Maria Compte Ejarque

Ecological and socioeconomic aspects of subsistence fisheries in the Central Africa: The case study of “peixinho” fishery of São Tomé and Príncipe

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Mestrado em Aquacultura e Pescas
Especialidade em Pescas

Supervisor:

Dr Vânia Baptista, Algarve Centre o Marine Sciences,
University of Algarve

Co-supervisor:

Dr Marta Albo Puigserver, IEO/CSIC,
Spanish Institute of Oceanography

Faculdade de Ciências e Tecnologia

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Declaração de Autoria

Ecological and socioeconomic aspects of subsistence fisheries in the Central Africa: The case study of “peixinho” fishery of São Tomé and Príncipe

Declaro ser a autora deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

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Maria Compte Ejarque

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Abstract

The riparian goby-fry fishery of São Tomé and Príncipe, or “peixinho” fishery, is part of the culture of the fishing communities located next to the water courses from the archipelago. The fishery consists on the capture of amphidromous gobiid post-larvae species, *Sicydium brevifile*, *Sicydium bustamantei*, *Awaous bustamantei* and *Awaous lateristiga*, during their up-stream migration. This study attempts to describe the fishery and its role in their communities, through the local ecological knowledge (LEK) from fishers gathered throughout semi-structured interviews and cross-checked with the fishing communities and the fishery expert using a member-checking approach. The majority of the fishers are middle-aged women who use nylon nets, traditional traps called "tchanga", mosquito nets and cloth nets. The choice of fishing gear and tactics varies geographically and depending on the age. Correlation between rainy season and lunar phases, specifically the new moon and last quarter phases, with higher catches was indicated by the fishers. However, this association could not be completely confirmed based on the catch per unit effort (CPUE) collected in the interviews. Although fishers consider the fishing activity as commercial, most do not sell the entire catch, revealing that the fishery still has a subsistence component due to its importance for the livelihood and food security of the fishing communities, who are aware of the detriment of the fishery, but remain hesitant of management measures. This study outlines for the first time the socio-ecological system of the “peixinho” fishery, in order to comprehend the ecosystem services in which fishing communities depend on and to promote participatory approaches.

Keywords: local ecological knowledge (LEK), epistemic diversity, goby-fry fisheries, Small Island Developing State (SIDS), food security

Sumário

Devido às suas características locais e artesanais, a pesca das pós-larvas de gobiídeos tende a ser ignorada e pouco valorizada pela comunidade científica, já que são pescarias específicas para cada região e não atraem tanta atenção como outras economicamente mais rentáveis. Além disso, a maioria dos estudos mais recentes foca-se em descrever a ecologia e a taxonomia dos gobiídeos anfídromos que fazem parte das pescarias, do que em descrever a própria pesca e o seu impacto nas comunidades locais. Este estudo tem como objetivo caracterizar a pescaria de pós-larvas de gobiídeos localizada no arquipélago de São Tomé e Príncipe, no Golfo da Guiné, também conhecida como a pesca do peixinho, através do conhecimento ecológico local (CEL) recolhido a partir de entrevistas semiestruturadas e verificado com as comunidades piscatórias e o especialista da pesca. Embora os pescadores se refiram às pós-larvas com apenas um nome comum, “peixinho”, suspeita-se que os cardumes de pós-larvas sejam compostos por pelo menos quatro espécies diferentes de gobídeos anfídromos: *Sicydium bustamantei* Greeff, 1884, *Sicydium brevifile* Ogilvie-Grant, 1884, *Awaous lateristriga* Duméril, 1861, e *Awaous bustamantei* Greff, 1882.

Os pescadores utilizam principalmente quatro tipos de artes de pesca, a rede de nylon, a rede de mosquiteiro, uma rede improvisada feita de pano, e uma armadilha tradicional, localmente conhecida como "tchanga", que consiste numa cesta feita de fibras vegetais unidas por uma tira plástica. No entanto, estes equipamentos são usados de maneira diferente, definindo cinco técnicas de pesca, já que alguns pescadores tendem a usar uma combinação de artes de pesca ou uma técnica multiarte. Além disso, enquanto as redes de pesca são usadas para "apanhar" os cardumes de pós-larvas de gobídeos, as "tchangas" são colocadas no final de canais feitos de pedras e material vegetal, construídos pelos pescadores para guiar as pós-larvas em direção à armadilha, aproveitando a migração ascendente das pós-larvas de gobiídeos. Os gobiídeos anfídromos têm um ciclo de vida único, no qual crescem e se reproduzem em ambientes de água doce, e depois, as larvas são levadas pelo rio até o mar, onde passam por uma metamorfose para se tornarem pós-larvas. Uma vez desenvolvidas em pós-larvas, são capazes de receber o sinal migratório e iniciam a migração ascendente. É na foz dos rios que a pescaria de pós-larvas de gobiídeos ocorre, capturando os indivíduos que estão retornando ao rio para completar as fases de crescimento.

