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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Marinha Aplicada, realizada sob a orientação científica do Doutor José Augusto Alves, Investigador Principal do CESAM e Departamento de Biologia da Universidade de Aveiro.

"*Sometimes, instead of cutting through the waves it's better to just let them carry you*".

Catarina Santos Ramos

o júri

presidente

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vogais

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palavras-chave *S. senilis*, *T. adansonii*, apanha de bivalves, gestão traditional, limícolas.

resumo

A exploração humana de bivalves no arquipélago dos Bijagós é uma atividade ancestral que está fortemente ligada a práticas culturais, mas que serve também como importante fonte de nutrição para as populações locais. Alguns destes recursos, tais como o bivalve *Tagelus adansonii,* são essenciais para a realização de certas cerimónias tradicionais, e limitam o progresso da hierarquia social quando as suas reservas são escassas. Outras espécies, como o bivalve *Senilia senilis*, são fontes de proteína cada vez mais relevante para as populações locais.

Neste estudo investigou-se quais os fatores que influenciam a atividade de recolha destas duas espécies de bivalves neste arquipélago, considerando a variação no nível de proteção de recursos naturais (área protegidas), e na existência e cumprimento de leis tradicionais, em diferentes ilhas. Foram assim selecionadas quatro áreas de estudo (ilhas) com diferentes estatutos de proteção: Parque Nacional, Área Marinha Protegida Comunitária, área não protegida com fortes valores tradicionais e área não protegida com valores tradicionais em declínio.

Um total de 182 mulheres (que são as responsáveis pela colheita de bivalves na sociedade Bijagó) foram entrevistadas em 20 aldeias. Os resultados sugerem que os padrões de colheita de ambas as espécies são principalmente influenciadas pelo propósito final da colheita, o que também afeta a frequência, o tamanho dos grupos coletores e as quantidades recolhidas. O estatuto de proteção e gestão nas diferentes ilhas indicia efeitos positivos nestas espécies de bivalves, e as leis existentes combinadas com as crenças tradicionais são uma forma de preservar estes recursos para as próximas gerações.

keywords *S. senilis*, *T. adansonii*, bivalve collection, traditional management, waders.

abstract

The human exploitation of bivalves in the Bijagós archipelago is an ancestral activity that is strongly linked to cultural practices, but also acts as an important nutritional source of for local populations. Some of these resources, such as the bivalve *Tagelus adansonii*, are essential for the realization of certain tradtitional ceremonies, and limit the progress on the social hierarchy when scarce. Other species, such as the bivalve *Senilia senilis*, are increasingly relevant sources of protein for the local populations.

This study investigated the factors that influence the collecting activity upon these two bivalve species in this archipelago, taking into account the variation on the level of natural resource protection (i.e. protected areas), and in the existence and enforcement of traditional laws, in different islands. Four study areas (islands) with different protection status were thus selected: National Park, Community Marine Protected Area, unprotected area with strong traditional values, and unprotected area with declining traditional values.

A total of 182 women (who are responsible for collecting bivalves in the Bijagó society) were interviewed across 20 villages. The results suggest that the collection patterns of both species are mainly influenced by the final purpose of the harvest, which also affects collection frequency, the size of the collecting groups, and the quantities collected. The protection and management status on the different islands indicates positive effects on these bivalve species, and existing laws combined with traditional beliefs are one way to preserve these resources for future generations.

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Introduction

The increase of human population over the last century and the associated technological progress place increasing pressure on the natural resources, especially those associated with the production of food and energy (Boyden & Dovers, 1992). Future projections for the period from 2020 to 2050 indicate that most of the world's population growth will take place in undeveloped and developing nations, thus considerably increasing demand on natural resources, including those from marine sources, in many areas that are already affected by multiple stressors such as over fishing, pollution, contamination, climate change and coastal degradation (Garcia & Rosenberg, 2010; Starnes & Darwall, 2021). The collection of marine resources has increased drastically over the last century due to overexploitation, owing to our capacity of optimizing catching techniques as a response to human population growth (Brotherton et al., 2020; Maxwell et al., 2016), and also the combination of overexploitation with weak governance and conservation measures (Garcia & Rosenberg, 2010). The overall amount of species threatened with extinction averages 23.7 % across multiple taxonomic groups (Secretariat of the Convention on Biological Diversity, 2020). And 28 % of all the species listed in the IUCN Red List are threatened with extinction with several approaching it at vertiginous rates (IUCN, 2020). This is particularly notorious in marine ecosystems, as biologically unsustainable fish stocks increased from 10 % in 1974 to 34.2 % in 2017 (FAO, 2020). With about one-third of the world's stocks being currently overfished, the extinction risk of species impacted by fisheries is increasing and species which currently have a declining trend are outnumbering those improving (Secretariat of the Convention on Biological Diversity, 2020).

Fishery resources are one of the most important protein sources among coastal and low-income communities (Bene & Neiland, 2003; Garcia & Rosenberg, 2010), but overexploitation and the lack of representation and transparency in fisheries management, especially in west Africa, is known to increase negative impacts and to compromises food security and the livelihood of local populations (Belhabib et al., 2015; Bene & Neiland, 2003). Artisanal fisheries have an important role in west Africa, especially the collection of invertebrates in intertidal flats, particularly mollusks (P. Campredon & Cuq, 2001). Despite an increase in commercial and artisanal fishing over the past decades (PRCM, 2011), during the last 10 years observations from the field and some studies report that the main purpose of mollusk collection in the region has shifted

from own consumption to commercialization (Niang et al., 2020). This region also has two of the most important sites along the East Atlantic Flyway for migratory waders that travel here to spend the winter season feeding on macrobenthos, when their breeding areas at higher latitudes are under harsher weather conditions (Veen et al., 2004): the Bank d'Arguin in Mauritania and the Bijagós Archipelago in Guinea-Bissau (Alves et al., 2021; Delany et al., n.d.; Dodman & Sá, 2005; Robertson, 2001; Salvig et al., 1997).

Invertebrate fisheries have shown to have ecosystem effects such as changes in the substrate (altering its coarseness), biomass and settlement success (decline), benthic–pelagic coupling and trophic chain (influencing top-down and bottom-up interactions) (Eddy et al., 2017; Van Gils, Piersma, Dekinga, Spaans, et al., 2006). For example, in Europe industrialized bivalve collection is known to affect migratory waders that consume this resource (Van Gils, Piersma, Dekinga, Spaans, et al., 2006). In fact, shellfishing activities can cascade to affect waders in multiple ways because of changes in the substrate composition due to the removal of sections of it, the disturbance caused by human presence, and the rapid decline of food resources (which can limit waders' intake rates due to depressed prey density), (Dias et al., 2008; Piersma et al., 2001; Van Gils, Piersma, Dekinga, Spaans, et al., 2006). Yet, in areas affected by mechanical dredging, including inside a protected area, the density of waders' prey (such as cockles, bivalves, polychaetas and crustaceans) can remain stable, whereas their quality declines, because the prey become smaller. Conversely, when compared to unexploited areas, prey density increases while quality remains the same (Piersma et al., 2001). Such decline in prey quality in the exploited areas is a result of the change in the coarseness of the substrate (increase in grain size) which negatively affects mollusks' feeding capacity, making these areas unattractive to them and, as a result, also to their predators (Van Gils, Piersma, Dekinga, Spaans, et al., 2006). As long as the decline in prey quality and density is not substantial and does not occur simultaneously, shellfish-eating waders seem to be able to adjust their digestive capacity by increasing the size of their gizzard when prey quality declines, as a way of obtaining the daily amount of energy required to maintain their energy balance (Van Gils, Piersma, Dekinga, & Battley, 2006; Van Gils, Piersma, Dekinga, Spaans, et al., 2006). However, changes in prey density and/or quality caused by industrial forms of commercial exploitation such as mechanical dredging can end up affecting waders, if they occur simultaneously and in a

short time period, not giving the waders enough time to respond to those changes. Thus, Van Gills and co-workers' concluded that, even when inside a protected area, the populations of shellfish-eating waders can decline as a response to the decline of prey quality.

In order to preserve their resources native and indigenous nations all around the world have managed ecosystems in a holistic way, recognizing their interconnections and intertwining both cultural and biological aspects (Emperaire & Peroni, 2007; Gadgil & Berkes, 1991; Vierros et al., 2010). The concept of conservation of biological resources has therefore often been part of ancestral traditions (Heritage Centre, 2004, p. 86; Vierros et al., 2010). Locals developed practices of resource use considering ecological resilience and protecting and minimizing the risks of biodiversity loss by establishing rules, cultural practices and beliefs and by passing them from one generation to the next (Fikret Berkes, 2000), as a way of ensuring the sustainable future of new generations. Rules can consist on seasonal or temporary bans on collecting, regarding some species or groups of people and temporary closed (no-take) or tabu (no-access) areas, established by traditional leaders (Fikret Berkes, 2000; Gadgil & Berkes, 1991; Vierros et al., 2010). These are in fact traditional ways of succession management, landscape patchiness management, resource rotation, and multiple species management (Berkes & Davidson-Hunt, 2006). Site specific rules are often linked to sacred locations which can be parts of forests, islets, beaches or any other site with traditional, religious or considered of livelihood resource importance, e.g. fish nursery site (Mahachi & Kamuhangire, 2008). Locations where natural environment and cultural practices are linked by the existence of a traditional respect and access restrictions are termed 'mixed properties' on the World Heritage List (Rössler, 2004). This ancestral type of management can sometimes, and in some places, get disregarded by governmental institutions and the scientific community, and with increasing modernization these management systems are also increasingly threatened by social, religious, cultural, economic and environmental pressures (Araujo & Campredon, 2017; Mumma, 2004; Rotherham, 2015; Secretariat of the Convention on Biological Diversity, 2020; Tahoux-Touao, 2004). However, it has been shown that learning from and supporting traditional and customary management systems, is important for broadening conservation objectives and approaches (Berkes & Davidson-Hunt, 2006; Fikret Berkes, 2000;

Gadgil & Berkes, 1991; Mumma, 2004; Rössler, 2004; Rotherham, 2015; Secretariat of the Convention on Biological Diversity, 2020; Vierros et al., 2010).

In the Bijagós archipelago of Guinea-Bissau, the Bijagó culture has a strong connection with nature, having its own traditional rules for area and resource management, as a way of ensuring the future of forthcoming generations (Biai et al., 2003; Pierre Campredon, 2014; Tiniguena & IBAP & FIBA, 2013). This type of management system is inseparable from this ethnic group and forms the core of its social structure, culture and spiritual beliefs. Having community level conservation processes and maintaining sacred areas that are important for the preservation and continuation of this group of people, also originates positive outcomes regarding nature conservation (Fikret Berkes, 2000; Maretti, 2015). However, climatic, social, religious and economic pressures are a threat not just to the Bijagó culture but also to the archipelago's biodiversity, with the settling of fishing camps from outsiders, the use of illegal fishing technics, overfishing and the increase in tourism, being the main concerns in this group of islands (Biai, 2015; Instituto da Biodiversidade e das Áreas Protegidas, 2014a; Saraiva, 2015).

While in the Bank d'Arguin fishing is the main local activity in the intertidal areas and is exclusively done by the locals, (Araujo & Campredon, 2017; Pierre Campredon, 2019), in the Bijagós archipelago, artisanal fishing and the collection of bivalves are the main activities in the coastal and intertidal areas, with the later done exclusively by women (Biai, 2015; P. Campredon & Cuq, 2001; Dodman & Sá, 2005). Women account for more than half of the whole country's workforce, having an important role in the communities and in the continuation and preservation of cultural values that are the support of different economic activities (Cardoso et al., 2018). In the archipelago, they are the ones responsible for shellfishing and the traditional management of this resource which is their main economic activity (Biai, 2015; Cardoso et al., 2018). Using spoons or machetes they collect bivalve species such as *Tagelus adansonii*, *Senilia senilis*, *Crassostrea gasar* and *Cassostrea tulipa* during low tide and often gathered in groups over the mudflats.

