



Social memory and niche construction in a hypervariable environment

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Abstract

Background: Communities in southwest Madagascar have co-evolved with a hypervariable environment and climate. The paleoclimate record reflects major fluctuations in climatic conditions over the course of Holocene human settlement. Archeological evidence indicates short-term occupations of sites, suggesting that frequent residential mobility and flexible subsistence strategies have been central features of life on the southwest coast for millennia. Today, despite rapid changes linked to globalization and increasing market integration, mobility and subsistence flexibility remain key to the lives of communities of the region.

Aims: In this article, we advocate closer consideration of the social dimensions of the human niche, and their inextricable links to the biophysical world. Specifically, we explore the theoretical implications of applying a Niche Construction Theory framework to understanding the role of social memory in constructing the human niche of SW Madagascar. We look at how social memory facilitates mobility, resource use, and the creation and maintenance of social identities and ties among communities of foragers, farmers, herders, and fishers living under hypervariable climatic conditions.

Materials & Methods: We conducted an extensive oral history survey in SW Madagascar between 2017 and 2018. We interviewed over 100 elders from 32 different communities.

Results: Our analysis of the oral history archive resulted in the development of a theoretical model of human niche construction centered on the maintenance and transmission of social memory.

Discussion: We argue that social memory and the ability to transmit oral histories of exchange, reciprocity, and cooperation, as well as ecological knowledge are key adaptive mechanisms that facilitate mobility and access to resources in a hypervariable environment.

Conclusion: The preservation and transmission of oral histories and ecological knowledge are thus critical to future resilience and sustainability.

1 | INTRODUCTION

Niche construction theory (NCT) provides a framework for making predictions about how organisms actively change the

selective pressures they experience, in order to increase their fitness (Odling-Smee et al., 2003). Originally developed by evolutionary biologists (Lewontin, 1983; Waddington, 1968; Waddington, 1969), NCT has been integrated into



anthropological investigations of human-environment interaction (Crawford, 2014; Dortch et al., 2014; O'Brien & Laland, 2012; Smith, 2016; Stiner & Kuhn, 2016; Zeder, 2016). Anthropological applications of NCT, ranging from studies of the emergence of agricultural lifeways (e.g., McClure, 2015) to caring for country through the use of fire (e.g., Bliege Bird et al., 2020), are diverse in terms of questions addressed and methodologies employed. Despite efforts to apply NCT to understanding the cultural and social dimensions of the human niche (e.g., Boyd et al., 2011; Kendal et al., 2011), the emphasis of anthropological research has been on the biophysical and economic aspects of human niche construction (HNC; Flynn et al., 2013; Gerbault et al., 2011; Smith, 2009; Wallach, 2016). Social and cultural processes, however, cannot be disentangled from the biophysical dimensions of human life and evolution. Although this last point has been cogently argued by anthropologists advocating greater integration between evolutionary and cultural anthropologies (Fuentes, 2016), much can still be done to exploit the integrative potential of NCT to explain human evolution in light of its complex genetic, epigenetic, behavioral, and symbolic dimensions (Andersson et al., 2014; Bonduriansky & Day, 2009; Jablonka & Lamb, 2005). In this article, we use ethnohistorical data to develop a model of the role of social memory in the construction of the human niche of southwest Madagascar, a landscape subject to increasingly variable climatic conditions and resource distributions. Our aim is to build on biocultural approaches to evolutionary questions (e.g., Dressler 2019; Marcantonio & Fuentes, 2020) and integrate local, Indigenous and descendant (LID) knowledge with evolutionary theory. Our approach aligns with efforts to counter the persisting colonial dynamic in which scientists treat African peoples and contexts as sources of raw data, but not as sources of theory for their analysis and interpretation (Comaroff and Comaroff 2012).

Southwest Madagascar has long experienced a hypervariable climate (Dewar & Richard, 2007). Proxy records of the region's climate extend back several thousand years and provide evidence of dramatic shifts, including in the availability of rainfall (Burney et al., 2004; Crowley, 2010; Ferry et al., 1998; Zinke et al., 2004). Today, unpredictability and low abundance of rainfall are underlying causes of subsistence risk among the region's diverse communities of herders, farmers, and foragers (Tucker, 2007; Tucker et al., 2015). The unpredictability of limited rainfall affects both the distribution and availability of resources that are critical to the livelihoods of LID

communities. Climate in the rapidly warming Indian Ocean region is forecasted to become more variable in future (Hermes et al., 2019; Roxy et al., 2014) and climate-driven impacts on local ecologies, such as widespread coral bleaching, have already been observed and are negatively affecting local livelihoods, including those of fishers (Gillibrand et al., 2007; Le Manach et al., 2012; Nadon et al., 2007). Added to the extreme challenges of climate variability are growing pressures on resources due to intensifying industrial extractive industries targeting forests, fisheries and mineral resources (Blanc-Pamard, 2009; Grenier, 2013).

These threats place LID communities in a precarious position. Decreasing biodiversity and biological productivity along with increasing globalization and market integration have shifted practices away from traditional forms of subsistence and exchange toward a cash economy, in which LID communities are located at the impoverished end of a complex international supply chain (Cripps et al., 2015; Fauroux, 1994; Grenier, 2013; Huff, 2017; Scales et al., 2017).

Human and natural communities in SW Madagascar thus face significant and linked socioecological threats (Douglass et al., 2019). As a result of economic and social changes linked to the above threats, SW communities report increasing fragmentation and loss of traditional knowledge and oral histories relating to their landscape and local ecologies (Mr. A. Ediedy, Congressman representing Morombe District, personal communication). In response to deteriorating ecologies, conservationists and non-governmental organizations have stepped up efforts in the region through the implementation of community-based conservation and development programs (Harris, 2007). These programs institute collaborations with LID communities to modify aspects of community life, especially with regard to reproductive choices, health, education, and resource use (Cripps & Harris, 2009). Despite some positive economic outcomes from conservation and development programs (Benbow et al., 2014; Oliver et al., 2015; Westerman et al., 2012), policy centered on behavior modification at the level of LID communities ultimately places the burden of conservation and sustainability planning on often impoverished rural peoples, despite the more significant impacts of entities engaged in industrial-scale, commercial resource extraction (Huff, 2017). Other consequences of top-down policy include rising gender and wealth inequality (Baker-Médard, 2016; Tucker et al., 2011), and loss of autonomy with regard to land-use and subsistence (Tucker et al., 2010). These negative policy impacts are undoubtedly exacerbated by the fact that limited efforts have been made to understand holistically how

LID communities have co-evolved with their landscapes over centuries and millennia and document LID traditional ecological knowledge and practices.

In this article, we hypothesize that the interplay between diverse social identities and ties, shifting subsistence strategies and community mobility is key to how LID communities of SW Madagascar reduce subsistence risk in a hypervariable environment. To investigate this interplay, we analyze an oral history archive compiled through interviews with over 100 knowledge holders from 32 different communities located in the Velondriake Marine Protected Area (Velondriake). Using a NCT framework, we develop a theoretical model of how LID communities of SW Madagascar modify their socio-biophysical environment in ways that reduce subsistence risk. Our theoretical model suggests that social memory, its maintenance, and transmission play an essential role in regulating the interplay between social identities and ties, shifting subsistence strategies and community mobility. We argue that social memory, thus, is a key mechanism in

the construction of a niche that makes human life ways possible in an environment where the availability and productivity of common pool resources, including forests, grasslands, reefs, estuaries and sources of freshwater, are, and have always been, hypervariable.

2 | METHODS

2.1 | Research area

Our work is based on generous knowledge sharing by elders and other knowledge holders in Velondriake, southwest Madagascar (Figure 1). Velondriake, a name that means “to live with the sea” or “fed by the sea”, is home to diverse communities of fishers, herders, foragers and farmers united today through community-based conservation and development partnerships (Figure 2; Harris, 2007). The peoples of Velondriake are also connected to one another and to communities beyond the Velondriake area through a complex history of kinship,

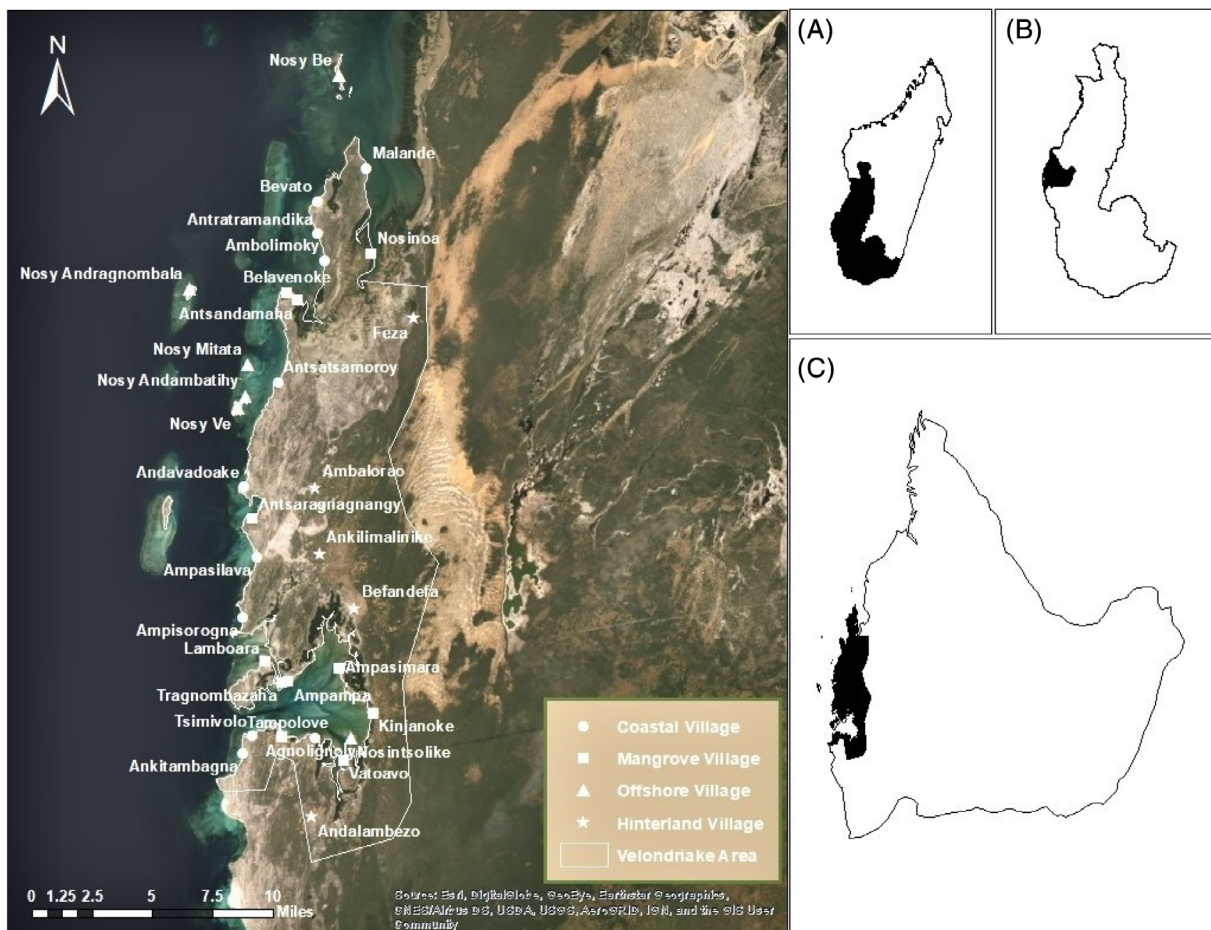


FIGURE 1 The Velondriake area and the 32 villages where interviews were conducted. (A) Province of Toliara; (B) District of Morombe; (C) Velondriake Area

clan affiliation and other forms of social identity and exchange (Tucker, 2003; Yount et al., 2001). The land- and seascapes of Velondriake are characterized by diverse ecologies, including coral reefs, sand bars, seagrass meadows, estuaries, mangrove forests, dry forest, spiny thicket, and grasslands (Figure 3; Roy

et al., 2009). The flora and fauna of the region are diverse and feature the highest levels of endemism on the island (DuPuy & Moat, 1996; Gautier & Goodman, 2003; Jasper & Gardner, 2015; Rakotomalaza & McKnight, 2006; Raselimanana et al., 2012; Raselimanana & Goodman, 2004).