Na pescaria de pós-larvas de gobiídeos em São Tomé e Príncipe, as técnicas de pesca variam significativamente com base na região e na idade. Enquanto na costa Oeste de São Tomé, pescadores mais velhos geralmente usam a armadilha tradicional, "tchanga", na costa Este de São Tomé, pescadores mais jovens tendem a usar diferentes tipos de redes. Também, na Ilha do Príncipe, os pescadores preferem usar apenas redes de mosquiteiro. A adoção de redes de malha fina na pescaria de peixinho provavelmente foi induzida pela introdução de redes de mosquiteiro e de nylon distribuídas por organizações para prevenir a transmissão da malária. No entanto, devido à falta de materiais e ao alto preço das artes de pesca tradicionais, essas redes acabaram sendo usadas principalmente como redes de pesca, como documentado em outras pescarias artesanais.

A periodicidade da pescaria do peixinho está intimamente ligada ao ciclo de vida do seu alvo, dado que depende das migrações das pós-larvas. Os pescadores indicaram que as maiores capturas ocorrem durante a estação chuvosa, e por volta do último quarto até a lua nova, com uma temporada de pesca de quase duas semanas, coincidindo com resultados semelhantes de outras pescarias de pós-larvas de gobiídeos, como na Ilha de

Reunião ou na Colômbia. Apesar dessas ligações, não foi possível associar completamente as capturas por unidade de esforço (CPUE), indicadas pelos pescadores, com os padrões sazonais.

As mulheres têm um papel importante na pescaria do peixinho, já que a pesca é maioritariamente representada por mulheres. Neste caso, a maioria dos pescadores tende a guardar parte da pesca para consumo próprio e vender o excedente para manter as despesas domésticas, como material escolar ou para obter comida ou roupa. Além de ser uma atividade económica, as pescarias de pós-larvários gobiídeos podem ser um evento cultural em algumas comunidades piscatórias. Como foi observado em outros estudos, a migração ascendente é celebrada com festivais locais e encontros comunitários. Por exemplo, em uma das maiores comunidades pesqueiras deste estudo, os pescadores seguem um ritual em que as primeiras capturas são compartilhadas entre os membros da comunidade.

Apesar da relevância económica e cultural da pescaria do peixinho, ele permanece sem regulamentação. Os pescadores estão cientes da degradação da pescaria de "peixinho", no entanto, parecem duvidosos quanto às intervenções de gestão, embora estratégias de gestão baseadas na comunidade sejam apoiadas por uma minoria que concorda com a criação de medidas de gestão. A pesca do peixinho representa a união da herança cultural, biodiversidade e atividade económica das comunidades piscatórias ribeirinhas de São Tomé e Príncipe. Assim, a compreensão das ligações entre o sistema sócio-ecológico em que se baseia esta pescaria, permite-nos desenvolver medidas de gestão mais eficazes, com processos participativos em que todas as partes interessadas estão presentes.

Palavras-Chave: conhecimento ecológico local (CEL), diversidade epistémica, pesca de pós-larvas de gobiídeos, pequenos estados insulares em desenvolvimento (PEID), segurança alimentar

Table of contents

Index of figures

Index of tables

1. Introduction

1.1 Goby-fry fisheries and their target species

1.1.1 Review of the goby-fry fisheries around the world

In tropical areas with high rainfalls, torrential streams, high rates of disturbance and volcanic habitats, a type of fishery based on the periodic migration of gobiid post-larvae to the rivers, also known as goby-fry fishery, has been documented (Bell, 1999). Gobies, particularly, from Sicydiinae subfamily, are the primary target of these fisheries, which exhibit an amphidromous life cycle, namely, they migrate between freshwater and marine environments, a strategy commonly used among gobies (Manacop, 1953; Bell, 1999). The goby-fry fisheries are documented mostly in volcanic tropical islands but also in continental areas (Bell, 1999). To the date the goby-fry fisheries have been reported in the Pacific, such as French Polynesia (Keith et al., 2002), Hawaii (Titcomb, 1977), Indonesia (Salam et al., 2016), Philippines (Manacop, 1953) and Taiwan (Yuan, 1969); in the Caribbean, such as Cuba (Pichardo y Tapia, 1862), Dominica (Atwood, 1791), Guadeloupe (Vauchelet, 1862), Jamaica (Aiken, 1988) and Puerto Rico (Erdman, 1961); in the Indian ocean, such as Réunion (Cuvier and Valenciennes, 1837), Madagascar and Mauritius (Catala, 1982); and in the Gulf of Guinea, in São Tomé and Príncipe (Ribeiro, 1877). Additionally, they have been documented in continental areas, such as Ecuador (Jiménez-Prado, 2014), the Northern Pacific coast (Castellanos-Galindo et al., 2011) and the Caribbean coast of Colombia (Silva-Melo and Acero, 1990; Figure 1.1).

