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Human migration and marine protected areas: insights from Vezo fishers in Madagascar

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Abstract

Human migration may negatively impact biodiversity and is expected to increase in future, yet the phenomenon remains poorly understood by conservation managers. We conducted a mixed-methods investigation of a contemporary migration of traditional fishers in western Madagascar, a country which has been expanding its protected area system through the establishment of both strict and multiple-use sites, and critically evaluate different models of marine protected area in light of our findings. Interviews with fishers in major destination areas revealed that most migrants come from southwest Madagascar, use non-motorised vessels, and principally target sharks and sea cucumbers. Drivers of the migration include both push and pull factors (i.e. declining resource availability in areas of origin and the continued availability of lucrative resources for export to China). Traditional fisher migrants cause limited social conflict with residents and a number of environmental problems in destination areas: however artisanal fishers with motorised vessels probably represent a greater threat to marine resources than migrants, due to their greater harvesting capacity. We suggest that multiple-use arrangements may be more appropriate than strict protected areas in both source and destination areas, because they integrate the interests of migrants rather than marginalising them: however seascape-scale management provides the best approach for managing the threats and opportunities provided by the migration at the appropriate scale.

Keywords: Community-based Natural Resource Management; Customary institutions; Locally Managed Marine Areas (LMMA); Population-environment relationship; Small-scale fisheries; Trade

1. INTRODUCTION

The movement of people across the planet has been a defining characteristic of human history and tends to have major environmental impacts. Indeed human migrations, coupled with climate change and other factors, have triggered substantial environmental change on all inhabited landmasses over the last 50,000 years, including extensive ecosystem conversion and the extinction of both continental and insular faunas (Cincotta and Engelman, 2000; Kirch, 2002). Migration may be characterised along both the temporal and spatial dimensions. In temporal terms, it may take the form of permanent changes of residence from one location to another, or temporary mobility such as seasonal, circular movements (Bell and Ward, 2000; Chapman and Prothero, 1983; Rothman et al., 1977). Research on the spatial aspects of modern migrations has concentrated principally on international and rural-urban migration (Boyle et al., 1998; Carr, 2009), but in fact the scale of rural-rural movements may exceed these in many tropical developing countries (Bilsborrow, 2002). The dispersed and variable nature of rural-rural migration makes it difficult to research, however, and as a result we know little about its determinants (including pull factors in destination sites and push factors in areas of origin), or its cultural, social and environmental impacts in source and destination areas (Curran and Agardy, 2002). Such knowledge is essential to underpin the development of evidence-based conservation strategies (St. John et al., 2013), yet our understanding of how to reduce, manage and mitigate the impacts of human migration on biodiversity remains poorly developed (Oglethorpe et al., 2007).

Understanding rural-rural migration and its impacts is important for conservationists since it can be expected to negatively impact remaining areas of high biodiversity, such as forests and shallow coastal seas. This is because such areas represent resource frontiers harbouring

concentrations of little- or unexploited natural resources, and there are often few legal, social or technical barriers to their utilisation (Carr, 2009; Sunderlin et al., 2005): they thus become attractive destination areas for the poor and displaced. Once established, the presence of migrants may encourage the arrival of others, such as family members or members of social networks, thus reinforcing the movement in a positive feedback loop (Palloni et al., 2001). Migration to resource frontiers is likely to increase in future, as a result of multiple interacting factors including population growth, climate change, environmental degradation, globalised trade, emerging diseases, growing wealth inequalities, resource scarcity and armed conflict, which may negatively affect economic or social conditions in populated rural areas and push residents to seek a better life elsewhere (Oglethorpe et al., 2007). In addition, conservation activities may themselves trigger migration, either attracting people to protected area boundaries through a 'honeypot' effect (Wittemeyer et al., 2008, though see Joppa, 2012), or displacing communities through eviction or the imposition of access restrictions (West et al., 2006; Ewers and Rodrigues, 2008; Mascia and Claus, 2008).

Migration may also pose a particular challenge for conservation managers. It is widely thought that migrants may be 'exceptional resource degraders' whose land and resource use practices in destination areas have greater environmental impacts than those of residents (Jacobsen, 1994; Cassels et al., 2005; Codjoe and Bilsborrow, 2012). This may arise because their poverty and tenure insecurity cause them to have short time horizons, where future benefits are heavily discounted against short term gains (Ostrom et al., 1999; Codjoe, 2006) or because, lacking social ties to, and knowledge of, their settling areas, they value resources and landscapes differently to residents and thus have less incentive to manage them sustainably (Begossi et al., 2002; Codjoe and Bilsborrow, 2012). In addition, migrants may

exploit resources more destructively as a result of the harvesting methods and technologies they employ (Bremner and Perez, 2002; Williams, 2002; Perz, 2003), or because they do not respect the social norms and customary institutions that regulate access to common pool resources amongst resident populations in their destination areas (Jodha, 1998; Curran, 2002; Sandy, 2006). The latter is a particular concern since the breakdown of these institutions can cause residents to stop regulating access to resources or join the race to exploit them, thus turning common property systems into open access ones and precipitating a 'tragedy of the commons' (Ostrom et al., 1999; Katz, 2000; Curran and Agardy, 2002). On the other hand, people may migrate as part of an adaptive resource management strategy to prevent overexploitation in their areas of residence, and this may not only reduce their environmental impacts but also lead to conservation opportunities through the temporary or permanent reduction of pressure on natural resources in their areas of origin (Andersen et al., 2014; Arunotai, 2006; Klooster, 2012; Koocheki and Gliessman, 2005; Sabogal, 2012).

Despite the importance (and indeed probable ubiquity) of migration as an underlying contributor to resource use patterns in frontiers and other high biodiversity areas, the phenomenon is rarely discussed in the conservation literature and there are few guidelines for managers on how to influence and mitigate human movements in the places they work (Oglethorpe et al., 2007). This applies in particular to the management of protected areas, our principal tool for the conservation of global biodiversity, which now cover over 15% of global land area and 3.4% of the oceans (Juffe-Bignoli et al., 2014). Protected areas are complex social-ecological systems (Ostrom, 2009; Milner-Gulland, 2012) in which extractive natural resource use is forbidden or tightly regulated. As such, migration from or (in particular) to them will alter patterns of local resource use and thus require a management

response (such as surveillance, enforcement or mitigation), and may also influence governance processes by disrupting local social dynamics. Since protected areas tend to be managed as static rather than dynamic institutions (Bengtsson et al., 2003; Folke et al., 2005), this greatly increases management complexity. Protected areas include an array of models and approaches from 'strict' sites in which extractive uses of biodiversity are not permitted, to 'multiple-use' categories in which sustainable natural resource use is central to management aims (Dudley, 2008). Regardless of category, all protected areas must be effectively managed (CBD, 2010), but this will depend in part on understanding and adapting to the social dynamics that influence them (Geoghegan and Renard, 2002; Gardner et al., 2015).