FIGURE 2 Community members of the Velondriake region illustrating diverse livelihood strategies, including (A) cultivation of manioc (*Manihot esculenta*); (B) herding zebu cattle (*Bos taurus indicus*); (C) foraging and hunting tenrec (*Tenrecidae sp.*) in the dry forest; and (D) fishing on the reef (Credit photos A–C: G. Cripps; D: J. Haile)



FIGURE 3 Aerial photographs of land- and seascapes of Velondriake illustrating the diversity of local ecologies: (A) dry forest in the Namonte basin; (B) Lamboara peninsula and the Fagnemot estuary; (C) Namonte freshwater lake system with visible areas of crop cultivation at the lake margins (Credit photos A, C: G. Cripps; B: J. Pons)

2.2 | Oral history interviews

Between September 2017 and May 2018, members of the Morombe Archeological Project (MAP) team conducted 120 oral history interviews with 111 knowledge holders (91 males, 20 females) across 32 villages and hamlets in the Velondriake region. Knowledge holders were consulted based on their social status and role within the community. They include *mpità hazomanga* or *mpitoka* (heads of clans), *olo be antanà* (village elders) and local authorities and leaders. We attribute male bias in the group of interviewees to the patriarchal nature of Velondriake communities, in which men are more likely to be identified as knowledge holders. The interview team was led by Mr. Roger Samba, the founder and first president of the Velondriake Association, a local organization that manages the fisheries and coastal resources of Velondriake. His popularity, familiarity, and close relationships with village elders and local authorities facilitated the interviews, though also likely contributed to male bias in the group of knowledge holders interviewed. His assistants Laurence Hubertine and Harson Léonce, also originally from the Velondriake area, are members of a younger generation. Their participation in the interview process motivated knowledge holders to share their knowledge following *tapasiry*, a local tradition of storytelling and intergenerational knowledge transfer.

Semi-structured interviews were conducted in a mix of southwest Malagasy dialects, though Vezo was predominantly spoken, and based on a series of 26 questions collaboratively developed by KD and the MAP team (S1). Our semi-structured approach was designed to show mutual respect between interviewers and interviewees and to give interviewees control over knowledge sharing (House, 1990). Interviews were conducted in an open setting within each knowledge holder's community. This open context mitigated the male bias in our sample by allowing attendees, including many women, to chime in spontaneously. To reduce time lapse and promote the natural flow of conversations, interviews were fully recorded with a digital audio recorder (Tascam DR-40). A total of 100 h of audio were recorded.

2.3 | Transcription and data organization

Audio recordings were transcribed by the interviewers and transcriptions were revised to ensure consistency in spellings and completeness by TR. To our knowledge, the transcriptions and audio recordings compiled during this project constitute the most extensive digital archive of southwest Malagasy oral histories to-date. Funding is

being sought in collaboration with community members to maximize community access to this digital archive and ensure its preservation.

Our qualitative analysis of the interviews aimed to understand not only what was shared, but also how and why information was shared (see Abrams, 2016, p. 1). This approach required close and repeated reading of the transcripts while simultaneously listening to the audio recordings. As part of this close listening and reading, we also organized the information from the interviews in tables to enable quantitative analyses, including but not limited to the categorization of described phenomena, occurrences and frequencies, correlations, and geospatial data. Observations consist of the names of interviewees, while variables include (1) interviewees' age, (2) interviewees' gender, (3) village names, (4) GPS coordinates of village, (5) interview dates, (6) name of *tarike* (group affiliation), (7) livestock earmarks, (8) migration history of the *tarike*, (9) size of the migrating group, (10) push factors, (11) pull factors, (12) location of the group's *hazomanga* (ritual post), (13) practice of *savatse* (rite-of-passage), (14) practice of *bilo* (healing ritual), (15) *ziva* (joking relatives), (16) burial place, (17) taboo, (18) warfare memories, (19) subsistence strategies, (20) livestock herded, (21) crops farmed, (22) wild resources foraged, (23) landscape changes, (24) changes in climate, (25) bartering regions and partnerships, (26) imported goods, (27) exported goods, (28) pottery-making, (29) archeological sites, (30) historical sites, (31) paleontological sites.

We further organized the archive according to 8 key themes, including (1) traditional ecological knowledge (TEK) and social memory, (2) cultural identity and identity shifts, (3) migration and mobility, (4) climate and environmental changes, (5) human response to climate and environmental changes, (6) social networks, (7) warfare memories, and (8) historical, archeological, and paleontological knowledge. This article combines information from the first six key themes to discuss the role of social memory in constructing the human niche.

3 | RESULTS

3.1 | Model of the human niche of SW Madagascar

Through qualitative and quantitative assessment of the oral history archive, we saw emerge an evolutionary logic to the human-environment-climate dynamics knowledge holders described. We iteratively analyzed the interviews and built a theoretical model reflecting these evolutionary dynamics (Figure 4). Knowledge holders frequently

spoke about challenges to LID livelihoods (pressures), responses to mitigate the impacts of these challenges (niche construction mechanisms) and the outcomes of these responses (effects; Figure 5; Table 1 in S4).

In our model, the selective pressures (Figure 4A–C), niche construction (NC) mechanisms (Figure 4; social memory, D–F) and effects (Figure 4G–I) described all influence one another in a web of inputs and feedbacks.

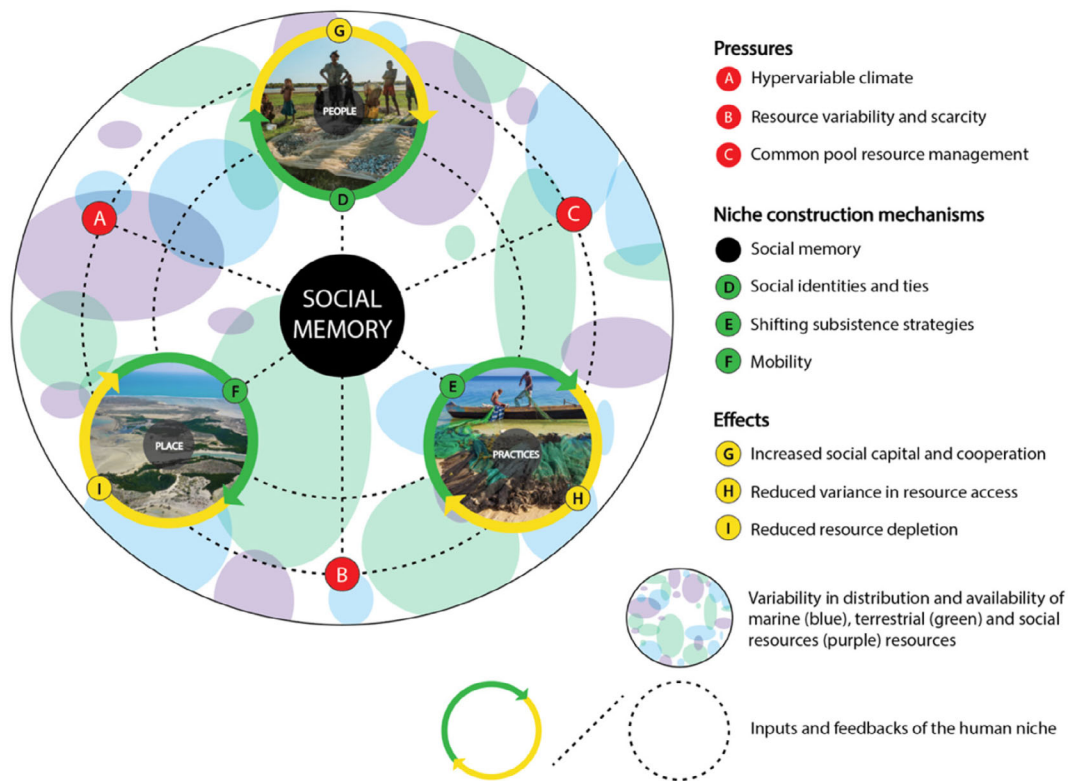


FIGURE 4 Diagram illustrating the central role of social memory of people, practices and place in constructing the human niche of Velondriake. Figure conceptualized as a “web” of inputs and feedbacks in the construction of the human niche, inspired by the example of a spider’s web as a form of niche construction (Laland et al., 1999). (Photo credits: G. Cripps, “People”; J. Pons, “Place”)

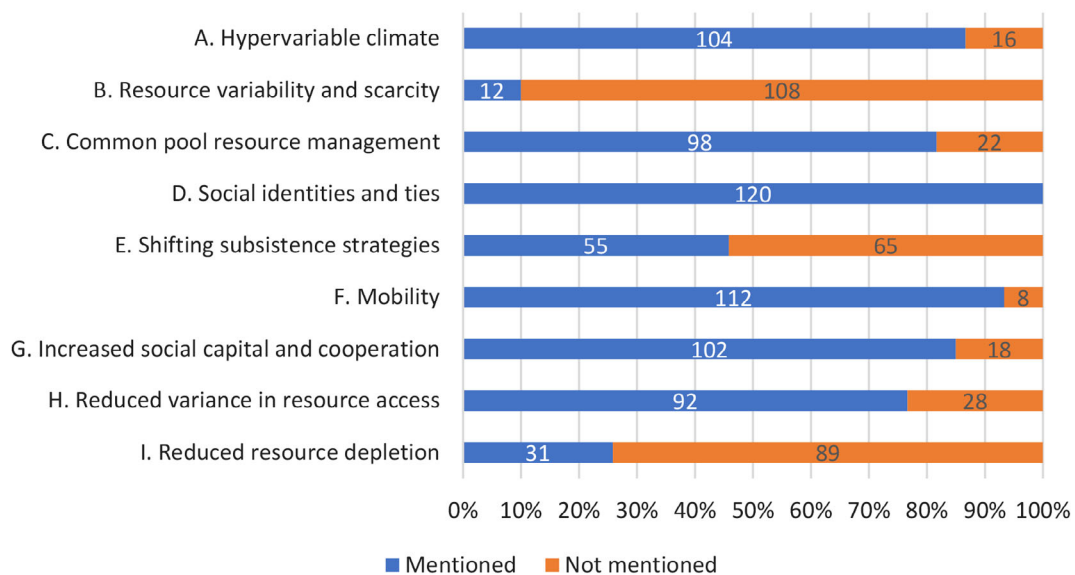


FIGURE 5 Numbers and percentages of interviews in which components of the model (Figure 4) were discussed. (A–C) Represent pressures; (D–F) Represent niche construction mechanisms; and (G–I) Represent effects. Social memory as a model component is not represented here, as the interviews themselves represent the transmission of social memory and reflect its centrality to the model

Social identities and ties (people), shifting subsistence strategies (practices) and mobility (place) are NC mechanisms (Figure 4D–F) developed in response to selective pressures (Figure 4A–C). For example, the challenges of common pool resource management (Figure 4C) can be met through the development of social ties (Figure 4D) that promote cooperation and reciprocity. Meanwhile, cooperation and reciprocity are examples of effects (Figure 4G–I) that can, in turn, feedback to shape future behaviors. Effects like reduced resource depletion (Figure 4I), for instance, feedback into future mobility strategies as people alter the frequency, distance and duration of movement (Figure 4F). NC mechanisms influence one another as much as they influence particular pressures and effects. For example, community mobility (Figure 4F) and subsistence shifts (Figure 4E) are facilitated by shifts in social identities and the (re)configuration of social ties between communities (Figure 4D).

