their demographic models to the empirical SPD.

First, in any analysis of radiocarbon dates, one must make a clear connection between the dated radiocarbon event and the target event of interest (Dean 1978). In the case of SPD analyses, the radiocarbon-dated events (e.g., death of the organism) must have a contextual linkage with the target event of demography, such as occupation deposits or other settlement sites (Mulrooney 2013; see Brown and Crema 2019). While Lima et al. (2020) did exclude the most problematic samples from their analyses (based on Mulrooney's [2013] chronometric hygiene), they did not consider this dated-event target-event relationship. While Lima et al. (2020, p. 7) correctly assert that dates from ceremonial contexts, along with the results in DiNapoli et al. (2020b) reflect "the 'continuities/discontinuities' in a given cultural tradition (i.e. the 'ahu moai' tradition), not a demographic process," they inexplicably included ca. 70 dates from these contexts in their analysis.

Second, a crucial concern is the consequences of ^{14}C normalization, which is a common step in radiocarbon calibration where the posterior density is normalized to one. While this is a reasonable step in calibrating single radiocarbon dates, when these dates are then summed to create SPDs, normalization causes spurious peaks at steep portions of the calibration curve (Weninger et al. 2015; Weninger and Edinborough 2020). For these reasons, one must either account for these artifacts of the radiocarbon calibration curve during any model fitting or simply choose not to normalize the dates when creating an SPD (Crema and Bevan 2021). Lima et al. (2020), however, did neither. Figure 22.2 shows the radiocarbon dataset used by Lima et al. (2020) with and without normalization along with the SHCal20 calibration curve (Hogg et al. 2020). The large peak observed by Lima et al. (2020) in the normalized SPD is an artifact of the steep portion of the Southern Hemisphere calibration curve, an issue Mulrooney (2013, p. 4382) also raised caution about in her original study. Once corrected for normalization, this spurious spike in the SPD is removed and evidence for "collapse" disappears.

Third, while Lima et al.'s attempt to compare the fit of multiple demographic models to the Rapa Nui SPD is hypothetically a useful approach, the attempt to directly fit these models to the normalized SPD has several problems: (1) they uncritically treat the sample size as the number of years in the analysis rather than the much smaller, correct sample size—the number of dated archeological contexts; and (2) they do not account for sampling error, measurement error, or the effects of the calibration curve, all of which can have a substantial impact on the shape of an observed SPD (Crema and Bevan 2021). Critically, because sampling error is not properly accounted for, the maximum likelihood estimates for their models are biased, and thus all other derived statistical results are incorrect and misleading (see Carleton 2021; Carleton and Groucutt 2020; Crema and Shoda 2021; DiNapoli et al. 2021; Stewart et al. 2021; Timpson et al. 2021 for similar criticisms). Essentially, Lima et al. (2020) have treated the SPD as a census of past population size rather than the idiosyncratic samples that they are.

When one adequately accounts for these sources of error and uncertainty, the results indicate opposite conclusions for Rapa Nui. DiNapoli et al. (2021) analyze the fit between an SPD of radiocarbon dates securely associated with Rapa Nui settlement sites and Lima et al.'s (2020) four logistic demographic models: (1) simple logistic growth, and three additional models that consider the effects of (2) changes in palm forest cover, (3) changes in the Southern Oscillation Index (SOI), and (3) a logistic model that includes both of these effects. Using an Approximate Bayesian Computation (ABC) approach to compare the fit of these four models to the Rapa Nui SPD that captures the uncertainty caused by sampling, measurement, and calibration errors, the results show that patterns in the SPD are