The development of management guidelines and appropriate policy for protected areas will depend, in large part, on the publication of in-depth, empirical case studies from a range of cultural and environmental contexts (Oglethorpe et al., 2007). Here we present the results of a mixed-methods investigation into the characteristics, drivers and impacts of a rapidly-evolving traditional fisher migration in coastal western Madagascar, and critically evaluate existing models of marine protected area in the region in light of our findings. Since 2003 Madagascar has been in the process of tripling the coverage of its protected area system (SAPM) through the development of two parallel sub-networks employing fundamentally different approaches to protected area management and governance: while the existing network of centrally-governed, strict protected areas (IUCN categories I, II and IV) is being expanded by its para-statal managers Madagascar National Parks (MNP) through the creation of several new parks and the expansion of existing ones, a raft of new protected areas is also being created. The latter areas are primarily established by non-governmental organisations

(NGOs), designed as multiple-use sites (IUCN categories V and VI), and are administered by shared-governance structures integrating local resource users (Gardner, 2011; Virah-Sawmy et al., 2014). The objectives of the expanded protected area system include the conservation of biodiversity, the maintenance of Madagascar's cultural diversity and the sustainable use of natural resources for poverty alleviation and development (Gardner et al., 2013). An evaluation of the appropriateness of different protected area models in managing fisher migrations is particularly pertinent given that the Malagasy government committed in 2014 to tripling marine protected area coverage (Rajaonarimampianina, 2014). Given that many anticipated new marine protected areas will likely be located in western Madagascar where marine conservation priorities lie (Allnutt et al., 2012) and will thus be influenced by the activities of Vezo fishers, we discuss the strengths and weaknesses of existing protected area models in managing fisher migrations towards the multiple objectives of biodiversity conservation and improved human wellbeing. Our specific objectives are to: i) characterise the principal fisher migrations of western Madagascar in terms of origins and destinations; ii) identify the origins and livelihood activities of migrants in principal destination areas; and iii) use our findings to critically evaluate the appropriateness and potential effectiveness of new protected area models employed in areas experiencing fisher migrations. We also investigate conflicts between residents and migrants in so far as they impact on resource management.

2. MATERIALS AND METHODS

2.1 Study system

The coastal and shallow marine areas of western Madagascar (defined here as the region between Androka in the south and Maintirano in the north) form part of the Southern Mozambique Channel Marine Ecoregion (Obura, 2012). The region is characterised by

extensive coral reefs, notably fringing and barrier reefs in the south-west region (Androka to Morombe), and an ancient submerged reef manifested as a string of banks, shoals and small islets running parallel to the coast north to Maintirano. These habitats support a number of species of global conservation concern including cetaceans, sea birds, sea turtles (five species), sawfish, sharks and the coelacanth (*Latimeria chalumnae*) (Cooke et al., 2003). Conservation priority areas are centred on two island groups: i) the 'Belo-sur-Mer Islands', a group of seven islets off Belo-sur-Mer and Andranompasy, of which three are inhabited and the remainder comprise sand cays submerged during spring tides; and ii) the Barren Isles, an archipelago of 12 islands 15-65 km offshore from Maintirano, of which seven are vegetated and the remainder are sub-tidal sand cays (Fig. 1, Table S1). The Barren Isles, in particular, contain some of the healthiest and most resilient reefs in Madagascar (Cripps, 2010; Allnutt et al., 2012).

The region's marine and coastal ecosystems hold immense economic and cultural value to the Vezo, a traditionally semi-nomadic seafaring people who originate from south-western Madagascar between Toliara and Morombe (Marikandia, 2001). The Vezo lifestyle is based on earning a living from the sea, and the Vezo identity itself is performative rather than ethnic – one is not born Vezo, but becomes Vezo by learning to master the sea and deriving a livelihood from it (Koechlin, 1975; Astuti, 1995a,b). As such Vezo communities are composed of individuals of diverse ancestry, the descendents of both fishers and agro-pastoral peoples including Mahafaly, Tanalana, Tandroy, Masikoro, Bara and Sakalava (Pascal, 2008). Despite this diversity of origins certain 'pure Vezo', who see themselves as descendants of Vezo lineages, share a number of traditions including a taboo on mutton and a founding myth involving a mermaid, Ampelamananisa (Marikandia, 2001). The Sara are

198 fishers who occupy the same coast as the Vezo, with whom they are often grouped. However
199 they differ in several cultural aspects (Marikandia, 2001; Pascal, 2008). The centre of Sara
200 origins is the area around the mouth of the Onilahy River, and in particular the village of
201 Anakao. Sara people self identify as Vezo, since they are fishers, but primarily as Sara.
202
203 Widely referred to as semi-nomadic due to their propensity to migrate along the coast in
204 response to resource scarcity or to take advantage of seasonal resource availability elsewhere
205 (Koechlin, 1975; Rejela, 1993), Vezo livelihoods are characterised by their flexibility and
206 mobility. Fishers target a wide range of marine species (Barnes-Mauthe, et al. 2013),
207 including fin-fish (Laroche and Ramananarivo, 1995), invertebrates (Barnes and Rawlinson,
208 2009), marine turtles (Lilette, 2006; Humber et al., 2011) and some marine mammals (Cooke
209 et al., 2003). Although some trade has existed since the early 20th Century, the Vezo economy
210 was primarily subsistence-based until the 1970s, with fin-fish caught for consumption and
211 bartered for starch (maize, manioc or wild yams, *Dioscorea* spp.) with agro-pastoralist tribes
212 inland (Astuti, 1995a; Iida, 2005; Langley, 2006; Grenier, 2013). However, the growth of
213 export markets for products such as gastropod shells, lobster, octopus and sea cucumber
214 triggered a transition from subsistence to a market economy based on species not traditionally
215 targeted (Iida, 2005; Muttenzer, 2013; Grenier, 2013). In particular, the demand for sea
216 cucumber (class Holothuroidea, sold as trepang or bêche-de-mer) and shark fin for export to
217 China has grown immensely since the early 1990s, and these have become the most lucrative
218 fisheries products along the length of the coast (Rasolofonirina and Conand, 1998; McVean
219 et al., 2005, 2006; Cripps et al., 2015). In addition to traditional fishers (defined in Malagasy
220 legislation as using non-motorised vessels), the region's waters are fished by artisanal fishers
221 using SCUBA gear and motorised boats (< 50 hp) (though sometimes using old industrial

222 trawlers as mother ships to operate from) from the major port cities of western Madagascar
223 (Rasolofonirina et al., 2004; Andrianaivojaona, 2012), and industrial fleets from Asia and
224 Europe that may operate legally or illegally (Le Manach et al., 2012).
225
226 Although Vezo fishers frequently state that '*riake tsy mana tompo*' (the sea has no owner)
227 and thus that nobody can restrict the free movement of fishers on the sea, access to marine
228 resources may be regulated through customary institutions such as *faly* ('taboo/forbidden',
229 *fady* in official Malagasy) and informal reef tenure (Pascal, 2008; Muttenzer, 2013). *Faly*
230 tend not to be universal but are held by particular groups or lineages, and are respected
231 through fear of misfortune or ancestral retribution (Astuti, 1995a; Jones et al., 2008;
232 Westerman and Gardner, 2013). These informal institutions exist alongside formal resource
233 management mechanisms including national fisheries legislation and, increasingly, marine
234 protected areas. Three major marine protected areas (Velondriake, Barren Isles and Kirindy-
235 Mite Marine National Park) have been established over the last decade, as well as numerous
236 smaller locally managed marine areas (LMMAs) not included within SAPM (Fig. 1, Harris,
237 2011). Velondriake is an LMMA (IUCN category VI) legally established in 2009 that covers
238 over 600 km^2. It unites 24 villages in Befandefa Commune in a shared governance system
239 supported by the NGO Blue Ventures. The Barren Isles is an LMMA covering approximately
240 3400 km^2, administered through a shared governance system including traditional fishers,
241 Blue Ventures, and the regional government agencies responsible for fisheries and the
242 environment. Both LMMAs comprise a number of temporary and permanent no-take zones
243 enclosed within a larger envelope in which traditional resource harvesting is permitted
244 subject to gear-based restrictions. The Belo-sur-Mer Islands are included in the marine
245 extension of Kirindy-Mite National Park, an IUCN Category II national park with an area of

173 km^2 legally created in 2010. It is managed by MNP with local communities playing a limited role in shared governance structures. Thus Kirindy-Mite Marine National Park is managed as a strict protected area, while the Barren Isles and Velondriake LMMAs can be classified as multiple-use protected areas.

