Conservation Biology

Review

Historical perspectives on contemporary human–environment dynamics in southeast Africa

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Abstract: *The human communities and ecosystems of island and coastal southeast Africa face significant and linked ecological threats. Socioecological conditions of concern to communities, governments, nongovernmental organizations, and researchers include declining agricultural productivity, deforestation, introductions of non-native flora and fauna, coastal erosion and sedimentation, damage to marine environments, illegal fishing, overfishing, waste pollution, salinization of freshwater supplies, and rising energy demands, among others. Human–environment challenges are connected to longer, often ignored, histories of social and ecological dynamics in the region. We argue that these challenges are more effectively understood and addressed within a longer-term historical ecology framework. We reviewed cases from Madagascar, coastal Kenya, and the Zanzibar Archipelago of fisheries, deforestation, and management of human waste to encourage increased engagement among historical ecologists, conservation scientists, and policy makers. These case studies demonstrate that by widening the types and time depths of data sets we used to investigate and address current socioecological challenges, our interpretations of their causes and strategies for their mitigation varied significantly.*

Keywords: conservation, fisheries, forests, historical ecology, Madagascar, southwest Indian Ocean, waste, Zanzibar

Perspectivas Históricas sobre las Dinámicas Contemporáneas entre Humanos y el Ambiente en el Sureste de África

Resumen: *Las comunidades humanas y los ecosistemas de las costas del sureste africano enfrentan amenazas ecológicas significativas y vinculadas. Las condiciones socio-ecológicas que preocupan a las comunidades, los gobiernos, las organizaciones no gubernamentales y a los investigadores incluyen la poductividad agrícola en declinación, la deforestación, la introducción de flora y fauna no nativa, la sedimentación y erosión costera, el daño hacia los ecosistemas marinos, la pesca ilegal, la sobrepesca, la contaminación por desechos, la salinización de las cuencas de agua dulce, y la creciente demanda de energía, entre otras. Los retos humanos – ecosistema están conectados con historias más largas, y frecuentemente ignoradas, de dinámicas sociales y ecológicas en la región. Argumentamos que estos retos se entienden y se tratan con mayor efectividad dentro de un marco de trabajo de ecología histórica con un periodo más largo. Revisamos casos de pesquerías, deforestación y manejo de desechos humanos en Madagascar, la costa de Kenia y el archipiélago de Zanzíbar para propiciar una mayor participación entre los ecologistas históricos, los científicos de la conservación, y los*

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legisladores. Estos estudios de caso demuestran que al ampliar los tipos y la temporalidad de los conjuntos de datos que usamos para investigar y tratar los retos socio-ecológicos contemporáneos, nuestras interpretaciones de las causas de estos retos y las estrategias para su mitigación variaron significativamente.

Palabras Clave: bosques, conservación, desechos, ecología histórica, Madagascar, pesquerías, suroeste del oceáno Índico, Zanzíbar

Introduction

Our aim was to encourage the use of historical ecology methods in conservation in island and coastal southeast Africa. Through 3 case studies—fisheries, deforestation, and management of human waste—we examined the integration of diverse data at varying spatial and temporal scales, as practiced by historical ecologists, and the implications of different intepretations of contemporary land and seasscapes for conservation policy and outcomes. Historical ecology is based on the assumption that human–environment interaction is a dynamic exchange that results in cumulative signatures (i.e., contemporary landscapes and seascapes) (Balée 2006; Crumley 2017). One of several theoretical toolkits used to understand human–environment interactions (Fitzhugh et al. 2018), historical ecology is applied to investigations of evolutionary processes and historical events as they play out in social–natural systems (Fig. 1). Leveraging multiple methods and data types, historical ecologists have emerged as significant contributors to ecological restoration, conservation, economic development, and environmental justice (Armstrong & Veteto 2015; Armstrong et al. 2017; Morrison et al. 2017).

Though not always referred to explicitly as "historical ecology," research in several African regions has yielded results relevant to conservation and resource management. For example, Fairhead and Leach (1996) demonstrated that the forest islands in the savanna of Guinea are the result of indigenous land management that encouraged the growth of woody species, not remnants in a landscape degraded by human action. They also found that contemporary policies were detrimental because they failed to factor in past practices. A full review of African historical ecology is beyond the scope of this paper, but mainland Africa is not lagging behind in the study of long-term records of human–environment interaction. We focused on southeast Africa's coastal and island areas, which have remained at the margins of global debates on historical ecology (Braje et al. 2017).

We advocate for the application of historical–ecology approaches in coastal and island southeast Africa conservation and economic development for several reasons (Fig. 2). First, contemporary communities face significant threats to their livelihoods, including declining agricultural productivity, deforestation, introductions of non-native flora and fauna, coastal erosion and sedimentation, damage to marine ecosystems, illegal fishing, overfishing, pollution, salinization of freshwater supplies, and rising energy demands.

Second, many historical contexts for contemporary human–environment dynamics in the region are constrained by legacies of colonial politics that established social relations and policies often detrimental to people and ecosystems. This is a result of agendas to dispossess nonelite African citizens of land and the means of production, a sign of governmentality through the application of *terra nullius*. The latter by nature modifies, diminishes, and even erases archives of indigenous or local landscape management to legitimize colonial control of territory and natural resources (Tucker et al. 2010; Herman 2015). In Madagascar, for instance, French naturalists and colonial administrators linked indigenous land use for swidden cultivation to mismanagement of resources as early as the 17th century (de la Bâthie 1921; De Flacourt 2007; Pollini 2010). Swidden farming caused decline of forest cover, but not at the magnitude described by colonial administrators. Customary management practices minimized agricultural expansion over forests, but were disrupted by colonial efforts to seize land and resources, ultimately accelerating deforestation. Declensionist narratives of indigenous land degradation are a formal component of colonial enterprises in Africa and elsewhere (Davis 2007). Colonial legacies thus act as points of rupture that obscure records of human–environment interaction, including indigenous strategies for resource management, food production, sustainability, and resilience. Historical ecology can cut through politically biased narratives by integrating data from multiple time scales and diverse socioecological archives.

Finally, coastal and island southeast Africa are rooted in a complex and ancient Indian Ocean interaction sphere (Kusimba 1999; Alpers 2000; Beaujard 2005; Radimilahy & Crossland 2015). The Indian Ocean is characterized by over 6 millennia of migration and exchange extending from China to Africa's eastern coast. As people, organisms, objects, and ideas intersected and influenced Africa's peoples and environments, so too did African communities influence the Indian Ocean world (Fuller et al. 2011; Haaland 2014; Campbell 2016). Understanding these interactions and how they shaped contemporary landscapes and seascapes requires synthesis of data from—but not limited to—archaeology, paleoecology, written and oral histories, and ethnography.