As we reflected on the interview process itself, we understood that the way in which interviewees and attendees were transmitting their knowledge to us followed established traditions of intergenerational knowledge transfer (*tapasiry*) that engender, facilitate and perpetuate the NC mechanisms being described (Figure 4; center). This revelation led to the centrality of social memory in our proposed model of the human niche of SW Madagascar. As knowledge holders spoke, the transmission of ecological knowledge and local histories reinforced and reminded interview attendees of connections to place, practices, and people, especially with regard to exchange, reciprocity and cooperation. This process was not limited to the active recording of the interviews. Community members who subsequently listened to recordings during the transcription process actively engaged with the stories they heard through conversation with others around them, corroborating recounted events and posing further questions for those interviewed.

Ultimately, our model posits that HNC mediated by social memory shapes the distribution and availability of

marine, terrestrial, and social resources on the landscape in ways that are beneficial to LID livelihoods and promote livelihood sustainability. We represent this conceptually in our model diagram in two ways. First, we show how “effects” (Figure 4; yellow components), are connected to “pressures” and “NC mechanisms” in a web of inputs and feedbacks. Second, we represent the spatial dimension of variable marine, terrestrial, and social resources via blue, green, and purple ellipses over which the web of inputs and feedbacks in the human niche is overlaid. These two conceptual approaches provide opportunities to test a range of hypotheses regarding the human niche of SW Madagascar.

In addition to tallying mentions of pressures, NC mechanisms, and effects (Figure 5; Table 1 in S4), we measured linear correlations between mentions of pressures versus NC mechanisms, and NC mechanisms versus effects (Tables 1 and 2). The relationships between variables whose mentions were highly correlated should be prioritized in future hypothesis testing with regard to the dynamics of this human niche. For example, mentions of a hypervariable climate and mentions of specific types of social ties (e.g., *tarike*, neighbors, and bartering partners) were highly correlated (Table 1). The same was true for mentions of a hypervariable climate and mentions of mobility and migration (Table 1).

In the following sections, we present further results of our analysis of the oral history archive, including translated quotations, to emphasize the niche construction mechanisms observed and highlight how these interact with pressures and effects within the niche (Figure 4).

3.2 | Pressures

3.2.1 | Hypervariable climate

Over 85% of knowledge holders mentioned the region's hypervariable climate during interviews (Figure 5) and mentions of climate variability were more highly

TABLE 1 Correlations between knowledge holder mentions per village of pressures versus NCT mechanisms (see Table 1 in S4)

	Hypervariable Climate	Resource Scarcity	Common Pool Resources
Social Tie: Tarike	0.925427	0.256256	0.717581
Social Tie: Ziva	0.383724	0.214523	0.328131
Social Tie: Marriage	0.777173	0.341793	0.58205
Social Tie: Neighbors	0.931645	0.106407	0.671002
Social Tie: Bartering Partner	0.91584	0.222222	0.628655
Social Tie: Subsistence Identities	0.514563	0.266711	0.548735
Social Tie: Blood Brotherhood	0.122658	0.535288	0.029145
Subsistence Shift	0.547159	0.546645	0.652385
Mobility and Migration	0.869771	0.286888	0.67166

<0: Negatively linearly correlated; 0 = No linear correlation; 0.01-0.20: less linearly correlated; 0.21-0.49: somewhat linearly correlated; 0.5-0.79: linearly correlated; 0.8-1 = highly linearly correlated

correlated with mentions of niche construction mechanisms than mentions of resource scarcity and the challenges of managing common pool resources (Table 1). Past climate variability and downturns (e.g., droughts) were described (Q1), but most descriptions emphasized the recent intensification of climate changes, specifically with regard to the timing, spatial extent, frequency, and abundance of rainfall (Q2), and highlighted causes and consequences of these changes (Q3).

Q1: *In the past, there were recurrent droughts. People failed to grow crops. I am afraid this is what reoccurs today. People are now starving. Cows are dying. There is less rain. How can we survive with this?* Tsognene, 85, Agnolignoly

Q2: *In the past, the rainy season started around the month of October. It starts with a northerly wind. But now, we have southerly wind all the time. Things have changed a lot.*

We used to have rains way before Christmas. But now, there is no rain during Christmas and New Year days. There is a dramatic change. Jules Freddy, 74, Ambalorao

Q3: *This is how climate works. Due to deforestation, there is variability. It rains early inland, while it rains late along the coast.* Totototo, 54, Agnolignoly

3.2.2 | Resource variability and scarcity

Few interviews contained explicit mentions of resource scarcity (12/120; Figure 5). When mentioned, present-day scarcity was contrasted with past abundance (Q4, 5). Resource scarcity was infrequently described as a push factor contributing to a change in behavior (e.g., migration; Figure 6). On the other hand, a majority of interviews (88/120) cited proximity to key natural resources as pull factors (Figure 6). Descriptions of

TABLE 2 Correlations between knowledge holder mentions per village of NCT mechanisms versus effects (see Table 1 in S4)

	Increased Social Capital and Cooperation	Reduced Variance in Resource Access	Reduced Resource Depletion
Social Tie: Tarike	0.88283	0.61581	0.378599
Social Tie: Ziva	0.293292	0.434689	0.017846
Social Tie: Marriage	0.781858	0.531658	0.264375
Social Tie: Neighbors	0.919912	0.561617	0.423218
Social Tie: Bartering Partner	0.805732	0.559835	0.377722
Social Tie: Subsistence Identities	0.398686	0.541493	0.252126
Social Tie: Blood Brotherhood	-0.0115	0.101712	0.332576
Subsistence Shift	0.440214	0.597794	0.122163
Mobility and Migration	0.837457	0.531315	0.357983

<0: Negatively linearly correlated; 0 = No linear correlation; 0.01-0.20: less linearly correlated; 0.21-0.49: somewhat linearly correlated; 0.5-0.79: linearly correlated; 0.8-1 = highly linearly correlated

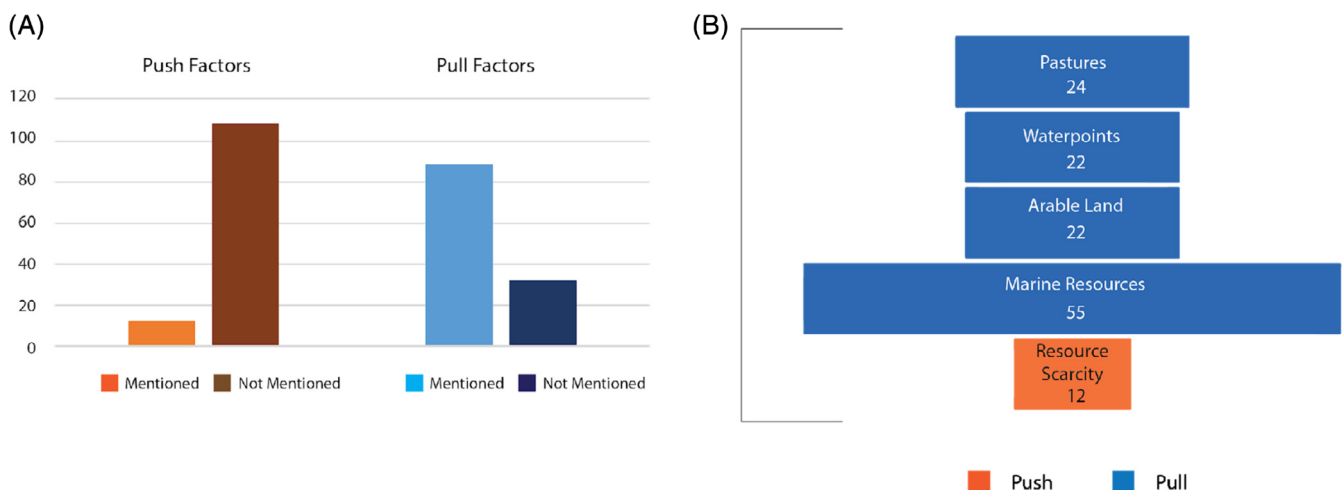


FIGURE 6 Summary of mentions of resource-related push and pull factors

resource variability and scarcity were sometimes directly linked to changes in climate (Q6).

Q4: *Fishing is no longer productive. Fishes have become scarce. People catch less. At most, people catch 10 to 20 kg of fish. Otherwise, people merely catch 3 kg of fish ... But in the past, if you went out to the sea early in the morning until this hour, you might fill the half of a large pirogue with fishes. That can fill 3 to 4 sacks of fishes.* Tombokarady, 101, Ampasimara

Q5: *It is no longer like what happened in the past, because in the past, as the name Bedeka means, there were more deka fishes in the area. The same applies to the name Bevahoho which witnessed the abundance of vahoho fishes. But today, there are fewer fishes around the area.* Totototo, 54, Agnolignoly

Q6: *Climate is changing. When they still lived in Tragnombazaha, there were more marine resources. That is why they liked to stay there. Even line-fishing was productive. Octopus gleaning was prosperous. But later on, there are fewer marine resources. The climate has changed a lot.* Lipo, Ampampa-Tragnombazaha

in promoting cooperation in their use and management (Q7–9).

Q7: *Tafaragnitse's mother was married in Antsepoke. But Tafaragnitse did not live with her. He preferred to live here with his maternal uncles. His maternal uncles however told him "you are a Vezo fisherman. You do not know how to watch herds. So, you better move and stay at Antsaragnasoa bay to fish."* Jules Freddy, 74, Ambalorao

Q8: *They loved this place because it suited their herds. It was a good prairie. It is located far from the sea and the beach. The place is on a crossroad. Roads from Andavadoake and Befandefa meet here. At its north is a good prairie. Even herders from Ambatomilo and Antaniloba used to bring their herds here.* Dertelefa, 90, Ambalorao

Q9: *The village was located along the coast. As a herder, they had to leave and move here. There were many of them. Those who did not have cows stayed in coastal villages such as Tampolove, Agnolignoly, and Vatoavo. Those who had cows moved here.* Zemene, Andalambezo

3.2.3 | Common pool resources

A majority of interviews highlighted common pool resources (99/120; Figure 7). Fisheries were mentioned most frequently, followed by farmlands and grasslands, suggesting intensive reliance on these resources by a majority of communities and the importance of social ties

3.3 | Niche construction mechanisms

3.3.1 | Social memory

The maintenance and successful transmission of social memory via *tapasiry* (storytelling and intergenerational knowledge transfer) were described as being essential in maintaining ties and access to people, place, and practices (Q10–12):

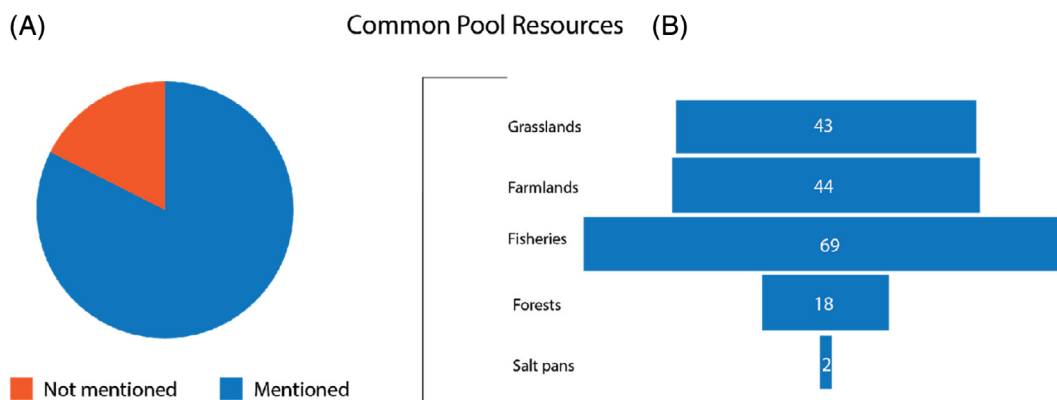


FIGURE 7 Summary of mentions of common pool resources. (A) Overall proportion of mentions and (B) number of interviews mentioning specific common pool resources (out of 120 interviews)