[FIGURE 1]

2.2 Data collection

We used a mixed-methods approach to generate qualitative and quantitative insights into the Vezo migration, including participant observation, semi-structured interviews of a range of key informants in source and destination areas, and quantitative surveying of migrant leaders in major destinations. During March 2009 the first author (GC) conducted interviews in most of the principal villages of Befandefa Commune known to be a source of migrants. Subsequently, from early April to mid May 2009, GC travelled the principal migration route from Andavadoaka to Maintirano with Vezo fishers from Befandefa Commune (Fig. 1). Two Vezo experienced in translating and carrying out socioeconomic surveys served as guides and translators throughout the expedition. In the Commune of Befandefa and over the course of the voyage to Maintirano, GC made landings at 29 locations (islands and mainland villages, Table S2); these were not randomly selected but based on known source and destination areas for migrants on the principal route from Befandefa Commune to Maintirano. Not all destination and migrant camps were surveyed and sampling was focused principally on destinations identified by migrants from Befandefa Commune: the Belo-sur-Mer Islands, certain mainland villages and the Barren Isles.

At each site GC presented himself to the *Chef de Fokontany* (= village head, in established villages) or migrant leaders (in migrant camps), explained the purpose of the research, and asked for suitable survey respondents to be suggested: the sampling of respondents was therefore purposive (snowball sampling) rather than random, in order to ensure sufficient representation of key stakeholder groups. Semi-structured interviews were carried out with 59 key informants, of whom 81% were fishermen, 10% were shark or sea cucumber traders and 34% held a position of leadership within their community: 32% of informants were resident in the interview location and 68% self-identified as migrants (Table S2). Each interview took place in a location chosen by the informant and was carried out in the Vezo dialect. Interviews focused on four themes (general migration characteristics, migration chronology, push and pull factors and migrant-resident conflicts), and employed participatory mapping and timeline exercises to aid dialogue. In some cases time constraints prevented all themes being discussed, while in others interviews were carried out over two or more days to avoid respondent fatigue. Data were subsequently analysed using categorised content analysis.

GC also conducted a brief questionnaire survey of the heads of 100% of migrant groups (n = 56) in 10 key migrant destinations in the Belo-sur-Mer islands (3 islands), the Barren Isles (4 islands) and on the mainland (4 villages). The questionnaire focused on the composition and origins of the migrant fisher team, and their history of migration. In addition, migrant leaders were asked to list the fishing activities they practice and rank them in order of importance, in terms of their activity budgets.

3. RESULTS

3.1 Principal migration types

294 Respondents identified six principal types of migration in western Madagascar, differentiated
295 in terms of area of origin, destination, drivers and targeted resources (Fig 1):
296 A) *Northward migrations for shark and sea cucumber*. Fishers travel north in search of still-
297 productive fisheries of these high-value resources for the Chinese export market, following
298 the collapse of these fisheries in southern areas.
299 B) *Northward long-distance migration for fin-fish*. Fishers who are no longer able to catch
300 sufficient fish in their areas of origin (particularly Morombe, but also villages closer to
301 Toliara) move northwards beyond the region of their customary use, mostly seasonally but
302 some also definitively. This inter-regional migration is smaller in volume than A) but
303 becoming increasingly important and extending into areas on the mainland and islands
304 pioneered by shark and sea cucumber fishermen, from whom migrants seeking fin-fish learn
305 of new fishing grounds.
306 C) *Local, seasonal fisher migrations*. Fishers in many areas undertake smaller local or intra-
307 regional movements to take advantage of seasonal resources. For example, the Sara of
308 Morombe move regularly between the town and numerous fishing camps within 20 km, and
309 fishers in Befandefa Commune move seasonally to offshore islands (Nosy Hao and Nosy
310 Andragnombala). This migration most closely resembles the ‘traditional’ Vezo migrations
311 described in the literature.
312 D) *Sara migration*. Sara fishers from Anakao and Toliara have moved northwards to the
313 urban centres of Morombe, Morondava and Maintirano since the 1960s to harvest the
314 gastropod ‘casque rouge’ (*Cypraecassis rufa*). This migration continues (though targets have
315 changed, with fishers concentrating more on beach seine netting), with migrants settling in
316 established Sara communities in these towns.

E) *Inland to coastal migrations*. Masikoro, Mikea, Mahafaly, Tanalana and Tandroy agro-pastoralists in the southwest move to the coast to become fishers in times of crop failure or scarcity, or in response to the opening of new markets. In addition, rice farmers from the Mangoky valley and Ankililoaka also move to the coast at Morombe to fish seasonally, and Masikoro farmers from the Mikea area migrate to the coast as a result of armed banditry inland.

F) *Mangoky migration*. Vezo and Sara from throughout the region follow the Mangoky River upstream to the Beroroha area to source *farafatsy* (*Givotia madagascariensis*) trees required for construction of the *laka* fishing vessel, since the tree has been exhausted elsewhere. The journey lasts 3-6 months.

While migrations C to F have been established for many decades, the northward migration for shark and sea cucumber (A) is a more recent phenomenon that began in the early 1990s and has become the principal driver of the northward expansion of Vezo fishers into new frontiers, specifically the Belo-sur-Mer Islands and Barren Isles, and more recently mainland villages such as Benjavily. With near-shore resources in decline, migrants from Befandefa Commune and Morombe began targeting the Belo-sur-Mer Islands when demand rose for these products in the early 1990s, and subsequently mainland villages between Morondava and Maintirano by the mid-1990s. Although some shark fishers were already travelling to the Barren Isles in the early 1990s, numbers increased markedly after 2000, and by 2006 the number of migrants settling on the islands began to provoke conflict with local fishers from Maintirano. The story of the establishment of Bemakoba migrant camp is illustrative of the expansion: an important shark fin buyer spent 2006 testing the fishing grounds between

340 Morondava and Benjavily and, having found a productive site, sponsored teams from
341 Andavadoaka and Morombe to settle there.
342
343 **3.2 Migration characteristics, demographics and temporal trends**
344 Fishers start to migrate north at the end of the cyclone season (March-April) and return south
345 in December: however, many do not migrate until after Independence Day on June 26th,
346 preferring to celebrate in their home villages. During the austral winter the prevailing winds
347 favour sailing north, but the strong winds and cold water mean that the conditions for shark
348 fishing and particularly sea cucumber diving far offshore are not ideal until after August.
349 Migrating fishers travel and work as a team, under a leader who owns the vessels (*laka*) and
350 nets and who recruits family members or acquaintances to work for him, as well as their
351 wives and children in many cases. The team leader is responsible for looking after the team
352 and pays them a part of the profits at the end of the season. Team leaders require sufficient
353 capital to be able to undertake the migration, including large, oceangoing *laka* and expensive
354 gears such as shark nets. Poor fishers therefore migrate long distances only if recruited as part
355 of a team or sponsored by shark fin buyers who provide materials and food. Migrants with
356 sufficient means travel directly to their final target destination, while those without money to
357 buy provisions work their way up the coast, harvesting as they go.
358
359 Surveys of all migrant leaders in 10 destination areas revealed a total of 499 migrants, of
360 whom 26% originated from Morombe, 50% from Befandefa Commune and 19% from
361 Maintirano (Table 1). However, these numbers are an under-estimate of peak numbers
362 because surveying was carried out in May, but the majority of migrants arrive only in July.
363 Estimates of maximum and minimum numbers of migrants in 2008 provided by key

informants at eight of the ten locations suggest that peak numbers may be 2–4 times higher (Table 1). Respondents on Nosy Manandra describe overcrowding of the island and the difficulty of finding space to land a *laka* during peak times, highlighting the fact that fishery resources, rather than the size or carrying capacity of the island, determine its popularity as a destination: Nosy Manandra is an evolving sand cay that was approximately 300 m by 80 m at the time of the surveying and is completely inundated during spring tides, but key informants estimated the presence of over 160 vessels in 2008, each carrying 4-5 passengers (Fig. 2).