Those bivalves are the main protein and monetary income sources for locals, particularly during the seasonal food shortage periods which happens between July and November (the period where there is no rice and there is a deterioration of the nutritional state of the population) (Programa Alimentar Mundial, 2013). At the same time these bivalves also have strong ties to cultural practices, forming the main base of

several cultural ceremonies (Biai, 2015; Biai et al., 2003; Pierre Campredon, 2014; Cardoso et al., 2018; Tiniguena & IBAP & FIBA, 2013). The most important ceremony is called “Paga Garandeza” and is the foundation of the Bijagó social structure. This ceremony is based on the transmission of knowledge from older generations to younger ones, with the last ones offering services in return (Catry & Regalla, 2018; Saraiva, 2015), and the passage of individuals from younger to older social groups. The realization of this ceremony strongly depends on benthic resources (used to cook dishes as offerings) especially for women, as the ceremony can only take place above a given threshold of collected *T. adansonii,* and its low availability can stagnate the progression across the Bijagó social structure (hence without them they cannot make the dishes).

During the dry season, between November and April, women go “*campaigning*”, a more intensive way of bivalve exploitation. *S. senilis* which is often targeted then, is not directly used in cultural practices but is very important as it is part of many meals cooked not only for the ceremonies but on a daily basis. In recent years, observations from the field suggest that *S. senilis* campaigns with solely commercial purposes are becoming increasingly frequent, as also seen in the Sine Saloum Delta, Senegal (Niang et al., 2020).

Women share the intertidal flats of the Bijagós with many waders that spend the winter in this area and find in these their prime foraging habitat. Species such as Sanderling (*Calidris alba*) , Red knot (*Calidris canutus*), Curlew sandpiper (*Calidris ferruginea),* Ringed plover (*Charadrius hiaticula*) and Whimbrel (*Numenius phaeopus*) feed upon species like *Tagellus adansonii, Senilia senilis* and *Uca tangeri* (Lourenço et al., 2017; Zwarts, 1988). Therefore, the collection of benthic species with commercial purposes and/or for human consumption may create conflicts with their natural predators, such as waders (and fish). It is therefore important to improve the current knowledge on bivalve collection patters by local populations in the Bijagós, not only from the perspective of the humans that are dependent on them, but also on the potential effects associated to other species that also rely on these same resources to complete their annual cycle.

The main objectives of this study were to determine (i) factors influencing bivalve collection and (ii) how the protection status or traditional regulations on different islands may influence bivalve collection patterns.

Materials and Methods

Study area

The Bijagós archipelago is composed by 88 islands and islets located in the West Coast of Africa, in Guinea-Bissau. Of those, 21 islands are inhabited, with the archipelago comprising a total area of 100000 km^2 with 2624km^2 being of land zone. The archipelago has the only active delta islands in the Atlantic Coast of West Africa, conferring it unique characteristics, such as vast areas of sand and mudflats, mangroves, and shallow water channels (Instituto da Biodiversidade e das Áreas Protegidas, 2014a). Guinea-Bissau protected areas cover 26.3% of the national territory, with a total extension of approximately 7500 km^2. Of these,12.4% are marine protected areas and 13.9% terrestrial protected areas (Republic of Guinea-Bissau, 2019). The Bijagós archipelago has three protected areas: the Marine Community Protected Area Urok, the João Vieira and Poilão National Park and the Orango National Park, which shelter a great variety of species of mammals, reptiles, birds, fish, and other species, some of these are vulnerable or endangered, like marine turtles (*Dermochelys coriacea*, *Eretmochelys imbricata* and *Chelonia mydas*) manatee (*Trichechus senegalensis*), hippopotamus (*Hippopotamus amphibius*), sawfish (*Pristis pristis*) and grey parrot (*Psittacus timneh*) (Biai, 2015; Biai et al., 2003; Catry & Regalla, 2018; Instituto da Biodiversidade e das Áreas Protegidas, 2014a). The archipelago was designated as a UNESCO Biosphere Reserve in 1996 (UNESCO, 1996), as a RAMSAR site in 2014 (Dia Sepa Maria Ié Có & Campredon, 2014) and it is also considered the second most important site in the west coast of Africa for migratory birds, especially waders, after the Banc d'Arguin (Biai, 2015; Biai et al., 2003; Instituto da Biodiversidade e das Áreas Protegidas de Guiné Bissau, 2018; Robertson, 2001; Zwarts, 1988).

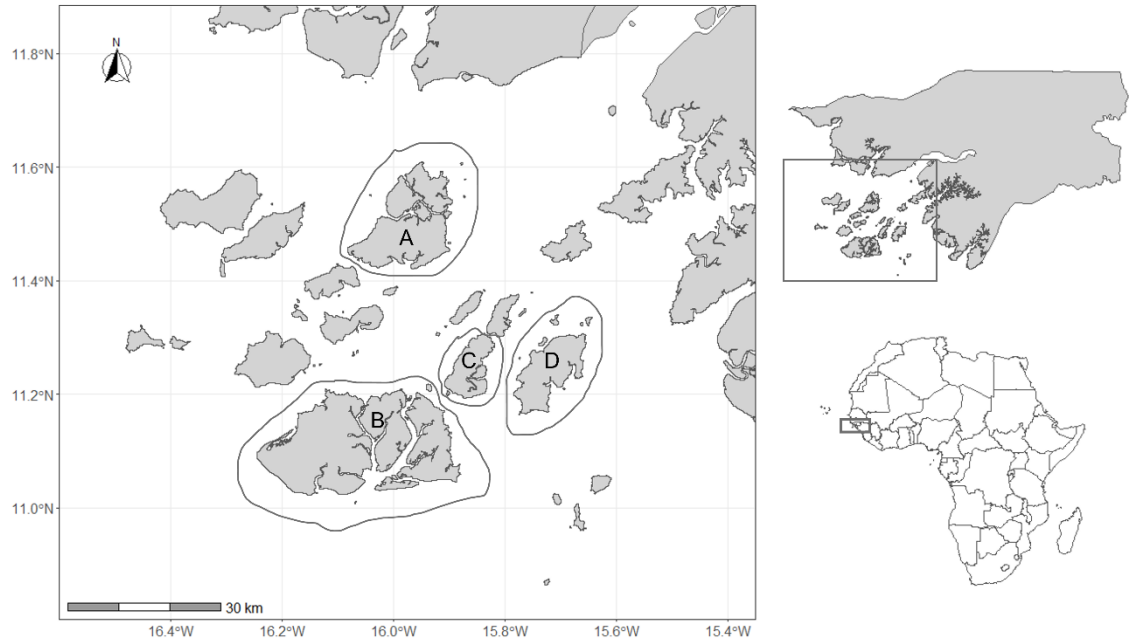

Figure 1 ***The Bijagós Archipelago.*** *Geographic representation of the Bijagós Archipelago and the location of the four study areas/islands: Urok* ***(A)****, Orango* ***(B)****, Bubaque* ***(C)*** *and Canhabaque* ***(D)****.*

The study areas were chosen according to their protection status: The Marine Community Protected Area Urok, located in the northwestern side of the archipelago (11.5207557 N, 15.9602166 W), has a participatory management regimen including the locals; The Orango National Park, located in the southwestern part of the archipelago (11.1767991 N, 15.9858278 W), is managed by IBAP (Institute of the Biodiversity and Protected Areas of Guinea-Bissau), which belongs to the Ministry of Environment; The island of Canhabaque, located in the southeastern part of the archipelago (11.2977759 N, 15.8361912 W), with no formal protection status but with exceptionally strong cultural rules; And the island of Bubaque, located in the central part of the archipelago (11.2784268 N, 15.7362971 W), also without any protection status and where outside influence is most pronounced via tourism and regular flow of people and goods from/to Bissau, considerably eroding the original cultural traditions and rules.

Data collection

Data was collected by interviewing local people that actively collected bivalves on each island. A questionnaire was designed (expanding the work done in a previous pilot study) which comprised a total of 58 questions, divided in 8 sections: interviewee's socio-demographic information; timing of campaigns and regulations; patterns of mudflat usage; purpose and rules of collecting; economic parameters; extinction events and stock status perception; stock management and tendencies; and regulations for stock

management and perception of other mudflat users. The answers to the questions on each section could be either open, numeric or in the Likert scale.

Being the sole responsible for shellfishing, woman where the target group for this study. We aimed for a total of 50 interviews per study area (island) with 10 per village to avoid village specific biases. The study focused on shellfishing of two of the most common bivalve species: *Tagelus adansonii* and *Senilia senilis*, so only women that explored either of these were considered. Since women collect in groups, often starting at a young age, interviewee age started at 10 years old.

The interviews were conducted between March 29th and May 4th 2021. Each interview was made individually whenever possible, lasting around 10 minutes, and questions were asked directly in the local language (crioulo) or translated to the local dialect (Bijagó) when needed. The questionnaires were filled by the interviewer and later the answers transferred into digital format.

Data Analysis

In order to explore variation between islands with different management systems, different comparisons tests were performed for each question type:

1) For the numeric questions normality and homoscedasticity were tested using Shapiro-Wilk and Levene's tests respectively, which showed in all cases that the data was non-parametric. Kruskal-Wallis tests were then used to test for differences between islands, followed by a pairwise Wilcoxon test with the Bonferroni adjustment method whenever needed. Often numeric responses were given in an interval format, so further processing of such responses was undertaken. In those cases, when an interval was reported, the mid-point value of the interval range was considered.

2) For the agreement level questions, where interviewees were asked to rate their agreement level with the presented statements on the Likert scale, and given the data was again non-parametric, a Kruskal-Wallis test was used to investigate differences in the distribution of the answers between islands, followed by a Dunn's test for multiple comparisons of independent samples whenever post-hoc tests were needed.

Some open questions regarding main occupation and income generating activities needed further grouping as follows: Sea (fishing, shellfishing, etc), Land (agriculture, wood, etc) and Other (studying, cooking, etc).

The amounts of *S. senilis* collected was converted to dried volume (interviewees indicated that a 25 L bucket of *S. senilis* equates 3 L when dried). And for *T. adansonii* the raw amount collected was considered since women do not dry it as is the case with *S. senilis*.

All data was analyzed using Rstudio 1.4.1717, with functions ggplot2, dplyr, carData, plyr, reshape2, PMCMR.

Results

Interviewee's socio-demographic information

A total of 182 interviews were completed (46 in Urok, 42 in Orango, 50 in Bubaque and 44 in Canhabaque). Most of the interviewees had between 20 and 30 years of age, with women in their 20's being present at higher frequency in Bubaque and Canhabaque and women in their 30's in Urok (Fig. 2A). The majority of their families were composed by approximately 4 to 10 elements (Fig. 2B). Regarding the main occupation, women with both sea and land-based activities were predominant (Fig. 2C), with the main source of income originating from sea-based activities (Fig. 2D).

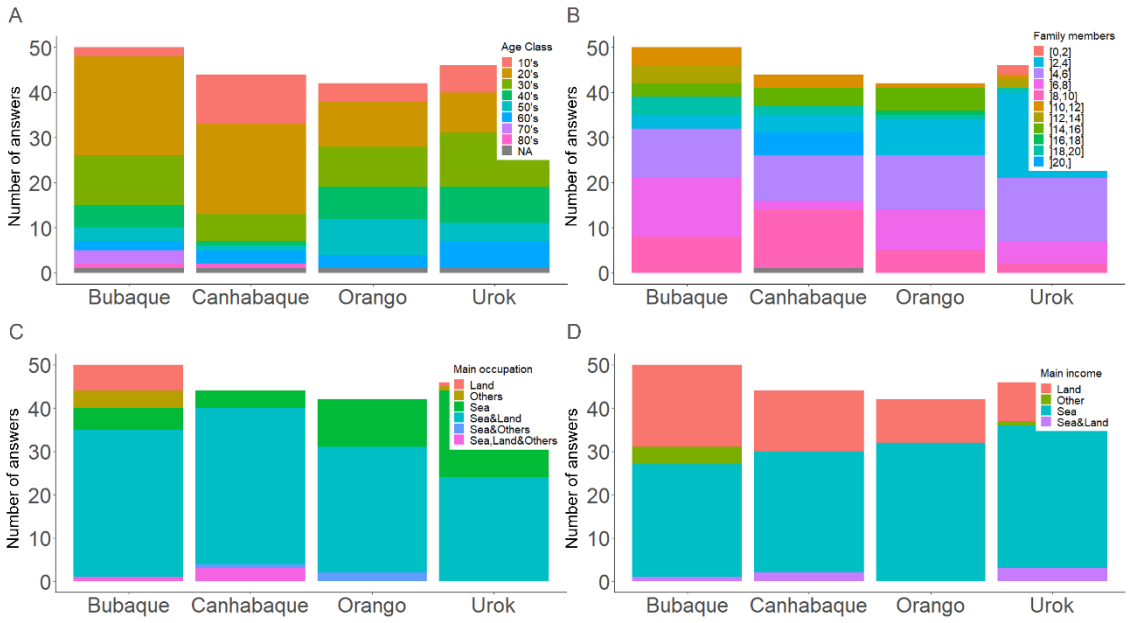

Figure 2 ***Socio-Demographic information of the interviewees.*** *Between island variation on age classes (A), number of family members (B), main occupation (C) and main source of income (D).*

Timing of campaigns and regulations

The shellfishing collection campaigns usually start during the dry season (November-April), most often between November and December and usually last 2 to 3 months (Fig. 3A&B). According to the women interviewed the most targeted species are *S. senilis* followed by *Crassostrea sp*.