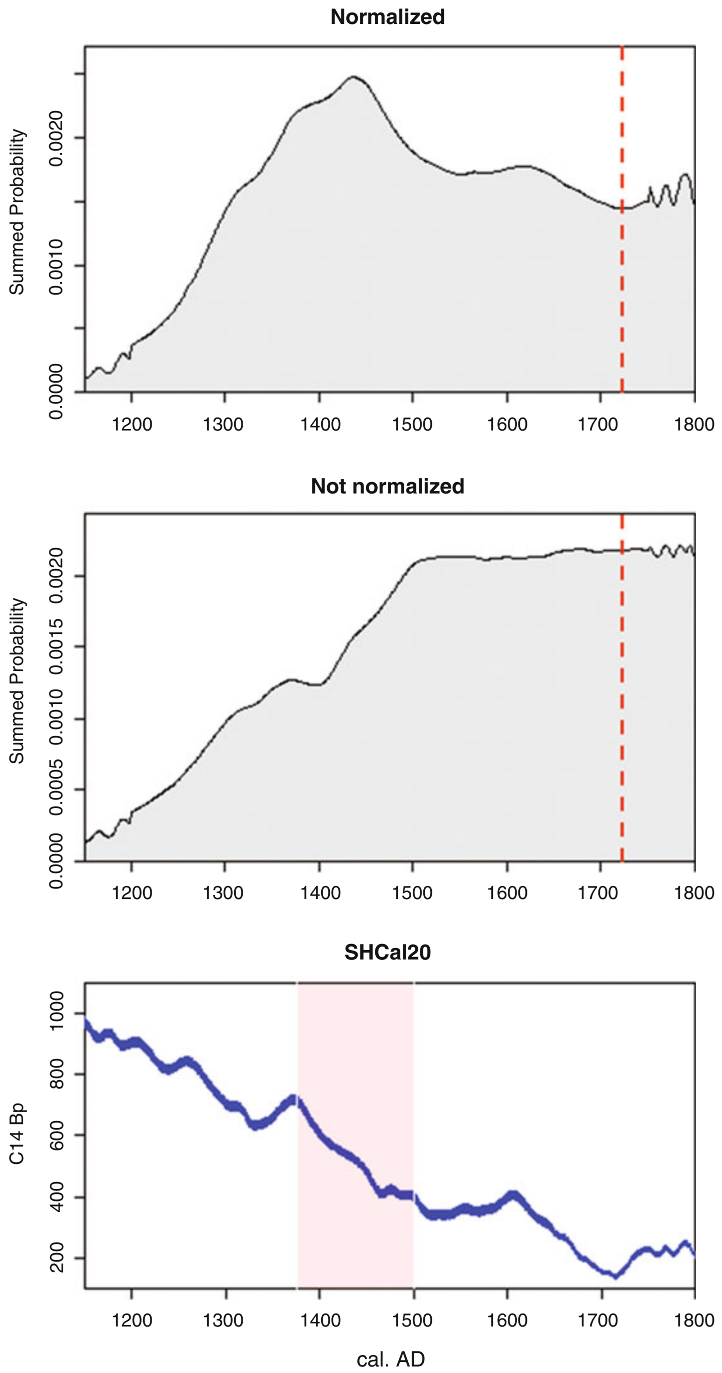

Fig. 22.2 Top: summed probability distribution (SPD) of normalized radiocarbon dates from Lima et al. (2020); Middle: the same SPD but with non-normalized dates; Bottom: the Southern

consistent with a logistic growth pattern (i.e., rapid initial growth followed by a plateau) and no evidence for a pre-contact demographic collapse (DiNapoli et al. 2021). Significantly, the results falsify previous claims that deforestation or SOI had negative demographic impacts on Rapa Nui and instead demonstrate that Rapa Nui people were resilient to any impacts from this environmental change.

4.2 Skeletal Age Distribution-Based Estimates

In an innovative evaluation of pre-contact population size on Rapa Nui, Boersema and Huele (2019) compared the age-at-death profiles of a human skeletal assemblage from Rapa Nui to published profiles for variation in rates of population growth. Boersema and Huele's (2019) results suggest that the osteological dataset they examined best fits a growth rate of ca. 0.5%. Assuming a maximum founding population size for the first Polynesian colonists of ca. 100 individuals, they conclude "a slow growing population in the pre-European period, which never exceeded 3000 people" (Boersema and Huele 2019, p. 90), a conclusion that fits the eyewitness accounts of eighteenth-century European visitors.