[TABLE 1]

[FIGURE 2]

Although the oldest leader had been migrating since 1983, two-thirds (68%) of migrant leaders surveyed only began migrating after 2004 and the modal first year of migration was 2009. Only one third (36%) of leaders had parents who had undertaken migrations.

3.3 Fishing gear, targets and preferred activities

Without exception Vezo residents and migrants use a single-hull outrigger sailing pirogue (*laka*) dug from the trunk of a *farafatsy* (*Givotia madagascariensis*) tree. Migrant pirogues tend to be longer (7–8 m), deeper-hulled and better suited to oceangoing than those used around mainland villages. Fishers use a range of gears and techniques targeted to different marine resources (Table 2). Shark fishing and sea cucumber diving are the two most important activities (Fig. 3), although the high incidence of sea cucumber diving as an activity of secondary importance is an artefact of the methodology. Many fishers will target

388 both when conditions permit, first setting their shark nets before free-diving for sea
389 cucumbers at nearby reefs: if conditions are good for diving fishermen will concentrate on
390 sea cucumbers, while if diving conditions are poor they will focus on shark fishing. Some
391 fishermen who do not own nets will dive for sea cucumbers as a way of saving the money to
392 buy a big net. Nineteen percent of teams were fishers from Maintirano (first and second
393 generation Sara migrants) who practised *ZDZD kirara* to target large pelagic fish; when these
394 fishers are excluded, over 90% of fishers used *jarifa* to target sharks, and over 80% targeted
395 sea cucumbers as a primary or secondary activity. Spear fishing and the use of small nylon
396 nets were activities of tertiary importance, principally carried out for subsistence and baiting
397 *jarifa* and hand lines, while gleaning, hand-line fishing and trolling for large pelagic fish were
398 carried out primarily for subsistence and the production of salt-fish for later trade.
399
400 Sharks and sea cucumber are targeted because of their high value. High quality shark fin sold
401 for 94-105 US$/kg (dry weight), while the sought-after sea cucumber species (such as
402 *Holothuria scabra*) earned 13US$/individual or 17 US$/kg (unprocessed weight). This
403 compares to the sale value of 0.5 US$/kg for fresh fish and octopus in Befandefa Commune.
404
405 [TABLE 2]
406 [FIGURE 3]
407
408 No traditional migrants encountered in this study used outboard motors or had access to
409 SCUBA gear. However, we did observe two teams of artisanal SCUBA-equipped sea
410 cucumber divers from northwestern Madagascar: one operated a large motorised pirogue, and
411 the other operated three motorised fibreglass boats and a 30 tonne capacity sail boat (*botry*)

412 equipped with a diesel motor, with a team of 15 divers. We also regularly observed industrial
413 shrimp trawlers, with a maximum of 12 operating simultaneously to the north of Morondava.
414
415 **3.4 Migration drivers**
416 Contemporary Vezo migrations can be described according to Lee's (1966) theoretical
417 framework dividing drivers into push and pull factors (Fig. 4). The relationship between push
418 and pull factors is mediated by positive and negative feedback loops. In general terms, the
419 principal Vezo migrations (migrations A and B) reflect a livelihood strategy of poor,
420 resource-dependent fishers moving from areas of high poverty, high dependency on fishing
421 as a livelihood and depleted coastal fisheries to areas of lower poverty, low dependency on
422 fishing and more productive fisheries (Fig. S1, Fig. S2). In particular, push factors including
423 the widespread degradation of coastal ecosystems underpinning fisheries in southwest
424 Madagascar, combined with a rapidly growing population and a lack of alternative
425 livelihoods to fishing, have decreased the *per capita* availability of resources in migrants'
426 areas of origin and forced them to move elsewhere. In combination, strong market demand
427 and the extremely high value of shark fin and sea cucumbers, coupled with the existence of
428 still-productive (and accessible) fisheries for these products, provides a strong pull attracting
429 migrants to their destination areas.
430
431 [FIGURE 4]
432
433 **3.5 Customary institutions and migrant-resident conflicts**
434 Informants resident in Andranompasy, Belo-sur-Mer and Maintirano reported conflict with
435 migrant fishers arising for several reasons, including the sheer numbers of migrants arriving,

migrants' disrespect of customary institutions (*faly*), the perceived impacts of migrants of fishing resources, and the small contribution made by migrants to local community life. Few conflicts were said to have arisen previously when migrants fished the islands in smaller numbers and respected residents' customs, but the huge increase in migrant numbers since 2006 had triggered a change in relations.

Both the major migrant destinations, the Belo-sur-Mer Islands and the Barren Isles, were said to be subject to a number of *faly* by the residents of the mainland villages and towns nearest to them, Andranompasy/Belo-sur-Mer and Maintirano respectively (Table 3). Migrant fishers also held a number of *faly* for the islands, often the same as those held by the residents. For residents of Andranompasy and Belo-sur-Mer the islands were said to be traditionally a place of refuge where they were sure to find food in case of catastrophe (e.g. cyclone) on the mainland. They are also the dwelling place of spirits central to a number of beliefs and ceremonies held by local lineages; these spirits are said to only manifest themselves on the islands, and may depart if these sacred places are desecrated. Residents in Maintirano held similar views of the Barren Isles, and variously described them as "a place that is not of our world", (Interview 38, resident fisherman and elder, Maintirano) and "a sacred place that is not of our ancestors" (Interview 27, resident and elder/local leader, Maintirano). Many migrants also held them in a similar regard, viewing them as "a sacred place that is different from here [the mainland]" (Interview 29, Sara migrant and elder). Theoretically, these *faly* would serve as effective resource management institutions: in particular, prohibitions on spending the night, taking women or infants and cultivating plants on the islands would serve to prevent any form of settlement, thus limiting fishers to short visits and minimising their resource harvesting capabilities.

[TABLE 3]

The breaking of *faly* relating to the islands by migrant settlers was reported to be an important source of conflict by politicians and local leaders in mainland towns, though not by resident fishers. In the Barren Isles migrants break a key *faly* by staying for months at a time, and are also accused of keeping cats and chickens, cultivating plants and burying their dead children on the islands. Migrants settled on the Belo-sur-Mer islands were said to have broken *faly* by living there most of the year, giving birth, and burying their dead on the islands, as well as cutting down sacred trees. However, the migrants themselves also have a clear set of *faly* for all of the isles and are adamant that they respect these. We never observed any burial sites, chickens or cultivation on any islands. While both migrant and resident fishers believe strongly in *faly*, other outsiders exploiting the islands since the 1990s are said to have paid little respect to them. Examples include people involved in the construction of a hotel on Nosy Be (Belo-sur-Mer isles), guano mining operations in the Barren Isles and illegal sea cucumber diving in both archipelagos. These activities coincided with the first instances of large numbers of migrant fishers staying on the isles for extended periods.