Q10: My grandparents moved here because they herded livestock. They raised their cows here. My grandfather first lived in Lamboara. His wife was from there. But then, 'Ah, let us move over there to plant some crops'. They had farming fields around Vatoavo. That land still belongs to them ... My father showed me that land. 'This is our village. This is our land. This is this'. 'Yes father', I said, 'That is good to know. I will memorize all that'. Long story short, every time we visit the place, I remind the current occupants 'This is not your land. It is our ancestors' land. Totototo, 54, Agnolignoly

Q11: Those people were honey gatherers from the east, as our father told us. Even him, he did not witness it. They heard the waves from the west. 'Hey. That must be a bee colony. Let us track that sound' [...] They arrived at a wetland called Anjàboba. 'Ah, this is a prairie, and we are thirsty'. So, they dug a well and drank the water from it. 'Let us sleep here'. The next day, they continued their route following the sound. They finally discovered that it is the wave that makes sound. 'Let us go back to that prairie, and settle there'. They went back and stayed in Anjàboba [...] They collected honey around the place [...] They had many children. Some started to know how to fish. 'Let us move to the coast' [...] Some of them herded cows, while others planted crops [...] Those who knew how to fish, including my grandfather moved to Tampolove [...] But there was a family quarrel. That is why I decided to go back here, because this is part of my ancestral lands. That is the story my dad told me, so I am telling it to you too. Dondoke, 80, Andalambezo

Q12: Our grandparents from our mother's side came here first. They were here. They were indigenous to this land. But those from my father's side, they were not from here. They were warthog hunters. But when my grandfather could no longer hunt, while my father married here and stayed with our maternal uncle, they moved my grandfather from the forest to here. They stayed here in Kinjanoke. This place was still forested. There was no village yet. My grandfather from my mother's side, Matesoa, still lived in those islands. When my paternal grandfather arrived, they

said 'ah, our ziva has arrived. So, let us join them, so that they will not feel alone'. People in the past embraced tapasiry. So, they came here. Then this place grew larger. My paternal grandparents decided to stay. They died here. Velomahasoa, Kinjanoke

3.3.2 | Social identities and ties

A diverse array of social identities and ties were described during all interviews (Figures 5 and 8). Social identities and ties varied in terms of the duration of the identity/tie, and the justification for why they are established (Figure 9). Almost all identities and ties, however, were described as being established during a community or individual's lifetime ("created" as opposed to "inherited"; Figure 9), and as bringing collective benefits related to accessing marine and terrestrial resources, as well as social resources, such as mutual support, protection, knowledge, and cooperation. Justifications for the establishment of identities/ties during a community or individual's lifetime centered on two primary issues: resource scarcity and maintaining cooperation/reducing conflict (Figure 9). This is consistent with the results in Table 2, showing high linear correlations between mentions of social identities and ties, and increasing social capital and cooperation. The social identities and ties mentioned most frequently (Figure 8), *tarike*, neighbors, bartering partners and marriage, were the most highly linearly correlated with increased social capital and cooperation (Table 2).

Individual interviews reveal numerous additional insights and nuance as to the formation of social identities and ties. We present a selection of quotations

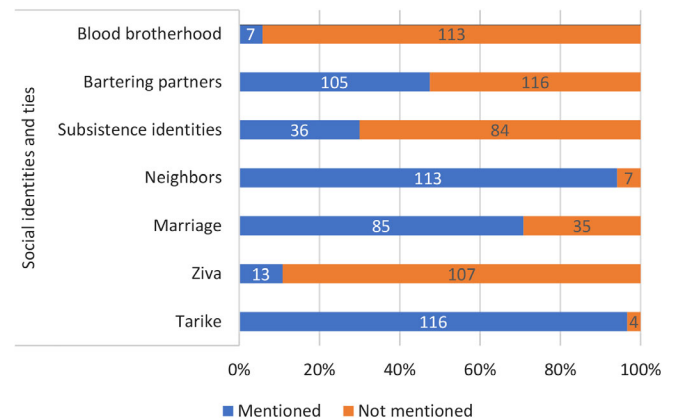


FIGURE 8 Numbers and percentages of interviews in which different kinds of social identities and ties (Figure 4, model component "D") were discussed

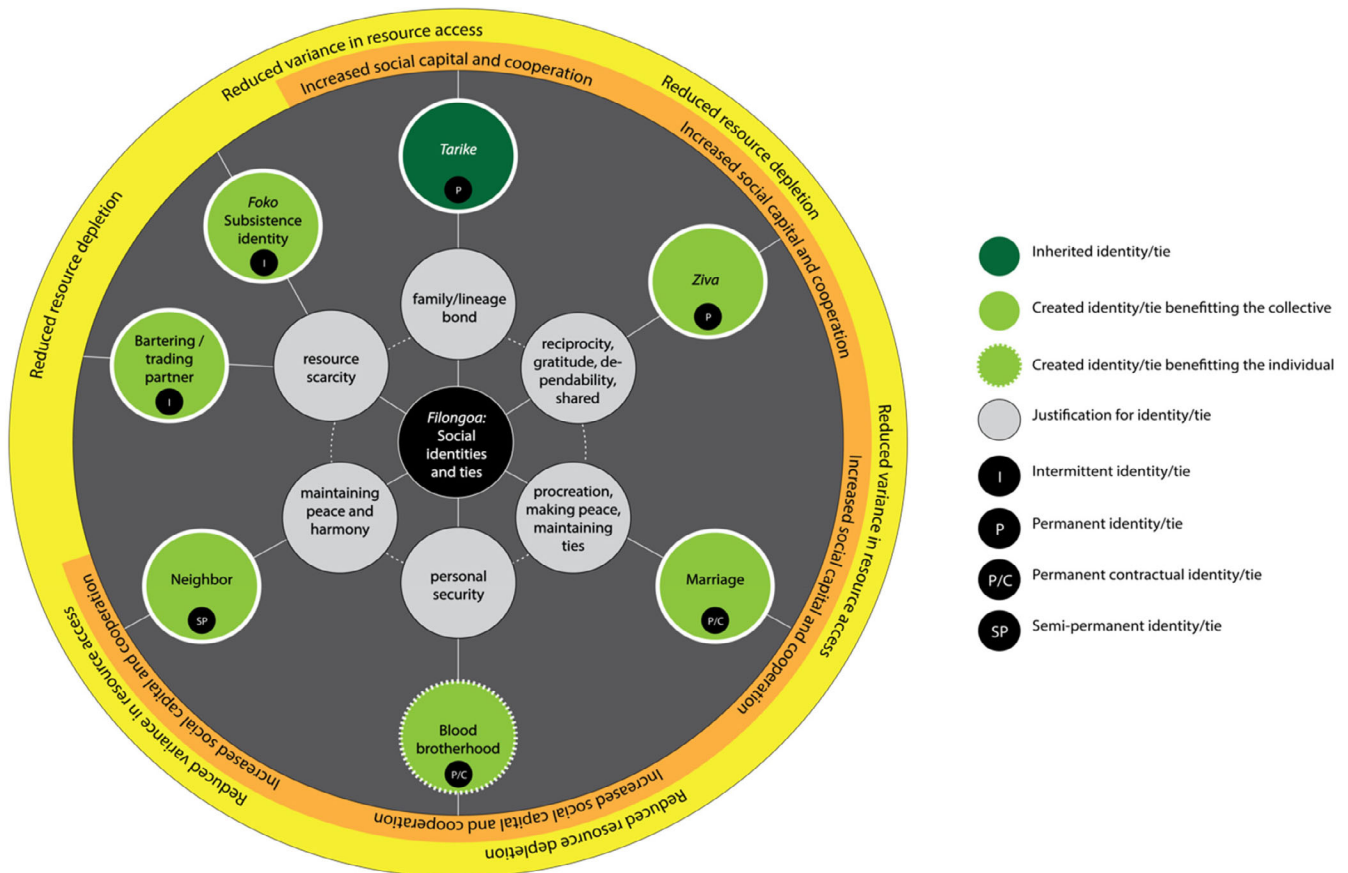


FIGURE 9 Diagram illustrating the range of social ties (*filongoa*) and identities described by knowledge holders in Velondriake, including the drivers of their formation and maintenance, the benefits they provide, whether they are created or inherited, permanent or intermittent, and of benefit to individuals or communities. Further details provided in Table 2 in S4

(Q) from interview transcriptions to capture several, although by no means all, relevant insights. In many cases, these insights were shared by multiple knowledge holders, but we generally have selected one quotation to serve as an example for each finding.

The establishment of new social identities/ties involves the observance of *fomba* (traditions, rituals, cultural norms) with material and spatial dimensions (Q13):

Q13: *What brought them here, they were 2 brothers who herded cows. His younger brother was eaten by a crocodile. So, he decided to bring his herds here and cohabit with Jabalà people [...] He asked permission from the Jabalà people to stay here. While following his herds around, he discovered a place where there are many tamarind trees. 'The soil where I am staying now is too salty. I want to move here'. So, he discussed this with them. 'So, what do you guys think if I stay near the tamarind trees?' 'It is a nice spot with tamarind trees', said*

his Jabalà fellows, 'but we are only interested in hunting warthog. We do not mind if you want to stay there. Yes'. So, he moved to that place. He herded his cows around, while clearing the area for agricultural fields as well [...] Jabalà people bury their dead in the vicinity. One of his (Marofoty) descendants died ... 'Hey guys, our ancestral land is too far, so what do you think if we bury our dead here?' 'Yes. We are neighbors. We have been cohabitating here for a long time and have not quarreled yet. So, you can bury here'. That is why Jabalà and Marofoty are still buried at the same burial place until today. Tsimandoa, 80, Mpitoka of Marofoty people, Befandefa

New identities/ties are influenced by and in turn influence existing ties. Marriage, for example, was described as a social tie, but also as a mechanism by which *tarike* expand their spatial distribution across the landscape (Q14):



Q14: *There are many villages where you can find Marofoty people, including Andavadoake, Ambalorao, Belavenoke. While moving from place to place, some of them decided to stay. This is because of marriage. Marriage distributes them in different villages. Even in Bevato there are Marofoty people. They move to different villages and marry there. They have many children and grandchildren at those places.* Tobokarady, 101, Ampasimarà

Knowledge holders often described the establishment of new social identities/ties in the context of group migration (Q15):

Q15: *Tahoambe people were from the east. They are Masikoro farmer-herders, but they were chased by enemies. They moved here. Mahafale people, on the other hand, are not indigenous to Andalambezo. They are from the south, while Tahoambe people are from the east moving their herds here ... They then established blood brotherhood, a pact like ziva. This is why Tahoambe people are the ziva of Mahafale people today.* Attendee of Velomanasana interview, Agnolignoly

Shared subsistence identities (e.g., as herders, farmers, fishers, foragers) facilitate access to resources in new areas following group migration, as described for the Marofoty and Tsimagnavadraza people, both farmer-herders, at Ampasimarà (Q16):

