Community perceptions about mangrove ecosystem services and threats

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28 **Abstract**

29 The Ecosystem Service Framework discloses the ecosystem's benefits to society and

30 provides support to preserve threatened systems while considering the economic and

31 social dimensions of the communities more dependent on its resources. Mangroves

32 provide important and valuable goods and services to communities, at different spatial

33 and temporal scales. Nevertheless, over-exploitation of these resources can generate

34 poverty traps, where rural households can no longer use the ecosystem as a source of

35 food security or income. This study uses three communities that live in surrounding

36 areas of mangroves from São Tomé Island (Diogo Nunes, Angolares, and Malanza) as a

37 case study. The main aim was to evaluate locals' perspectives about ecosystem use,

38 threats, and conservation. Questionnaires were conducted among local populations

39 and provided valuable information to identify the major beneficiaries of mangrove

40 resources. These results also indicated that the services and threats identified locally

41 are different from those identified in the literature. The importance of considering the

42 impact of local values and traditions in the use of ecosystem resources was also

43 highlighted by the obtained results since São Tomé residents do not acknowledge the

44 existence of services that do not bring a direct benefit. The absence of awareness

45 about mangroves and their threats can cause severe damages to the ecosystem's

46 health, requiring the implementation of specific awareness-raising policies among

47 populations that interact with mangrove ecosystems.

48 **Keywords** Transitional Systems; Ecological Conservation; São Tomé and Príncipe;

49 Socio-ecological evaluation

50

1. INTRODUCTION

Social-ecological systems represent independent interactions between different sub-systems, such as biological, social, economic, and cultural, and may vary with temporal and spatial scales (Anderies et al., 2004). Every sub-system is interconnected and can have real impacts on each other. The outcomes provided by Ecosystem Services (ES) are not only a result of the ecosystem alone but a mixture of different sources of capital, *i.e.* natural, manufactured, human, and social (van Reeth, 2013). The concept of ES supports a broader view of the interaction between human society and nature, linking both concepts and addressing environmental degradation (Hicks and Cinner, 2014). The concept of ES has been also used as a tool to support ecosystem conservation, by emphasizing the benefits that they provide to human populations while integrating the social-ecological system in the decision-making process (Daily et al., 1997).

The valuation of ES requires the quantification of each service, thus, this value will be influenced by cultural constructions and conditioned by preferences and principles that people idealize. Socio-cultural valuations are comprehensive approaches since they encompass not only the quantification of the services but also the social aspects of the cultural context. Moreover, they can assess how human well-being may be affected by the environment (Chan *et al.,* 2012). In theory, this interdisciplinary approach is broader, although it can be hard to apply due to the difficulties in integrating areas with such different philosophies (Solé and Ariza, 2019). The study of perceptions has a higher probability of capturing how ES contribute to human well-being than biophysical assessments (Martín-López et al., 2012).

74 To better comprehend measures for ecosystem management and to alleviate poverty

75 in communities dependent on the ecosystem, it is necessary to understand the social-

76 ecological system in which the community is integrated, and the types of stakeholders

77 involved. One way to understand this is with direct observations of how people live

78 and analyze their perceptions about the system under-study (Adams *et al.,* 2018).

79 Social assessments are important to understand the perspectives of the beneficiaries

80 of socio-ecological systems (Potschin-Young and Haines-Young, 2011). Human

81 behavior can be affected directly by the perception of an individual and indirectly by

82 socio-economic variables. This logic has been applied in the study of the impact of

83 demographic indicators on environmental perceptions (Allendorf *et al.,* 2006).

84 Transitional ecosystems like mangroves are present in the interface between fresh and

85 marine systems and are present in coastal zones from tropical and temperate

86 countries. These systems are considered the third most productive ecosystems in the

87 world, and the mangrove species are the most likely to survive to climate change

88 effects do to their rapid growth and reproductive cycles (Mukhopadhyay et al., 2018;

89 Polidoro et al., 2010).

90 These wetland systems provide various exclusive goods and services, very important

91 to the human communities, such as coastal protection against natural hazards and

92 nursery areas to several species (Badola and Hussain, 2005; Basset et al., 2013; Mumby

93 et al., 2004). However, a high proportion of mangrove uses and benefits are not

94 marketable, therefore their full value cannot be captured through economic systems.

95 However, these benefits play an important role in supporting communities located in

96 the surrounding area (Glaser, 2003). As an example, Mozumder and Shamsuzzaman

97 (2018) reported 3.5 million individuals in Bangladesh with some level of dependency

98   on mangrove systems. Activities such as fishing and timber harvesting in mangrove

99   areas are commonly used by locals and have been proved to contribute substantially

100   to the economy and food security of local communities (Datta *et al.,* 2012).

101   Consequently, studies seeking to assess the value of mangroves at the regional level

102   are becoming more common in order to facilitate decision-making (Adekola *et al.,*

103   2015; Bandaranayake, 1998; Glaser, 2003; Iftekhar and Takama, 2008; Naylor and

104   Drew, 1998; Palacios and Cantera, 2017).

105   Most ES provided by mangroves are public goods with open-access and poorly defined

106   property rights. These situations can lead easily to over-exploitation, degradation, and

107   too the so-called *tragedy of the commons*, that can trap households in poverty

108   (Chaikumbung et al., 2016; Hardin, 1968). When households become poorer, they can

109   turn to mangrove and fish resources as a 'safety net'. This is beneficial when there is a

110   lack of substitute or alternatives, however the uncontrolled exploitation of the

111   mangrove system can cause damages to the ecosystem and reduce the provision of

112   services, therefore increasing the risk of poverty traps (Uchida *et al.,* 2019).

113   Traditionally, people prioritize short-term needs above long-term sustainability, this

114   mostly is result of the lack of safety nets and access to resources and secure income

115   (Poppy *et al.,* 2014). Community-based resource management coupled with the tools

116   provided by the ES framework could improve ecosystem conservation, environmental

117   health, and empower local communities, by enabling them to participate and influence

118   decision-making, while achieving both food security and environmental sustainability

119   (Poppy et al., 2014; Thompson et al., 2017). Moreover, it has been proven that the

120   support of local communities can improve ecosystem conservation (Roy, 2016). This

121   type of management can develop inclusive decision-making processes that ensure the

122   provisioning and equitable distribution of benefits (Orenstein and Groner, 2014).

123   This study attempts to understand the importance of mangrove ES for local

124   communities from a socio-ecological perspective encompassing local views and

125   dependencies from mangrove systems. Thus, the main aim of this paper is to assess

126   the perceptions of local inhabitants about mangrove ecosystems and their perspective

127   on the threats and mangrove conservation approaches. This assessment will use São

128   Tomé Island as a case study to understand how local inhabitants: i) perceive mangrove

129   ecosystems and human impacts on ecosystem health; ii) identify mangrove threats; iii)

130   envisage strategies to ensure mangrove conservation.