Few residents of Andranompasy, Belo-sur-Mer or Maintirano traditionally fish for shark and sea cucumber, with the result that there is limited competition with migrants targeting these species. However other migrants settle along the mainland coast and target shallow water inshore resources such as fish, crab and shrimp, placing them in direct competition with residents. Among informants resident in mainland villages there was a strong perception that these migrants “harvest all of [our] resources” (Interview 52, local leader, Belo-sur-Mer, but

484 also a view expressed by Sara migrants (who first arrived in the 1960s) of more recent Vezo
485 migrants), and that “migrants come here to over-exploit our fishing resources so that their
486 own are able to recover in their absence” (Interview 54, local leader, Belo-sur-Mer). In
487 addition, such migrants may cause conflict through the use of destructive techniques; for
488 example, Sara migrants from Anakao and Toliara are notorious for using beach seine nets
489 with mosquito net pockets or bunts. For this reason they are often forbidden by residents from
490 settling in their villages, and tend to settle in urban areas or larger villages where they already
491 have relatives using beach seines. Migrants from inland who do not know how to fish with
492 nets or lines often use poison fishing (*laro*).
493
494 A further cause of conflict is that migrant fishers based on the isles make little contribution to
495 the community life of the resident mainland communities even though they are earning more
496 from the residents' natural resources than the residents themselves do. Coupled with this is
497 the fact that young male migrants cause offence and create social problems when in Belo-sur-
498 Mer by ostentatiously spending money earned from shark fishing and sea cucumber diving in
499 bars. As migrants sell their catch to middlemen in the large coastal cities and spend their
500 earnings in stores owned by traders of Indo-Pakistani origin, they bring little economic
501 benefit to the local fishing communities themselves.
502
503 **4. DISCUSSION**
504 We have carried out the first mixed-methods investigation into the characteristics and drivers
505 of contemporary migrations in Madagascar’s marine environments, and one of the few to
506 have been carried out worldwide (Oglethorpe et al. 2007). From our data, a picture emerges
507 of a dynamic phenomenon that has made a transition from a predominantly subsistence-based

508 migration to one largely driven by lucrative markets created by the globalisation of seafood
509 trade, coupled with the collapse of local fisheries for targeted species. The fact that only one-
510 third of migrant leaders had parents who had migrated is indicative of the migration's
511 changing nature, driven by both push and pull factors: new generations do not have the
512 livelihood opportunities and productive fisheries that sustained their parents, but do have
513 access to new markets.
514
515 Trade is not a new influence on Vezo livelihoods: for example, Sara fishers from Anakao
516 migrated south in the early 20th Century (and to Maintirano in the 1960s) to harvest gastropod
517 shells (particularly *Cypraecassis rufa)* for sale to European and Indo-Pakistani traders, while
518 Betsileo buyers have bought dried fish for sale in the southern highlands since the 1970s.
519 However, it was limited in scope until the early to mid 1990s when seafood export companies
520 began to purchase fin-fish and subsequently octopus, and the now ubiquitous markets for
521 shark fin and sea cucumber developed and exploded in value (Iida, 2005; Langley, 2006;
522 L'Haridon, 2006; Grenier, 2013; Muttenzer, 2013, 2015). Our data show that by 2009,
523 export-driven shark fin fishing and sea cucumber harvesting were the principal activity for
524 over 80% of migrants surveyed.
525
526 The contemporary migrations are strongly influenced by both push and pull factors, although
527 the relative weight of these influences differs between migration types. On the push side, the
528 productivity of marine and coastal ecosystems in southwest Madagascar has been in rapid
529 decline for several decades and many reef systems are now highly degraded (Harris et al.,
530 2010; Bruggemann et al., 2012; Andréfouet et al., 2013). This is the result of a suite of factors
531 (a 'wicked problem'), including sedimentation of coral reefs linked to deforestation in inland

532 watersheds (Maina et al., 2012; Sheridan et al., 2015), the use of destructive techniques such
533 as gleaning that physically damage reef flats (Andréfouët et al., 2013), coral bleaching
534 associated with sea temperature anomalies (McClanahan et al., 2009) and overfishing driven
535 by the rapid increase of fisher populations and novel or growing markets (Bruggemann et al.,
536 2012; Grenier, 2013; Muttenzer, 2015). Population growth in coastal areas is the result of an
537 extremely high fertility rate, which at 6.2 births per woman in south-west (Atsimo
538 Andrefana) region is higher than the national average (INSTAT and ICF Macro, 2010), and
539 the migration of agro-pastoralist and urban people from inland to the coast in response to
540 declining yields and low land availability (Marikandia, 2001; Chaboud, 2006; Bruggemann et
541 al., 2012), rural insecurity (Epps, 2008), and the decline in industry in towns such as
542 Morombe (formerly a major cotton and butterbean export centre). As a result, the population
543 of Atsimo Andrefana region grew by 53% between 1993 and 2008 (INSTAT, 2007), while
544 the number of fishers exploiting the Toliara Bay fishery tripled between 1972 and 2007
545 (Brenier et al., 2012). The push factors influencing fisher migrations are likely to grow
546 further with climate change because, beyond migration, Vezo fishers lack resilience and
547 adaptive capacity (Westerman et al., 2012), while fisher populations are expected to grow as
548 climate change diminishes agricultural productivity inland and drives farmers to the coast
549 (Thornton et al., 2011). Climate change will also have direct impacts on coral reefs and
550 marine productivity (Hoegh-Guldberg et al., 2007), but these are likely to be outweighed by
551 the physical impacts of current human activities in both coastal and inland regions (i.e. reef
552 damage, sedimentation arising from deforestation) (Bruggeman et al., 2012; Maina et al.,
553 2013).
554

555 Although marine protected areas can also cause human displacement (Mascia and Claus,
556 2008), none of our key informants mentioned the implementation of access restrictions as a
557 motivation for their migration, despite 50% of surveyed migrants originating from Befandefa
558 Commune where the Velondriake LMMA covers much of the coast and most islands (Harris,
559 2007). However, our survey was carried out prior to the 2010 establishment of Kirindy-Mite
560 Marine National Park, a strict protected area, around the Belo-sur-Mer islands. It should be
561 noted that migration is but one of several ways to adapt to declining resources and other
562 fishers may opt to exit the fishery altogether (Cinner et al., 2011; Daw et al., 2012): in
563 Atsimo Andrefana region, for example, some Vezo are abandoning fishing in favour of
564 producing charcoal for the urban market in Toliara (Gardner et al., 2015).
565
566 On the pull side, the growth of the lucrative export market for shark and sea cucumber to
567 China provides a strong incentive for migrants to seek out these products in areas retaining
568 populations of target species (McVean et al., 2005, 2006; Barnes and Rawlinson, 2009;
569 Grenier, 2013; Cripps et al., 2015; Muttenzer, 2015). These resources are extremely high
570 value compared to fin-fish or octopus, with prices of over 100 US$/kg for high-grade, dry
571 shark fin reported by our respondents. Within the Velondriake LMMA, by comparison, mean
572 *per capita* income is 1.7 US$/day (Oliver et al., 2015). China became the world's top seafood
573 importer in 2012 (Radobank, 2012) and Chinese demand for shark fin and sea cucumber rose
574 rapidly with economic growth from the early 1990s. This demand was felt even in remote
575 Vezo villages. Exports from Madagascar mirrored the growth in demand (Cripps et al.,
576 2015), triggering rapid overfishing of the most southerly and accessible sites: as a result, the
577 'frontier' for these resources has been moving steadily north over the last two decades
578 (Muttenzer, 2015). Thus Madagascar's experiences conform to the global pattern, which has

seen both sea cucumber and shark fisheries expand into ever-more remote areas, subsequently declining just as rapidly following fishery collapse (Bremner and Perez, 2002; Berkes et al., 2006; Dulvy et al., 2008; Ferretti et al., 2010; Anderson et al., 2011). The globalisation of trade and increasing reach of markets into the world's remote places represents an increasing threat to global biodiversity, but remains a little-understood driver of livelihood change in conservation priority regions (Kramer et al., 2009).