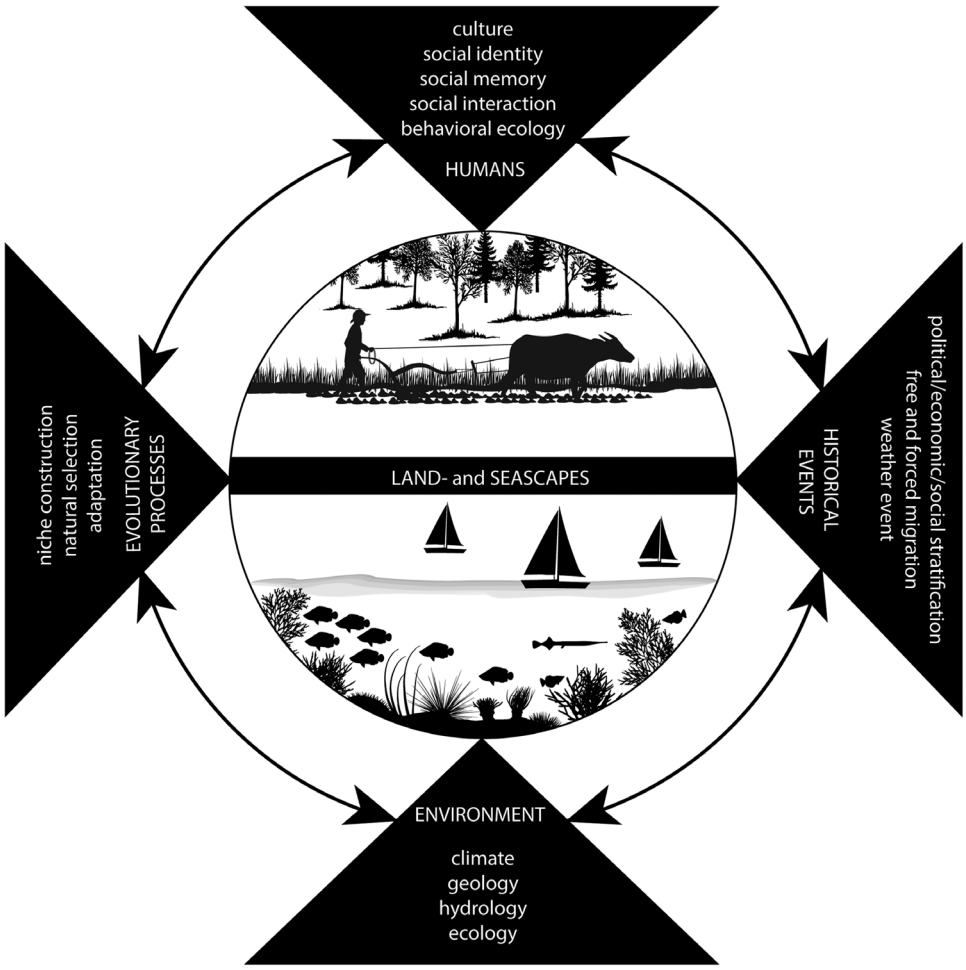

Figure 1. Aspects of 4 key interlinked social and natural forces that shape landscapes and seascapes.

Methods

We focused our review on 3 case studies, fisheries, deforestation, and management of human waste, the themes of which do not represent a comprehensive overview of historical-ecology research. We selected them as examples of socioecological challenges faced by communities in the region, such as food security, resource management, and disposal of human waste. Each case study provides a concrete example of the different intepretations of present-day landscapes and seascapes that are possible when different kinds of data spanning a range of temporal and spatial scales (Fig. 3) are combined. We considered the differences between historical ecologists from anthropological versus ecological backgrounds (Szabó 2015) and focused on sources in archaeology, anthropology, and political ecology because this literature may be less familiar to conservation scientists. Finally, we considered potential conservation outcomes for each case study if a historical-ecology approach were taken. There are currently no established historical-ecology projects in island and coastal southeast Africa.

Emerging Historical-Ecology Research on Coasts and Islands

Given their unique biogeographies and histories of human, plant, and animal introductions, coastal and island landscapes and seascapes can be productively understood through the lens of historical ecology (Erlandson & Rick 2010; Rick et al. 2013; Fitzpatrick et al. 2016). Islands, in particular, are critical for biodiversity conservation (Kueffer & Kinney 2017). The historical ecology of islands is an established field of research in the Pacific (Kirch & Hunt 1997), the California Channel Islands (Rick et al. 2014), the Caribbean (Fitzpatrick & Keegan 2007; Siegel 2018), and the North Atlantic (McGovern et al. 2007). On islands of southeast Africa, however, this approach has only recently been taken to mean human–environment interaction (Crowther et al. 2016; Douglass et al. 2018). Nevertheless, the archaeology of southeast African islands has been influenced by the archaeology of Pacific islands. Specifically, Pacific archaeology has influenced how island colonization and the beginnings of human–environment interaction in oceanic southeast Africa are characterized. Despite diverse island biogeographies in the Pacific, each with its own