131

2. METHODOLOGY

Study Area

2.1.1 Study site

135 The Democratic Republic of São Tomé and Príncipe is an island country (Gulf of Guinea

136 - 0°25'N - 0°01'S, 6°28'E - 6°45'E) known for its richness in endemic species, as well as

137 diverse ecosystems. Three of the 12 mangrove systems located at the largest island,

138 São Tomé (854 km^2) were selected as study area: Diogo Nunes, São João dos Angolares

139 and Malanza (**Figure 1**). These systems were selected because they represent different
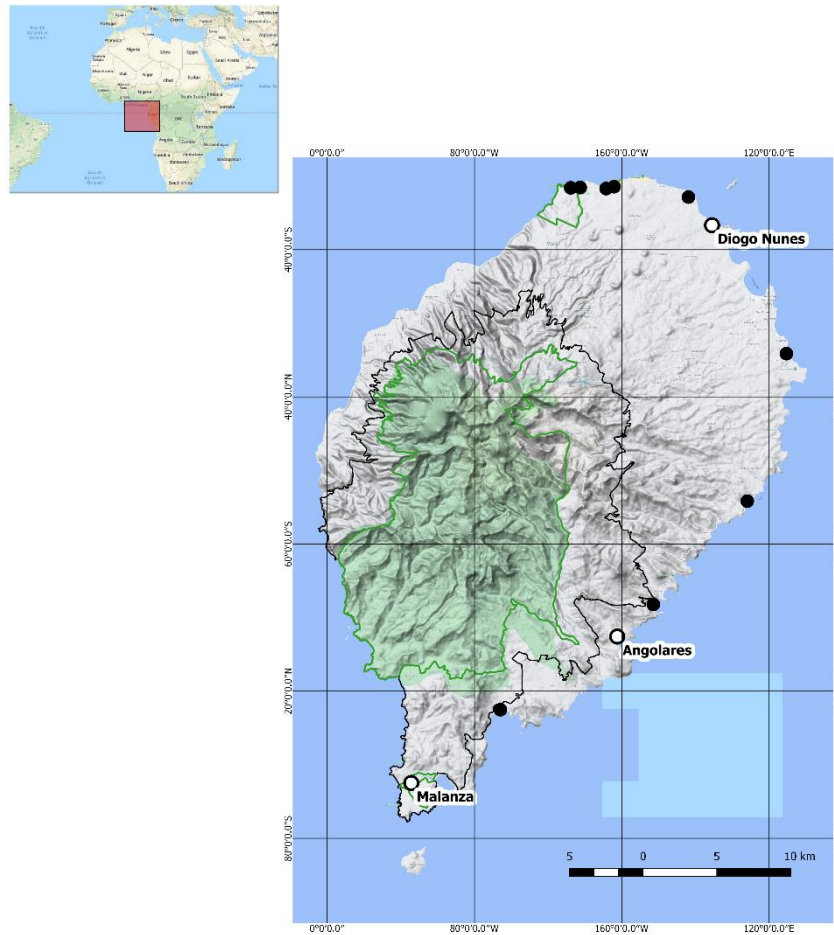

Figure 1 São Tomé and Príncipe location in Gulf of Guinea (left corner). São Tomé island

with mangrove systems identified black circles and study areas by white circles. The green

and black line delimitate the Obô Natural Park and their buffer area, respectively

140 environmental conditions and have surrounding communities with different social

141   contexts. The smallest mangrove, Diogo Nunes, has a total area of 0.01 km^2 (**Figure**

142   **S1A** – Afonso et al., 2021) and is the most degraded of all case study mangroves. The

143   nearest community has 392 residents (INE, 2014). São João dos Angolares (0.13 km^2,

144   **Figure S1B** – – Afonso et al., 2021) is located in the vicinities of a city with 2037

145   inhabitants (INE, 2014). Malanza is the biggest mangrove system on the island, with a

146   total area of 1.52 km^2 (**Figure S1C** – Afonso et al., 2021). Two communities are located

147   in the surrounding areas, namely Vila Malanza and Porto Alegre, accounting for a total

148   of 1345 inhabitants (INE, 2014). In Malanza there is a local group of guides that is

149   responsible for conducting tours in the mangrove area. This is an activity that has a

150   strong influence on the attitude of locals towards the mangrove systems since it brings

151   profit to the community. A recent study has shown that most mangroves represent a

152   relevant source of ES in São Tomé, providing a total of 27 services to the nearest

153   communities, mostly services with indirect benefits, such as *erosion regulation* and

154   *water cycling* (Afonso et al., 2021). Nevertheless, they have highlighted the difficulties

155   in identifying ES in mangroves.

156   [insert **Figure 1**]

157   **2.1.1**   **Population and Demography**

158   São Tomé has a population density of 197.5 persons per km^2 with a sex ratio of 1:1

159   (49.6% males to 50.4% females - INE, 2018). The dominant age group is between 0 and

160   9 years old, with a population structure in a pyramid with a large base, and with a life

161   expectancy of 67 years (INE, 2016). Most of the inhabitants have access to school

162   (87%). As a developing country, the population of São Tomé is highly dependent on

163   direct ecosystem products and activities like agriculture of cocoa and banana and

164 livestock farming (*i.e.* pig and goat farming). Some inhabitants also produce liquors (i.e.

165 palm wine) to sell within the community and obtain an additional income.

166   **2.2 Questionnaires**
167 **2.2.1 Structure**

168 A semi-structured questionnaire was used in this study. It consisted of a set of pre-

169 established questions, but also the possibility of approaching other topics during the

170 interview (Longhurst, 2016). This is particularly important when there are language

171 barriers (Barribal and While, 1994), as it happens in São Tomé where Portuguese is the

172 official language but creole, forro and angolar are commonly spoken by most of the

173 population. This questionnaire was developed and previously applied (for details see

174 Clara et al., 2018; Afonso, 2019), after being validated by an appropriate ethics

175 committee. The questionnaires were conducted to inhabitants older than 18 years old

176 during August 2017 during in-person visits to the surrounding areas of the studied

177 mangroves. The present study was focused on the small rural communities that were

178 considered the primary mangrove ES beneficiaries and, thus, the target group (**Table 1**

179 - Afonso et al., 2021).

180 **2.2.2 Survey Design**

181 The respondents were approached in social gatherings, streets, or mangrove

182 surroundings, as well as at the front of their houses, to facilitate communication during

183 the survey. Similar approaches have been helpful in ethnographic studies (Bryman,

184 2015).

185 Only one member *per* household was interviewed to avoid duplication since each

186 questionnaire was designed to integrate information about one household as a unit of

187 measure. No ES lists were provided when the respondent was asked to identify

188 mangrove ES, in order to assess the perception of the local community avoiding

189 external influences. Each ES identified was compared with a list of ES provided by

190 mangroves (Afonso et al., 2021) and quantified, based on indicators previously

191 selected (Afonso et al., 2021 -**Table 1**). The data obtained with the questionnaires

192 allowed not only to quantify the services provided to those communities but also to

193 predict the number of households that benefited from the mangrove presence. To

194 qualitatively estimate ES beneficiaries while accounting for differences in the ES use by

195 different households, and knowing that in each household can benefit from the ES just

196 one person or everyone, it was defined that the minimum value was 1 and the

197 maximum was the total of household members. The maximal value was defined, for

198 each community, by calculating the mean value of number of persons per household.

199 **[**insert **Table 1]**

200 **Table 1** Mangrove Ecosystem Services identified in mangroves on a global scale (Afonso et al.,
201 2021), services identified by local communities (in bold) and associated quantification
202 indicators. In grey services not identified by locals. ● data available to quantify the ES; ○ no data
203 available.

Ecosystem Services		Indicators	Data
	Capture Fisheries	Yearly market species biomass (kg year^{-1})	●
	Crops cultivation		
	Aquaculture		
	Wild Foods	Number of wild species used as food	●
Provisioning	**Timber**	Yearly consumption of bark mangrove (kg km^{-2} year^{-1})	●
	Fibers and ornamental resources		
	Biomass fuel	Yearly consumption of fuelwood (kg km^{-2} year)	●
	Genetic resources		
	Medicine and pharmaceuticals		
	Water for non-drinking purposes	Yearly freshwater runoff (m^3 year)	○
	Air quality regulation		
	Global climate regulation		
	Regional climate regulation		
	Water regulation		
Regulating	Coastal Erosion regulation		
	Groundwater recharge		
	Wastewater treatment		
	Disease regulation		
	Soil quality regulation		

	Pest regulation		
	Pollination		
	Natural hazards regulation		
	Nutrient cycle		
Cultural	**Aesthetic/ethical values**	Yearly number of visitors for sightseeing (visitors year^{-1})	o
	Recreational and ecotourism	Guided tours profit (€ pax^{-1} year^{-1})	●
	Spiritual and religious values		
	Cultural heritage		
	Scientific/education		
Supporting	Primary production		
	Nutrient flow		
	Water cycling		
	Habitat heterogeneity		
	Nursery area		

2.3 Socio-demographic and economic characterization of respondents

During fieldwork, 202 individuals were interviewed, with the male gender showing a bigger interest in answering the questionnaire (73.3%). Respondents had an average age of 41 years. The best-represented community was Malanza (58.9%), followed by São João dos Angolares (36.1%). Although a minority of respondents had access to a high school level (8%), most of them attended primary school at least for one year (94%). In general, São Tomé inhabitants that live in the rural communities do not earn a fixed salary (78.2%) and most of them have multiple sources of income (93.1%), mainly from livestock farming, and/or agriculture. The average monthly income of each household is 82€. Considering an average of 5 people *per* household, this indicates a daily income of 0,55 € per capita, which is below the poverty threshold of 1.9$USD person^{-1} day^{-1} (1.7€ using conversion rates consulted in 20th August 2019). Most households are dominated by adults between 15 and 64 years old (**Figure 2**).