The Belo-sur-Mer Islands and Barren Isles archipelago, which are remote, highly exposed, vulnerable to tropical storms, and lack fresh water, have not been widely settled historically, and resident communities of adjacent mainland villages did not traditionally target sharks or sea cucumbers. As a result, these fisheries were largely untouched when the first migrants arrived. Further, there were no formal access restrictions preventing exploitation of the islands and their fisheries, which were instead 'regulated' by mainland populations through *faly* that prohibited fishers from staying overnight or settling on the islands. It could be argued that these customary institutions would have effectively limited fishing pressure and thus helped to maintain the resources of the islands as a 'safety net' for exploitation when required, as in the case in some Pacific societies (Johannes, 1978; Colding and Folke, 2001). Indeed, the 'safety net' role of the Belo-sur-Mer islands was explicitly stated by respondents in Andranompasy and Belo-sur-Mer. However, although adjacent resident fishers rarely used the islands prior to the arrival of migrants, it may not have been the *faly* that prevented them from doing so; rather, they lacked the oceangoing vessels and knowhow to safely and regularly reach them, and they were not affected by the strong push and pull factors (i.e. diminished resources and new market opportunities) that pervade today. Although migrant fishers do break the key *faly* of settling on the islands, some of the behaviours that resident

603 leaders reported of them are probably unfounded accusations: for example, it is unthinkable
604 for a Vezo not to bring a dead family member 'home' to be buried in their family burial
605 ground, and it seems unlikely that fishers who rarely if ever cultivate in their home areas
606 would do so in temporary camps lacking water. We suggest that, rather than serving as a
607 resource management mechanism, the *faly* that residents emphasised when asked about
608 conflicts with migrants are an expression of their 'ownership' – lacking any formal rights or
609 tenure, the statement of these cultural institutions is the only way for residents to assert their
610 prior claim to the islands over migrants. In this respect it is notable that *faly* tended to be
611 invoked by local leaders and politicians, rather than resident fishers.
612
613 Customary institutions have attracted much recent attention from conservationists interested
614 in community-based fisheries management (Cinner and Aswani, 2007), because compliance
615 with rules in such systems tends to be high (Berkes et al., 2000; McClanahan et al., 2006).
616 However, they may be vulnerable to erosion following the commercialisation of resources or
617 breakdown of traditional authority, or due to the dilution of reciprocal social interactions
618 arising from an influx of newcomers (Ruddle, 1994; Katz, 2000; Curran and Agardy, 2002;
619 Pollnac and Johnson, 2005). This appears to have occurred in our study area since, while
620 migrants still strongly respect certain *faly*, they do not respect those that pose a complete
621 barrier to successfully fishing sharks and sea cucumber. There has also been a weakening of
622 these institutions amongst residents. For example, 19% of fisher teams we surveyed in the
623 Barren Isles were residents of Maintirano rather than migrants from the south. However, any
624 breakdown of respect for *faly* was not necessarily triggered by the behaviour of migrants,
625 since other factors certainly also played a role. These include the influence of new markets
626 leading to the commercialisation of local resources, and, in particular, an increase in

627 interventions on the islands by outsiders who pay no attention to *faly* (i.e. people involved in
628 hotel construction, commercial guano exploitation, and illegal artisanal and industrial
629 fishing). It is likely that the non-respect of local customary institutions by these outsiders
630 since the 1990s contributed to the subsequent weakening of respect for *faly* among migrants.
631
632 Management of the contemporary migration and its impacts is a priority for managers of the
633 Kirindy-Mite and Barren Islands protected areas. At least 14 shark and eight sea cucumber
634 species targeted by Vezo fishers are globally threatened with extinction (McVean et al., 2006;
635 Gough et al., 2009), while both groups are keystone species (responsible for top-down trophic
636 regulation and nutrient cycling respectively) (Uthicke, 2001; Ferretti et al., 2010; Anderson et
637 al., 2011). In addition, migrant fishers cause a range of environmental problems on the
638 islands including clearing vegetation, destroying colonies of breeding seabirds (*Sterna*
639 *dougallii* and *S. anaethetus*) and causing rat and cat infestations. However, migrant
640 traditional fishers probably do not constitute the greatest threat to these resources or the
641 marine ecosystems of these archipelagos as a whole, since artisanal and industrial fishers
642 targeting sharks and sea cucumbers, assisted by SCUBA equipment and motorised fleets that
643 may carry as many as 200 divers, have far greater capacity to overharvest stocks
644 (Rasolofonirina et al., 2004; Andrianaivojaona, 2012). In addition, industrial fleets targeting
645 shrimp, pelagic fish, tuna and sharks operate freely in the area, inflicting damage on benthic
646 habitats (in the case of shrimp benthic trawlers) and shark populations (industrial longliners)
647 (Le Manach et al., 2012). Although we did not systematically enquire about artisanal and
648 industrial fleets in our interviews, subsequent surveys have revealed that resident fishers in
649 Belo-sur-Mer and Maintirano perceive artisanal and industrial fishers to represent a far
650 greater threat to their livelihoods than migrant traditional fishers. In villages around Belo-sur-

651 Mer, 48% of resident fishers cited industrial shrimp trawlers as the cause of declining
652 catches, while these trawlers also caused conflict by endangering traditional fishers,
653 entangling or tearing their nets, and damaging benthic habitats (Jones, 2011). In Maintirano,
654 31% of household heads perceived artisanal sea cucumber divers to be the principal threat to
655 their livelihoods and 7% cited industrial trawlers, compared to only 3% citing migrant fishers
656 (Cripps, 2010). Indeed, by 2014 the problem of artisanal SCUBA divers had become rampant
657 in the Barren Isles following the 2009 political coup and subsequent prolonged political
658 crisis: migrant fishers were no longer able to find sufficient sea cucumbers as all areas
659 accessible to free divers had been exhausted by illegal divers exploiting the same shallow
660 reefs (G. Cripps, unpublished data). This follows the collapse of the local shark fishery on the
661 islands by 2012 (Muttenzer, 2015).
662
663 Building on achievements that included the creation of three major new marine protected
664 areas within our study area since 2003, Madagascar committed in 2014 to further tripling its
665 coverage of marine protected areas (Rajaonarimampianina, 2014). Since many of the priority
666 areas for new protected area establishment lie in western Madagascar in areas influenced by
667 contemporary Vezo migrations (Allnutt et al., 2012), it is important to consider the
668 appropriateness of existing marine protected area models in light of new understandings
669 generated by our study. In purely social terms, our data and the literature suggest that the
670 Vezo migration is an important adaptive resource management strategy allowing fisher
671 communities to make the most of available resources and prosper in times of scarcity
672 (Muttenzer, 2015). Given the socio-economic importance of this ‘release valve’, the
673 establishment of strict protected areas in key destination areas may deprive migrant fishers of
674 critical resources and therefore worsen the poverty they are seeking to escape. Strict protected