Fisheries based on post-larval goby migrations are typically local and artisanal, and even though they do not attract significant attention, they are strongly linked to religious and cultural events within the communities (McDowall, 2007; Sánchez-Garcés et al., 2011). Furthermore, the constant and regular supply of post-larval gobies represents an important resource for the island communities' livelihoods (Thomas, 2017). For instance, in the Philippines, their yields peaked at 20,000 tonnes per year during the 1930s, whereas, in Northern Pacific Colombia, catches varied between 1.37 and 2.43 tonnes per month, which corresponds to a total number of 19.4-24.3 million individuals approximately (Manacop, 1953; Carvajal-Quintero 2011; Castellanos-Galindo et al., 2011).

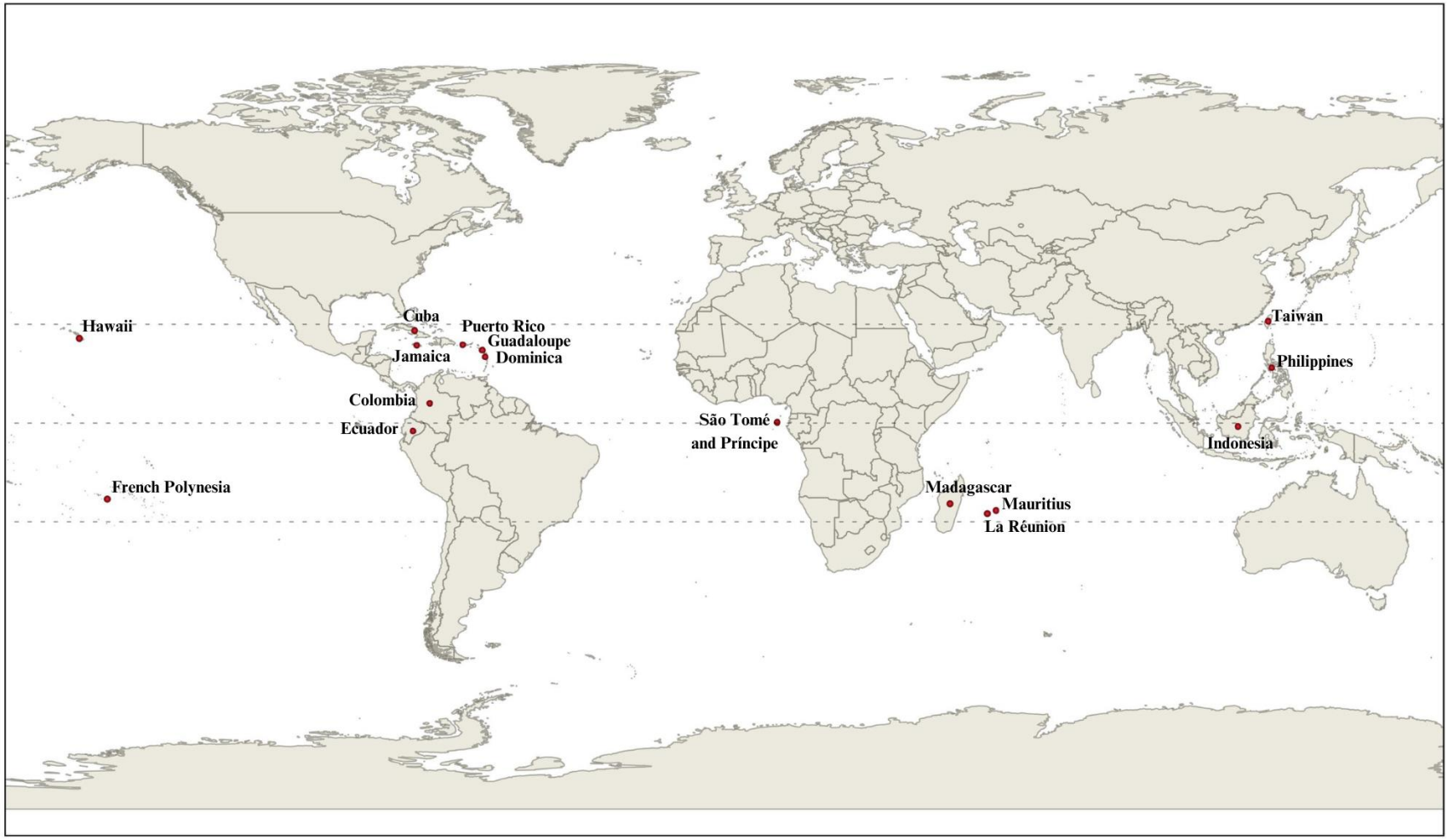

Figure 1.1. Distribution of the referenced fisheries based on the migrations of the post-larval gobies in the intertropical region between the tropics of Capricorn and Cancer. Source: modified from Thomas (2017).

Since goby-fry fisheries take advantage of the upstream migration or recruitment phase of the amphidromous gobies, most of the fishing activity is focused on the areas around the mouth of the rivers, estuaries, beaches and even in the river itself (Jiménez-Prado, 2014; Thomas, 2017). Thereby, the factors which interfere with the recruitment phase will have an impact on the success of their migration, and consequently, in the fishing activity.

Regarding the fishing methods, they vary depending on the type of substrate, depth and other characteristics of the lower course of the river basins (Sánchez-Gárces, 2017). While, in Indonesia, in deeper water of the estuarine, the fishers tend to use boats to trace the schoolings of post-larval gobies, and then, they catch them with nets (Nurjirana, et al. 2022). In Réunion, traditionally, fishers construct channels at the river mouth using pebbles to funnel the water, and they place one or more traps, locally called "vouves". Additionally, there are some locations where it is possible to see the combination of both techniques, such as Colombia or Dominica, where traditional traps remain restricted to the rivers, whereas, the beach seine or the mosquito net, are mainly operated in sandy bottoms and from boats or canoes (Bell, 2009; Sánchez-Gárces, 2017). Furthermore, this fishery presents a high diversity of fishing gears, for instance, only in Indonesia, three different types of nets were identified during amphidromous post-larvae fishing activity, scoop nets (“seser”), push nets (“dariq” or “bunde”) and casting nets (“panesser”), apart from other traditional fishing equipment (Nurjirana et al., 2022).