[insert **Figure 2**]

218   A stakeholder characterization was conducted to understand the social dynamics at

219   São Tomé mangroves, based on Vallet *et al.* (2019) approach, in which every

220   stakeholder is categorized based on three attributes: power, legitimacy, and urgency

221   (**Figure 3,** adapted from Mitchell *et al.,* 1997). Each category is defined by these

222   attributes, even if some attribute is absent, for instance, a non-profit organization has

223   the legitimacy, however, does not have the power or the urgency. The categories

224   represented in the mangrove areas of São Tomé are: **i)** the *civil society*, i.e.

225   government, Obô National Park and Fisheries and Environment Departments, **ii)** the

226   *non-governmental organizations*, e.g. Oikos and MARAPA, **iii)** the *public sector*, i.e.

227   common beneficiaries, **iv)** the *business* sector, i.e. fishermen, fishermen-wives and

228   Mangrove tours, and **v)** the *scientific research* (e.g. MARE, CE3C). Based on (Mitchell et
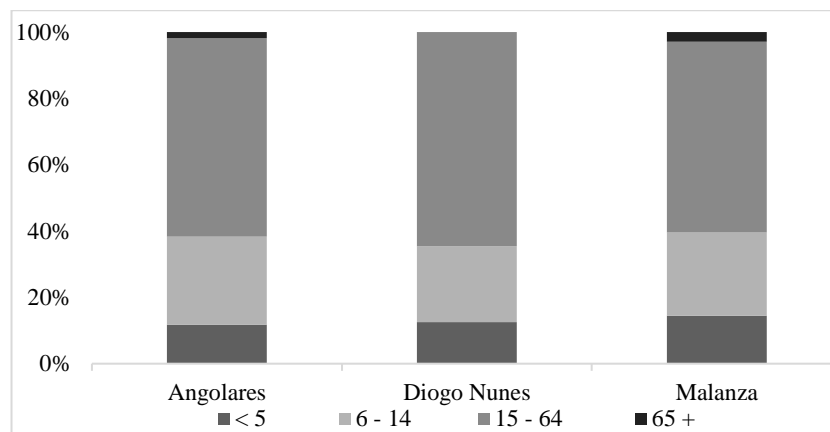

Figure 2 Age of household' members from different communities (Classes based on Instituto Nacional de Estatística from São Tomé and Príncipe)
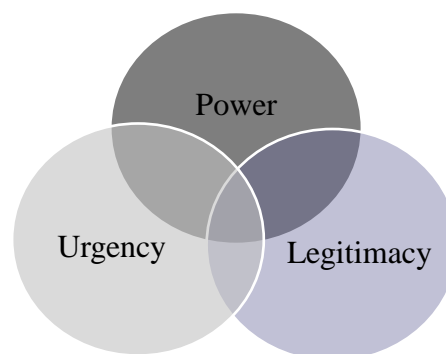

Figure 3 Attributes used to categorize stakeholders' groups (adapted from Mitchell *et al.,* 1997)

229 al., 1997) *civil society* has both the power and the legitimacy (**Figure 3**), being defined

230 as a dominant stakeholder. *Non-governamental organization* and *scientific researchers*

231 only have the legitimacy attribute, social responsibility but no obligation (**Figure 3**),

232 thus are considered discretionary stakeholders. *Public* and *business sector* have the

233 urgency and legitimacy (**Figure 3**), so are dependent stakeholders, they have needs but

234 no power to solve it. The questionnaire respondents were mostly part of the *business*

235 and *public* sectors, and some belonged to the *civil society*, none of the respondents

236 belonged to the *non-governmental organizations* and *scientific research* category.

237 Additionally, some stakeholders accumulated categories, for example, some members

238 of the civil society were workers in the Mangrove tours. This class was designated as

239 *civil society with business*.

240 [insert **Figure 3**]

241   **2.4 Data analysis**
242 Data obtained with the questionnaires was divided into three variable groups:

243 **demographic** (numerical), **ES-related** (categorical: presence or absence), and

244 **conservation opinions** (categorical). The categories were defined based exclusively on

245 the questionnaire results (**Table 2**). The demographic variables were chosen based on

246 other studies using the same social approach (Frank *et al.,* 2017; Lau *et al.,* 2019;

247 Oteros-Rozas *et al.,* 2014; Owuor *et al.,* 2019). The *monetary contribution for*

248 *conservation* variable had 5 defined categories, based on the willing of locals to pay for

249 conservation and the value they were able to give (< 0.4€; 0.4 – 1€; 1 – 2€; > 2€). The

250 *contribution in free time for conservation* variable had also 5 defined categories, based

251 on the willing of locals to participate and the number of weekly hours they were able

252 to spent (< 2 h; 2 – 4 h; 4 – 6h; 6 – 10h). The *ES chosen to preserve in the future*

253   variable was categorized based on the willing of people to preserve or not the ES, and

254   if they wanted to preserve them if they prefer non-extractive (i.e. ecotourism,

255   aesthetic value) or extractive services (i.e. wild foods, biomass fuel).

256   Different demographic variables were available to translate the level of households'

257   financial resources, which were: i) power and water in the home; ii) own house and/or

258   car; iii) the presence of bathroom division in the house; iv) the number of bedrooms.

259   These variables were correlated in a factorial analysis and a single variable was

260   extracted using the scores vector as a socioeconomic continuous variable reflecting

261   the economic condition

262   of a household (SPSS, IBM v25). A Kaiser-Meyer-Olkin (KMO) and a Bartlett's test were

263   applied first to assess the suitability of the method and the correlation between

264   samples (variables), which was followed by Principal Components Analysis (PCA) to

265   extract the variable that assessed the economic household condition.

	Variables	Number of classes	Class	
			Minimum	Maximal
Demographic	Gender	2	Female	Male
	Age	*	Young	Elderly
	Country	2	Foreign	National
	Formal educational level	4	No access	At least primary school
	Level of financial resources	*	Fewer goods	More goods
	Children in the household	2	None	At least one kid
	Household size	4	1 or 2 individuals	10 – 14 individuals
	Marital status	2	Single, divorced or widower	Living together or married
Mangrove conservation	Differences identified over the years	2	No differences	Identified differences
	Threats	2	None	At least identify one
	Changes in the number of tourists	2	No changes	Some changes
	ES importance	4	Low importance	High importance
	Monetary contribution for conservation	4	No contribution	Monetary Contribution of 2€
	Contribution in free time for conservation	4	No contribution	Contribution of 6 – 10h weekly
	ES chosen to preserve in the future	3	No ES preserve	Extraction ES (i.e. wild foods, biomass fuel)

266   **[insert Table 2]**

267   **Table 2** Classification of Demographic and Conservation variables. Each class indicates the minimum
268   and maximum value based on individuals' answers. * Quantitative continuous variable

269   Permutational analyses of variance (PERMANOVA – PRIMER 6 v6.1.13 &

270   PERMANOVA+ v1.0.3) were used to assess differences in **ES** and **conservation**

271   perceptions between communities (Anderson, 2001). Additionally, multifactorial

272   PERMANOVA tested differences for the same ES and conservation variables but

273   considering two fixed factors: 'community' (3 levels: Diogo Nunes, Angolares, Malanza)

274   and a 'stakeholder' factor (4 levels: *business*; *civil society*; *civil society with business*;

275   *public*). Data were log-transformed (log (x+1)) and the Bray-Curtis similarity coefficient

276   was used as a resemblance measure. In case of significant differences, a Simper test

277   was applied to assess which independent variables were responsible for the

278   differences (cut-off of cumulative percentage: 90%).