Q16: *Marofoty people came from Ankililale. While still staying there, one of their children was eaten by a crocodile while playing. The Marofoty parent was frustrated. 'How come my son did not die naturally, but was eaten by a crocodile? No, let us move from here'. They then moved here. When they arrived, they asked for a piece of land from the Tsimagnavadraza people. 'We are moving here, because my son was eaten by a crocodile. So please give us a piece of land so that we can stay here with you, the Tsimagnavadraza (litt. those who do not discriminate based on lineage) people'. 'Yes', said the Tsimagnavadraza people, 'we do not hate longo. We welcome you here. You can take that eastern side of the land. You can clear it'. Then the Marofoty people cleared the area and settled there.* Tobokarady, 101, Ampasimarà

The establishment of new social identities and ties facilitates reciprocity and shared access to terrestrial, marine, and social resources, often during periods of resource scarcity. The reliance on social identities and ties to ensure access to resources was described as superseding market-based systems of exchange (Q17):

Q17: *Those around Andalambezo though, they got those caves, because they are ziva. Jabala people are ziva to Mahafale people. Then, 'hey Jabala people, we are starving. Can you please give us the things we saw? We want to raise our herds over there'. 'Yes,' they said, 'if you wanted to buy these places, we would not give them to you. But being ziva is very important. Take them! But you should allow our children to forage there if they want to'. This is why Mahafale people allow us to forage at that place, even if they are the current occupants. Mahafale people cannot react, because the land still belongs to us. They are only raising their herds over there.* Velomahasoa, Kinjanoke

Flexibility in the adoption of "created" identities was made clear in numerous instances, but flexibility was also described in relation to "inherited" *tarike* identities and how they are expressed, a finding that stands in contrast to previous research (e.g., Astuti, 1995; Q18):

Q18: *There are two tarike at that place now. One is the Tahoambe people, while the other is the Jabalà people. However, there are also other eclipsed groups. For instance, Zafisily and his relatives are originally Ntavaratse and Mahafale people. However, their forefather married a Jabalà woman. So they switched their identity, and identified themselves as Jabalà people ... They ignored their Mahafale and Ntavaratse identity. They did not use Ohintsotro earmarks before. But now, I saw Zafisily putting Ohintsotro earmarks on his cows' ears. Maybe they feel lucky identifying themselves as such ... They used to use a Jabalà earmark before because their forefather was hosted by the Jabalà people. They accordingly identified themselves as Jabalà.* Bonava, 60, Vatoavo

Analysis of individual interviews revealed consensus among knowledge holders overall about existing social ties, suggesting shared social memory across the Velondriake area. For example, no disagreements or

discrepancies were identified with regard to *ziva* relationships (Table 3 in S4).

3.3.3 | Shifting subsistence strategies

Nearly half of the interviews contained mentions of shifting subsistence strategies, involving a mix of fishing, foraging, herding, and farming (Figure 5). Shifting subsistence strategies were correlated with all pressures and one effect (reduced variance in resource access) outlined in our model (Figure 4; Tables 1 and 2). Knowledge holders firmly asserted that subsistence strategies are not exclusive to any group. Subsistence strategies can be claimed at will and group affiliation does not dictate which subsistence strategies an individual or group may adopt (Q19):

Q19: *Subsistence strategies do not belong to a firazagna or a tarike. You can practice whichever subsistence strategy you want. Yes. There is no such thing like you belong to this firazagna, so you have to practice this subsistence strategy.* Romelson, 52, Nosy Andragombala

Shifts in subsistence strategies are accompanied by shifts in subsistence identities (e.g., Vezo fisher, Mikea forager, and Masikoro herder/farmer). We recorded several stories about shifts in subsistence and associated shifts in identity. These included shifts from one dominant strategy and identity to another (e.g., Vezo to Masikoro; Q20), as well as shifts from one dominant strategy and identity to a hybrid strategy and identity (e.g., from Mikea to Masikoro/Vezo; Q21):

Q20: *Davirongo, our forefather was from the south. He came here for marriage. He and his wife first lived in Tampolove. But as he was a Vezo and Sarà fisher, he sought other places to fish. After they had many children, they decided to move and settle on an offshore island [...] then they moved to a prosperous place in Vatoavo. They raised many chickens at the place, as he said. I still remember when I saw their goats roaming around the place when I was a child. They had a lot of them. Mahazomora, our grandfather also had many cows.* Bonava, 60, Vatoavo

Q21: *A Mikea from the hinterland was following the sound of the sea waves assuming that it was a colony of bees. On the way, they slept around the prairies of Anjaboba. Then the*

next morning, they continued to follow the sound until they discovered that it was the sound of the sea waves. They then decided to return to the Anjaboba prairies. While exploring the area, they discovered that there were Mahafale people settling in the vicinity. They then intermingled with the Mahafale people. They learned how to raise herds, plant crops, and fish at the sea. Ndongoke, 80, Andalambezo

Despite the enduring and central importance of cattle in the *fomba* (rites and traditions) of all Velondriake communities (Figure 10), shifts from agropastoralism (Masikoro) or forest-based foraging (Mikea) to coastal fishing (Vezo) were the most commonly described shifts and accounts of these shifts to coastal fishing highlighted the view that the sea is full of resources, even when other parts of the landscape experience resource scarcity (Q22–26):

Q22: *We were herder agriculturists, but then learned how to fish as well.* Andreavola, 30, Andalambezo

Q23: *We, the Marofoty people, are Masikoro farmers from inland but migrated towards the coast. While staying in Befandefa, we came seasonally to Ampasimara for fishing. But eventually, we decided to permanently stay here in Ampasimara and become Vezo fishers.* Rapaoly Joseph, 45, Ampasimara

Q24: *While in Bory, they relied more on agriculture. However, the agricultural fields did not produce enough due to climate change, low precipitation, and soil degradation. So they decided to move to the coast.* Velomanasana, 53, Agnolignoly

Q25: *As I said during the chiefdom period, people were hiding. But the sea provides inexhaustible marine resources. But the taste and energy from those fishes are different. There were many moky tubers that people dug around the adjacent forests in the past. People ate these moky tubers with fish.* Ferson dit Betsa, 63, Ambolimoky-Nosinoa

Q26: *We now live in Ampasimarà. We used to have two homes, one in Ampasimarà, and another in Befandefa [...] We love this place because it is a small peninsula and has many marine resources. In addition, there is a water source nearby. We love this place because it makes our livelihood easier. It is close to a harbor, so it is as if we live on the coast. The sea*



FIGURE 10 Herd of zebu cattle (*Bos T. indicus*) in the Mangoky River delta, just north of Velondriake, Southwest Madagascar

around here provides many marine resources, so we decided to stay. That is why we decided to live here. Mamono, 46, Ampasimarà

Subsistence shifts and changes in linked subsistence identities were associated with contexts of climate-driven resource scarcity (Q27), insecurity and loss of wealth (Q28, 29) and long-distance migration (Q30):

Q27: We used to practice mixed herding and fishing strategies. But due to the unpredictability of climate today, we decided to rely only on fishing strategy. Midine, 44, Ampisorogna

Q28: I was originally a cattle herder. But after I lost my herds to cattle raiders, I decided to become a Vezo fisher. I no longer need to return to Antaniloba, because I am now a Vezo fisher. Tsangatahe, 72, Malande

Q29: In our group, those who lost their herds, and could no longer own livestock decided to move to Tampolove, Agnolignoly, Vatoavo to fish, while those who had livestock stayed in Andalambezo. Zemene, Andalambezo

Q30: Marofoty people were originally Baralahy from the east. But once arriving in the southwest, they became Masikoro. Edmond Tsitondro, 82, Befandefa

3.3.4 | Mobility

The vast majority of the interviews contained mentions of mobility and migration (Figure 5). Geospatial data shared by knowledge holders provide insights into the spatial dimensions of social identities and ties, as well as resource use. Specifically, we recorded justifications for movement (e.g., to maintain or create social ties, access resources, mitigate climatic impacts, etc.), as well as connections to place and the nature of these connections (e.g., names and locations of villages in which members of the interviewee's *tarike* are found). Although drivers of community mobility were described in diverse ways by knowledge holders, migration was often centered on mitigating livelihood risk (Q31):

Q31: Jabalà people are from the east, from Masikoro land. They moved from place to place searching for better livelihoods. They ended up here on the coast, and decided to stay. [...] “Kimija people are from the south. Southeast. They spread northwards searching for better livelihoods. They ended up here on the coast. Ede, attendee of Kaliziny interview, Bevato

Livelihood risk was also described in diverse ways, ranging from lack of access to potable water to limited agricultural productivity and the presence of toxic flora (Q32):

Q32: They lived in Antsirarabe. They had a tradition, like every time one of them died, they

moved to another place. 'Let us leave this cursed place, one of us died here.' They moved from Antsirasirabe to a place called Andombiry. A bird was passing by. Sarotroe followed it and discovered a waterpoint. However, there are poisonous plants - lombiry - growing in the water. That is why the place is called Andombiry. Some of them died again. They moved to Antsirasira. But they still drank water from Andombiry, so one of them died again. Then they moved here. Sarotroe married three Namanoa women from Ambalorao. They had a lot of children here. Then their children engendered more children. All these people you see here were born here. They tilled the soil here. But farming did not produce well. So their children started to leave. Only we stayed here. But our parents urged us not to work on a botry boat. 'You should not work on a botry. Just stay here.' 'Okay. But what kind of livelihood should we practice?' So we foraged moky tubers, honey, lamoty berries. In addition, we fished around Ampasilava. I had cows. I took them to Ankoabe. While I was there, I followed a bird, and discovered a waterpoint at the actual place of Ampisorogna. Our parents decided to stay in Ankoabe. But they sometimes came back here to farm their agricultural fields. When the winds do not allow fishing, we return here. Meanwhile, the son-in-laws of our grandparents who lived together with them here used to go to Ampasilava to fish. Eventually, they asked permission to move and settle on the coast. "We ask your blessing, my father-in-law, we want to settle on the coast together with our children". 'You want to settle there?' 'Yes.' 'That side of the land is exposed to foreign people. So, you may have problems there.' 'We can no longer live from the products of farming. Please give us your blessing to settle on the coast.' Then he gave them his blessing. They moved to Ampasilava with their wives and children. All those many people living at Ampasilava today are their descendants. But the land still belongs to Sarotroe, their father-in-law. They lived there because of marriage.' Dakoro, Ankilimalinike

Interviews resulted in geospatial information about the distribution of *tarike* and trading partnerships, as these are often described in the context of specific

villages. These data reveal that *tarike* are rarely limited to one area or village and are frequently widely distributed across the landscape (Q33; Table 4 in S4).

Q33: Jabalà people are found in Andalambezo, Soarano, Kinjanoke, Tampolove, Lamboara, Befandefa, Ankilimalinike, Andavadoake, Belavenoke, Ampasilava, Bevato, and Morombe. [...] Kimija people are distributed from Anakao, Toliara, Sarodrano, Fitsitike, Faramasay, Lamboara, Andavadoake – they are numerous here –, Bevato, Morombe, Andranompase, and Beló. Ede, attendee of Kaliziny interview, Bevato

This, in turn, indicates that most villages are home to several *tarike* (Table 4 in S4). Generally speaking, villages located along the mainland coast and the adjacent hinterland are home to more *tarike* per village than villages located on offshore islands and inland (Figure 11).

Geospatial data relating to trading partnerships reveal that the majority of villages in Velondriake barter with several other villages distributed widely across the landscape and connecting villages to a range of habitats and resource types (e.g., coastal, inland, estuaries, offshore islands; Figure 12; Table 5 in S4). Velondriake villages maintained a mean of five trading partners (Table 5 in S4).

3.4 | Effects

The niche construction mechanisms outlined in our model (Figure 4) were primarily correlated with two effects: increased social capital and cooperation, and reduced variance in resource access (Table 2).