5 Conclusions

Beginning with the English and French accounts of Rapa Nui in the eighteenth century, scholars have long had an interest in Rapa Nui demography due to the extraordinary monumental architecture found on the island. Given the numbers and magnitude of *moai* and *ahu*, many visitors and researchers have assumed there must have been a much larger pre-contact population. From the nineteenth through the mid-twentieth century, though, population estimates consistently remained in the low thousands (Fig. 22.1). It was only after the widely influential publication of collapse narratives by Mulloy (1974) and Kirch (1984), we begin to see speculative estimates in the literature. These estimates increase exponentially through the 1990s and 2000s, with estimates as high as 20,000 people or more (e.g., Diamond 1995).

These large estimates are merely speculation, lacking any correlates in the archeological record, and indeed would require population growth rates unknown

Fig. 22.2 (continued) Hemisphere radiocarbon calibration curve (SHCal20) for the period of interest (Hogg et al. 2020). The red shaded rectangle shows a particularly steep portion of the curve that results in a spurious spike in the normalized SPD used as the basis for Lima et al.'s (2020) analyses. The red vertical dashed line is the timing of initial European contact in 1722 AD. Note that these SPDs are based on radiocarbon dates binned by site in 50-year intervals and with a 100-year running mean for any other pre-industrial population (Boersema and Huele 2019). For example, a population in the tens of thousands on such a small island would be expected to leave traces of relatively dense, nucleated settlements, yet settlement pattern analyses show that Rapa Nui is characterized by relatively low-density and dispersed communities (e.g., McCoy 1976; see also Stevenson 1984; Stevenson and Haoa Cardinali 2008; Morrison 2012). Lacking a fine-grained chronology for a large sample of domestic features, absolute population estimates based on “house counts” remain problematic. Lima et al.’s (2020) recent SPD analyses tell us more about artifacts of the radiocarbon calibration curve than about pre-contact Rapa Nui demography (Fig. 22.2). Indeed, time series analyses of radiometric dates that properly account for issues of archeological context and radiocarbon dating uncertainties consistently show population stability and resilience in pre-contact times (e.g., DiNapoli et al. 2021; Mulrooney 2013; Stevenson et al. 2015; Vargas Casanova et al. 2006; see also Mulrooney et al. 2010). These results are also supported by Boersema and Huele’s (2019) osteological analyses suggesting growth rates resulting in population size around 3000. A lack of evidence for a major relative decline in the pre-contact population also provides useful information for further parameterizing the demographic simulations presented by Puleston et al. (2017). In particular, because relative analyses do not suggest a large pre-contact demographic decline, and the contact era population was ca. 3000 (Boersema 2015, Boersema and Huele 2019), then Puleston et al.’s (2017) “low-N” models that estimate mean maximum population sizes of ca. 3500 are the best fit to the available archaological and historic data.

Assembled as a whole, we can evaluate these numbers in the context of our current understanding of the archeological record. Overall, we have no evidence of a substantial pre-contact decrease in population size. Instead, the existing archeological evidence points to a population that increased after European arrival in the twelfth century and then reached a relatively stable state in the early sixteenth century: a logistic growth pattern. This population size was maintained after this point until the arrival of Europeans in the early eighteenth century. Thus, the island’s peak population was between 2000–3000 as observed by these early explorers. After that point, the history of the island is well-documented: populations ultimately declined in the eighteenth and nineteenth centuries with the impacts of disease, slave raiding, and other post-contact events. We echo the challenge recently given by Boersema and Huele (2019, p. 91)—researchers who insist on continuing to argue for a pre-contact collapse on Rapa Nui should avoid rehashing the same “population problem” and build stronger claims based on empirical archeological evidence. Based on this understanding and until new evidence becomes available, future researchers should avoid variants of the two papers we described earlier. Following the advice of Elias (1958), we suggest that we direct our energy and efforts to better understanding the archeological record of Rapa Nui.

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