279   Lastly, when the PERMANOVA and Simper tests revealed significant differences

280   between the communities, a Canonical Correspondence Analysis (CCA - CANOCO

281   version 4.5.) was used to identify patterns in the individual's perceptions about **ES** and

282   **conservation**, and relate them to socio-economic parameters mentioned in **Table 2**

283   and to the social-groups mentioned in **Section 2.3** (Ter Braak, 1988). Every social

284   variable was included. In the CCA the first and second ordination axis was extracted

285   from the socio-economic parameters that maximized the separation between the

286   groups of individual's perception.

287

288

3. RESULTS

3.1 Ecosystem Services provided by mangroves to São Tomé communities

Only 50% of questionnaire respondents considered themselves as beneficiaries of

mangrove ES and none of them mentioned restrictions on the use of mangroves, even

when mangroves are part of São Tomé Obô National Park. Relatively to mangrove

benefits, two aspects were evaluated: services indicated by locals; and the

quantification of those services based on the actual quantities expressed by their

answers.

The respondents acknowledge the use of 7 provisioning and cultural services (**Table 1**),

out of 27 previously identified in São Tomé mangroves (Afonso et al., 2021). The most

mentioned services were *wild food* and *aesthetic values* (24.3% and 15.3%,

respectively – **Table 3**) and these were also the only ES mentioned by all communities.

In Angolares and Malanza were identified more ES than in Diogo Nunes (**Table 3).**

Since most households' habitations did not contain sanitation areas (e.g. bathroom,

restroom), households from Diogo Nunes and Angolares used the mangroves for

hygienic purposes, included in *water for non-drinking purposes*. The *Recreation and*

ecotourism service was exclusively identified for the Malanza community and it

consisted of four types of beneficiaries (N=20, 16.8% - **Table 3**): i) the Mangrove tours

guides (60.0%); ii) Santomeans who primarily work as tourist guides and are

responsible for transporting people to and from the mangrove location (25.0%); iii) the

participants on the process of mangrove cut and preparation for the tours (10.0%); iv)

harvesters of macrobenthos captured on mangrove systems (e.g. bivalves - babanca,

crabs 5.0%). Moreover, the only services that generated revenue were *fisheries* and

recreation and ecotourism, although the last one only occurred in Malanza.

[insert **Table 3**]

314 **Table 3** Percentage (%) of questionnaire respondents from each mangrove community that
315 identified each category of Ecosystem Services
316 It was possible to quantify 5 of the 7 identified ES based on the questionnaires, mostly

Ecosystem Services identified		Inquired inhabitants' percentage by ES user household			
		DN (%)	Angolares (%)	Malanza (%)	Total (%)
Provisioning	Fisheries	0.0	4.1	0.8	1.9
	Wild food*	20.0	39.7	15.1	24.3
	Timber (mangrove bark)**	0.0	1.4	2.5	1.9
	Biomass fuel	0.0	1.4	0.8	0.9
	Water for non-drinking purposes	0.0	5.5	0.0	3.5
Cultural	Aesthetic values	20.0	20.5	11.8	15.3
	Recreation and ecotourism	0.0	0.0	16.8	9.9
Total number of questionnaires performed (one *per* household)		10	73	119	202
Total number of individuals who consider themselves as mangrove ES beneficiaries		4	46	50	100
Average number of individuals per household		4.8	5.1	5.1	5.1
Total ES beneficiaries by community		33 - 160	252 - 1284	111 - 565	9.70 – 49.47
Total population		392	2037	1345	3774

* Only seafood

** Extraction of the mangrove tree bark used for coloring fishing nets

317 provisioning services (**Table 4**). Although the Angolares mangrove is smaller than

318 Malanza, its community benefited more from services provided by the mangrove

319 (*fisheries*, *timber,* and *biomass fuel*). *Wild foods* was the only quantifiable service

320 identified by the Diogo Nunes community.

321 [insert **Table 4**] **Table 4** Quantification of mangrove Ecosystem Services in Diogo Nunes (DN),
322 Angolares and Malanza.

| Ecosystem Services	Indicator	Quantification value			
		DN	Angolares	Malanza	Total
Fisheries	Yearly market species biomass (kg year^{-1})		168	12	180
Wild foods	Number of wild species used as food	3	13	15	21
Timber	Yearly consumption of bark mangrove (kg km^{-2} year^{-1})		1384.6	256.6	1641.2
Biomass fuel	Yearly consumption of fuelwood (kg km^{-2} year^{-1})		461.5	39.5	501
Recreation and ecotourism	Yearly guided tours profit (€ pax^{-1} year^{-1})			1920	1920

323 **3.2 Social groups and ES use**
324 The results of the PERMANOVA test on the differential use of ES by stakeholders

325 indicated that ES were used in different ways per social group and community (p-value

326   = 0.0077 – **Table S2**). The PERMANOVA pairwise tests used to evaluate how social

327   groups use ES in each community showed that in Angolares and Diogo Nunes ES uses

328   were not influenced by social groups (p-value > 0.05). However, in Malanza differences

329   were identified, especially between *civil society with business* & *public sector* and

330   *business* & *public sector* (p-value = 0.0191 and 0.0001 respectively – **Table S4**). The

331   SIMPER procedure was used to identify which ES were used differently between the

332   classes of stakeholders. The differences between *civil society with business* & *public*

333   *sector* were mostly associated with the *recreation and ecotourism* service (45.24% -

334   **Table S5**), while *wild foods* service contributed mostly to the differences between

335   *business* & *public sector* (35.13% - **Table S5**).

336   The Canonical Correspondence Analysis (CCA) was only performed for communities

337   that showed significant differences, thus, only for Malanza. The *business* sector was a

338   user of ES *recreation and ecotourism*, however, did not benefit from the service *wild*

339   *foods.* The *civil society with business* possibly has a higher tendency to use the ES

340   *aesthetic value,* but did not appreciate the use of *timber*, *fisheries,* and *biomass fuel*

341   services from mangroves. And the *public sector* benefit from the ES *wild foods* and did

342   not benefit from the *recreation and ecotourism* service (**Figure 4**).
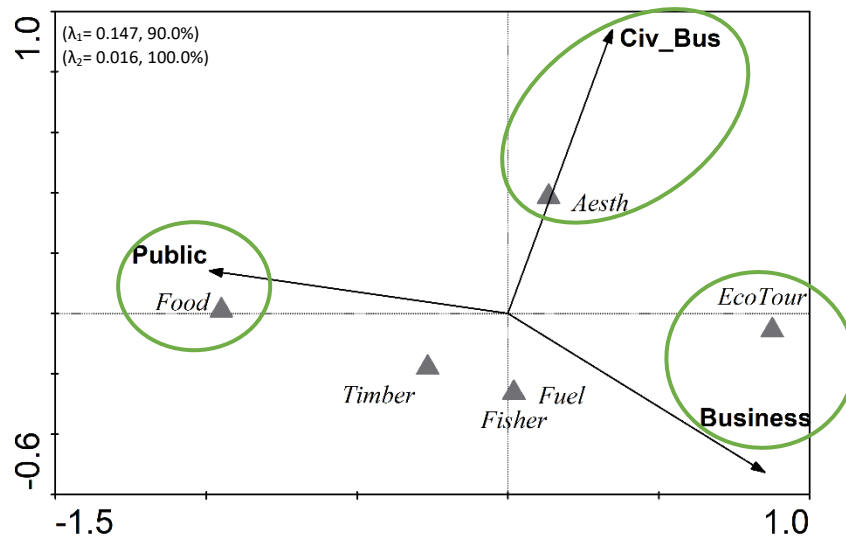
343   [insert **Figure 4**]

Figure 4 CCA based on variables that characterize mangrove ES used by local communities of São Tomé.