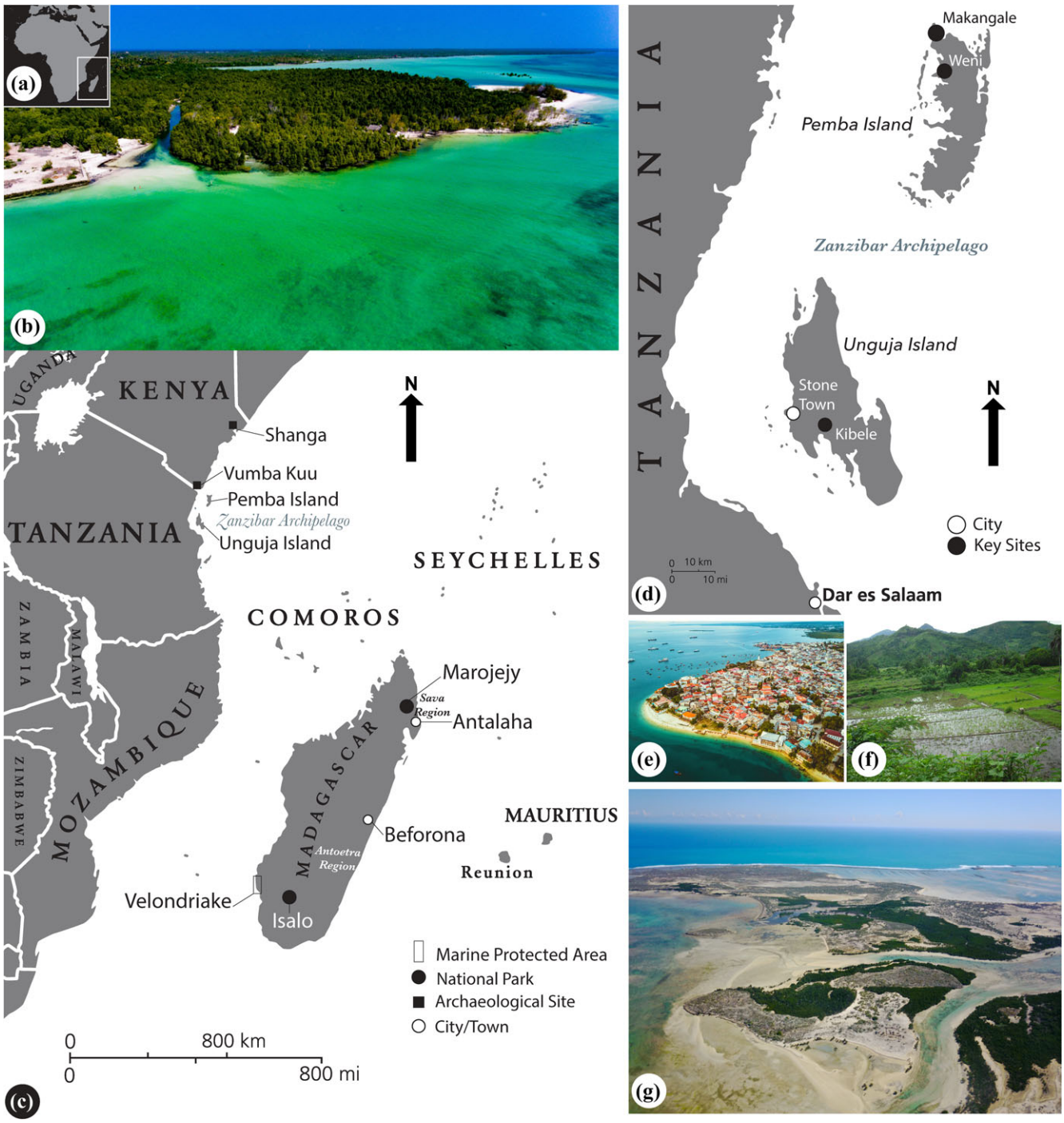

Figure 2. (a) Location of coastal and island southeast African region, (b) mangrove stands in the Zanzibar Archipelago, (c) location of sites discussed in the text in coastal and island southeast Africa, (d) location of sites discussed in the text in coastal and island Tanzania, (e) Stone Town's urban landscape seen from above, Unguja Island, Zanzibar Archipelago, (f) forest conversion for agriculture (rice) bordering Marojejy National Park, Sava Region, Madagascar, and (g) mangrove, fringing reef, sand flats in Velondriake Marine Protected Area, Madagascar.

susceptibilities to anthropogenic impacts (Braje et al. 2017), the vulnerabilities of the islands of remote Oceania to the arrival of people and their commensals in the Late Holocene have encouraged a focus on first arrivals and early settler periods as the most powerful explanatory mechanisms for the impacts of human settlement on southeast African islands. Moreover, given the confluence of human arrivals on islands and biotic extinctions in

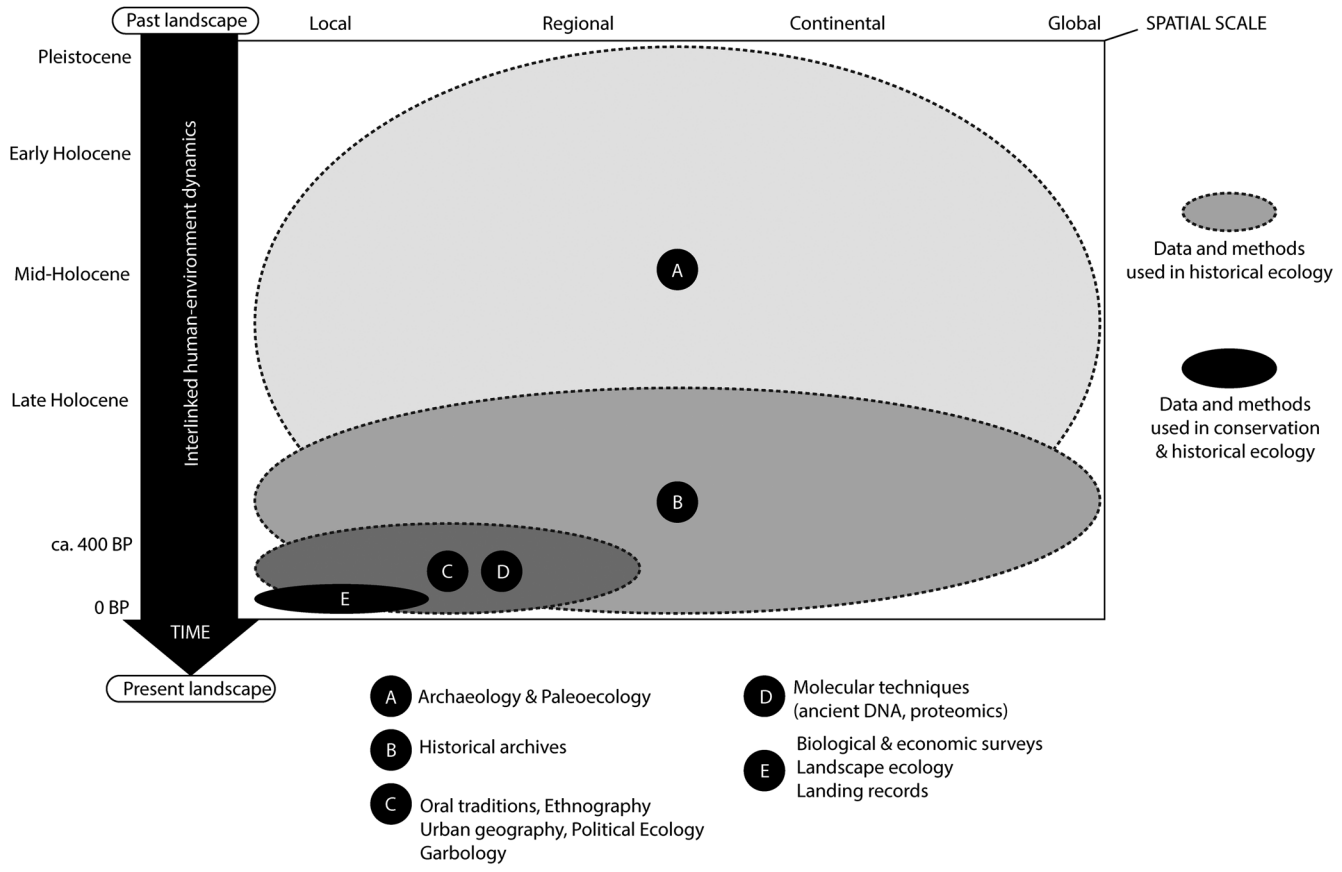

Figure 3. The main types of data and methods used to study interlinked human–environment dynamics at different spatial and temporal scales in the fields of conservation and historical ecology.