1.1.2 Biology of the gobies

Gobiidae is among the largest families of acanthomorph fishes, encompassing at least 1,120 described species within 170 genera, with many more species still waiting for description (Thacker, 2011). Pezold (1993) divided the Gobiidae into five subfamilies (Amblyopinae, Gobiinae, Gobionellinae, Oxudercinae and Sicydiinae), but with the development of molecular techniques, Thacker (2009) suggested a new classification, in which Gobionellidae was considered a sister clade of Gobiidae, and it included the taxa Gobionellinae, Sicydiinae, Amblyopinae and Oxudercinae. However, this new classification is still not accepted in taxonomic databases, such as WoRMS (World Register of Marine Species), where the Pezold’s classification is still followed (Froese and Pauly, 2024).

Morphologically, gobies have a small body size, often measuring less than 50 mm in length, and most possess pelvic fins that are fully or partially fused into a ventral disc (Thacker and Roje, 2011). In some taxa, such as Sicydiinae, the ventral disc functions as a sucker allowing them the attachment to the substrates and climbing natural obstacles, like waterfalls (Keith, 2008). They generally have separate spinous and rayed dorsal fins, and their coloration varies widely, from colourless tones to a high diversity of bright patterns (Thacker and Roje, 2011).

Even though gobies are distributed globally, including marine, estuarine and freshwater habitats (Thacker and Roje, 2011), the rivers from Indo-Pacific areas, Caribbean region, West Africa and Central America regions, are occupied specifically by amphidromous gobies, with 90% of their diversity concentrated in the Indo-Pacific areas (Keith and Lord, 2012). They are represented approximately by 200 species, which belong mainly to the Sicydiinae, Gobionellinae and Gobiinae subfamilies (Froese and Pauly, 2008; Keith and Lord, 2012). For instance, the subfamily Sicydiinae contributes most to the diversity of fish communities in tropical island systems and exhibits the highest levels of endemism in these habitats (Radtke and Kinzie, 1996; Lejeune et al., 2016).