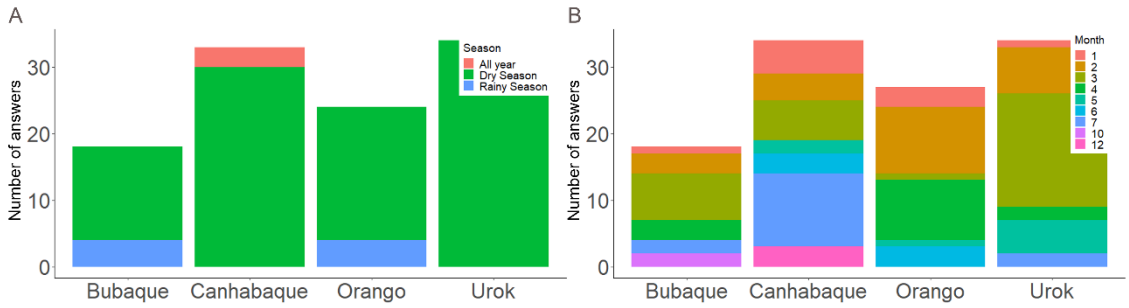

Figure 3 ***Shellfish collection campaign timings.*** *Between island variation on starting season (A) and duration of campaigns (B).*

The rules for collecting *S. senilis* remain the same during and outside the campaigns period in every island. In Urok, women normally only collect large individuals and are forbidden to sell individuals with the shell to outside of their island, with the campaigns usually taking up to 3 months. In Orango the size and shell "rules" are the same as in Urok (only large individuals can be taken and only individuals without shell can be sold outside of the island). Some mudflats are interdict and if they collect in other islets and must use boats as a way of travel, boat owners limit collection to a quota of 2 rice bags (50-60 kg) of bivalves per person. When processing the individuals in the mudflats, women don't throw the boiled water from opening them on the waterline (arguing that if thrown near the waterline it will kill the growing *S. senilis*), but rather throw it in higher ground far from the waterline. The same happens in Canhabaque, with the addition that women also ask the "*régulo*" (local figure of authority, elder) for permission before the starting collection. In Bubaque, similarly to the other islands, women normally only collect large individuals, even though women from Bruce village also reported that selling is prohibited.

For *T. adansonii* some of the described rules for collecting were: not selling (Orango and Bubaque); not selling with shell outside of the island (Canhabaque and Urok); collecting mostly for own consumption and ceremonies; collecting medium to large sizes.

Even though is not a rule, women sometimes do ceremonies and or offers before the season for collecting, asking the "*régulo"* of where they collect for his permission.

Patterns of mudflat usage

S. senilis was collected more often in Canhabaque (5.4 ± 0.3 days), Orango (4.5 ± 0.3 days) and Urok (4.4 ± 0.3 days), with Bubaque having significantly lower collection frequency (2.8 ± 0.3 days) than all other islands ($P < 0.01$ in all cases; Fig. 4A). For *T. adansonii*, Bubaque showed the lowest collection frequency (1.5 ± 0.3 days), Orango and Urok had similar collection frequency (2.1 ± 0.3 days and 2.1 ± 0.5, respectively). And Canhabaque had the highest collection frequency (4.8 ± 0.5 days) being significantly different form all other islands ($P < 0.001$; Fig. 4B).

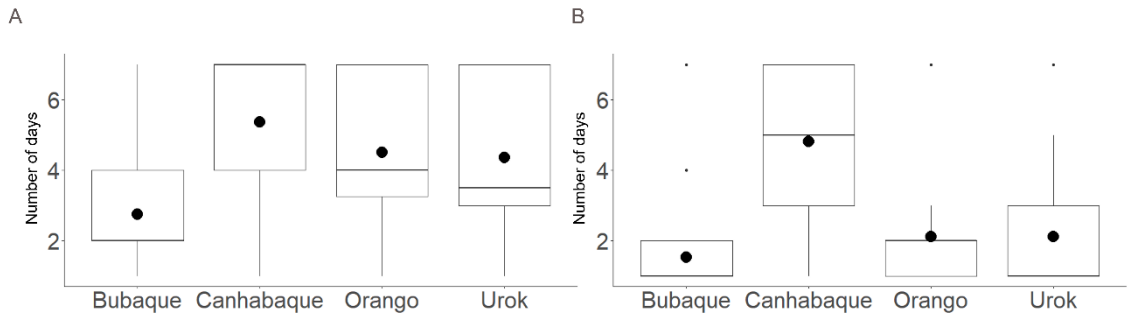

Figure 4 ***Weekly frequency of collection of S. senilis (A) and T. adansonii (B).*** *The whiskers on the boxplot represent the maximum and minimum value and the mean value is shown with a dot.*

In Urok and Canhabaque women mostly agreed to always using the same mudflats. Conversely, in Bubaque, approx. 70% of the interviewees strongly disagreed to going to the same mudflat, thus differing significantly from those two islands ($P < 0.001$ in both cases). In Orango, the answers were mixed with no clear pattern emerging (Fig. 5A). Even though women mostly agreed with using only the mudflats attributed to their village, there were differences between islands ($KW = 10.426$, $df = 3$, $P < 0.05$). In Orango about one fifth disagreed with this statement (± 20%) which differed significantly from Canhabaque and Bubaque ($P < 0.05$ for both cases), with both having approximately 90% of the women strongly agreeing to always going to the same mudflat. But there were no significant differences found between Urok and Orango ($P > 0.05$) (Fig. 5B).

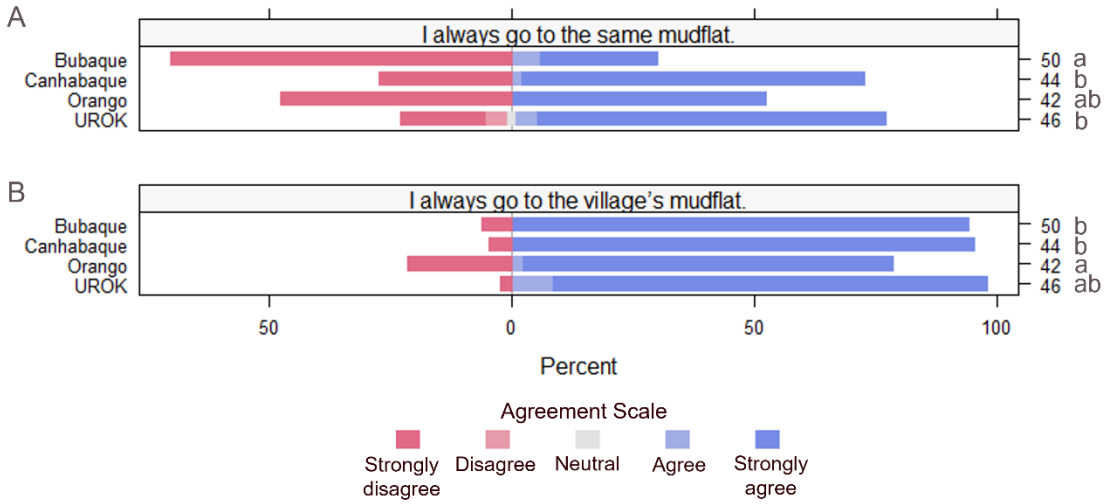

Figure 5 ***Fidelity to shellfish collection patch at the mudflat (A) and village scales (B)****. Different letters indicate significant differences found between study areas. In A: (P < 0.001); in B: (P < 0.05).*

Group size was mostly of 2-10 women in Bubaque and Orango, of 10- 20 in UROK, and groups of more than 50 people were only recorded in Canhabaque.

Women generally disagreed with collecting at the same frequency throughout the year, but significant differences were found between islands ($KW= 11.549$, $df =3$, $P < 0.01$). The differences were found between Urok and Canhabaque, with about 20% of women agreeing to collecting at the same frequency through the year in Urok and Bubaque (Fig. 6A). It is in Bubaque and Urok where most woman disagreed with collecting during the campaigns, whereas in Orango is where they mostly agreed (Fig. 6B).

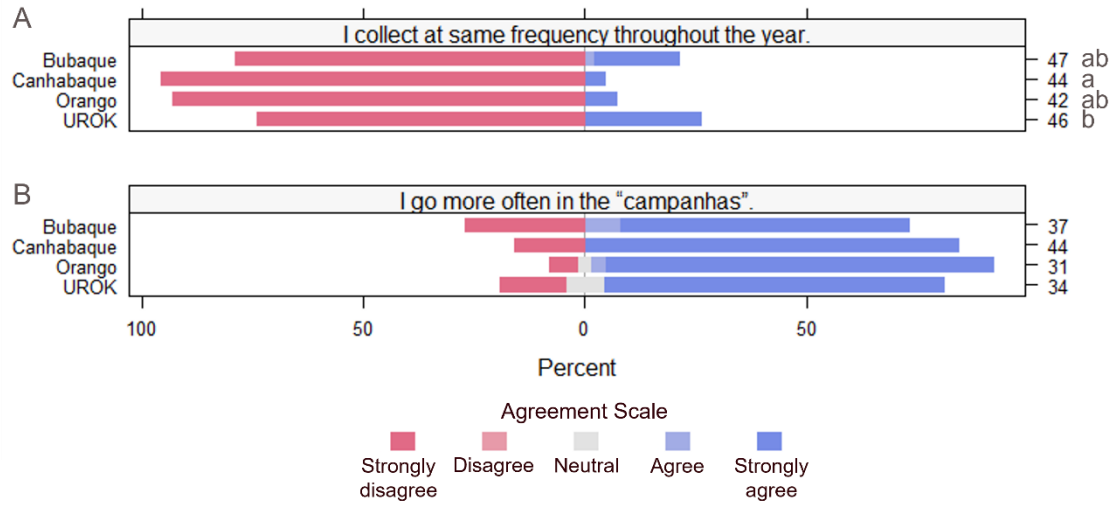

Figure 6 ***Frequency of shellfish collection throughout the year (A) and during campaign season (B).*** *Different letters indicate significant differences found between Study Areas. In A: Canhabaque x Urok (P < 0.05).*

Purpose and rules for collecting

The primarily collection purpose in most islands for *S. senilis* is selling (Fig. 7A) whereas collection for cultural practices is seldom the purpose, with vast the majority of the interviewees strongly disagreeing to it (Fig. 7B). Collection for own consumption was the second purpose of collection, although most women in Canhabaque and Urok strongly disagreed with the latter (Fig. 7C).

For *T. adansonii*, selling was rarely reported as the purpose of collection, except in Canhabaque and some women in Urok (Fig. 8A). Cultural practices were the second purpose of collection, with women in Bubaque and Orango agreeing with this being a relevant objective (Fig. 8B). The primarily collection purpose is own consumption in almost all islands except in Canhabaque (Fig. 8C).