the Pacific, the archaeology of southeast African islands has also emphasized extinction in understanding anthropogenic impacts. This is exemplified on Madagascar, the largest and most biogeographically diverse island in the region, where the persistent view is that human arrival precipitated catastrophic changes in the island's environment, including the extinction of megafauna (Douglass & Zinke 2015; Salmona et al. 2017). Other prominent examples include Mauritius and Zanzibar (Rijsdijk et al. 2011; Florens 2013; Prendergast et al. 2016). Diachronic perspectives can nuance understanding of major shifts and disruptions, such as migrations, introductions, and extinctions (Rival 2006).

FISHERIES

In the fisheries case study, we focused on the importance of integrating data sets spanning a long temporal scale (Fig. 4). People have been fishing for millennia across the southwest Indian Ocean (SIO), an area with rich marine biodiversity. Researchers recognize the SIO as a priority region for marine conservation because its concentration of endemic species is threatened by habitat loss and overfishing (Roberts et al. 2002; Stein et al. 2018). Threats to marine biodiversity also threaten people who depend on these resources, through loss of food security and the loss of ecological knowledge, for example (Barnes-Mauthe et al. 2013; Ratsimbazafy et al. 2016). Global estimates fail to capture the extent of small-scale, artisanal fishing (Pauly & Zeller 2016) or the sensitivity of local communities to changes in a fishery (Cinner et al. 2012; Le Manach et al. 2012). Thus, one of the major challenges of SIO fisheries is to understand the impact of fisheries changes on local livelihoods and identities, especially considering the long history of fishing in the region.

Some fishing methods, such as the common use of basket traps along most of the eastern African coastline, are described in historical records dating to as early as the first century CE (Casson 1989). A developing body of archaeological data, based on the excavated remains of discarded marine animals, allows for the identification of exploited species and reconstruction of the long history of fishing practices and environments in the SIO (Quintana Morales & Prendergast 2017; Douglass et al. 2018). A range of scientific approaches can be integrated into a historical-ecology study of archaeological marine fauna remains from the SIO. Researchers studying the archaeology of fisheries in other regions have used carbon and nitrogen stable isotope analysis to characterize past aquatic environments associated with marine taxa, for

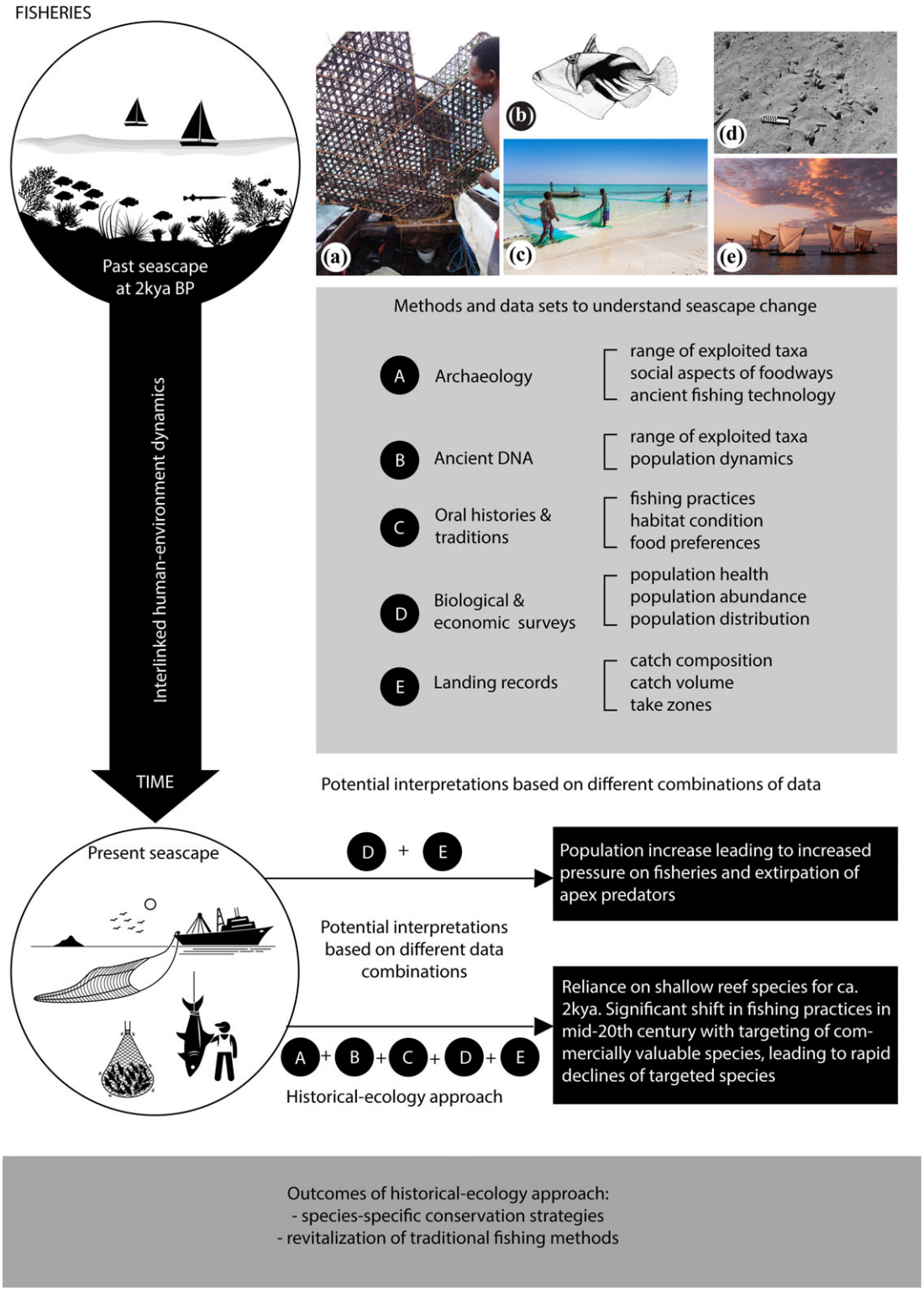

Figure 4. Summary of different data sets and potential interpretations of southwest Indian Ocean fisheries: (a) traditional Swahili basket trap fishing in the southern Kenyan coast; (b) Rhinecanthus aculeatus (Froese & Pauly 2015), a historically exploited macroinvertebrate finfish species in coastal and island southeast Africa that feeds on sea urchins and keeps their populations in check, preventing excessive predation on other species, including corals; (c) Vezo fishers pulling in their nets in Velondriake, Madagascar; (d) archaeological shellfish remains of Terebralia palustris, an estuarine species, Velondriake, Madagascar, and (e) traditional Vezo lakana fishing boats heading out for night fishing.