Jointly with anadromy and catadromy, amphidromy is considered one of the three categories of diadromy (Myers, 1949). However, some researchers do not differentiate between anadromous and amphidromous fishes, and they enclose these fishes under diadromy term, moreover, amphidromy is usually confused with the anadromy strategy (McDowall, 2007; Watanabe et al., 2014). But there are significant differences between these two life cycles, whereas in the anadromy the somatic growth and reproduction occurs in different habitats of the freshwater and sea, and the migration is carried out by adult fish. In the amphidromy, the somatic growth and reproduction take place mainly in freshwater, and the migration is undertaken by small juveniles (McDowall, 2009). Therefore, the anadromy is considered more as a reproductive migration, while the amphidromy is related to a “trophic” migration (Myers, 1949; McDowall, 2007; McDowall, 2009).

Amphidromous gobies are adapted to the particular tropical island environments, such as, oligotrophic rivers with climatic and hydrological seasonal variations (Keith and Lord, 2012). Since seasonal variables, as rainfalls, droughts or floods, can impact to the

survival of amphidromous goby populations, reaching to the point of local extinctions, given that the reproduction, the spawning and the dispersal of larvae are dependent on these events (McDowall, 2003; Keith, 2003). Thereby, this specific life strategy allows the colonization of new habitats and the recolonization of those, after possible seasonal extinctions (McDowall, 2007; Thomas, 2017).

The amphidromous life cycle is characterized by the adults spawning in rivers, and then, the larvae drift towards the sea (downstream migration), afterwards there is a post-larval residency where they undergo a planktonic phase. Then, the post-larvae and small juveniles return to the river where they complete the life cycle (upstream migration) (Keith, 2003; Lord et al., 2010; Keith et al., 2011; Figure 1.2).

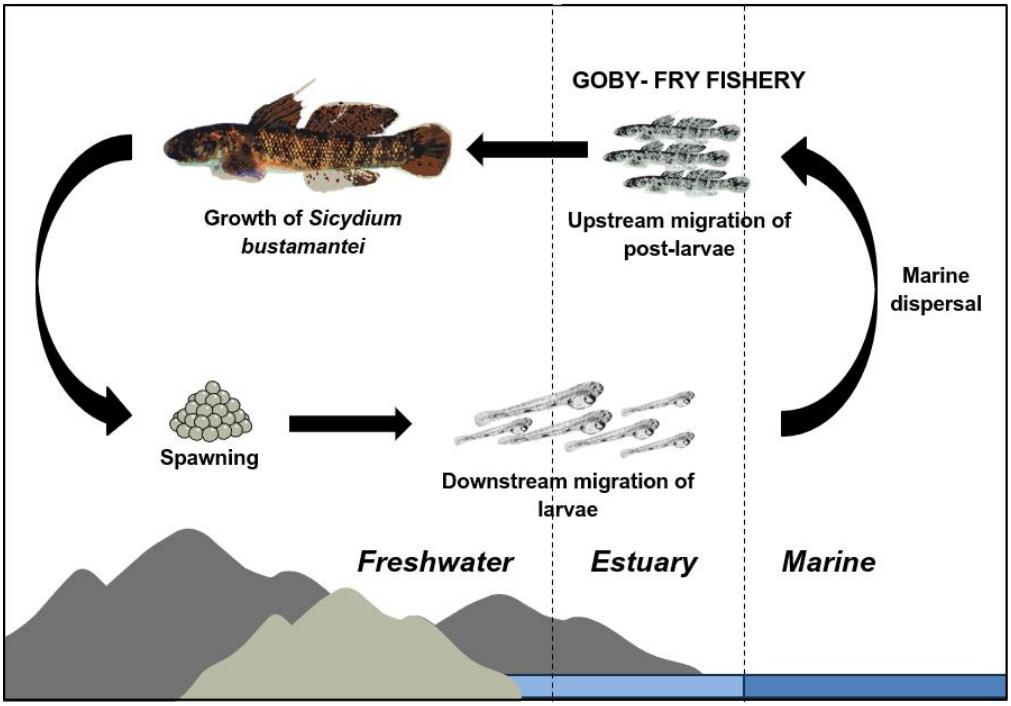

Figure 1.2. Life cycle of *Sicydium bustamantei* in São Tomé and Príncipe, Gulf of Guinea. Adults spawn in rivers, typically under rocks. After hatching, larvae migrate downstream towards the sea. In the marine phase, larvae undergo dispersal and development into post-larvae. These post-larvae migrate upstream, returning to the freshwater ecosystem, where they grow into adults. During the recruitment phase, gobiid post-larvae are caught in the goby-fry fishery, locally known as "peixinho" fishery in São Tomé and Príncipe. Source: modified from Pezold et al. (2006) and Bell (2009).