areas may therefore be inappropriate given global calls for conservation to avoid worsening poverty, and the Malagasy government's own objectives for its protected area system to contribute to poverty alleviation (Gardner et al., 2013). Furthermore, strict protected areas do not reduce or mitigate the impacts of migrant fishers but merely displace them elsewhere, a phenomenon known as leakage (Ewers and Rodrigues, 2008). For example, forced clearances of migrant camps on the Belo-sur-Mer islands since 2010, following the establishment of the Kirindy-Mite Marine National Park, have closed off important livelihood opportunities for migrant fishers utilising the archipelago and may have exacerbated the impacts of migrants in other destination areas such as the Barren Isles. Importantly, camp clearances also marginalise and worsen relations with the key stakeholders in the management of the region's fishery resources (migrant fishers), and do nothing to reduce the greater threat of illegal artisanal and industrial fishing within the marine protected area. Traditional migrant fishers make a soft target for marine protected area managers, because they do not have the political influence that industrial fishers have in negotiating boundaries, nor to break the law with impunity as more powerful actors will when opportunities arise.

In contrast to the Belo-sur-Mer islands, the Barren Isles are managed as an LMMA with a shared governance structure that integrates resident and migrant fishers with the relevant authorities at the regional and national level. The protected area serves as a mechanism to promote rights-based fisheries management that empowers traditional fishers to manage their fishery resources and enforce rules against artisanal and industrial fleets. By integrating all stakeholders into governance structures, such an approach is more likely to meet the government's socio-economic and cultural objectives of its protected area system, and also provides greater scope for integrating and building upon existing customary institutions, such

699 as *faly*, than do strict protected areas under top down governance regimes. However, the
700 interests of migrants may still be marginalised if the governance structures come to be
701 monopolised by resident fishers from Maintirano, who retain a strong interest in excluding
702 migrants from the islands. Further, while LMMAs theoretically provide a strong foundation
703 for collaborative resource management, in practice the shared governance structure of the
704 Barren Isles has not been able to stop illegal SCUBA divers operating with impunity inside
705 the LMMA. Not only has this greatly undermined a key fishing resource of traditional fishers,
706 but also diminished their respect – previously strong – for local regulations. This is critical
707 because the key reason traditional fishers, both resident and migrant, support the
708 establishment of a protected area around the Barren Isles is that they expected it to control
709 illegal SCUBA teams and shrimp trawlers (Cripps, 2010). If mechanisms to ensure the
710 application of rules can be established, gear-based rules may be sufficient to promote the
711 sustainable exploitation of sea cucumbers due to the variation in sea depth: with SCUBA-
712 assisted diving not permitted, deep water areas beyond the reach of free divers may serve as
713 natural 'reserves' ensuring the maintenance of source populations. For the conservation of
714 sharks, however, the establishment of protected areas alone is insufficient because many
715 shark species range well beyond them. Threats to sharks from the global fin trade have to be
716 addressed at the domestic and international policy level: priority actions for Madagascar
717 include the development of appropriate legislation and a national shark management action
718 plan including provisions for stock assessment, monitoring and surveillance and a range of
719 spatial, gear-based and market-based mechanisms (Cripps et al., 2015; Humber et al., 2015).
720 Efforts to reduce global demand should also be undertaken simultaneously.
721

722 Given that migrations are influenced by both push and pull factors, the implementation of
723 actions in destination areas alone is unlikely to be a sufficient management response
724 (Oglethorpe et al., 2007). Strategies focused on arresting and reversing recent declines in
725 resource availability in areas of origin, such as reducing fishing pressure and improving
726 productivity through fisheries management, may serve to reduce the flow of migrants towards
727 the north. An example is provided by the Velondriake LMMA in Befandefa Commune,
728 source of half the migrants surveyed in this study, where temporary octopus fishery closures
729 have increased local incomes (Oliver et al., 2015) and livelihood diversification initiatives
730 such as aquaculture of algae and the sea cucumber *Holothuria scabra* (Robinson and Pascal,
731 2009; Rougier et al., 2013) aim to reduce dependence on fishing. Coupled with conservation
732 interventions such as gear-based restrictions and permanent reserves in key reef and
733 mangrove areas, these initiatives are managed within a population, health and environment
734 (PHE) framework that also seeks to meet unmet demand for family planning services and
735 thus reduce runaway population growth in coastal communities (Harris et al., 2012; Mohan
736 and Shellard, 2014). Notwithstanding this progress, established reserves are small (<1% of
737 the area of the protected area) and aquaculture initiatives benefit <10% of the population.
738 Nevertheless, although data are lacking, LMMAs (or other forms of multiple-use protected
739 area) appear a more appropriate conservation approach in migrant areas of origin than strict
740 protected areas because they address the push factors (i.e. reduced *per capita* resource
741 availability) that encourage fishers to migrate: strict protected areas, on the other hand, may
742 exacerbate push factors by placing fishing grounds off-limits, potentially contributing to
743 greater migration pressure.
744

Although the Velondriake LMMA has been highly successful, increasing local incomes (Oliver et al., 2015) and catalysing the viral replication of community-based fisheries management initiatives across Madagascar and other parts of the western Indian Ocean (Mayol, 2013; Rocliffe et al., 2014), it is important to recognise the role of migration in this success: the fact that a large proportion of the fisher population (~60%, Muttenzer, 2015) migrates away either annually or permanently, thus reducing fishing pressure, is probably a significant factor in the continued productivity of these fisheries-based management interventions. This highlights the fact that, while multiple-use protected areas in both origin and destination areas may offer a useful tool with which to manage and mitigate the migration and its impacts, protected areas alone are not sufficient if managed in isolation because they are spatially defined and limited, while the human migration that influences them operates at a much broader scale. It also shows how migration may present management opportunities, such as temporary fishing closures in both source and target areas during the seasonal absence of migrants. LMMAs that are integrated into a larger regional network and able to enact complementary management actions are a mechanism through which this can be achieved, while a seascape approach that considers both protected and unprotected areas across the range of the migration may be best placed to manage the threats – and conservation opportunities – arising from the Vezo migration.

Conclusions

Our research has generated novel understandings of the Vezo migration, and this has allowed us to critically reflect on recent conservation initiatives in the region, i.e. the proliferation of strict protected areas and LMMAs. Our findings suggest LMMAs are more appropriate than strict protected areas in destination areas because they allow the integration of all stakeholder

769 interests and do not impose access restrictions over large areas that may worsen the poverty
770 of traditional migrants by depriving them of a critical coping mechanism. Furthermore, while
771 strict marine protected areas effectively enforce access restrictions against traditional migrant
772 fishers – an already marginalised and vulnerable group – they have proven no more effective
773 than LMMAs in addressing key threats to marine resources posed by politically powerful
774 artisanal and industrial fishing interests. LMMAs are also more appropriate in migrant areas
775 of origin, as they serve to reduce rather than exacerbate the push factors (declining *per capita*
776 resource availability) inciting migrants to leave. However while protected areas may be our
777 principal approach to conservation globally and do provide a useful mechanism at both ends
778 of the migration, they alone are insufficient because seascape-level approaches are required
779 to take advantage of the opportunities that the migration presents.
780
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List of Figures

Figure 1. Map of western Madagascar showing principal migration routes (A, northward migration for shark and sea cucumber; B, northward migration for finfish; C, local, seasonal fisher migrations; D, Sara migration, E, inland to coastal migrations; F, Mangoky migration), marine protected areas (inset a, Barren Isles LMMA; inset b, Kirindy Mite Marine National Park; insect c, Velondriake LMMA) and locations mentioned in the text. Migration routes indicated by arrows are indicative and generalised, and in reality not as discrete as indicated.