For both bivalves, Canhabaque was the island where most of the women agreed that the main purpose of collection was selling, whereas in Orango most disagreed with selling being the main destiny of collected bivalves.

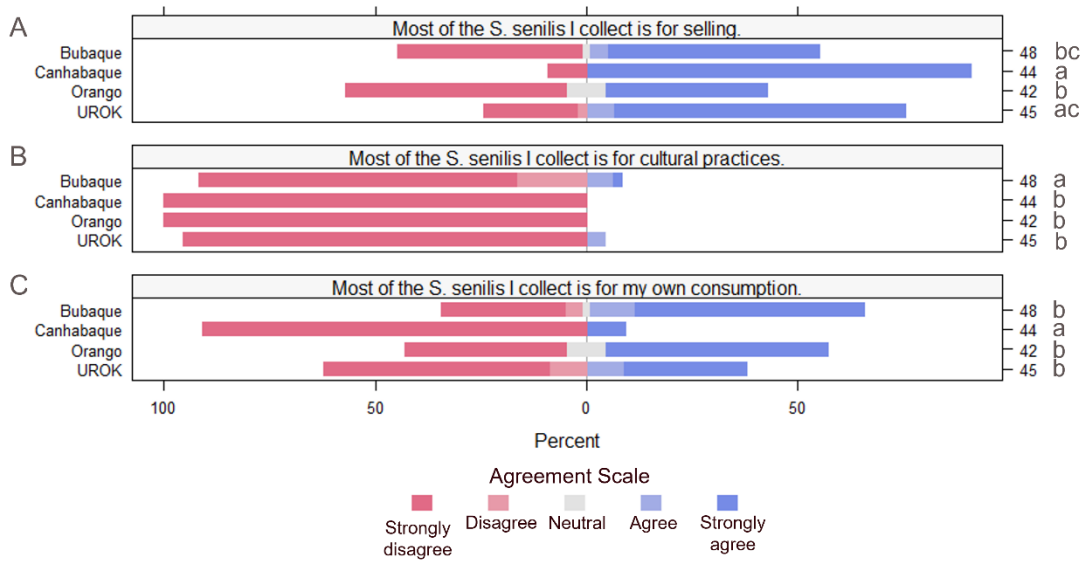

Figure 7 ***Main purpose of S. senilis collection: selling (A), cultural practices (B) and own consumption (C).*** *Different lowercase letters indicate significant differences found between study areas. In A: (P < 0.05); in B: (P < 0.01); in C: (P < 0.05).*

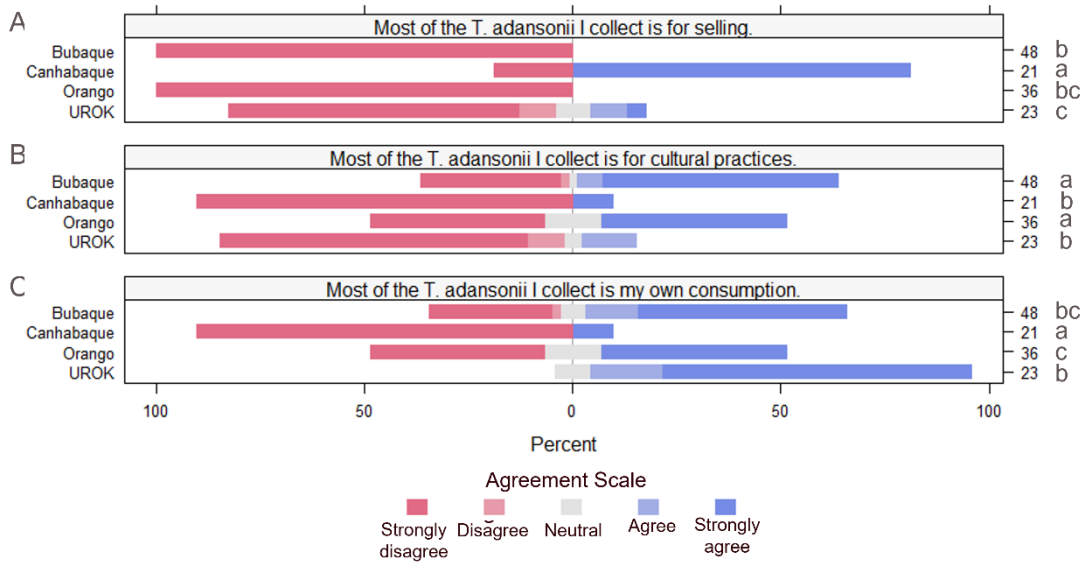

Figure 8 ***Main purpose of T. adansonii Collection: selling (A), cultural practices (B) and own consumption (C).*** *Different lowercase letters indicate significant differences found between study areas. In A: (P < 0.05); in B: (P < 0.05); in C: (P < 0.05).*

All women from Orango and Canhabaque strongly agreed to the existence of traditional rules for collecting both species. However, for *S. senilis*, the answers in Bubaque were significantly different from those of the other three islands, with Bubaque having a higher percentage of women strongly disagreeing with the existence of rules (>25%) (Fig. 9A). For *T. adansonii*, there were no significant differences between islands, even

with few women in Urok and Bubaque strongly disagreeing with the statement. (Fig. 9B).

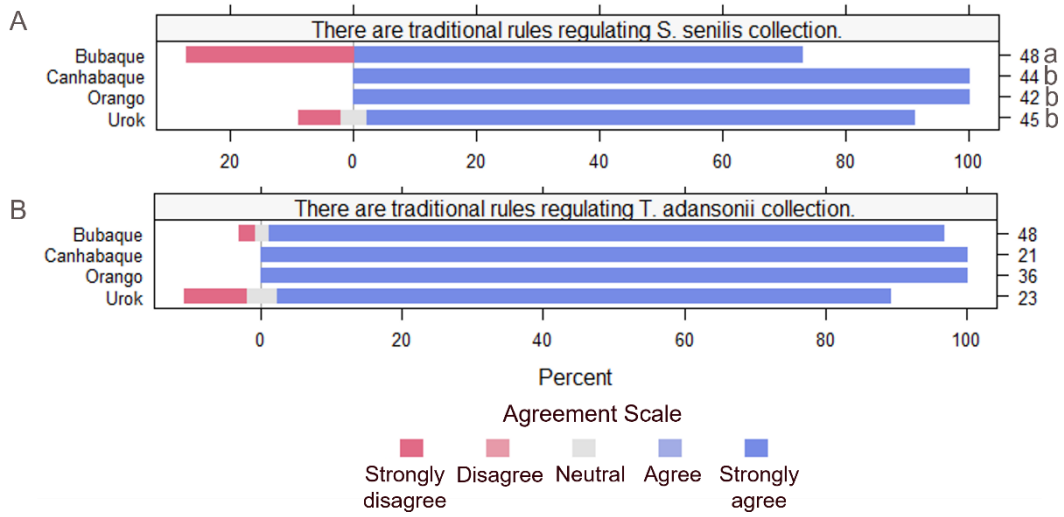

Figure 9 ***Traditional rules regarding S. senilis (A) and T. adansonii (B) collection.*** *Different lowercase letters indicate significant differences found between study areas. In A: (P < 0.05).*

Economic parameters

Regarding the amounts collected. there were no significant differences found between the islands for *S. senilis*, (P = 0.059) with most women reporting to collect on average less than 5 L daily on every island. Bubaque had the lowest average amount collected of all islands (1.89 ± 0.39 L), followed by Canhabaque (2.68 ±0.37 L) and Urok (3.25 ± 0.40 L) with Orango having the highest (3.67 ± 0.38 L), but no statistically significant differences were found (Fig. 10A). On the other hand, *T. adansonii*'s quantities can range from 1 to 25 L (with shell). Woman from Canhabaque report to collect on average more than in the other three islands (11.24 ± 1.48 L), followed by reports from Bubaque and Orango (9.4 ± 0.98 L; 8.26 ± 1.15 L, respectively), with Urok having the least amount collected on average (2.33 ±1.72 L; Fig. 10B) and being significantly different from all the other islands (P < 0.001 in all cases).

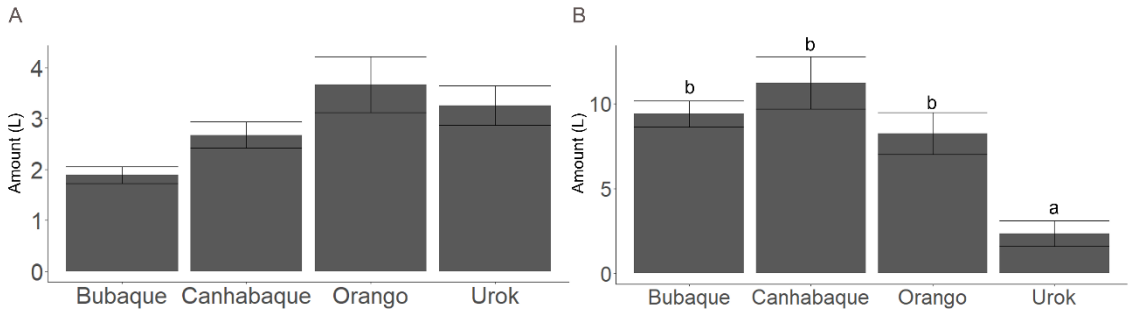

Figure 10 ***Variation on daily average (±SE) amounts (in L) of S. senilis (A) and T. adansonii (B) collected.*** *Different lowercase letters indicate significant differences found between study areas. In B: (P < 0.001).Y axis represents the dry amount for S. senellis and raw for T.adansonii.*

When it comes to selling prices, 1 L of *S. senilis* can vary between 350 xoF and 1000 xoF (ca. 0,5€ to 1,5 €) across islands, but most women sell at 500 xoF (0,76 €). Bubaque was the island with the highest average price reported (845 ± 46 xoF; ca. 1.29 ± 0.07€), followed by Orango (643 ± 35 xoF; ca. 0.98 ± 0.05 €) and Canhabaque (519 ± 33 xoF; ca. 0.79 ± 0.05 €), with Urok having the lowest reported average (457 ± 35 xoF; ca. 0.70 ± 0.05 €; Fig. 11A). The weekly income reported ranged from 500 xoF to 35000 xoF (53,50 €), with most women reporting a weekly income up to 5000 xoF (7,64 €). Orango is the island with maximum reported income (up to 35000 xoF). Also on average, the island with the highest reported income was Orango (19571 ± 2183 xoF; ca. 29.84 ± 3.33 €), followed by Urok (6931 ± 1673 xoF; ca. 10.57 ± 2.55 €) and Canhabaque (5049 ± 1517 xoF; ca. 7.70 ± 2.31 €), with Bubaque having the lowest average (3037 ± 1828 xoF; ca. 4.63 ± 2.79 €) (Fig. 11C). Across the islands women usually sell *S. senilis* on their own island, with only a small part being sold to Bissau, but women from Orango sell more to Bissau than in their own island (59%) (Fig. 11E).

For *T. adansonii* women only sell on the islands of Canhabaque and Urok (Fig. 8A), and the price ranges from 500 xoF to 2500 xoF (ca. 0,76 € to 3,84 €), with the women selling mostly between 700 xoF (ca. 0,76 €) and 1500 xoF (ca. 1,5/2,3 €) (Fig. 11B). The average reported price was similar in Urok (1167 ± 198 xoF; ca. 1.76 ± 0.30 €) and in Canhabaque (1111 ± 124 xoF; ca. 1.69 ± 0.19 €), and no statistical differences were found between the islands (KW = 0.16935, df = 1, P > 0.05). The weekly income ranged from 1500 xoF to a maximum of 15000 xoF (ca. 2.29 € to 22.87 €), with most of the women reporting a weekly income up to 5000 xoF (ca. 7,64 €). The reported weekly average income was higher in Canhabaque (5833 ± 819 xoF; ca. 8.89 ± 1.25 €) than in

Urok (5500 ± 1577 xoF; ca. 8.39 ± 2.40 €), but again, no statistically significant differences were found between the two islands (KW = 0.97426, df = 1, P > 0.05, Fig. 11D). Women usually sell *T. adansonii* on their own island, with few selling to Bissau and Bubaque. (Fig. 11F).