3.4.1 | Increased social capital and cooperation

Mentions of increased social capital and cooperation was highly correlated with mentions of social identities and ties (Q34–36), with the exception of *ziva*, subsistence identities and blood brotherhood, and mobility (Table 2).

Q34: Eventually, I told my wife, for the safety of our children and our remaining cows, before the rustlers come and take them, let us move to your father's place. That is why we live here now. Fanay, 55, Ambolimoky

Q35: People living around here are all connected. But there are some people who prefer

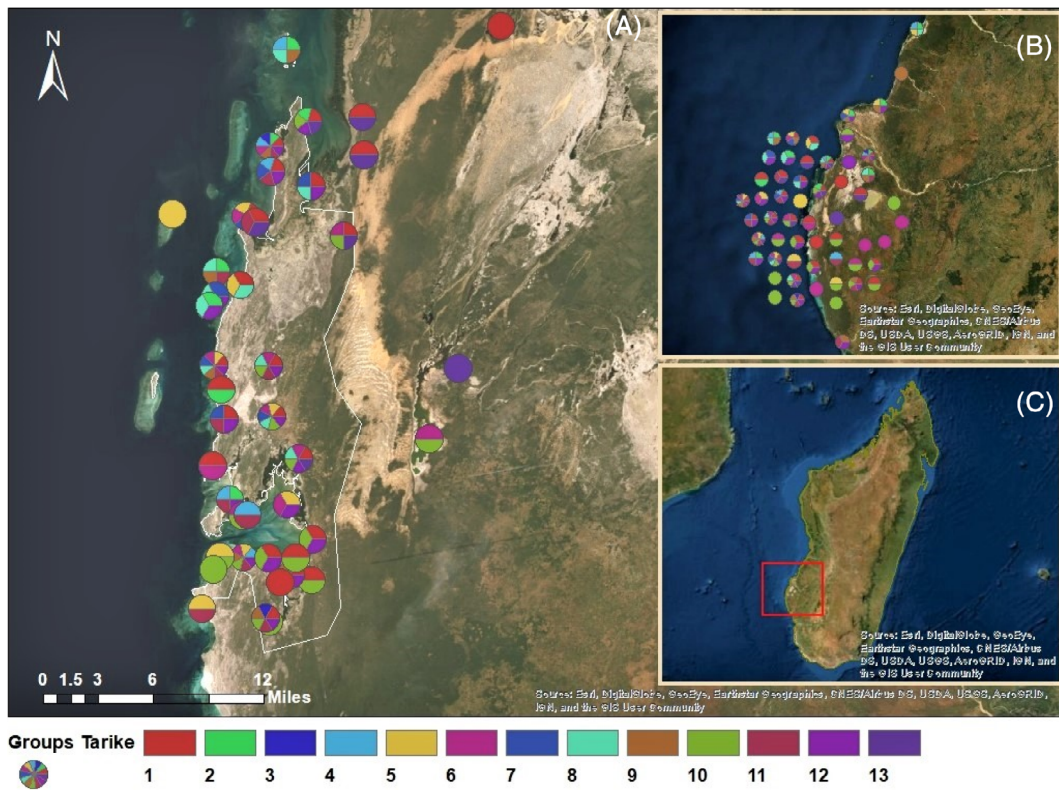


FIGURE 11 Distribution of *tarike* by village, as mentioned by knowledge holders: (A) Velondriake; (B) the wider region of the Morombe District, in which Velondriake is located; and (C) location of Morombe District on Madagascar. Represented *tarike* are: 1. Jabalà; 2. Kimija; 3. Mahafale; 4. Marobe; 5. Marofohe; 6. Marofoty; 7. Marolahy; 8. Namanoa; 9. Ohintsotro; 10. Tahoaoombe; 11. Tsagnala; 12. Tsimagnavadraza; 13. Tsimitiha

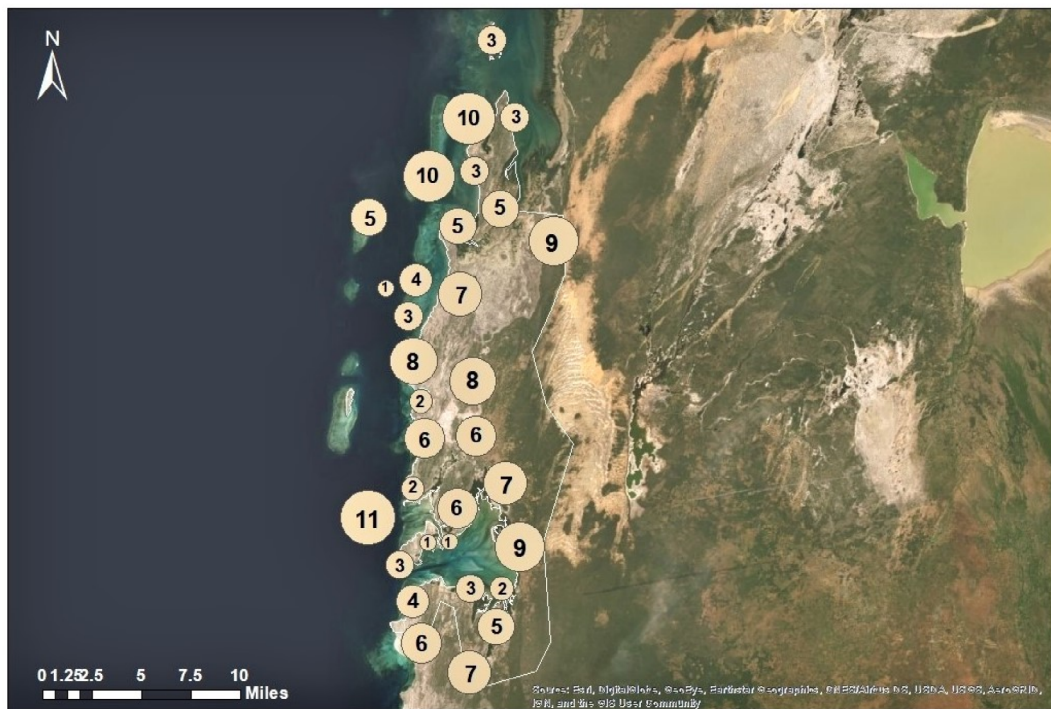


FIGURE 12 Map showing the location of Velondriake villages and indicating the number of villages with whom they share a bartering relationship for the exchange of resources

to gossip around. I for one cannot do something bad or quarrel with my fellow neighbors. The fact that our herds drink at the same waterpoint around here motivates me not to quarrel with anyone ... we are all one, so we better live in peace. Dertelefa, 90, Ambalorao

Q36: *The people staying on that side are from Lamboara. They came here to make a living like the way people from Toliara came to Morombe for the same purpose. They then socially bonded together and formed what you see now.* Alifasiny, Ampasilava

3.4.2 | Reduced variance in resource access

We observed a linear correlation between mentions of reduced variance in resource access and all niche construction mechanisms, with the exception of *ziva* and blood brotherhood social ties (Table 2). Knowledge holders highlighted the changing spatial dimensions of social ties (via community mobility) as being central to reducing variance in resource access (Q37–39).

Q37: *Hey, said the Lamboara guys, the Jabalà people have many daughters. Let us find wives over there'. They then stayed and married women in Ankilimalinike. But what else can they do over there? They are just Vezo fishermen ... So, they asked 'we are grateful you gave us wives, but we cannot make a living here. We cannot afford to go back and forth, so we better move to the coast and stay there permanently'. 'That is okay guys. We have already considered you as our own children. So, it is fine if you want to stay there. You can watch our harbor.* Dobake, 80, Ampasilava

Q38: *During the dry period like this, the inland receives rains before the coast. So, our fathers used to move our herds inland. Their host was Tsilisare, their mother's husband. They moved there every year. Later, their sister also was married to an inland man named Tsitiaro. They then decided to permanently stay there with the herds.* Velomana Sana, 53, Agnolignoly

Q39: *Tavaratse people are the descendants of Tsimalemy from Namonte. From Namonte, he moved to Voreha to farm. While farming*

there, he married the locals and had children. They managed to have many cows. Due to insecurity, they moved here, and asked for a tract of land. All Tavaratse people living here moved from Voreha, but they are originally from Namonte. Jules Freddy, 74, Ambalorao

3.4.3 | Reduced resource depletion

Despite widespread resource scarcity in Velondriake, knowledge holders made infrequent mention of resource scarcity (Figure 5) and did not significantly link niche construction mechanisms to mitigating scarcity (Table 2). Instead, resource scarcity in the present was contrasted with past abundance (Q40, 41).

Q40: *In the past, there were many moky tubers in the forest. People dug them and ate them with fish. There were fewer moky tubers around Nosinoa. So instead, people preferred to go to the forest near Ambolimoky to dig some.* Ferson, 63, Ambolimoky

Q41: *In the past, there were more rains. Agriculture was profitable. Planting manioc was enough for people to survive. If you have a wider farming field, you could fill a hut with it. If you planted sweet potatoes, you could harvest a lot when ponds are dry. During the watermelon harvesting period, you could not consume them all. You still could sell some of them on the coast. If you went out to collect honey, you never came back home empty handed.* Zemene, Andalambezo

4 | DISCUSSION

In an environment of high subsistence risk, NCT predicts that people in SW Madagascar modify pressures in their environment, in order to construct a niche in which risk is reduced. Although this article is the first to apply an explicit NCT framework to investigate the relations between climate, environment and people in the region, previous work has investigated behaviors and practices that we have characterized as niche construction mechanisms. Specifically, prior research has elucidated patterns of mobility and resource use in archeological and contemporary communities (e.g., Douglass et al., 2018; Gardner et al., 2015; Grenier, 2013). Archeological evidence suggests that SW communities have relied on frequent mobility and diverse subsistence strategies for at least



two millennia. Ancient sites reflect the existence of seasonal foraging and fishing camps interspersed with short-lived villages in which people exploited a wide range of taxa (Douglass, 2016b; Douglass et al., 2018; Grealy et al., 2016). Historical records also recount frequent population movements, including migrations of communities into and within the region (De Bry, De Constantin, and François Martin de Vitré cited in Grandidier, 1903, pp. 145, 197, 284). Meanwhile, ethnographic accounts highlight the nomadic nature of contemporary communities of fishers, herders, and foragers (Astuti, 1995; Cripps, 2009; Kelly et al., 2005; Koechlin, 1975) as they pursue a range of terrestrial and marine resources.

To-date, community mobility in SW Madagascar has been described in terms of the push and pull of declining resources in one area and their availability in another. Resource-related push and pull factors are a standard explanation for community mobility in anthropology (Kelly, 1992; Salazar, 2010). A community of herders, for instance, may move seasonally with their herds following the availability of pastures (De Bry, De Constantin, and François Martin de Vitré cited in Grandidier & Grandidier, 1903, pp. 145, 197, 284; Kaufmann, 2004). A community of fishers may move from one fishing ground to another as marine species migrate or are depleted in one area (Cripps, 2009). Our results reflect the influence of resource-related pull factors as drivers of community mobility. Knowledge holders often linked changes in resource abundance to changes in climate (Q5, 12, and 15), though scarcity itself was rarely mentioned, suggesting communities perceive resources to be variable in their distribution, rather than simply scarce.

Our model proposes that social memory ultimately influences the patchy distribution of resources, which itself feeds back into changing relationships between communities, patterns of mobility and resource use. As communities move, reconfigure their social ties, and shift their subsistence practices, social memory thus creates a palimpsest of social and ecological inheritances communities continuously shape and negotiate within the human niche (Rotman and Fuentes, 2016). In our case, social memory is analogous to caring for country through the use of fire in Western Australia, where Aboriginal communities have created a vast ecological inheritance of landscape pyrodiversity that continues to draw people back to place (Bird et al., 2016; Bliege Bird et al., 2020).