example, to indicate shifts from nearshore to offshore fishing during the late Holocene in the Beagle Channel (Zangrando et al. 2016). Other molecular techniques, including ancient DNA (aDNA), are developing rapidly. Bulk aDNA sequencing of fish remains has been used successfully in southwestern Madagascar to identify the range of taxa exploited by an ancient fishing community (Grealy et al. 2016). Star et al. (2017) recently used aDNA to trace the extent and impacts of ancient seafood trade across the North and Baltic Sea regions. The study of marine fauna remains can also reveal declines in the abundance of important populations of food fish, such as the Pacific herring (*Clupea pallasii*) on the northwest coast of North America (McKechnie et al. 2014). Other researchers have applied regression formulas to reconstruct exploited fish sizes over time (Jiménez-Cano & Masson 2016), providing important evidence of past fishing methods and human impact on fish populations.

A historical-ecology approach is also emerging from research in coastal Kenya. Researchers are documenting the more recent impact of multigear artisanal fisheries managed through a combination of traditional management systems and, since the 1960s, zone closures or marine protected areas (McClanahan et al. 2016; Chirico et al. 2017). Additionally, detailed analyses of archaeological fish remains are available for 2 sites. Records from Shanga (Mudida & Horton 1996) and Vumba Kuu (Quintana Morales 2013) show that the practice of nearshore and reef fishing in Kenya extends back to at least the 8th century CE (Fig. 2c). Work comparing archaeological data (~750–1400 CE) with current fisheries data (1995–2009) from both fishing closure and nonclosure zones shows that the most drastic changes in species composition occurred after the 15th century and were likely driven by overfishing (McClanahan & Omukoto 2011). More recently, reconstruction of exploited fish species from the 8th century CE to the present indicate the most depleted and vulnerable historically exploited taxa are piscivores and macroinvertivores (Buckley et al. accepted article). Macroinvertivores play key roles in the ecology of the reef by controlling populations of sea urchins, which unchecked can reduce the survival of new coral (O'Leary et al. 2013) (Fig. 4b). A historical-ecology approach can contribute to the development of more targeted conservation strategies by identifying species that are susceptible to local extinction and require protection most urgently, which is particularly important for local communities with limited resources. Species-specific management, such as size restrictions for fishing vulnerable species, may enhance management practices currently focused on zone closures.

A historical-ecology framework is also being applied in southwestern Madagascar's Velondriake Marine Protected Area. This area is home to over thirty communities of fishers, farmer-herders, and foragers who collaborate to sustainably manage natural resources. An environmental monitoring program established in a partnership between local communities and Blue Ventures Conservation has resulted in a decade worth of data on contemporary fisheries (Harris 2007). These efforts present a unique opportunity in coastal Madagascar to build long-term records of human–environment interactions by combining archaeological and contemporary data sets. To date, comparison of archaeological and modern subsistence practices reveals that people have long relied on shallow coral reefs, and there is limited evidence of interaction with open ocean (Douglass et al. 2018). An important finding relevant to conservation efforts in the region is that evidence for the taking of large apex predators, such as sharks, is relatively scant in the archaeological record. Sharks, however, are severely overfished today and many taxa have been locally extirpated (Cripps et al. 2015).

Though rich data are emerging with regard to finfish exploitation, relatively little is known about the contributions of shellfisheries to ancient and contemporary livelihoods in the SIO. Shellfish remains are ubiquitous and abundant on archaeological and modern settlements throughout the region, suggesting their importance to local communities, yet their study has been extremely limited (Douglass 2016; Faulkner et al. 2018). From excavations in Velondriake, it is clear that ancient communities foraged a diverse range of shellfish species—remains of close to thirty different families are documented from sites ranging in date from 500 to 1900 CE (Douglass 2016). No data are currently available for modern shellfishing in Madagascar, making shellfisheries a critical research gap. In addition to their use as food items, shellfish play an important role as raw materials for tools (including fishing tools, such as net weights), crafts, and objects of ritual and trade. Shellfish may also reveal periods of resource stress based on relative proportions of lower return taxa in archaeological assemblages.

Although researchers are only beginning to understand the socioecological impacts of past fisheries in the SIO, available information highlights the importance of fishing for ancient communities. Modern fisheries data in the region suggest a trend of "fishing down the food web" (Pauly et al. 1998; Grealy et al. 2016). When combined, archaeological and modern data indicate a rapid shift in fishing practices in the mid- to late 20th century that resulted in a precipitous decline in keystone species central to reef health, as opposed to a long-term and more gradual process of intensive exploitation. The results of these historical-ecology studies are preliminary. Furthermore, gaps in both modern and ancient data sets, particularly with regard to seagrass beds, mangrove stands, and taxonomic groups other than finfish, preclude a comprehensive picture of socioecological interactions (Partelow et al. 2018). These results do, however, begin to shed

light on historic baselines and the rapid rate of fisheries declines in the 20th century.

FORESTS

In the forest case study, we examined integration of data on state-level political dynamics based on long-term environmental records (Fig. 5) to identify the impacts of historical changes in land management strategies on deforestation. Malagasy ecosystems were changing before the earliest recorded human presence in the Early to Mid–Holocene (Dewar et al. 2013; Hansford et al. 2018) and have continued to change since. The island experienced 6 cycles of cooling and warming during the last 150,000 years that caused major ecological transformations. A paleorecord from Lake Tritrivakely (15 km from Antsirabe) shows a progressive shift in the highlands from heathland to grassland and then to grassland-forest mosaic during this period (Gasse & Van Campo 2001). Madagascar began to warm after the last glacial maximum 18,000 years ago and grassland ecosystems spread over the island, well before the arrival of humans (Bond et al. 2008). During the last 6,000 years, ecosystems shifted several times from coastal forest to woodland and grassland in the southwest (Virah-Sawmy et al. 2010).

The first known villages of farmers appeared around 700 CE (Wright and Fanony 1992). Between these first villages and the arrival of Europeans around 1500 CE, the "full spectrum of human-linked agents of environmental change was introduced: cattle, goats, rats, swidden agriculture, and densely populated settlements" (Dewar 2014) (Fig. 5c). There is evidence that humans created urban centers, such as the northwest stone town of Mahilaka, that caused significant deforestation in their surroundings as early as the 11th or 12th century CE (Radimilahy 1998; Burns et al. 2016).