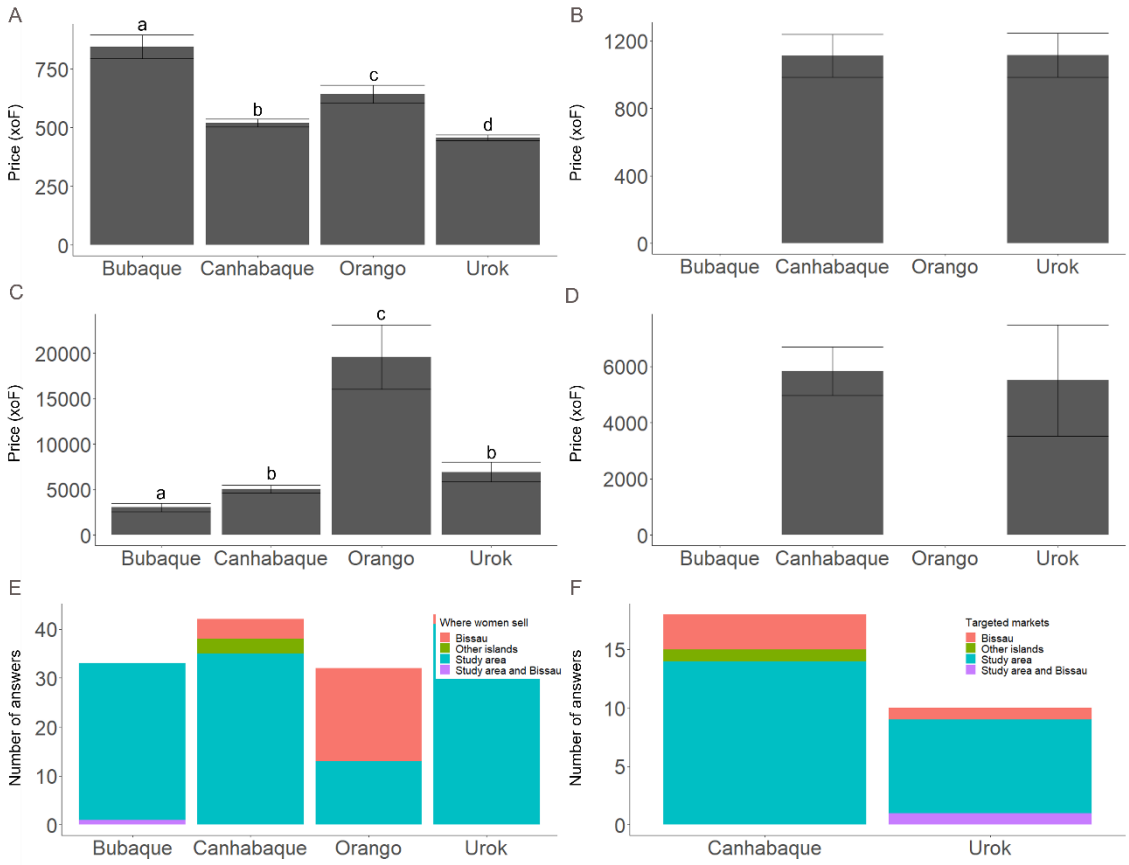

Figure 11 ***Variation on S. senilis and T. adansonii on average (±SE) selling prices (A, B), average (±SE) weekly income (C, D) and selling locations (E, F).*** *Different lowercase letters indicate significant differences found between study areas. In A (P < 0.05); in C (P < 0.05).*

The profit made from selling both *S. senilis* and *T. adansonii* is used for all basic needs such as food, medicines, clothes, utensils, etc. The most common answer was rice (for both species). For *S. senilis* it was followed by "other uses" such as cooking and collecting utensils and medicine, with the third most common answer being school expenses, with other alimentary products as the fourth and clothes as last. For *T. adansonii* the second most common answer was school expenses, followed by alimentary products and clothes, with other expenses appearing last.

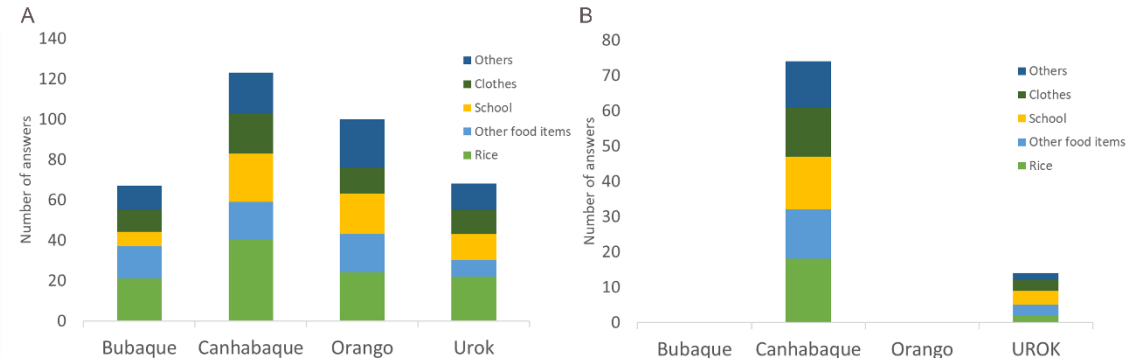

Figure 12 ***Uses for the profit made from selling S. senilis (A) and T. Adansonii (B).***

Extinction events and stock status perception

Periodic stock reductions and extinction events of *S. senilis* were reported by 23% of all women interviewed. Of those 76% were periodical stock reductions and 24% were extinction events. Periodical stock reductions were reported in the islands of Orango (78%), Bubaque (16%) and Canhabaque (6%). The extinction events were reported to happen between 2006 and 2010, lasting around two to three years and were reported in Orango (Eticoga), Bubaque (Ancamona) and Canhabaque (Inorei and Menegue).

For *T. adansonii*, 31% of the women reported extinction events with a lot of variation regarding their timing. These can be grouped in: before the 2000's; from 2000 to 2010; and from 2010 to 2020, with population recovery noticed between 2013 and 2020. Eighteen percent of those women belonged to Urok, with their age range being from 18 to 59 years old, indicating extinctions occurred between 2000 and 2010. Forty one percent belong to Orango, with an age range from 21 to 65 years old, and reported extinctions from the 90's to around 2018. Twenty three percent of the women belonged to Bubaque with ages from 20 to 45 years old and indicating extinction events between 2000 and 2019. Lastly, 18% of the women were from Canhabaque with and age range from 14 to 30 years old, and reporting extinctions from 2000 to 2020. Orango had a higher percentage of answers and an earlier time frame for the extinction events, but the causes of such events remain unknow.

Stock management and tendencies

The majority of women strongly agreed to collecting shellfishes even when the stock is low and no significant differences were found between islands (Fig. 13)

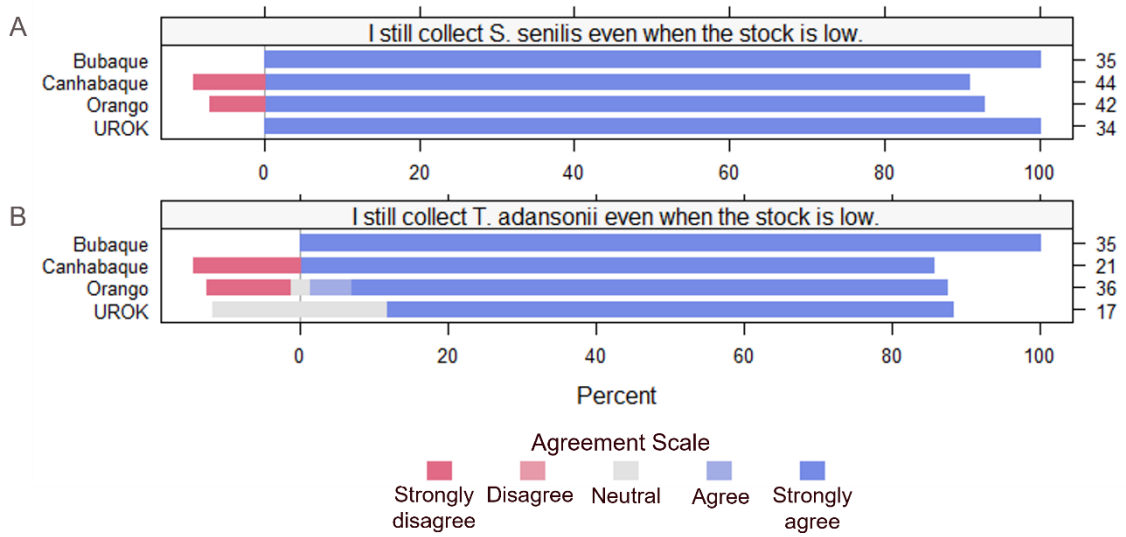

Figure 13 ***Collection of S. senilis (A) and T. adansonii (B) on low stocks.***

A high percentage of women strongly disagreed to collecting more *S. senilis* in the current year compared to the previous one (> 40% in all islands; Fig. 14A). But for *T. adansonii* a high percentage of women strongly agreed to collecting more in the current year compared to the previous one, in most islands. Bubaque and Urok showed an almost 50-50% split, but in Orango, approximately 70% of women disagree with that general pattern (Fig. 14B).

Regarding shell sizes (i.e., size of collected individuals) of *S. senilis* most women disagreed that this year's individuals were larger than those collected in the previous year, with no statistically significant differences found between the islands, even though in Urok the answers showing a ratio of approx. 50-50% (Fig. 14C). Likewise, for *T. adansonii*, no statistically significant differences were found between the islands (Fig. 14D).

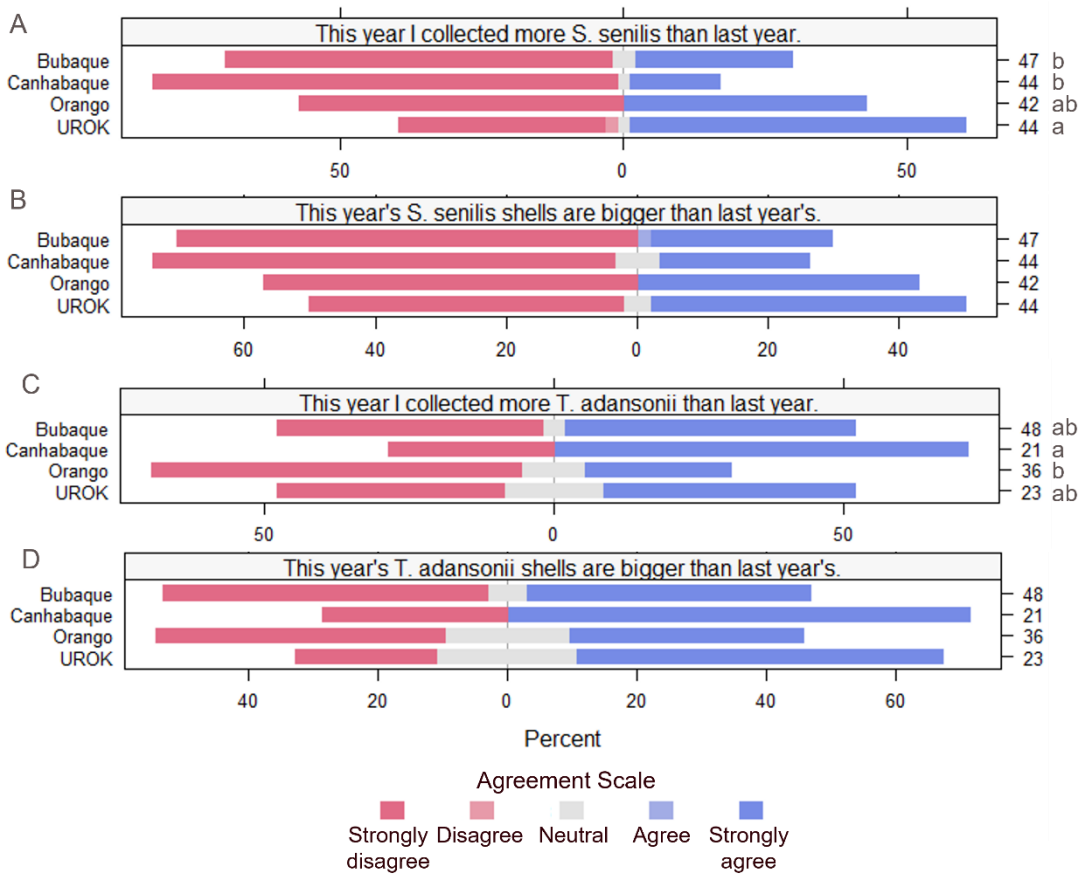

Figure 14 ***Amount and sizes of S. senilis (A, B) and T. adansonii (C, D) collected in relation to the previous year.*** *Different lowercase letters represent significant differences found between study areas. In A: (p-value ≤0.01); in C (P < 0.05).*

When considering a large time period (10 years instead of one), the majority of women strongly agreed that it is currently more difficult to collect *S. senilis* than 10 years ago (Fig. 15A). In Bubaque and Canhabaque the majority of women also strongly agreed that the individual collected were smaller compared with 10 years ago, whereas in Orango and Urok the reverse pattern was reported (Fig. 15C). For *T. adansonii* the majority strongly disagreed with being more difficult to collect it at present (55%-90%, Fig. 15B). And the same is apparent with regards to the size of individuals, with more than 50% of women disagreeing in all islands, that the individuals are smaller now compared to 10 years ago, resulting in no statistically significant differences being detected between islands (Fig. 15D).