Numerous knowledge holders recounted movements in pursuit of resources that were facilitated by existing identities and ties (e.g., *tarike* clan-based affiliation or marriage), resulted in changes in group and individual self-identification and ties (e.g., as herders, fishers, foragers, or a combination of these), and resulted in increased social capital and cooperation (see sections

3.3.2 and 3.4.1). Our work thus highlights that the creation and maintenance of social identities and ties are important mechanisms driving adaptive behaviors. Archeological evidence of the circulation of material culture, including ceramics and beads, suggests that dynamic social networks have been important through much of the region's human history (Douglass, 2016a; Parker, 2010; Rasolondrainy, 2019). Our findings call for further work investigating social networks (both archeological and contemporary), their emergence and structural re-organization, as these processes appear crucial to adaptation, including adaptation to climate change.

Another significant finding of our work relates to shifting regional demographics with increasing migration to the coast. The frequently recounted adoption of *Vezo* fisher identity is consistent with the greater diversity of *tarike* represented in coastal villages and their immediate hinterlands (see Figure 4). Our results also support previous findings that farmers in SW Madagascar experience much higher subsistence risk and food insecurity than fishers and foragers (Tucker et al., 2010). Furthermore, the interviews suggest that climate impacts and other constraints on the availability of resources drive inland communities to resettle on the coast (e.g., Q10–18), while coastal communities may only be making temporary trips inland, in order to barter for forest products. Coastal villages maintain many inland bartering partners (Table 5 in S4). Overall, this suggests that the creation and maintenance of social ties in expanding coastal populations will be critical to promoting cooperation and mitigating conflict, as common pool coastal and marine resources experience greater pressures in the coming years.

Finally, the performative and flexible nature of subsistence identities in southwest Madagascar has been the subject of previous anthropological research (Astuti, 1995; Yount et al., 2001), particularly as these shifting subsistence identities appear to co-exist with more rigid and seemingly conflicting forms of individual and community identities, such as *tarike* (ancestral clan affiliation; e.g., Astuti, 1995). The interplay between shifts in community identity and mobility evident in the interviews we recorded, however, calls for a re-thinking and integration of the theoretical lenses through which community mobility and identity are examined. Although the existence of specialized subsistence identities tied to distinct ecological zones, such as *Masikoro* (grassland herders and farmers), *Vezo* (coastal fishers), and *Mikea* (forest-dwelling foragers) suggest a form of niche partitioning that might reduce resource competition (Hector & Hooper, 2002; MacArthur, 1958), the flexibility and autonomy to easily shift subsistence identities does not support this theoretical approach.

We argue instead that the integration of NCT and LID knowledge offers a more productive theoretical

framework for understanding mobility, subsistence shifts, and identity on SW Madagascar's hypervariable landscape. Our proposed model can be used for the development of testable hypotheses regarding livelihoods, health, environment, resilience to climate change, and many other aspects of LID livelihoods (Figure 4). For example, we hypothesize that HNC in Velondriake results in a patchier distribution of marine, terrestrial, and social resources, and reduces variance in access to these resources for all communities in the niche, while simultaneously reducing competition and conflict. Another hypothesis, stemming from our model as well as from other biocultural models of HNC and cultural transmission (e.g., Dressler, 2019; Henrich & Broesch, 2011), is that success in maintaining and transmitting social memory at the community level (e.g., communities who have many elders who are also high-status storytellers) is associated with membership in polycentric networks at the regional scale and positively correlated with greater network centrality and resilience to stressors (e.g., climate change). Our model also provides a framework for addressing a range of questions about the effect of social memory and HNC on other species in SW Madagascar. The model should also prove useful in assessing the impacts of conservation and development policies on community livelihoods, sustainability, and resilience. In line with recent findings by Marcantonio and Fuentes (2020), our model suggests that fragmentation and loss of LID knowledge and traditions (e.g., social memory) pose a serious threat to livelihood sustainability. LID community members in SW Madagascar have expressed grave concern that erosion of social memory is resulting in the impoverishment of cultural and ecological inheritance (C. Ediedy, personal communication), a process likely to intensify with growing pressures from climate change and extractive industries. We thus argue that prioritizing the preservation and dissemination of oral histories and traditional ecological knowledge is a policy position that could have significant benefits in terms of biodiversity conservation and sustainability of human livelihoods.

5 | CONCLUSION

On Madagascar, a lot of attention is paid to the critical losses of biodiversity observed island-wide. Limited attention, however, is given to rapid losses of LID histories and knowledge, particularly related to landscapes and ecology. This lacuna presents a challenge to the long-term sustainability of Madagascar's human and other biotic communities, but also provides the opportunity to develop new approaches to investigate the co-evolution

of people and environment, integrating evolutionary theory with LID knowledge.

In this article, we combine LID knowledge, collected through an extensive oral history survey, with a NCT framework to theorize how social memory contributes to the construction of a niche that makes human lifeways possible in a hypervariable environment. As described in other regions subject to extreme climate variability (e.g. McIntosh 2000), we argue that social memory is a key mechanism shaping human adaptations to climate and resource variability, such as mobility, social identities and ties and subsistence shifts. Our theoretical model creates future opportunities to integrate data and methods from multiple sources, including ethnohistory, archeology, human ecology, and climate science, among others. It also provides concrete avenues for the development of testable and integrative hypotheses regarding human adaptation and resilience to climate and environmental challenges, with implications relevant to a range of stakeholders, including policymakers. Disregarding the importance of social memory as a key mechanism for HNC in SW Madagascar could lead to further erosion of local histories and knowledge. The *Olo Be* of Velondriake have demonstrated that these are essential to livelihood sustainability and resilience in a hypervariable environment.

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AUTHOR CONTRIBUTIONS

Kristina Douglass: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing-original draft; writing-review and editing. **Tanambelo Rasolondrainy:** Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing-original draft; writing-review and editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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REFERENCES

- Abrams, L. (2016). *Oral history theory*. Routledge.
- Andersson, C., Törnberg, A., & Törnberg, P. (2014). An evolutionary developmental approach to cultural evolution. *Current Anthropology*, 55(2), 154–174.
- Astuti, R. (1995). *People of the sea* (pp. 188–188). Cambridge University Press.
- Baker-Médard, M. (2016). Gendering marine conservation: The politics of marine protected areas and fisheries access. *Society & Natural Resources*, 30(6), 723–737.
- Benbow, S., Humber, F., Oliver, T. A., Oleson, K. L., Raberinary, D., Nadon, M., Ratsimbazafy, H., & Harris, A. (2014). Lessons learnt from experimental temporary octopus fishing closures in Southwest Madagascar: Benefits of concurrent closures. *African Journal of Marine Science*, 36(1), 31–37.
- Bird, D. W., Bird, R. B., Codding, B. F., & Taylor, N. (2016). A landscape architecture of fire: Cultural emergence and ecological pyrodiversity in Australia's Western Desert. *Current Anthropology*, 57(S13), S65–S79.
- Blanc-Pamard, C. (2009). The Mikea Forest under threat (Southwest Madagascar): How public policy leads to conflicting territories. *Field Actions Science Reports*, 3, 1–12.
- Bliege Bird, R., McGuire, C., Bird, D. W., Price, M. H., Zeanah, D., & Nimmo, D. G. (2020). Fire mosaics and habitat choice in nomadic foragers. *Proceedings of the National Academy of Sciences*, 117(23), 12904–12914.
- Bonduriansky, R., & Day, T. (2009). Nongenetic inheritance and its evolutionary implications. *Annual Review of Ecology, Evolution, and Systematics*, 40, 103–125.
- Boyd, R., Richerson, P. J., & Henrich, J. (2011). The cultural niche: Why social learning is essential for human adaptation. *Proceedings of the National Academy of Sciences*, 108(2), 10918–10925.
- Burney, D. A., Burney, L. P., Godfrey, L. R., Jungers, W. L., Goodman, S. M., Wright, H. T., & Jull, A. J. T. (2004). A chronology for late prehistoric Madagascar. *Journal of Human Evolution*, 47(1–2), 25–63.
- Comaroff, J. (2012). *Theory from the South: or, how Euro-America is evolving toward Africa*. London: Paradigm Publishers. p.247.
- Crawford, G. W. (2014). Food production and niche construction in pre-contact southern Ontario. *Midwest Archaeological Conference Occasional Papers*, 1, 135–160.
- Cripps, G. (2009). *Understanding migration amongst the traditional fishers of West Madagascar*. Blue ventures conservation report (p. 174). Blue Ventures Conservation Report for ReCoMap.
- Cripps, G., & Harris, A. (2009). *Community creation and management of the Velondriake marine protected area*. Blue Ventures Conservation.
- Cripps, G., Harris, A., Humber, F., Harding, S., & Thomas, T. (2015). A preliminary value chain analysis of shark fisheries in Madagascar. Indian Ocean Commission Report: Food and Agriculture Organization of the United Nations. p. 82.
- Crowley, B. E. (2010). A refined chronology of prehistoric Madagascar and the demise of the megafauna. *Quaternary Science Reviews*, 29(19–20), 2591–2603.
- Dewar, R. E., & Richard, A. F. (2007). Evolution in the hypervariable environment of Madagascar. *Proceedings of the National Academy of Sciences of the United States of America*, 104(34), 13723–13727.
- Dortch, J., Monks, C., Webb, W., & Balme, J. (2014). Inter-generational archaeology: Exploring niche construction in southwest Australian zooarchaeology. *Australian Archaeology*, 79(1), 187–193.
- Douglass, K. (2016a). An archaeological investigation of settlement and resource exploitation patterns in the Velondriake marine protected area, Southwest Madagascar, ca. 900 BC to AD 1900 [Doctoral]. New Haven: Yale University. p.466.
- Douglass, K. (2016b). The diversity of late Holocene shellfish exploitation in Velondriake, Southwest Madagascar. *The Journal of Island and Coastal Archaeology*, 12(3), 333–359.
- Douglass, K., Antonites, A. R., Quintana Morales, E. M., Grealy, A., Bunce, M., Bruwer, C., & Gough, C. (2018). Multi-analytical approach to zooarchaeological assemblages elucidates late Holocene coastal lifeways in Southwest Madagascar. *Quaternary International*, 471, 111–131.
- Douglass, K., Walz, J., Quintana-Morales, E., Marcus, R., Myers, G., & Pollini, J. (2019). Historical perspectives on contemporary human-environment dynamics in Southeast Africa. *Conservation Biology*, 33(2), 260–274.
- Dressler, W. (2019). The construction of the cultural niche: A bio-cultural model. *American Journal of Human Biology*, 32 (e23311), 1–11.
- DuPuy, D., & Moat, J. (1996). A refined classification of the primary vegetation of Madagascar based on the underlying geology: Using Gis to map its distribution and to assess its conservation status. In W. R. Lourenço (Ed.), *Proceedings of the international symposium on the 'Biogeography de Madagascar'* (pp. 205–218). ORSTOM.
- Fauroux, E. (1994). Les échanges marchands dans les sociétés pastorales de l'ensemble méridional de Madagascar. *Cahiers des Sciences Humaines*, 30(1–2), 197–210.
- Ferry L, L'Hote YA, and Wesselink A. 1998. Les précipitations dans le sud-ouest de Madagascar. Abidjan '98. Abidjan, Côte d'Ivoire: IAHS. p 89–96.