After 1500 CE, large irrigated rice fields were established northeast of Antananarivo and coastal settlement advanced inland, furthering the anthropization of Malagasy landscapes. During the 18th century, the Merina Kingdom in the highlands rose to prominence, creating a central state ultimately encompassing most of the island (Wright 2007). King Andrianampoinimerina (1745–1810 CE) promoted deforestation by encouraging farming on hilltops. Forest clearing was also practiced to open cattle pens on trails used to transport cattle to ports for export (Campbell 2013). During the 19th century, the Merina and British kingdoms formed powerful ties, helping drive Malagasy industrialization (Randrianja & Ellis 2009). By 1870 Antananarivo was a large military and trading center with 100,000 inhabitants. Elites built large wooden houses and palaces, and hilltops were scavenged for firewood. With Western technology, leather, iron, and textile industries grew to support military needs and drove forest exploitation for charcoal production (Campbell 2013).

Forest clearing accelerated after Madagascar became a French protectorate. Governor Joseph Gallieni allotted 900,000 ha to French settlers and newly chartered companies (Randrianja & Ellis 2009). He steered agricultural production toward coffee, rice, and beef (Jarosz 1993). Forest cover was converted (Dufils 2004) through swidden farming and extensive logging, and land grabbing and population displacements occurred to make way for colonial plantations (Jarosz 1993) and successive commodity booms (Scales 2011).

The arrival of the first Europeans after 1500 CE triggered the first conservation efforts in the Western sense. In the 17th century, Governor Étienne de Flacourt viewed swidden cultivation as an uneconomical use of land (Jarosz 1993; De Flacourt 2007) and promoted policies to change land-tenure and cultivation systems. In 1896, the French colonial government began creating regulations for forest conservation for the purpose of commercial logging (Sodikoff 2012). In 1927, the colonial administration designated 6 protected areas, and 19 additional protected areas were established before Malagasy independence. These policies concentrated conservation efforts at specific sites while creating massive devastation of arable lands through intensified use. Forests and land management became associated with colonial power and control. Being dispossessed of their land and traditional resource management institutions, local communities entered into competition to access land where it remained available (i.e., in the forest) and cleared it (Jarosz 1993; Bertrand & Sourdat 1998).

Deforestation persisted after independence, driven by land and resource grabs, poor policies, agricultural expansion, commodity booms, and population growth. It is in this setting that the government of Madagascar partnered with international donors and international NGOs in 1986 to develop a twelve-year environmental plan (World Bank 1988). Yet, even after 2 decades of policy reforms and hundreds of millions of dollars in conservation and sustainable development projects, deforestation in Madagascar continues unabated today (Vieilledent et al. 2018). Under the influence of empowered foreign NGOs that set the agenda for conservation and forest management (Corson 2016) and in a context of weak civil society and growing political power among corrupted elites, conservation policy has remained narrow in focus. Despite apparent changes in discourse, the logic of so-called fortress conservation remains the dominant paradigm in practice, furthering a now centuries-old power relationship in which forest management is a tool for top-down landscape engineering and community control. The nexus of power between government and foreign actors has marginalized local communities and undermined effective forest governance, and the collapsing Malagasy state and its shadow networks play a substantive role in forest degradation (Anonymous 2018). Resource extraction in Madagascar is tied to a logic of predation