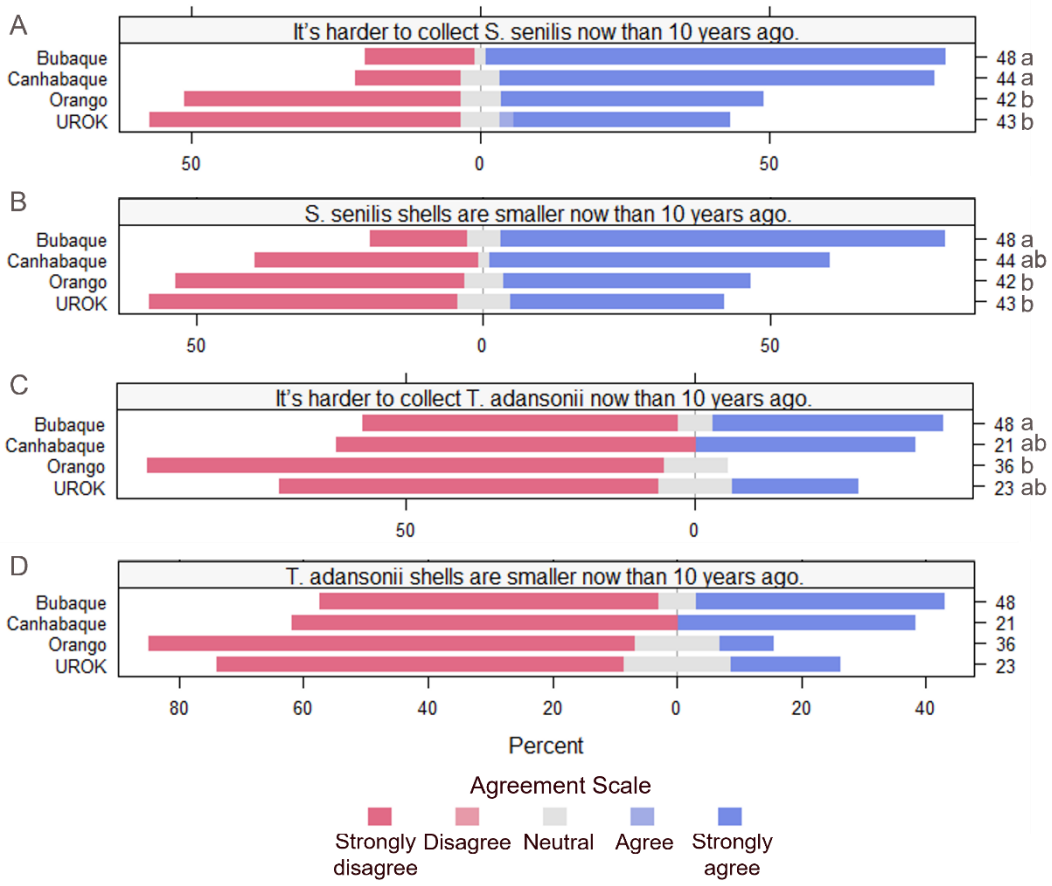

Figure 15 ***Amount and sizes*** *of* ***S. senilis (A, B) and T. adansonii (C, D) collected in relation to 10 years ago.*** *Different lowercase letters indicate significant differences found between study areas. In A: (P < 0.05); in B and C: (P < 0.01).*

Regulations for stock management and perception of other mudflat users

For both *S. senilis* and *T. adansonii*, the vast majority of women strongly agreed that the existing traditional rules are enough to ensure a sustainable use, with no need of extra regulation. However, some differences between islands were found for *S. senilis*. Woman from Bubaque strongly agreed (up to 90 %) that the existing rules are enough to ensure sustainability, which was significantly different from responses in Urok, where a larger percentage of neutral answers were given (approx. 10% of neutral responses) (P < 0.01; Fig. 16A&B).

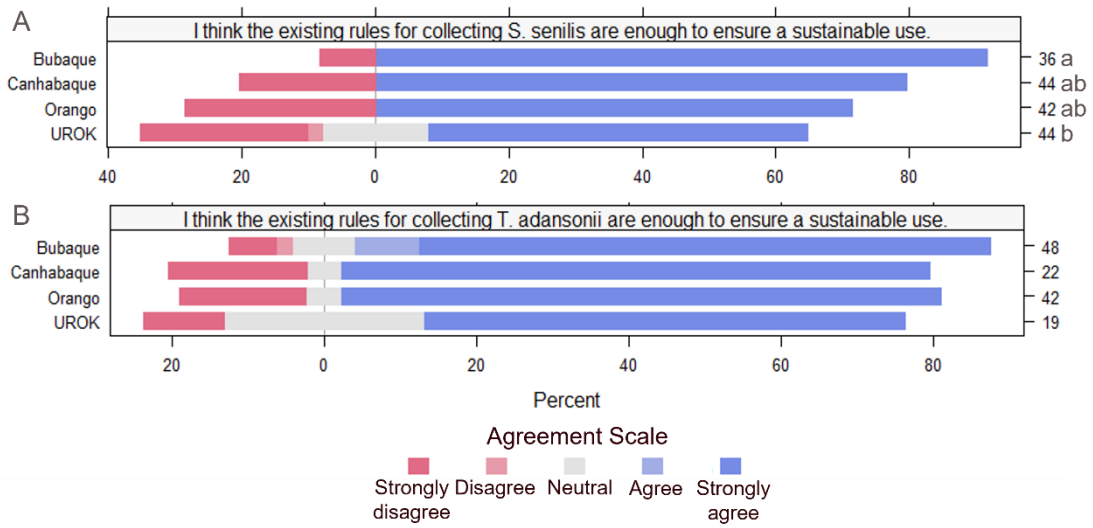

Figure 16 ***Efficiency of the existing rules for collecting S. senilis (A) and T. adansonii (B).*** *Different lowercase letters indicate significant differences found between study areas. In A (P < 0.01),*

Regarding the need for extra regulation for *S. senilis* collection, Urok had the highest percentage of strongly agree answers (approximately 55%), compared to the rest of the islands and showing significant differences from all (Fig. 17A). For *T. adansonii* most women strongly disagreed with the need of extra regulations, with no statistically significant differences found between islands. Nevertheless, women from Urok agreed the most (approximately 35% of strongly agree answers) that more regulations are needed (Fig. 17B).

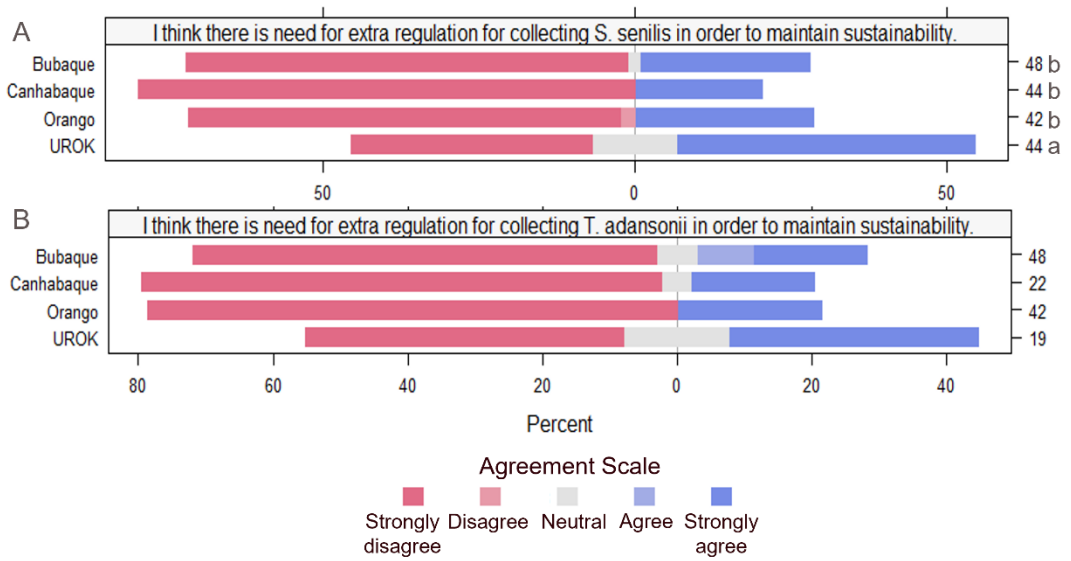

*Figure 17 N****eed of new or extra regulation for collecting S. senilis (A) and T. adansonii (B).*** *Different lowercase letters indicate significant differences found between study areas. In A (P < 0.05).*

Regarding other mudflat users, women were asked if they would encounter waders, other women, fishermen, tourists, students and researchers. Since women collect in groups to the mudflats all answered that they see other women there.

When asked if they would often see waders feeding close to them, most women strongly disagreed with the statement, with Canhabaque being the island with the highest strongly disagree percentage (approx. 80%) and differing significantly from Orango ($P < 0.01$) and Bubaque ($P < 0.05$; Fig. 18A). The opposite happens when asked if they see waders feeding far from them, with most women strongly agreeing with that statement. Canhabaque had the highest strongly agree answers (approx. 80%), but was only significantly different from Orango ($P < 0.01$; Fig. 18B)

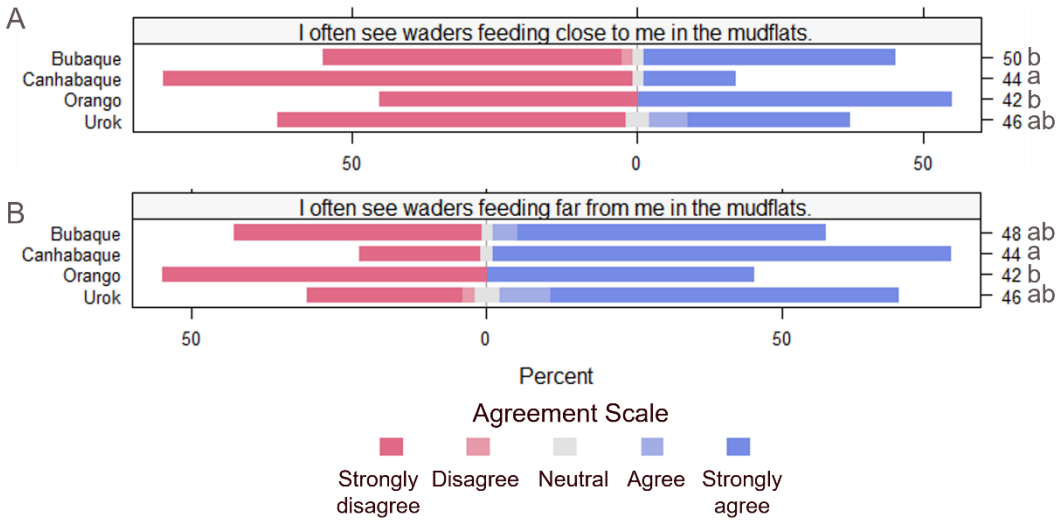

Figure 18 ***Waders proximity.*** *Different lowercase letters indicate significant differences found between study areas. In A and B ($P < 0.05$).*

Most women strongly agreed to see fishermen on the flats (> 70% in all cases) and no significant differences were found between the islands (Fig. 19A). Some reported that they approach them and ask for fish. Regarding the presence of tourists most women strongly disagreed with seeing them on the mudflats (> 50% in all cases), but significant differences were found between the islands of Canhabaque and Bubaque ($P < 0.001$; Fig. 19B) with more women from Bubaque reporting to seeing tourists while women from Canhabaque do not. Women mostly disagreed with seeing students or researchers on the mudflats and no significant differences were found between the islands. Even so some women in Bubaque and Orango agreed to seeing them (Fig. 19C).