- Flynn, E. G., Laland, K. N., Kendal, R. L., & Kendal, J. R. (2013). Target article with commentaries: Developmental niche construction. *Developmental Science*, 16(2), 296–313.
- Fuentes, A. (2016). The extended evolutionary synthesis, ethnography, and the human niche. *Current Anthropology*, 57(Supplement), S13–S26.
- Gardner, C. J., Gabriel, F. U. L., St. John, F. A. V., & Davies, Z. G. (2015). Changing livelihoods and protected area management: A case study of charcoal production in south-West Madagascar. *Oryx*, 50(03), 495–505.
- Gautier, L., & Goodman, S. M. (2003). Introduction to the Flora of Madagascar. In S. M. Goodman & J. P. Benstead (Eds.), *The natural history of Madagascar* (pp. 229–250). University of Chicago Press.
- Gerbault, P., Liebert, A., Itan, Y., Powell, A., Currat, M., Burger, J., Swallow, D. M., & Thomas, M. G. (2011). Evolution of lactase persistence: An example of human niche construction. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 366(1566), 863–877.
- Gillibrand, C. J., Harris, A., & Mara, E. (2007). Inventory and spatial assemblage study of reef fish in the area of Andavadoaka, south-west Madagascar (Western Indian Ocean). *Western Indian Ocean Journal of Marine Science*, 6(2), 183–197.
- Grandidier A. 1903. Collection des ouvrages anciens concernant Madagascar, [microform] publiée sous la direction de MM. A. Grandidier ... Charles-Roux, Cl. Delhorbe, H. Froidevaux et G. Grandidier.
- Grandidier A, and Grandidier G. 1903. Collections des ouvrages anciens concernant Madagascar. Paris, France: Comite de Madagascar.
- Grealy, A. C., Douglass, K., Haile, J., Bruwer, C., Gough, C., & Bunce, M. (2016). Tropical ancient DNA from bulk archaeological fish bone reveals the subsistence practices of a historic coastal community in Southwest Madagascar. *Journal of Archaeological Science*, 75, 82–88.
- Grenier, C. (2013). Genre De Vie Vezo, Pêche "Traditionnelle" Et Mondialisation Sur Le Littoral Sud-Ouest De Madagascar. *Annales de géographie*, 693(5), 549–549.
- Harris, A. (2007). "To live with the sea" development of the Velondriake community-managed protected area network, Southwest Madagascar. *Madagascar Conservation & Development*, 2(1), 43–49.
- Hector, A., & Hooper, R. (2002). Ecological experiment. *Science*, 295, 639–640.
- Henrich, J., & Broesch, J. (2011). On the nature of cultural transmission networks: Evidence from Fijian villages for adaptive learning biases. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, 366(1567), 1139–1148.
- Hermes, J. C., Masumoto, Y., Beal, L. M., Roxy, M. K., Vialard, J., Andres, M., ... Yu, W. (2019). A Sustained Ocean observing system in the Indian Ocean for climate related scientific knowledge and societal needs. *Frontiers in Marine Science*, 6 (355), 1–21.
- House, E. R. (1990). Methodology and justice. *New Directions for Program Evaluation*, 1990(45), 23–36.
- Huff A. 2017. Black sands, green plans and vernacular (in)securities in the contested margins of South-Western Madagascar. Peacebuilding:1–17.
- Jablonka, E., & Lamb, M. (2005). *Evolution in four dimensions: Genetic, epigenetic, behavioral, and symbolic variation in the history of life*. MIT Press.
- Jasper, L., & Gardner, C. (2015). *Life among the thorns: Biodiversity and Conservation of Madagascar's Spiny Forest* (pp. 317–317). Tien Wah Press Ltd.
- Kaufmann, J. C. (2004). Prickly pear cactus and pastoralism in Southwest Madagascar. *Ethnology*, 43(4), 345–361.
- Kelly, R. L. (1992). Mobility/sedentism: Concepts, archaeological measures, and effects. *Annual Review of Anthropology*, 21(1), 43–66.
- Kelly, R. L., Poyer, L., Tucker, B., & Poyer, L. I. N. (2005). An Ethnoarchaeological study of mobility, architectural investment, and food sharing among Madagascar's Mikea. *American Anthropologist*, 107(3), 403–416.
- Kendal, J., Tehrani, J. J., & Odling-Smee, J. (2011). Human niche construction in interdisciplinary focus. *Philosophical Transactions of the Royal Society B*, 366, 785–792.
- Koehlin, B. (1975). *Les Vezo du Sud-Ouest de Madagascar: Contribution à l'Etude de l'Eco-Système de Semi-Nomades Marins* (pp. 243–243). Mouton.
- Laland, K. N., Odling-Smee, F. J., & Feldman, M. W. (1999). Evolutionary consequences of niche construction and their implications for ecology. *Proceedings of the National Academy of Sciences*, 96, 10242–10247.
- Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S., & Zeller, D. (2012). Unreported fishing, hungry people and political turmoil: The recipe for a food security crisis in Madagascar? *Marine Policy*, 36(1), 218–218, 225.
- Lewontin, R. C. (1983). Gene, organism and environment. In D. S. Bendall (Ed.), *Evolution from molecules to men*. Cambridge University Press.
- MacArthur, R. H. (1958). Population ecology of some warblers of northeastern coniferous forests. *Ecology*, 39(1958), 599–618.
- Marcantonio, R., & Fuentes, A. (2020). A clear past and a murky future: Life in the Anthropocene on the Pampana River, Sierra Leone. *Land*, 9(72), 1–17.
- McClure, S. B. (2015). The pastoral effect: Niche construction, domestic animals, and the spread of farming in Europe. *Current Anthropology*, 56(6), 901–910.
- McIntosh, R. J. Roderick J. McIntosh Joseph Tainter & Susan K. McIntosh (2000). Social Memory in Mande. *The way the wind blows: climate, history, and human action*. New York, New York: Columbia University Press. p.141–180., (141–180). New York, New York: Columbia University Press. <http://cup.columbia.edu/book/the-way-the-wind-blows/9780231112086>.
- Nadon, M. O., Griffiths, D., Doherty, E., & Harris, A. (2007). The status of coral reefs in the remote region of Andavadoaka. *Southwest Madagascar. Western Indian Ocean Journal of Marine Science*, 6(2), 207–218.
- O'Brien, M. J., & Laland, K. N. (2012). Genes, culture, and agriculture: An example of human niche construction. *Current Anthropology*, 53(4), 434–470.
- Odling-Smee, F. J., Laland, K. N., & Feldman, M. W. (2003). *Niche construction: The neglected process in evolution*. Princeton University Press.
- Oliver, T. A., Oleson, K. L. L., Ratsimbazafy, H., Raberinary, D., Benbow, S., & Harris, A. (2015). Positive Catch & Economic Benefits of periodic octopus fishery closures: Do effective,

- narrowly targeted actions 'Catalyze' broader management? *PLoS One*, 10(6), e0129075–e0129075.
- Parker, P. M. (2010). *Pastoralists, warriors and colonists: The archaeology of southern Madagascar* (pp. 725–725). British Archaeological Reports.
- Rakotomalaza, P. J., & McKnight, M. (2006). Etude de la variation de la structure et de la composition floristique de la forêt des Mikea du sud-ouest de Madagascar. *Phelsuma*, 14, 13–36.
- Raselimanana, A., Raheirilalao, M. J., Soarimalala, V., Gardner, C. J., Jasper, L. D., Schoeman, C. M., & Goodman, S. M. (2012). Un premier aperçu de la faune de vertébrés du bush épineux de Salary- Bekodoy, à l'ouest du Parc National de Mikea, Madagascar. *Malagasy Nature*, 6, 1–23.
- Raselimanana, A. P., & Goodman, S. M. (Eds.). (2004). *Inventaire floristique et faunistique de la forêt de Mikea: Paysage écologique et diversité biologique d'une préoccupation majeure pour la conservation* (p. 106). Centre d'Information et de Documentation Scientifique et Technique.
- Rasolondrainy, T. (2019). *Decision-making in the face of unpredictable climate and intergroup conflicts in Southwest Madagascar, sixteenth to nineteenth centuries CE*. Yale University.
- Roxy, M. K., Ritika, K., Terray, P., & Masson, S. (2014). The curious case of Indian Ocean warming. *Journal of Climate*, 27(22), 8501–8509.
- Roy, R., Dunn, S., & Purkis, S. (2009). *Mapping Velondriake: The application of bathymetric and marine habitat mapping to support conservation planning, Southwest Madagascar* (p. 18). Blue Ventures Conservation.
- Salazar, N. B. (2010). Towards an anthropology of cultural mobilities. *Crossings: Journal of Migration & Culture*, 1(1), 53–68.
- Scales, I. R., Friess, D. A., Glass, L., & Ravaoarinorotsihoarana, L. (2017). Rural livelihoods and mangrove degradation in south-west Madagascar: Lime production as an emerging threat. *Oryx*, 52(4), 641–645.
- Smith, B. D. (2009). Resource resilience, human niche construction, and the long-term sustainability of pre-Columbian subsistence economies in the Mississippi River valley corridor. *Journal of Ethnobiology*, 29(2), 167–183.
- Smith, B. D. (2016). Neo-Darwinism, niche construction theory, and the initial domestication of plants and animals. *Evolutionary Ecology*, 30(2), 307–324.
- Stiner, M. C., & Kuhn, S. L. (2016). Are we missing the “sweet spot” between optimality theory and niche construction theory in archaeology? *Journal of Anthropological Archaeology*, 44, 177–184.
- Tucker, B. (2007). Perception of interannual covariation and strategies for risk reduction among Mikea of adagascar. *Human Nature*, 18(2), 162–180.
- Tucker, B., Huff, A., Tsiazonera, T. J., Hajaso, P., & Nagnisaha, C. (2011). When the wealthy are poor: Poverty explanations and local perspectives in southwestern Madagascar. *American Anthropologist*, 113(2), 291–305.
- Tucker, B., Humber, F., Benbow, S., & Iida, T. (2010). Foraging for development: A comparison of food insecurity. *Production, and Risk among Farmers, Forest Foragers, and Marine Foragers in Southwest Madagascar*, 69(4), 375–386.
- Tucker, B., Tsiazonera, T. J., Hajaso, P., & Nagnisaha, C. (2015). Ecological and cosmological coexistence thinking in a hyper-variable environment: Causal models of economic success and failure among farmers, foragers, and fishermen of southwestern Madagascar. *Frontiers in Psychology*, 6(1533), 1–16.
- Tucker, B. T. (2003). Mikea origins: Relicts or refugees? In Z. Crossland, G. Sodikoff, & W. Griffen (Eds.), *Ann Arbor, Mich* (pp. 193–216). Michigan Discussions in Anthropology.
- Waddington, C. (1968). Towards a theoretical biology. *Nature*, 218, 525–527.
- Waddington, C. (1969). Paradigm for an evolutionary process. *Biological Theory*, 3(3), 258–266.
- Wallach, E. (2016). Niche construction theory as an explanatory framework for human phenomena. *Synthese*, 193(8), 2595–2618.
- Westerman, K., Oleson, K. L. L., & Harris, A. R. (2012). Building socio-ecological resilience to climate change through community-based coastal conservation and development: Experiences in southern Madagascar. *Western Indian Ocean Journal of Marine Science*, 11(1), 87–97.
- Yount, J. W., Tsiazonera, R., & Tucker, B. T. (2001). Constructing Mikea identity: Past or present links to Forest and foraging. *Ethnohistory*, 48(1–2), 257–291.
- Zeder, M. A. (2016). Domestication as a model system for niche construction theory. *Evolutionary Ecology*, 30(2), 325–348.
- Zinke, J., Dullo, W. C., Heiss, G. A., & Eisenhauer, A. (2004). ENSO and Indian Ocean subtropical dipole variability is recorded in a coral record off Southwest Madagascar for the period 1659 to 1995. *Earth and Planetary Science Letters*, 228(1–2), 177–194.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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