Specifically, after the hatching, once the drifted larvae arrive to the sea, the saltwater will trigger new steps in their development, and they can remain in the sea several months until getting the signal to recruit into the rivers (Manacop, 1953; Keith

and Lord, 2012). Furthermore, the duration of larval phase in amphidromous varies from 50 to 300 days, depending on the species, allowing their displacement to the ocean and their migration back to the rivers (Thomas, 2017). Once they are subject to the colonisation signal, they are considered post-larvae, and their entrance to the river corresponds to the recruitment phase, in which, the post-larvae will undergo a metamorphosis resulting on juveniles (Keith et al, 2008). Post-larvae are mainly translucent or slightly coloured when they enter to the estuary, however during the metamorphosis, the pigmentation will appear progressively, and their forked tail will be turned into a more truncated form and, in some species, the characteristic ventral disc will be formed (Keith et al, 2008; Taillebois et al., 2012). Furthermore, the jaw, the mouth and their digestive system will be modified, given their planktonic diet during their post-larvae phase will be transformed into a benthic herbivorous diet in the river (Tomihama, 1972; Schoenfuss et al., 1997; Bielsa et al., 2003).

Regarding to their reproductive biology, amphidromous gobies seem to have different reproductive strategies, some species are semelparous, annual spawners or others spawn repeatedly, and the most common pattern is polygamy with males guarding the nests located underside of stones or rocks, even though the Sicydiines gobies do not show hermaphroditism (Keith and Lord, 2012). Additionally, the clutch size, in specific cases, like *Sicyopterus lagocephalus*, Pallas, 1770, in La Réunion Island, was around 50,000 and 70,000 ova (Delacroix, 1987; Keith et al., 1999).

1.1.3 Declines in the gobby-fry fisheries

The deterioration of goby-fry fisheries in tropical areas has been recorded since 1930, to such an extent that they have been banned in places like Hawaii (Bell, 1999; Thomas, 2017). As a consequence, the price of the post-larvae has increased, for instance, in La Réunion, where they are considered a delicacy, one kilo of "bichiques" could be sold for 35 euros, and as maximum, for 80 euros (Thomas, 2017). Additionally, the lack of data of most targeted species difficult the implementation of regulations to the goby-fry fisheries, the 51 Sicydiinae species evaluated by the International Union for Conservation of Nature (IUCN), 30 have been assigned a conservation status, but the other 21 are described as "data deficient" (Thomas, 2017).

Even though the threats to the amphidromous stocks can vary depending on the location, probably the main reason is the synergy of different factors, such as, the physical

barriers to their migrations, water extractions form human and agricultural usage which reduces the river flow and changes the ecological continuity, the degradation of the habitats due to the removal of riparian vegetation or materials, and the chemical and sedimentary pollution, which affects the spawning grounds (Keith et al., 2015; Thomas, 2017). Thus, the human impact on estuarine habitats is particularly significant for the amphidromous species, which assume two migrations between freshwater and sea, since it will influence their ability to find food and colonize the rivers (Lord et al., 2006, 2008). Therefore, the lack or the decreased amount of amphidromous post-larval gobies could be used as an indicator of health of estuaries (Keith et al., 2008).

1.2 New goby-fry fishery in São Tomé and Príncipe

Ribeiro (1877) in "A Provincia de S. Thomé e Principe e suas dependencias ou A salubridade e insalubridade relativa das provincias do Brazil, das colonias de Portugal e de outras nações da Europa", already mentioned the presence of species commonly known as "peixinho", its associated fishery and the way was prepared by the local communities, and he referred this activity as: "*prejudicial e barbara*" ("damaging and brutal" in English) addressing the need to manage this resource by authorities. Lately, the presence of amphidromous gobies and its related fishery in São Tomé and Príncipe has been documented more frequently, but there has not been an in deep characterization of the fishery yet (Risch and Audenaerde, 1979; Jones, 1994; Bell, 1999; Pezold et al., 2006; Wirtz et al., 2007; Baptista et al., 2020; Porriños et al., 2021).