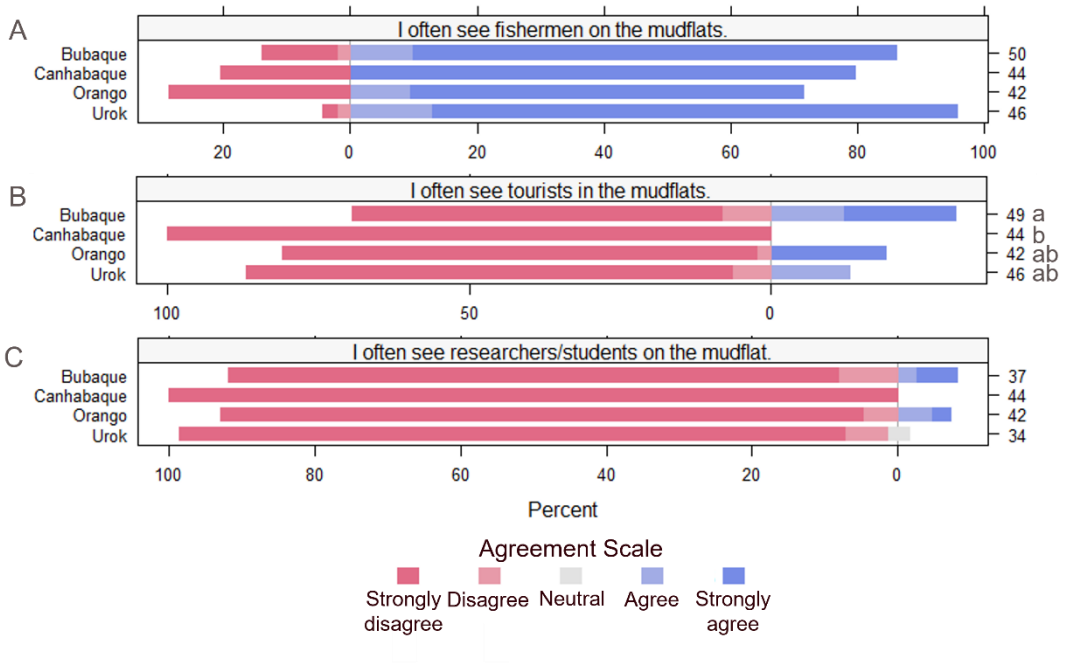

Figure 19 ***Other human presence in the mudflats.*** *Different lowercase letters indicate significant differences found between study areas. In B: Bubaque x Canhabaque (P < 0.001).*

Discussion

All women from any island develop the same main activities and have similar sources of income. All islands are extremely dependent on fisheries, but most women have sea and land-based activities due to the periodicity of resources (rice, salt, agriculture, among others), and rotate between these activities. The fidelity to the mudflats is influence by quality and quantity of bivalve available, alongside the previous knowledge of its location, with most women staying faithful to the mudflats used and owned by their village.

The main collection purpose of bivalves can affect the frequency of collection and the size of the groups that go to the mudflats. For selling purposes women can collect on a daily basis, but when for own consumption they go only when needed. The main reason for collecting *S. senilis* is monetary income, whereas for *T. adansonii* is usage on cultural practices. For both species, the highest frequency of collection (average) is reported on the study area where the main purpose is selling which is Canhabaque. This study area is the one with most strong cultural influences and can be considered the most isolated in terms of transportations and outside visitors. This can explain the importance of collecting *S. senilis* for selling and therefore the higher collection

frequency, since these could indicate a higher dependency on this resource for the families livelihood.

The dry season (November to April) is when women go with higher frequency to the mudflats and it is when the campaigns take place. *S. senilis* is the fastest way to generate income compared to other species targeted during the campaigns. This income, though low, is what sustains local families, and is used to satisfy all basic needs.

The influence of both the protection status and traditional regulations of the study areas, even though not noticeable on the average amounts collected, can explain the women stock perceptions for *S. senilis*. According to the results, women in Urok (study area with protection status) perceived to collect larger amounts than the women in the study areas with no protection status (Bubaque and Canhabaque) even though there were no differences found in the size collected. When it comes to the 10-year comparison women from both study areas with protection status (Orango and Urok) reported that is easier to collect nowadays while the opposite happened in the study areas with no protection status. Women also reported more large sized individuals in the study areas with protection status and less in Bubaque.

The existing rules, particularly in the non-protected areas are intertwined with traditional beliefs and specifically established for *T. adansonii*, as a way to promote its populations growth. Even though most women agree that the existing traditional rules are enough to ensure the sustainability of both *S. senilis* and *T. adansonii*, protection status and management of the island can positively affect bivalve stocks

Collection frequency, rules and purpose

Women go to the mudflats almost daily to collect bivalves with the intent of making income to sustain their families. *S. senilis* is collected more often in Canhabaque, Orango and Urok and less so in Bubaque (Fig 4A), which is likely due to the fact that in Bubaque even though women collect mostly for both selling and own consumption (similarly to the study areas with protection status) they have more protein sources (due to the constant traveling to and from the mainland), so collection of *S. senilis* likely happens only when needed (Fig. 7). Currently, the increasing shift tendency of the main purpose for collecting *S. senilis* from own consumption to selling, may be due to the increasing difficulties and pressures (financial, political – constant instability, environmental – climate change, sea level rising, social – younger generations leaving

the archipelago) the families face. Moreover, even though women do not collect *S. senilis* for cultural practices, it ends up being present because it is the main source of protein and is used in the dishes prepared for the ceremonies substituting fish. Canhabaque was the study area where own consumption was seldomly the main purpose of collection differing from all other study areas (even though it only differed from Bubaque and Orango when the main purpose was selling) this might be explained as mentioned above by the limited contact with transportation to and from the island to the rest of the archipelago and the mainland.

Canhabaque had the highest reported frequency of *T. adansonii* collection compared to the other islands (Fig. 4B). This could be because in Canhabaque women collect mostly for selling purposes, while in the other islands they only collect this species when needed, mainly for own consumption and cultural practices (Fig 8). In Orango and Bubaque it is also completely forbidden to sell, since this species started to reappear, recovering from its temporary extinction, as a way of preserving it not only for ceremonies but also for the future generations. The most common answer when asked why the lower collection frequency of *T. adansonii* in the study areas (except Canhabaque) was that this species is harder to collect, as it escapes through the mud more easily and requires a higher level of skill to collect. This is something that most women lack (also due to the absence of teaching) and the time spent collecting this species does not translate into the amounts obtained. So generally, when they only collect when they want to eat it (to change their protein source) or for specific occasions (ceremonies).

The use of the villages' mudflats and the fidelity to the mudflat (Fig. 5) can be influenced by multiple factors, most importantly if a specific village has its own mudflat or if it is shared with other villages, and also the conditions of the mudflats. The differences between Urok and Canhabaque (where women reported to mostly use the same mudflats) and Bubaque (whereas they did not) maybe due to knowledge of the best sites to collect each species, the local proximity of those specific mudflats on a given island and the type of shellfish species targeted. Orango had a higher percentage of women disagreeing with using the villages' attributed mudflats compared to Canhabaque and Bubaque which may be because one of the villages doesn't have mudflats nearby, so women must collect in another village's mudflat.

The fact that the number of women that go to the mudflat together is smaller in Bubaque compared to Canhabaque is likely because the women in the last study area collect mostly for selling purposes, and higher numbers means sharing the workload, while women in Bubaque collect mainly for own consumption (Figs.7 & 8).

Collection does not happen at the same frequency throughout the year, as women collect intensively during the campaigns (dry season – November to April) and normally less frequently during the period of rice or tara - *Raphia sp*. (rainy season – May to October). *S. senilis* reproduction starts in October (Tiniguena & IBAP & FIBA, 2013), and women can start collecting in November. The campaigns take about two to three months, but some women collect during the entire year, and the species more targeted are *S. senilis* followed by *Crassostrea sp*. (Fig. 3).

Regarding traditional rules for collecting both species, Bubaque and Urok were the only study areas that had women strongly disagreeing with their existence. A factor that might have contributed to these answers could be miscommunication between the interviewee and the interviewer, as most women do not consider the traditional impositions as "rules" but as cultural practices. The existing traditional rules and beliefs apparently shape the way women collect bivalves, for example, they search for medium and larger individuals, leaving the smaller ones behind as they report the need to "*leave it in order for their children to be able to have some when they grow up*". Women also believe that throwing hot water (used to open the bivalves on site) in the sea will kill the existing individuals, so they throw it at higher ground. In all islands it is forbidden to travel into another island with the whole bivalve, so the flesh needs to be removed from the shell thus, increasing the workload when traveling. Therefore, smaller collected amounts means less work and this "rule" can help reducing collection amount.

Economy

Both study areas with protection status (Orango and Urok) showed a tendency to have higher average amounts *S. senilis* collected when compared with the non-protected areas, additionally, Canhabaque (which has strong cultural influences) also had the same tendency with a higher average amount collected compared to Bubaque (Fig 10A). However, it should be noted that these results were not statistically significant ($P = 0.059$). In any case, this likely reflects the effects of protection status and management, combined with the traditional regulations that translate into higher abundance of

resources. Additionally, Bubaque is a place with higher tourism which allows for more importation of other food products from the mainland (particularly from Bissau) given higher boat movement, which can reduce the role of *S. senilis* as the main nutritional source.

The average amounts of *T. adansonii* reported to be collected are higher on the non-protected areas and in Orango, than in Urok (Fig. 10B). The high amounts reported in Canhabaque can be related to the fact that women on this island collect more with the intent of selling (Fig. 8). For Bubaque and Orango, the high collection skills of the women can also be a factor, as women in both these islands collect less frequently but manage higher amounts than in Urok.

The higher amounts of *S. senilis* collected during campaigns might be explained by the fact that women make camps where they stay for the duration of the campaigns, being able to collect multiple times and leave the collected individuals in higher grounds until at least the following day, drying and packaging the bivalves on the site, and thus not having to carry the individuals collected home and travel considerable distances every day. Also, during the campaigns, women that do not go to the camps have a system called "*abota*", where they make smaller groups (4 to 5 people) and each day all that is collected and the resulting money goes to one group member, in rotation. This can also contribute to the higher amounts and income as more women collect bigger amounts increasing their daily individual profit.

The overall smaller amounts of *T. adansonii* collected in relation to the *S. senilis* could be explained by the fact that collecting *T. adansonii* is much harder because it only occurs in soft sediments which difficult movement and also because this species is more sensitive to disturbance, so a higher level of skill is required for collection and not all women have it, which is likely the main reason why fewer women collect it.

The weekly income is rather small for *S. senilis* (approx. 7,64€), but it is the fastest way to make money, compared to other species such as both *Crassostrea spp.*, for which some women reported they profit more per liter but has a higher associated workload (both species of *Crassostrea spp*. have been part of the locals diet for a long period of time, but were not included in this study because they are not reported as part of waders diet). Orango had the highest reported weekly income average (Fig. 11C) which can be explained by the higher amounts collected and the fact that there is an agreement of the

women with a boat owner to exclusively take them to Bissau for selling the bivalves and sharing the costs.