The social groups (in bold) of the Malanza community are represented as vectors. The ES considered in

the CCA were: Aesth (*Aesthetic value*), EcoTour (*Recreation and Ecotourism*), Fisher (*Fisheries*), Food

(*Wild foods*), Fuel (*Biomass fuel*), Timb (*Timber*). The social groups considered in the CCA were: Civ_Bus

(*Civil Society with Business*), *Business sector* and *Public sector*. Green circles identify closer relationships

between social groups and ES.

3.3 Assessment of local perceptions about Ecosystem Services

The factorial analysis and single variable extraction were performed after validation

with the KMO and Bartlett tests (0.65 and [χ^2=240.089, df=28, sig=0.00], respectively).

From the PCA, the single economic household condition variable was extracted from

the vector scores of the first axis, which explained the most variance (28.9% - **Table

S1**).

The use of ES differed between communities (p-value = 0.0001 – **Table S2**), as

indicated by the PERMANOVA main test, pairwise comparisons showed that there

were differences only between the Malanza & Angolares communities (p-value =

0.0001) and between the Malanza & Diogo Nunes communities (p-value = 0.0179 –

Table S3). The SIMPER analysis showed a major contribution of ES *Wild foods* for

differences found between the Malanza & Angolares communities (42.57%), while ES

362   *water for non-drinking purposes* contributes most for differences between the

363   Malanza & Diogo Nunes communities (27.01% - **Table S6**).

364   The CCA which characterized the use of ES by the local communities showed that

365   people with less financial resources from Angolares and Malanza benefited more from

366   the ES *fisheries* service. Respondents from Angolares and Malanza with higher scholar

367   degrees were the beneficiaries of the ES *wild foods* service, although in Angolares

368   these individuals were also males born in foreign countries, while in Malanza this

369   service was mostly used by females born in the São Tomé Island. The ES *biomass fuel*

370   in Malanza and Angolares benefited poorer locals, although in Malanza they were also

371   married and in Angolares were single (**Figure 5B, 5C**). Inhabitants single from

372   Angolares and Diogo Nunes were the principal beneficiaries of *water for non-drinking*

373   *purposes* service (**Figure 5A, 5B**). The ES *aesthetic value* benefited younger people

374   from Diogo Nunes and Malanza, and older people from Angolares. This service also

375   benefited small households from Diogo Nunes and bigger households from Malanza

376   (**Figure 5A, 5C**). The ES *recreation and ecotourism* only benefited people from Malanza,

377   especially older males (**Figure 5C**). The other ES did not show any significant

378   relationship comparable between communities.

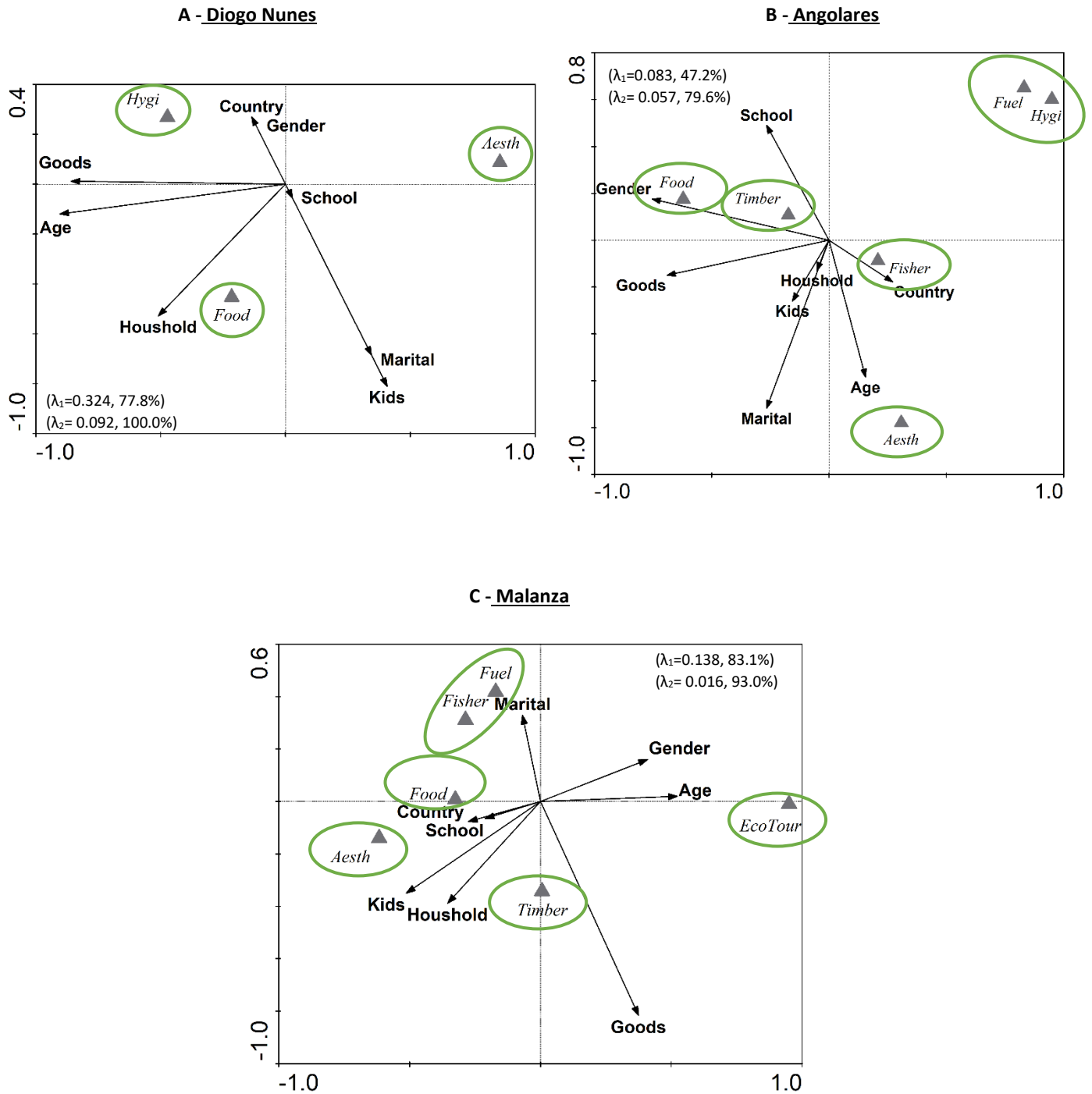379   [insert **Figure 5**]

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Figure 5 CCA based on variables characterizing ES used by local communities: A- Diogo Nunes, B- Angolares and C- Malanza. Vectors represent the demographic variables in the different communities under study. The ES considered in the CCA were: Aesth (*Aesthetic value*), EcoTour (*Recreation and Ecotourism*), Fisher (*Fisheries*), Food (*Wild foods*), Fuel (*Biomass fuel*), Hygi (*Water for non-drinking purposes*), Timb (*Timber*). The demographic variables considered in the CCA were: Age, Country (Country of origin), Gender, Goods (Level of financial resources), Houshold (Household size), Kids (Kids in the household), Marital (Marital status), School (Formal education). λ_1 Eigenvalue and percentage extracted for first ordination axis; λ_2 Eigenvalue and percentage extracted for first and second ordination axis. Green circles identify ES variables with closer distances.

384   **3.5 Community's perception of mangrove threats and conservation**

385   Of all 202 inquired locals, only 16.3% recognized the existence of threats to mangrove

386   systems, which included the input of pollutants, direct human impact (i.e. higher

387   human density), fishing, and deforestation (**Table 5**). The community from Diogo

388   Nunes was only aware of threats in the form of pollutant input (30%). Both Angolares

389   and Malanza communities identified the same threats, although fishing had a higher

390   expression for the former (5.5%), deforestation was the biggest threat considered by

391   the latter (5.9% - **Table 5**).

392   **[**insert **Table 5] Table 5** Threats identified in São Tomé mangroves by a literature review
393   (Bonfim and Carvalho, 2009; Brito et al., 2017; Félix et al., 2017) and fieldwork developed
394   during interviews period, and identified by interviewed inhabitants. ● Identified Threats, ○
395   Non-identified threats.