In the rivers and coastal areas of São Tomé and Príncipe, it is possible to find a goby-fry fishery which targets Sicydiinae fish, which dates back from more than a century ago and encompasses at least two species in the catches *Sicydium bustamantei* Greeff, 1884, and *Sicydium brevifile* Ogilvie-Grant, 1884 (Ribeiro, 1877; Pezold et al., 2006; Baptista et al., 2020). Furthermore, it is suspected that there are two more species involved in the fishery, from the Gobionellinae subfamily *Awaous lateristriga* Duméril, 1861, and *Awaous bustamantei* Greff, 1882 (Figure 1.3; Baptista et al., 2023; personal communication). The young juveniles or post-larvae from these species are recognised with the common name of "peixinho" (Portuguese name for little or small fish) by the local fishing communities. However, once they achieve their adult stage, they are commonly known as "dada", "alaba" or "canhogo" for *S. bustamatei* and *S. brevifile*, "bavu" for *A. lateristriga* and "blatu" for *A. bustamantei*.

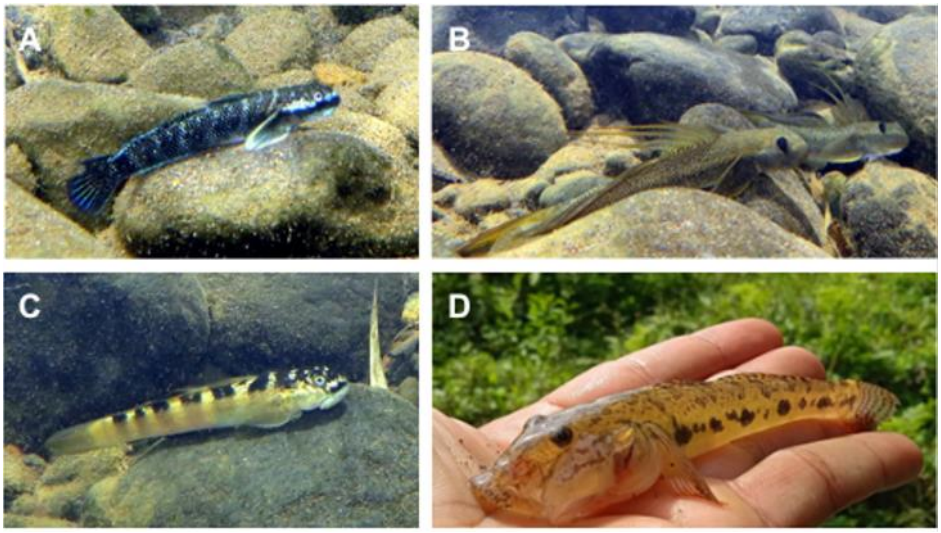

Figure 1.3. A) *Sicydium bustamantei* (Greeff, 1884) (Source: FishBase, Peter Wirtz); B) Male individual of *Sicydium brevifile* (Ogilvie-Grant, 1884) (Source: FishBase, Peter Wirtz); C) Female individual of *S. brevifile* (Ogilvie-Grant, 1884) (Source: FishBase, Peter Wirtz); D) *Awaous lateristriga* (Duméril, 1861) (Source: LittleFish-STP project).

They are caught by baskets, mosquito nets or cloths during the upstream migration, and then sold in the market, being one of the primary sources of income and protein for the local communities (Baptista et al., 2020; Figure 1.4).

Figure 1.4. A) Post-larval individual of "peixinho" captured in São Tomé and Príncipe in 2024 (LittleFish-STP project); B) "Peixinho" from São Tomé market, displayed in a plastic container with cans used to measure the quantity for sale (Source: LittleFish-STP project).

1.3 Role of artisanal fisheries in São Tomé and Príncipe

In 2019, São Tomé and Príncipe became the 17th member of the Small Island Developing States (SIDS) to have access to the SIDS Dock, United Nations (UN)

international organization addressing climate change, resilience and energy security in these islands (Global Network of Regional Sustainable Energy Centres, 2019). Furthermore, São Tomé and Príncipe economy is considered one of the smallest in Africa (Kerblat, 2023). Thereby, the fishing communities from São Tomé and Príncipe are defined by their extremely vulnerability to the climate change, due to their high dependence on marine resources, low economic development and poverty conditions, in which climate change can affect with the heightened floodings, coastal erosion and increasingly dangerous sea trips (Petzold and Magnan, 2019; Gorez, 2024).