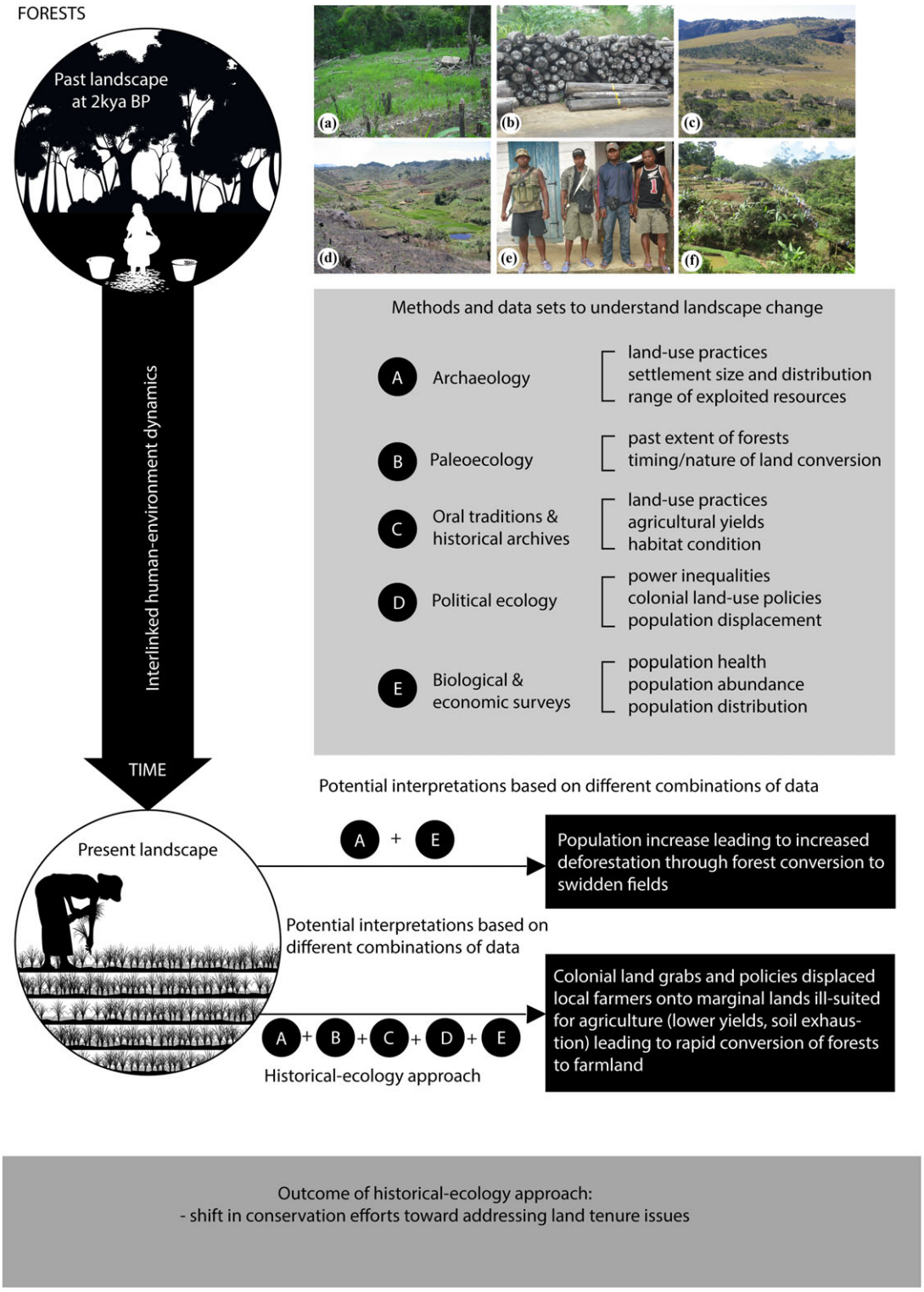

Figure 5. Summary of different data sets and potential interpretations of southwestern Indian Ocean forest management: (a) Swidden field, Marojejy National Park, Sava Region, Madagascar; (b) Rosewood stockpile, Antalaha, Sava Region, Madagascar; (c) Tapia forest in Isalo National Park, Madagascar (unclear if outcome of natural or anthropogenic fire regimes, degraded forest remnant, or natural ecosystem); (d) landscape transformation in the Antoetra Region, Madagascar (hillsides cleared for swidden farming); (e) illicit forestry task force (circa 2010) tasked with protecting forested areas, Sava Region, Madagascar; and (f) U.S. Agency for International Development model farm in Beforona, Madagascar.

(Fig. 5b) by which leaders are scaffolded in power by economic networks deeply rooted in the private sector (Marcus 2016), as well as to customary practices (swidden farming) that are legitimate and essential to sustaining the livelihood of a significant fraction of the population. No realistic alternatives to these land uses have been formulated (Pollini 2007, 2011).

This historical perspective on forests shows that the Malagasy environment has been in a constant state of change, and that one cannot always distinguish between anthropogenic and nonanthropogenic drivers of change. It also shows that human-induced changes are qualitatively different in 2 ways. First, they are oriented by choices and aims (sustaining livelihood) that cause ecosystem changes for the purpose of producing food and commodities and constructing new landscapes. Second, anthropogenic changes are magnified by desires and power, as exemplified by rosewood (*Dalbergia spp.*) logging by corrupted elites (Fig. 5b). In the Anthropocene (an era when environmental changes are the outcome of human choices), the magnitude of changes depends on the labor available (population density), the efficiency of tools (manual, animal powered, fuel powered), and the distribution of power within and between societies.

To improve conservation outcomes for Madagascar's forests, policy makers must address economic issues and the unequal distribution of power, along with its historical underpinnings. These issues, more than a supposed lack of technology or excessive population growth, may explain the persistence of forest degradation in Madagascar today.

MANAGEMENT OF HUMAN WASTE

In the final case study, we examined individual and household-level social dynamics to inform understanding of consumption and discard practices that can lead to public health and environmental crises (Fig. 6). Factors that make waste a critical issue in southeast coastal and island Africa include expanding populations, resource stress, demands of tourism, vulnerabilities of impoverished people and unique ecosystems, shallow surface soils, and near-surface freshwater tables (Kueffer & Kinney 2017). With increasing amounts of human excrement, plastic debris, and toxic materials, waste is a core threat to people and coastal environments. Inadequate management leads to negative impacts that cascade into the ocean and impact livelihoods (Walley 2004). An archaeological and contemporary study of waste—"garbology" (Rathje & Murphy 2001)—reveals the underpinnings and historical ecology of sanitation, public health, and global connections on Unguja Island, Zanzibar (Figs. 2d & 6). Organic and inorganic waste has influenced coastal settlement patterns and urban design since antiquity because locations of waste disposal and management relate to factors as diverse as wind direction and social class (Smith et al. 2016; Kukkonen et al. 2018).

Since the middle nineteenth century, Stone Town on Unguja Island has been caricatured as filthy (Fig. 6c). Service provisions for municipal waste were minimal and skewed toward the city's elite. Urban planning schemes used waste to solidify race and class categories that separated urban Stone Town from the outlying Ng'ambo neighborhood (Bissell 2010). For more than half a century (until the 1950s), excrement, dead bodies, and other solid and liquid waste formed a barrier in the creek between Stone Town and Ng'ambo. The sanitary policies (or lack thereof) that framed urban planning enabled colonial officials to segregate people—Europeans, Asians, and Africans—into different quarters and to treat them unequally (Bissell 2010:177–182, 246). Comprehensive sanitation plans for health purposes were not enacted during the colonial period (up to 1963 at independence).

Waste management in the West A and West B districts—the suburban zones in Zanzibar, where over half of the population resides—is of great concern, given its environmental and human vulnerability (Mohammed 2002; Myers 2014). There is little to no government capacity for urban service provisioning in these districts, which house overflowing informal landfills. The recent passage of a law making plastic bags illegal has improved the overall look of the city in relation to solid waste, but other plastic items have begun to fill that void (Vuai 2009). One such item is disposable diapers bleached with dioxin, a carcinogen and persistent organic pollutant.

Disposable diapers carry the mystique of cleanliness for the Swahili people of coastal and island East Africa. But in Zanzibar, disposable diapers present a public health threat to babies and to the archipelago's ecosystems (Ame et al. 2016; Leaska 2016). Disposable diapers were introduced to Zanzibar from Thailand, China, and Abu Dhabi in the early 1990s. They have boomed in use since 2005. Many popular brands (e.g., Pampers) are from U.S. companies and are distributed through global affiliates. According to the Tanzania Revenue Authority, 10s of 1000s of disposable diapers—comprised of cellulose pulp, polypropylene, polystyrene, adhesives, and dioxin—are imported every year (Ame et al. 2016). Disposable diapers now predominate in urban homes over traditional cloth diapers. They constitute at least 10% of inorganic solid waste at Kibele Landfill (Fig. 6b), the island's only official dump (Vuai 2009). Kibele is located at the edge of the urban municipality by Jozani-Chwaka Bay National Park (Fig. 2d).

The government housing units along Karume Road are bordered by small piles of used disposable diapers. Residents in town say these piles let people "know who I am" when they "see my trash outside each morning. My diapers are Pampers and so are my neighbors" (Leaska 2016).