Mangrove threats	São Tomé	Fieldwork	Inhabitants inquired (%) which identified threats		
			DN	Angolares	Malanza
Freshwater input	●	●			
Sediment input	●	●			
Nutrient input	●	○			
Pollutant input	●	○	30.0	2.7	4.2
Coastal development	●	●			
Direct human	●	●		4.1	1.7
Livestock grazing	○	●			
Fishing	●	●		5.5	2.5
Climate change	●	○			
Species invasion	●	●			
Ocean-based pollution	●	○			
Ecotourism	○	●			
Deforestation	●	●		5.5	5.9
Ecosystem conversion	●	●			
		Applied Questionnaires	10	73	119
		Inhabitants inquired which identified threats	3	13	17
		Proxy for community members which identify threats	118	363	192
		Community members	392	2037	1345

396   Regarding the availability and perception of respondents to preserve mangrove

397   ecosystems, most locals were willing to protect the system (93.1% of total inquired).

398   The vast majority was willing to contribute with free time and money (71.3%), only a

399   small percentage was willing to contribute only with money (5.3%). People who

400   preferred to provide their free time (21.8%) tended to offer 2 to 4 hours a week for the

401   activity. Those who were willing to pay for preservation were willing to do so in a

402   single payment, an amount greater than 2€ (44.4%). Moreover, this value is

403   independent of the type of ES considered (z / χ2 = 3,597; p = 0.463). Opinions about

404   conservation did not differ accordingly to the different social groups (p-value > 0.05).

405   When asked about changes in mangrove systems in the past 10 years, almost 50% of

406   the respondents did not know or had no opinion on the subject. Despite the benefits

407   that mangroves bring to communities and the willing of most of the respondents to

408   protect the mangroves, 34% of the respondents indicated that mangrove trees should

409   be cut, with the main motivation of cleaning the ecosystem to open the canal and

410   improve navigation for canoes. Only 4.5% of respondents considered that tourism has

411   increased in the last years.

412   In general, the most common opinion was that the ES provided by the mangroves are

413   not relevant in their daily activities (44%). Especially in Diogo Nunes, a large part of the

414   respondents considered that the ES had low relevance (75%).

415   The most common opinion from all respondents (72%) was that the only ES to be used

416   in the future should be within the non-extractive category, however, the Angolares

417   community showed a higher interest in the use of extractive services (40% of

418   interviewed people in Angolares). Regarding mangrove protection, 7 measures were

419   suggested by respondents, highlighting the cleaning and maintenance of the mangrove

420   by cutting it (54.46% - **Table S7**).

421   **3.6 Social groups and opinions about Mangrove Conservation**
422   Opinions about mangrove threats and conservation can differ accordingly to the

423   different social groups included in the study inquired, as indicated by the PERMANOVA

424   test, which demonstrated that opinions were significantly different between groups

425   and per community (p-value = 0.0279 – **Table S2**). The PERMANOVA pairwise tests

426   used to evaluate how social groups' opinions diverge in each community showed that

427   the differences were more noticeable in Malanza, especially between *business* & *public*

428   *sector* (p-value = 0.0427– **Table S4**). The SIMPER analysis indicated that differences

429   between these two groups were mostly associated with the *monetary contribution*

430   variable (24.89% - **Table S7**).

431   The CCA was only performed for communities that showed significant differences

432   between social groups, namely for Malanza. The *business* sector consider ES provided

433   by mangroves not important. The *civil society with business* identified changes in the

434   tourist number, in the last years, and they were not willing to pay for mangrove

435   conservation. The *public sector* did not identified threats to mangroves (**Figure 6**).

436   [insert **Figure 6**]

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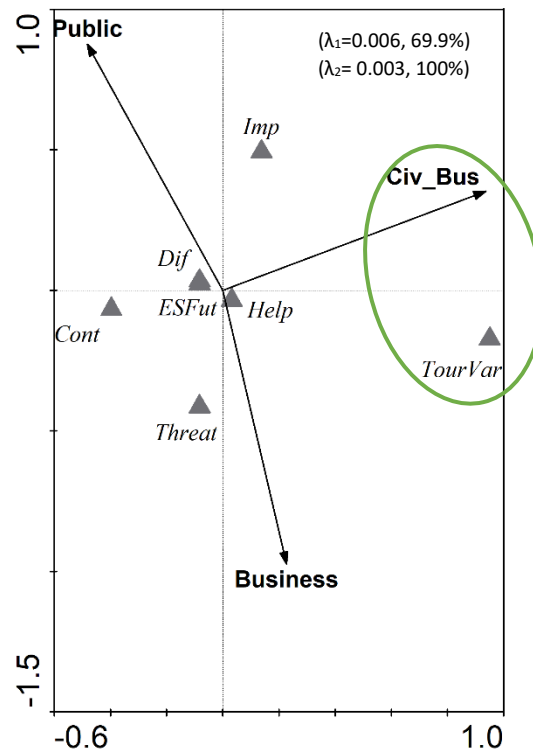**3.7 Assessment of local perceptions about Mangrove Conservation**

Figure 6 CCA based on opinions about threats and conservation of mangroves from Malanza, with vectors representing different stakeholders. The conservation variables considered in the CCA were: Cont (*monetary contribution to conservation*), Dif (*differences in the last 10 years in mangroves*), ESFut (*ES preserve in the future*), Help (*free-time contribution to conservation*), Imp (*ES importance*), Threat (*threats identified*), TourVar (*changes in the number of tourists*). The social groups considered in the CCA were: Civ_Bus (*civil society with business*), *Public sector, Business sector.* Green circle identifies closer relationships between conservation variables and social groups.

The opinions about mangrove threats and conservation were different in every community (p-value = 0.002 – **Table S2**), as demonstrated by PERMANOVA main test. Pairwise tests indicated significant differences between the Malanza & Angolares communities (p-value = 0.0034) and the Malanza & Diogo Nunes communities (p-value = 0.042 – **Table S3**). The SIMPER analysis identified the variables *ES importance* and *monetary contribution to conservation* contribute most for the differences between Malanza & Angolares (24.61% and 24.13% respectively - **Table S9**), while *monetary*

448 *contribution to conservation* and *ES importance* contributed most for differences

449 between Malanza & Diogo Nunes (23.82% and 17.52%, respectively – **Table S9**).

450 The CCA analysis showed the influence of different community attributes on the

451 perception of mangrove threats and conservation. People from the 3 communities

452 who consider that ES provided by mangroves are important had kids in the household,

453 however in Angolares and Diogo Nunes they were also married, and in Angolares and

454 Malanza they were born in São Tomé. People from Diogo Nunes and Malanza who

455 identify threats to mangroves and saw differences in national tourism had Santomean

456 nationality. People from Diogo Nunes and Angolares who agree that mangrove ES

457 extractive must be preserve were older. People from Diogo Nunes and Malanza who

458 were willing to contribute financially towards mangrove conservation had foreign

459 nationality (**Figure 7**). The other variables did not show any significant comparable

460 relationship between communities.