Figure 2. Images illustrating the livelihood practices and lifestyle of Vezo traditional fisher migrants in the destination areas of western Madagascar. A, traditional outrigger sailing vessel (*laka*) used for both travel and fishing: the vessel is unmotorised and made entirely of wood, and is the only vessel ever used by migrants; B, migrant traditional fishermen off the Barren Isles, with a hammerhead shark they have just extracted from their hand-made *jarifa* net; C, a sand cay upon which migrant traditional fishers camp in the Barren Isles, about 25 km from mainland Madagascar: the island is submerged during spring tides and rough seas; D, a migrant camp on a sand cay in the Barren Isles, with strips of drying shark meat. Photographs by [REDACTED].

Figure 3. Primary, secondary and tertiary fishing activities of migrant groups (n = 56) in ten destination areas within the Belo-sur-Mer islands, Barren Isles and the Madagascar mainland.

Figure 4. Schematic representation of contemporary Vezo migrations showing push and pull factors, threats (negative feedback loops) and opportunities (positive feedback loops).

Tables

Table 1. Numbers, origins and gender breakdown of migrants at ten major migrant destinations on the Belo-sur-Mer Islands, Barren Isles and Madagascar mainland recorded in 2010. Minimum and maximum estimates were provided by migrant leaders during interviews and refer to migrant numbers during peak season in a typical year.

Village of origin	**Destination village**											**Gender breakdown**		
	Mainland villages			**Belo-sur-Mer islands**			**Barren Isles**							
	Ampatike	**Bemakoba**	**Benjavily**	**Andrevoho**	**Andriamitaroke**	**Nosy Be**	**Manandra**	**Maroantaly**	**Nosy Lava**	**Nosy Mangily**	**Total**	**M**	**F**	**C**
Befandefa area														
Ampasilava			16		15		26				**57**	38	10	9
Andavadaoka				1	6	13	11		10	30	**71**	38	15	18
Belavenoke	4			29	8						**41**	18	9	14
Bevato	14			12		21					**47**	29	10	8
Bevohitse	7										**7**	4	2	1
Lamboara		18			7						**25**	16	4	5
Morombe		19		4	16	49	42		2		**132**	71	28	33
Other west coast, from south to north														0
Toliara		4									**4**	3	1	0
Belo-sur-Mer			12								**12**	12	0	24
Morondava								6			**6**	4	2	0
Maintirano							18	50	28		**96**	54	18	
Hellville									1		**1**	1	0	0
Total recorded	**25**	**41**	**28**	**46**	**52**	**83**	**97**	**56**	**41**	**30**	**499**	288	99	112
Minimum estimate	160	-	-	100	250	200	50	200	200	15	1175	-	-	-
Maximum estimate	210	-	-	150	400	200	800	200	360	30	2350	-	-	-

Table 2. Target species and fishing methods of migrant and resident Vezo and Sara fishers along the west coast of Madagascar (additional data from Gough (2009)).

Target species	**Technique**	**Description**
Sharks	*Palangre*	A form of long-lining using high-strength nylon fishing line and 8 cm hooks with trace made from steel cable; hooks often hung in pairs with c. 20 cm of trace separating them. *Palangre* is increasingly popular for fishing in shallow (c. 30 m) and deep (> 100 m) waters.
	Jarifa	Large gill net used in deep water and baited. Generally 100-200 m long with fall length of about 5 m and a mesh size of 12-25 cm. Introduced in 1990s and believed to originate from Morombe. Many fishers make their own.
	ZDZD	Another gill net, up to 150 m long with a fall length of 6-8 m and a mesh size of 8-10 cm. The name is derived from GTZ, the German development agency that introduced the net in northern Madagascar in 1992 to reduce pressure on near-shore reefs. The net is regarded as more effective than *jarifa*, but it is more expensive and harder to construct, and is therefore less popular. Not baited as it rapidly catches pelagic fish once set, and these bait shark.
Tuna and large pelagic fish	*ZDZD kirara*	Several *ZDZD* are attached to form a net 700-1000 m long, which is set on the surface in deep water, offshore at sunset. One end is attached to a *laka* which drifts through the night, before hauling in the net and returning to shore in the morning. Technique introduced by Japanese development agency in 2000.
Sea cucumber	*Mila zanga*	Women and children glean reef flats, mudflats and seagrass beds to harvest sea cucumbers on foot.
	Manirike zanga	Free diving for sea cucumbers, using a 4-5 m long spear with a slightly serrated edge.
Fin-fish	*Basy/Basimpia*	Spear guns used by free diving. Normally home made using wood, an iron reinforcing bar and rubber recovered from car tyres.
	Electronique/talirano, janoky, tondro roa	Small, monofilament nylon nets that vary according to mesh size (measured by finger width, *tondro*). Usually hand made.

	Tarikake	Beach seining, using *beangato* or *jaoto* nets 300-800 m long and with a fall length of 1-2 m. Have mesh size of 1 finger width and many have a large central pocket made of mosquito netting. Deployed by 5-15 people close to shore.
Sea turtles		Captured opportunistically while spear-fishing or as by-catch in *ZDZD* and *jarifa*. Targeted fishing (*Mihaza fano*) occurs by placing *jarifa* or *ZDZD* near turtle habitat, but is rare. Traditional hunting involves a specialised pirogue and a purpose-made harpoon (*teza* or *nato*) with a detachable spearhead.
Lobster	*Manirike tsitsike*	Free-diving for lobster using a small spear. Not commonly observed during surveying motivated by presence of itinerant collection boats.
Octopus	*Mihake*	Gleaning on exposed reef flats at high tide, using a small un-barbed spear to remove octopus from refuges in the reef.

Table 3. *Faly* (taboos) and cultural norms relating to the Belo-sur-Mer Islands and Barren Isles held by resident fishers in adjacent mainland towns and villages (Andranompasy, Belo-sur-Mer and Maintirano). *Faly* related by different informants may be slightly contradictory as beliefs are not universal and may be specific to particular lineages.

***Faly* regarding the Belo-sur-Mer Islands**	***Faly* regarding the Barren Isles**
- The islands are sacred places with many areas and trees that are *faly* - One can only urinate or defecate in specific places on the islands - One cannot live on the islands; it is acceptable to fish there, but not to stay overnight - One cannot take women or infants to the islands - Women cannot give birth on the islands - The dead cannot be buried on the islands - It is *faly* to kill or mistreat the rats on Andriamitaroke - It is forbidden to drink alcohol on the islands	- It is forbidden to take animals onto the islands - It is forbidden to cultivate plants on the islands - Women with infants are not allowed on the islands, since infants cannot respect *faly* (old *faly*, no longer respected) - It is forbidden to whistle or talk loudly, one must be calm - One cannot defecate or urinate on the islands above the high tide mark