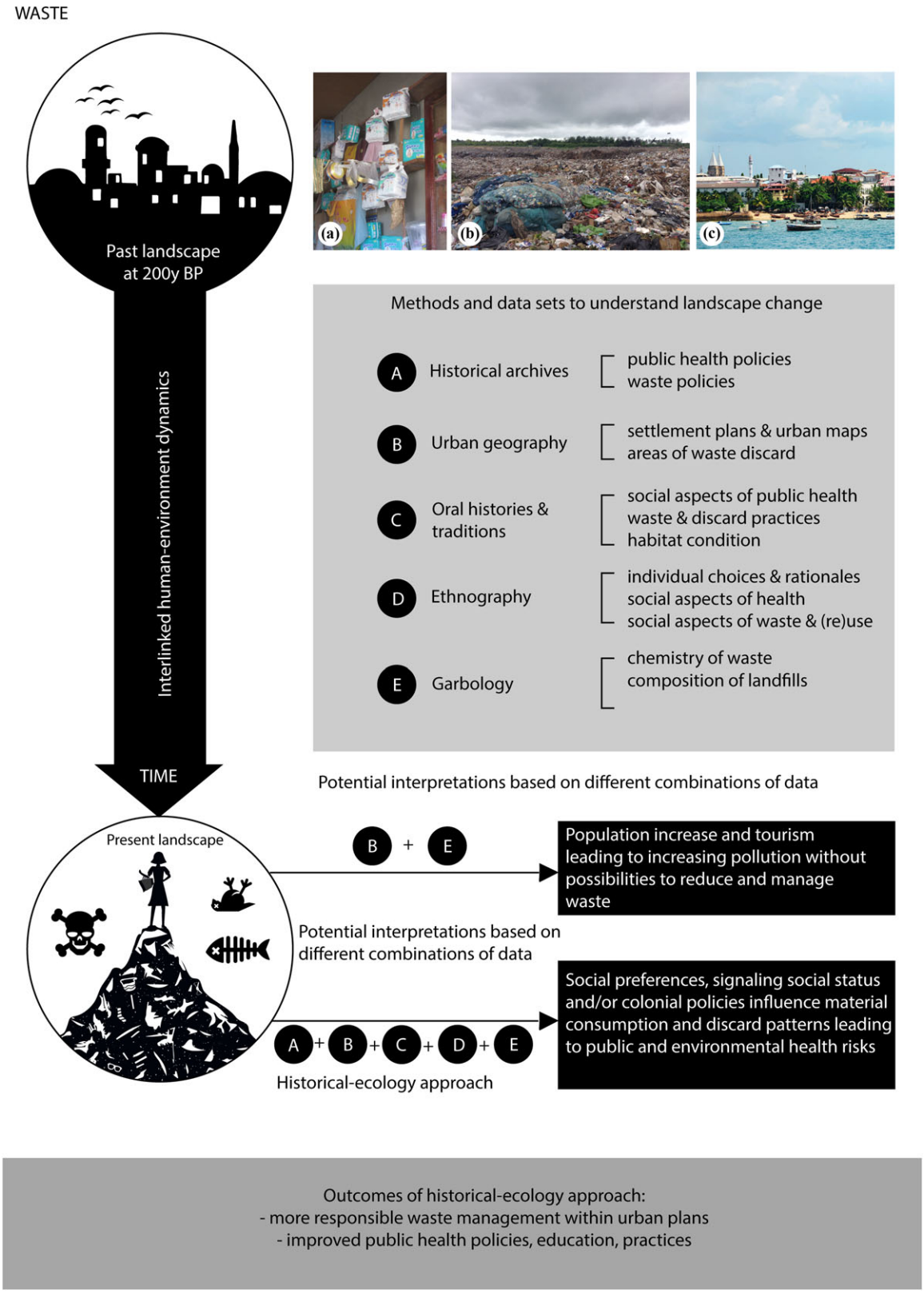

Figure 6. Summary of different data sets and potential interpretations of southwest Indian Ocean waste management: (a) disposable diapers on sale in a shop in Stone Town, Unguja Island, Zanzibar Archipelago, (b) disposable diapers and other solid waste in the Kibele Landfill, Unguja Island, Zanzibar Archipelago (photo by R. Heumann), and (c) view of Stone Town from the water, Unguja Island, Zanzibar Archipelago.

The propensity since antiquity for wealthy Swahili to display items externally to raise their social status (Meier 2016) is manifested in their disposal and use of these diapers. Infants are more frequently clothed in disposable diapers when in public. Poorer urban and rural residents attempt to live up to such expectations by buying disposable diapers one at a time and washing used disposable diapers, a practice that releases toxins when chemicals in the diaper mix with water and detergent.

On Unguja landfills and the Department of Environment have circuitous pasts that intersect (Majamba 2012). The first landfill was established at Saateni in the 1920s. In the 1980s, one was established at Jumbi, and then by 2002 one had been established at Kibele. Kibele Landfill lacks a liner to prevent the leaching of toxins into the soil and water table. Although discouraged, burning is a principal method of eliminating waste, which releases dioxin from diapers. The Zanzibar Municipal Council, in control of solid waste, and the Zanzibar Water Authority, in control of liquid waste, continue to debate the place of diapers as defined by either their material form or the liquid nature of their organic contents. Thus, diapers remain administratively unclaimed. This type of indecision was associated with the lack of waste management in the colonial era.

Waste practices, coupled with the desire for external association, drive a health threat in Zanzibar and elsewhere in the SIO. Nongovernmental organizations cannot address the problem of diapers without understanding unique environmental, historical, and social factors. Garbology and the integration of underlying histories of waste and the performances of well-meaning mothers provide historical-ecology data. Garbology also reveals opportunities to better care for waste and reduce its effects and to enhance environmental and public health by identifying problems and solutions that may not be apparent through more standard approaches to waste. The Kibele Landfill would be an excellent study site for a systematic excavation and analysis of waste disposal practices in Zanzibar. Such a project would provide opportunities to address rather than conceal the environmental and public health threats of hazardous waste. It would also present options to mitigate solid waste outcomes by indicating what components in the landfill could be targeted for recycling, repurposing, composting, and alternative energy strategies, like biogas from organic waste or solid inorganic waste used as fuel (Colon et al. 2010; Espinosa-Valdemar et al. 2014).

Conclusion

Communities of coastal and island southeast Africa face urgent challenges. We examined research in coastal and island southeast Africa that contributes historical-ecology data to demonstrate, as others have on the East African mainland (Marchant et al. 2018), that historical-ecology approaches offer critical information for effective conservation and sustainability. In the absence of more integrated, deeper time, and multiscalar perspectives, conservation scientists, development experts, and policy makers risk promoting strategies based on incomplete or biased data, particularly for periods that extend beyond African independence and the European colonial era. We recognize, however, that a historical-ecology approach poses challenges in its implementation. Among these are differences in the resolution of data sets at different temporal and spatial scales collected following protocols from multiple disciplines (Wolverton et al. 2016). Negotiating these challenges requires the establishment of collaborations between social and conservation scientists, governments, and local communities at early stages of research that are sustained up to the joint interpretation of results.

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