461 [insert **Figure 7**]
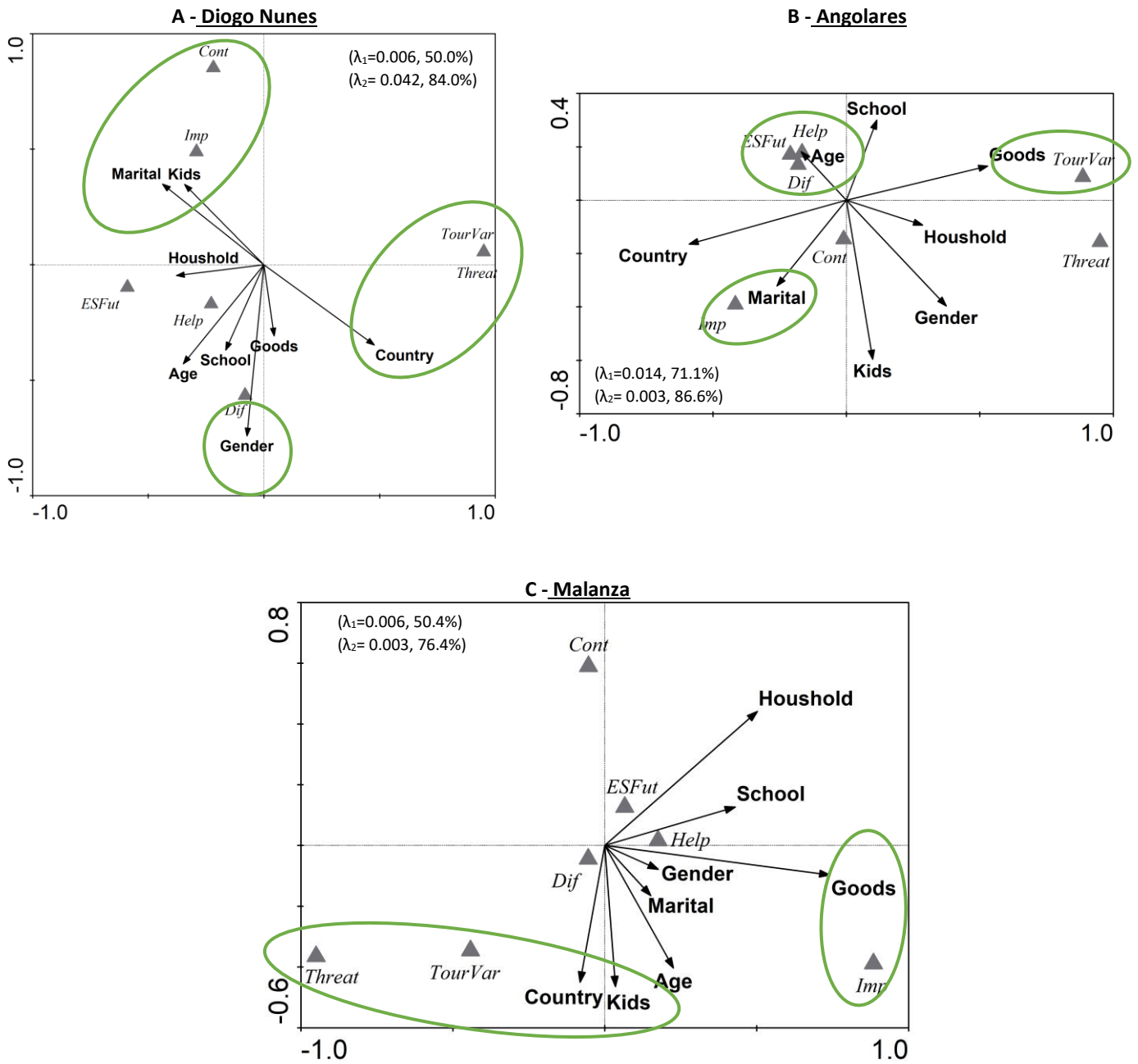
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Figure 7 CCA based on variables characterizing opinions about threats and conservation of mangroves study areas. The vectors representing the demographic variables and the triangles the conservation variables. The conservation variables considered were: Cont (*monetary contribution to conservation*), Dif (*differences in the last 10 years in mangroves*), ESFut (*ES preserve in the future*), Help (*free-time contribution to conservation*), Imp (*ES importance*), Threat (*threats identified*), TourVar (*changes in the number of tourists*). The demographic variables considered were: Age, Country (Country of origin), Goods (Level of financial resources), Houshold (Household size), Kids (Kids in the household), Marital (Marital status), School (Formal education). λ_1 Eigenvalue and percentage extracted for first ordination axis; λ_2 Eigenvalue and percentage extracted for first and second ordination axis. Green circles identify ES variables with closer distances.

469

470 **DISCUSSION**

471 The concept of ES was created to try to solve environmental degradation while

472 continuing to link society to nature. Governance and conservation will enable people

473 to benefit from the environment without damage (Hicks and Cinner, 2014). This study

474 gives information to understand the services provided by Santomean mangroves and

475 the perceptions about the damages that resulted from this intense use. Thus, it listed

476 and quantified the ES identified by locals. Later canonical correlation was used to

477 understand the social aspects that have a bigger influence on the perceptions about

478 mangrove ES. Furthermore, it analyzed the local perception of human impact on the

479 mangrove and the damage caused by it. Once again it used the canonical correlation to

480 assess the social aspects that influence local opinions.

481 **4.1 Locals perceptions about Ecosystem Services provided by mangroves**

482 Almost 75% of the respondents were male, not because it was purposeful for the

483 design, but because most women did not feel confident enough to answer and most

484 felt that the male's opinion should be the one expressed in the questionnaire. This is a

485 common situation in this type of study in developing countries because of the social

486 barriers resulting from cultural constructions of gender roles (Mwangi *et al.,* 2011;

487 Owuor *et al.,* 2019).

488 Notably, only half of the inquired (48.5%) realized that mangroves provide services for

489 their household and only 45% of them consider these services important, even though

490 the mangroves and coral reefs are the most valuable ecosystems from African

491 wetlands (Davidson *et al.,* 2019). The literature review about assessments in

492 Santomean mangroves disclosed a higher number of services than the results

493 presented in this study (7 out of 27; Afonso et al., 2021). These results also show a

494 different perspective of the São Tomé communities when comparatively to other

495   communities from mangrove surrounding areas from Kenya (15 services identified in

496   Rönnbäck *et al.,* 2007) or in pacific islands (13 services identified in Warren-Rhodes *et*

497   *al.,* 2011). All ES identified by locals were included in two categories: provision and

498   cultural. However, similar studies in wetlands showed that surrounding communities

499   had a preference for provision and regulation services, for instance, *nutrient cycle* (i.e.

500   Naylor and Drew, 1998). This is the opposite of what happens in rural areas, where

501   cultural services and well-being tend to be more important (Martín-López et al., 2012).

502   The questionnaires were applied to households, thus the beneficiaries' demographic

503   features (e.g. gender, age) may not fully represent the ES used by the household.

504   It has been demonstrated that mangroves are important for food security and the

505   subsistence of households (Adeel and Pomeroy, 2002). The strong role of women as

506   caretakers, and by consequence as main users of these services with a bigger impact

507   on the ecosystem damaging has been mentioned in several studies (e.g. Mwangi *et al.,*

508   2011). However, this was not so obvious in the communities of São Tomé, most

509   answers came from men. The ES *fisheries* was predominantly used in Angolares and

510   Malanza by individuals with lower financial resources, who use the ecosystem as an

511   income source. Moreover, the collection of fish (service *wild foods*) and benthic

512   macrofauna (e.g. bivalves and crabs) can also be used by adults for subsistence or as

513   bait, and by children for entertainment. In Angolares the beneficiaries of this ES were

514   males with bigger financial resources. Fishing activities usually require a higher

515   physical effort, which makes it more appropriate for males (Juma, 1998). The

516   individuals with bigger financial resources in this case study were characterized as

517   having an average wage of 82€ or more, thus even households with higher wages can

518   use mangroves as a source of products for subsistence or recreational fishing (Naylor

519   and Drew, 1998). In general, active workers are younger and tend to use and value

520   more provisioning services rather than other categories (Oteros-Rozas *et al.,* 2014).

521   The use of mangrove tree barks (ES *timber*) to dye fishing nets is an old tradition in São

522   Tomé. Likewise, it has been used in other African countries with similar functions and

523   obtained principally by the female caretakers of the household that are generally

524   responsible for these activities (Rönnbäck *et al.,* 2007).

525   The w*ater for non-drinking purposes* service includes clothes washing in the freshwater

526   courses and hygiene functions (Warren-Rhodes *et al.,* 2011) and sometimes this

527   service is less visible and disregarded in the literature. In São Tomé specifically, this ES

528   was used by people with diverse socio-economic characteristics, not being exclusive to

529   any group in specific. Thus, this service provided by the mangrove has been considered

530   a consequence of the lack of substitutes in the house or village for hygiene purposes.