Women in Canhabaque and Urok reported selling *T. adansonii*, which is forbidden in the other two study areas (Orango and Bubaque) and was a rule made after a local extinction of this species, as the elders believe that the reason it disappeared was a punishment for its overexploitation. In Canhabaque and Urok women can sell it as long as it is without the shell and according to people in the field, there is a specific time when women can collect with the purpose of selling to outside of the island. The weekly income is higher than from *S. senilis* (Fig. 11D) because this species is sold for almost double the amount. It has a higher market value both because it is harder to collect and because of high demand.

Women sell mostly inside the study areas with only a small portion being sold to Bissau (Fig 11E&F). Regular transportation to and from Bissau is difficult in some islands and also adds costs for travelling, therefore reducing income. Hence only some women sell directly to Bissau, those who can afford it. The others sell to people that come to the island that will later sell in Bissau.

Stock reductions, tendencies and future management

Some women indicated that *S. senilis* locally disappeared for a period of approximately 4 years (from 2006 to 2010), this might be due to changes in the climate, since abrupt shifts from the wet and dry years were recorded from 1993 to 2016, whereas from 1968 to 1992 there was a prevalence of dry years (Republic of Guinea-Bissau, 2019). For *T. adansonii* women had difficulty in reported extinction events with temporal precision. They were able to pinpoint sometime between important social periods as the *coups d'état* and also reported that 10 years ago there was no *T. adansonii*, but determining exact years was not straightforward. In addition, extinction events were reported to be asynchronous throughout the archipelago. For example, some reports from Urok indicate that people started noticing its disappearance approximately in 2005, whereas some nearby islands reported it during the 90's, with this specie returning to the archipelago between 2018 and 2020.

Since women search for sites with large individuals, they end up collecting even when the stocks are low (Fig 13). The *S. senilis* amounts collected in Bubaque and Canhabaque are reported to be lower compared to Urok and the individuals collected in

all study areas showed a tendency of being smaller compared to the previous year (Fig. 14A&B). These results may be explained by the depletion of resources throughout the whole archipelago, and the better and more strict management plan that exists in Urok. The present difficulty in collecting *S. senilis* compared to 10 years ago can be explained by the increased exploitation in the past decade and the fact that the main purpose is showing a tendency to be shifting from own consumption to selling (Fig. 15A). In fact, some reports indicate that this income is becoming as important as cashew nut, traditionally the largest seasonal income source of locals. *S. senillis* is reported to be smaller in Bubaque compared to 10 years ago, while in Orango and Urok the reverse happens (with Canhabaque having no differences with any of the other islands) (Fig. 15B), which can be a reflection of better management given the protection status of these two protected islands.

T. adansonii is still recovering from a local extinction event, so presumably it could be argued that over the last decade the stock as increased, which translates to being easier to collect it compared to 10 years ago (Fig 15). In addition, women from the island of Canhabaque reported to collect more than in the previous year differing only from the study area of Orango (Fig. 14C). This difference might be a result of both the increase in stock and of women from this study area collecting more for selling purposes.

Most women agree that the existing traditional rules are enough to help maintain the populations of both species and for those to be available for the next generations, while some stated during the interviews that having more rules could also be beneficial since it could help keep outsiders from overexploiting their resources. The differences found between Urok and Bubaque (marine community protected area and no protection status area) (Figs. 16&17) for *S. senillis* can reflect the impact of unregulated tourism and the "modernization" of these societies and how they can threat the culture and biodiversity in the archipelago (as referred by Biai, 2015; Instituto da Biodiversidade e das Áreas Protegidas, 2014b; Saraiva, 2015) but also the importance of the involvement of local communities in conservation projects and management of protected areas and also on how environmental education and awareness campaigns can also help change or improve the mindsets of the locals and make them more involved in preserving the environment, similarly to what was seen in a study in the Philippines (van der Ploeg et al., 2011). It can also serve as a reminder that traditional knowledge and practices of said local communities must not be disregarded as it has been showed they can improve

and broad the results of conservation and management projects and approaches while also empowering the locals as seen in other studies (Berkes & Davidson-Hunt, 2006; Emperaire & Peroni, 2007; Fikret Berkes, 2000; Maretti, 2015).

Besides fishermen and other women, the contact with tourists and researchers/students is very limited, and the islands with more reported contact are Bubaque and Orango likely due to the presence of higher touristic activity (Fig. 19). Women also do not report having close contact with waders, and mostly see them on the mudflats feeding while, they are collecting but have no knowledge about the species (Fig. 18).

Conclusions & recommendations for future research

S. senilis and *T. adansonii* are very important species for the local communities of the Bijagós archipelago, the first one because it is the main source of income in sustaining the families and of its nutritional value and the second for its high cultural value.

The collection patterns of both species are mainly influenced by the final purpose of collection which then affects the frequency of collection, the size of the collecting groups and the amounts collected. For *S. senilis* women that collect with the purpose of selling, tend to form larger groups and to collect more than women that collect for own consumption. For *T. adansonii*, where the main purposes of collection are for own consumption and cultural practices, women collect less frequently and smaller quantities, and for the cultural practices is only for specific ceremonies. The high level of expertise needed for collecting this species also influences the quantity collected.

The increase of *S. senilis* exploitation due to a large dependence on this resource for monetary income, combined with climate change such as higher frequency of drier years over the past years (that affect environmental factors such as sea level, salinity, temperature, and precipitation), likely influence both the quality and quantity of this bivalve stock. This threatens not only the livelihood and cultural practices of the local population, but also the environmental equilibrium since other species depend on these bivalves for their life and annual cycles.

The study suggests that the protection status and management of the islands affect its bivalve stocks and the existing rules combined with traditional beliefs are a way to preserve and even promote the return of species, as reported for *T. adansonii*. The

causes for *T. adansonii* temporary extinction in the whole archipelago and localized *S. senilis* reductions remain unknown and need to be studied further.

In order to better understand traditional laws and how elders, "*régulos"* and or "*baloberos"* decided those, it would be important to interview these key elements of the Bijagó people. As mentioned above, more bioecology and chemistry studies replicating the climate parameters in the years where temporary extinctions were reported are needed to determine which factors likely caused the temporary extinction and return of *T. adansonii* throughout the whole archipelago and *S. senilis* in some areas. For example, by using dates or years of particular events of local and national relevance on the interviews can help to better establish the timing of disappearance and return.

When women collect *T. adansonii*, they remove the individual from the shell and leave them in salty water to then proceed to cook them, not drying like with *S. senilis*. This makes it hard to measure dried amounts, and even the quantities collected without shell, because they are more certain of the capacity of the recipient used to collect. So, it is easier to estimate amounts with shell, by considering the volume of the recipients they use.

Since *Crassostrea gasar* and *Cassostrea tulipa* are also part of the most exploited species it would be interesting to better understand the collection patterns of these species.

More studies regarding the local knowledge and local perspective on waders that are present in the archipelago and the dynamics between locals and waders would be very interesting to further embrace local and traditional connections with local biodiversity.

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Annex I

Questionnaire

Main goal: Understand how the Bijagó culture influences shellfishing patterns.

Method: questionnaires with local women, using the Likert agreement scale, scored from 1 (strongly disagree) to 5 (strongly agree).

Sample size: 10 interviews x 3 villages x 4 islands =120 interviews

Study area:

- Urok (Formosa, Nago, Chediã): a marine community protected area;
- Canhabaque: no official protection status, managed by local communities with strong cultural values;
- Bubaque: no official protection status, poor community management with loss of cultural values.
- Orango: a National Park

1. Personal/Social/ Economical Questions

    i. Name:

    ii. Sex:

    iii. Age:

    iv. Study area:

    v. Village:

    vi. Social status:

    vii. Family members:

    viii. Main occupation:

    ix. Main source income:

2. Mudflat use habits

    i. How often do you collect *S. senilis*? _____ days/week

    ii. How often do you collect *T. adansonii*? _____ days/week

    iii. I always go to the same mudflat. ○ ○ ○ ○ ○

    iv. I always go to the village's mudflat. ○ ○ ○ ○ ○

    v. How many people do you go with to the mudflat?

    vi. I usually collect shellfish on mudflats. ○ ○ ○ ○ ○

    vii. I usually collect shellfish on sandbanks. ○ ○ ○ ○ ○

    viii. I usually collect shellfish on mixed banks. ○ ○ ○ ○ ○

    ix. I collect at same frequency throughout the year. ○ ○ ○ ○ ○

    x. I go more often in the campaigns. ○ ○ ○ ○ ○

        1. Which species are targeted?

        2. When does it starts?

3. How long does it last?
4. What are the existing rules for harvesting during the campaigns?

3. Purpose and rules of harvesting

   i. Most of the *S. senilis* I collect is for selling. ○ ○ ○ ○ ○

   ii. Most of the *S. senilis* I collect is for cultural practices. ○ ○ ○ ○ ○

   iii. Most of the *S. senilis* I collect is for my own consumption. ○ ○ ○ ○ ○

   iv. There are traditional rules regulating *S. senilis* harvest. ○ ○ ○ ○ ○

   v. What are the existing traditional rules for collecting *S. senilis*?

   vi. Most of the *T. adansonii* I collect is for selling. ○ ○ ○ ○ ○

   vii. Most of the *T. adansonii* I collect is for cultural practices. ○ ○ ○ ○ ○

   viii. Most of the *T. adansonii* I collect is my own consumption. ○ ○ ○ ○ ○

   ix. There are traditional rules regulating *T. adansonii* harvest. ○ ○ ○ ○ ○

   x. What are the existing traditional rules for collecting *T. adansonii*?

4. Economy

   i. I usually collect _____ / _____ L of *S. senilis* / *T. adansonii* per day.

   ii. One L of *S. senilis* / *T. adansonii* sells for _____ / _____ xoF.

   iii. How much do you earn per week on *S. senilis/ T. adansonii*?

   _____ / _____

iv. For what do you use the *S. senilis* / *T. adansonii* money (food, clothes, school, other)?

_____ / _____

v. Where do you usually sell *S. senilis* / *T. adansonii* (Bissau / own island)?

_____ / _____

5. Extinction events

i. Since I was little there were times when no *S. senilis* was found.

I. When did it happened?

ii. Since I was little there were times when no *T. adansonii* was found.

I. When did it happened?

6. Stock perception (change over time regarding size and abundance)

i. I still collect *S. senilis* even when the stock is low. ○ ○ ○ ○ ○

ii. This year I collected more *S. senilis* than last year. ○ ○ ○ ○ ○

iii. This year the *S. senilis* shells are bigger than last year. ○ ○ ○ ○ ○

iv. It's harder to collect *S. senilis* now than 10 years ago. ○ ○ ○ ○ ○

v. The *S. senilis* shells are smaller now than 10 years ago. ○ ○ ○ ○ ○

vi. I still collect *T. adansonii* even when the stock is low. ○ ○ ○ ○ ○

vii. This year I collected more *T. adansonii* than last year. ○ ○ ○ ○ ○

viii. This year the *T. adansonii* shells are bigger than last year. ○ ○ ○ ○ ○

ix. It's harder to collect *T. adansonii* now than 10 years ago. ○ ○ ○ ○ ○

x. The *T. adansonii* shells are smaller now than 10 years ago. ○ ○ ○ ○ ○

7. Stock management

    i. I think the existing rules for collecting *S. senilis* / *T. adansonii* are enough to ensure a sustainable use. ○ ○ ○ ○ ○/○ ○ ○ ○ ○

    ii. I think there is need for extra regulation for collecting *S. senilis* / *T. adansonii* in order to maintain sustainability. ○ ○ ○ ○ ○/○ ○ ○ ○ ○

8. Perception of others on mudflat.

    i. I often see waders feeding close to me in the mudflats. ○ ○ ○ ○ ○

    ii. I often see waders feeding far from me in the mudflats. ○ ○ ○ ○ ○

    iii. I often see other women collecting. ○ ○ ○ ○ ○

    iv. I often see fishermen on the mudflats. ○ ○ ○ ○ ○

    v. I often see tourists in the mudflats. ○ ○ ○ ○ ○

    vi. I often see researchers/students on the mudflat. ○ ○ ○ ○ ○