531   The differences between communities for this ES were also related to the distance to

532   the closest residential area. As an example, the Malanza community did not indicate

533   this use since the mangrove is more than 1 km away from the closest places (Malanza

534   and Porto Alegre) and the local communities use the closest rivers for hygiene

535   functions.

536   The ES *recreation and ecotourism* in São Tomé is only carried out by older men, as

537   observed in Kenya (Owuor et al., 2019), therefore, the perspective about the ES may

538   have been conditioned by the average age of the respondents. The *aesthetic value* is

539   traditionally more appreciated by elders (Oteros-Rozas *et al.,* 2014), but this was only

540   observed in the community of Angolares contrarily to the other two, where the

541   youngers tend to appreciate more this mangrove quality. This change of perspective

542   might be related to a higher tendency of young residents to have more access to

543   environmental education at school (Oteros-Rozas et al., 2014).

544   Each ES can benefit differently social-actors, which can affect the conception of

545   benefits to human well-being. This is translated in a social misrepresentation, that can

546   be even more intensified in coastal research (Butler and Oluoch-Kosura, 2006). The

547   stakeholders from the *Business sector* were predominantly males who had the

548   responsibility to address tourist activities in mangroves, like in many other regions

549   (Frank *et al.,* 2017; Rönnbäck *et al.,* 2007). Representatives of this category only used

550   the mangroves for these activities while the public sector only used them for *wild food*.

551   **4.2 Locals perceptions about Mangrove threats and their conservation**
552   Most respondents showed a lack of awareness about the mangrove presence in

553   nature, which ends up influencing all their perspectives about mangroves and their

554   level of damage. This is demonstrated by having 84% of respondents consider that

555   mangroves are not threatened when several threats have been identified in São Tomé

556   mangroves (Afonso et al., 2021). This lack of awareness was previously described in

557   other studies (e.g. Palacios and Cantera, 2017) but it is not always the case. Some

558   communities located in the surroundings of large mangrove ecosystems seem to be

559   very aware of changes over the years (Conchedda *et al.,* 2011). Some socio-cultural

560   factors can influence this lack of awareness, such as the gender of the respondent, as

561   women are more associated with domestic activities and do not visit the mangroves

562   regularly (Rönnbäck *et al.,* 2007). This can contribute to a low valorization of ES

563   provided by mangroves. Commonly, one of two conditions are more frequent: i)

564   communities identify their mangrove dependence (i.e. Rönnbäck *et al.,* 2007) or, like in

565   São Tomé, ii) communities are not aware of their mangrove dependence (Ghasemi *et*

566   *al.,* 2010). To work in favor of ecosystem conservation people need to be aware of the

567   importance of the mangrove resources so they can acknowledge how their use can

568   affect the recovery period of resources and their sustainability (Owuor et al., 2019).

569   For instance, it is common for local São Tomé communities to use the surrounding

570   areas of mangroves for agriculture, which is very important for their subsistence.

571   Nevertheless, there is a risk associated with this use in the future, particularly

572   considering the imminent effects of climate change that can result in the salinization of

573   the soils, making them infertile (Reed *et al.,* 2013). Considering the damages to the

574   ecosystem's health and changes in the perception of the ecosystem (Hartter, 2010),

575   this could have a severe impact on the future of these systems.

576   Almost half of the inquired Santomean individuals did not notice any change in the

577   mangrove ecosystem during the last 10 years. Commonly the elder individuals can see

578   changes in mangroves ecosystems (Owuor *et al.,* 2019), however, considering the

579   population structure of the case study with a high tendency to have more young

580   individuals and with low life expectancy, this group of people may have not lived

581   enough to see the changes in mangrove structure and forestry.

582   Afonso et al., 2021 has identified considerably more threats to these mangroves than

583   the respondents (4 out of 14 threats identified). This difference is caused by an

584   inherent viewpoint of each group that influences the way threats are perceived, i.e.

585   scientific experts can identify more easily threats to ecosystems based on its intense

586   study. Diogo Nunes stood out since a bigger percentage of inquired individuals

587   identified more threats and less ES, this can be explained by the excessive damage of

588   the mangrove area, with a more visual impact of threats in the ecosystem.

589 An interesting point is that respondents considered cleaning the mangrove as one of

590 the most important conservation measures. However, for them, this includes cutting

591 the mangrove trees, in order to enhance the navigation and improve access.

592 Additionally, this cleaning is also related to the need to control the occurrence of

593 mosquitoes (Warren-Rhodes *et al.,* 2011), especially in countries like São Tomé where

594 there is a risk of a malaria vector emerging in mangrove areas. This procedure can be

595 considered as a threat to mangroves conservation. Although the mortality due to

596 malaria has dropped in recent years, the country is still under the influence of the

597 disease (Bonfim and Carvalho, 2009), so the concern of the communities is reasonable,

598 which leads them to take protective measures, such as the application of products for

599 the extinction of the mosquito, which may act itself as a pollutant to the ecosystem.

600 The demographic factors have a stronger role than the economic benefits in the

601 willingness of local communities to participate in conservation strategies (Coulibaly-

602 Lingani *et al.,* 2011). For instance, formal education is considered the main driver for

603 perception and it has been suggested to increase conservation awareness (Roy, 2016;

604 Sinclaira et al., 2011) However, the results were not always evident, even though in

605 São Tomé young individuals were those showing a bigger interest in conservation,

606 more precisely to give money for this activity.

607 **4.3   How can local knowledge be used to develop better management strategies?**
608 The ES-framework is cyclical, beginning in the ecosystems and their processes and

609 having the benefits provided to the humans as the next step. The process of decision-

610 making affects the ecosystem and how the ES benefits are shared (van Oudenhoven et

611 al., 2012). Explaining the ES concept is not easy in any context (Riechers *et al.,* 2016),

612 but it can change the way ecosystem conservation is considered and applied. In

613   situations when a total dependency of mangrove resources happens the economic

614   value necessary to substitute this service will be higher and mostly the attitude of

615   locals will be more positive towards its preservation (Roy, 2016).

616   In general terms, it can be concluded that communities from the mangrove

617   surrounding areas of São Tomé have low knowledge about mangrove processes and

618   undervalue the high impact of human activities as a source of threats and stress to the

619   environmental quality of these systems. The best ecosystem governance can be

620   achieved with mangrove conservation while enabling people to benefit from the

621   environment and improve their well-being. The key to successful conservation is to

622   raise awareness to influence positive attitudes towards the preservation and

623   conservation of marine ecosystems (Rahman and Asmawi, 2016), assessments like this

624   one have the ability to show the degree of poor understanding of ecosystems value

625   and benefits, and the strong need for the implementation of environmental education

626   programs to all ages, which will motivate the dialogue between stakeholders, and by

627   consequence the development of an inclusive decision-making.

628   **CONCLUSIONS**

629   The Santomean communities showed a limited perception of mangrove benefits since

630   they were mostly interested in the services that have direct benefits (e.g. provision of

631   food). However, they can understand the value of mangroves for these benefits, but

632   there is also a lack of awareness about important regulating and supporting services

633   provided by mangroves, especially valuable in communities that live so near these

634   systems. Therefore, education is the most helpful tool which enables people to better

635   understand the relationship between natural resources conservation and human well-

636   being (Vodouhê et al., 2010). This will be one step forward to understand the impact

637   that humans can have on the environment and how we can recover environmental

638   health and guarantee the sustainable use of ES.

639

640 **Author Contributions**

641 Filipa Afonso: conceptualization and design of study; Data collection; Data analysis and

642 interpretation; Writing and preparation of original draft. Pedro Félix: conceptualization

643 and design of study; Data collection; Data analysis and interpretation; funding

644 acquisition. Paula Chainho: Data collection. Joshua Heumüller: Data collection. Ricardo

645 de Lima: Data collection. Filipe Ribeiro: Data collection. Ana Brito: conceptualization

646 and design of study; Data collection; Data analysis and interpretation. All authors

647 contributed to manuscript revision, read and approved the submitted version.

648

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