Even though the productivity is limited to the narrow insular shelf, artisanal fishing is the most significant source of income for low-income families, after cocoa (Costa, 2009; Amador et al., 2023). Fish is essential to the nation's food and nutritional security, since more than 50% of the protein consumption of São Tomé and Príncipe's population comes from fish and an average per capita consumption of 29.3 kg per year (Serkovic and Million, 2019; FAO, 2019). Furthermore, according to Article 18 of the General Reglementation on Fisheries, the first 12 nautical miles are reserved exclusively for artisanal fisheries (Diário da República, 2012). However, with special authorization, industrial fishing vessels are allowed to access to this area (Belhabib et al., 2019). Furthermore, catches in artisanal fisheries have undergone a steady decline in the last few years. Zacarias et al. (2022) suggest that this drop in the catches is associated with overfishing due to the considerable amount of bycatch from the foreign vessels, the presence of Illegal, Unreported and Unregulated (IUU) fishing in the exclusive economic zones (EEZ) of the country and the effects of climate change. Additionally, the lack of reliable data has worsened the situation jeopardizing the fisheries sustainability and efficient management, thereby resulting in a decrease in artisanal fishing catches and the impoverishment of local fishing communities (Carneiro, 2011; Belhabib, 2015; Zacarias et al., 2022). This demonstrates that poorer countries taking part in fisheries agreements, usually also present a lack of capacity of public administrations to properly manage marine resources, for instance, in São Tomé and Príncipe there is not yet a policy framework for the fisheries sector nor surveillance vessels (Carneiro, 2011; Caillart et al., 2017; Amador et al., 2023).

Apart from commercial artisanal fishing, subsistence fishing should be considered, since subsistence catches are usually integrated inside the artisanal fishing

sector, however, subsistence fishing is more likely to occur in isolated communities with no commercial nor distribution systems, contributing to limited livelihood benefits (Oceanic Développement et al., 2004). Even though the artisanal fishing sector has evolved towards a more commercial exploitation, thanks to the development of road infrastructures and allowing the sale of fresh fish on local markets, large amounts of fish catches are still used for direct consumption and for food nutrition of the local communities. This demonstrates that the economy of São Tomé and Príncipe still relies on subsistence agriculture and fishing (Belhabib, 2015; De Labra et al., 2023).

In the specific case of the goby-fry fishery, or "peixinho" fishery, from São Tomé and Príncipe, its importance to the diet of the São Tomean people was documented as early as 1877 by Ribeiro. However, it was only recently that more studies have considered this small-scale fishery, a pattern that is observed in other fisheries based on amphidromous species, which often attract limited attention in fisheries reporting (McDowall, 2007). Governments tend to focus on monitoring only commercial fisheries, emphasizing exportable products and leading to a downward bias in catch data (Pauly, 2006, 2009; Zeller and Pauly, 2007). This, in turn, contributes to the neglect of artisanal or subsistence fisheries, threatening the livelihood safety nets that prevent poverty and malnutrition, particularly crucial for marginalized households and local economies facing the effects of a changing climate (Cooley et al., 2022; Virdin et al., 2023). However, defining and measuring the role of small-scale fisheries as a livelihood safety net has proven to be challenging and frequently unclear in the literature, and the scarcity of information also leads to policymakers overlooking the issue (Smith and Basurto, 2019). Thereby, the limited understanding of traditional goby-fry fisheries further complicates the development of effective management strategies to safeguard marine resources (Thomas, 2017). Consequently, acquiring more comprehensive information is crucial for understanding their role within the socio-ecological fisheries system of São Tomé and Príncipe.

1.4 Local Ecological Knowledge (LEK)

Local Ecological Knowledge (LEK), also known as indigenous or traditional local knowledge, can be a useful source of information when data and funds are lacking, which is particularly apparent in the case of marine ecosystems, since they are relatively less studied than terrestrial (Silvano and Begossi, 2012; Thornton and Scheer, 2012). It is based on accumulative ecological knowledge conserved through generations, and it is

gained through extensive personal empirical observation and interactions with local ecosystems (García-Quijano, 2007; Davis and Ruddle, 2010). Fishers can provide new insights in the biology and ecology of some species, which can enhance the conservation planning and to resolve fisheries management disputes, given that LEK provides historical and contemporary baseline information (Thornton and Scheer, 2012; Begossi et al., 2016). For instance, Le Fur et al. (2011) demonstrated that fishers from Western Africa were able to design maps with the nursery areas and to identify the period of adult migration and juvenile recruitment. Moreover, the local knowledge obtained did not present many differences with the scientifically gathered data. This information could be used to establish marine protected areas (MPAs), specifically to determine the location and size of protection to maximize conservation, biodiversity and fishery benefits (Berkström et al., 2019).

However, LEK tends to be under-considered by the academic scientists and policymakers, since policies do not take into account what is known by the local fishing communities on the behaviour, reproduction, seasonality, as well as about the human-wildlife interactions (Renck et al., 2023). Castello et al. (2009) exposed that the inclusion of fishers in the management process was crucial to recover an overexploited small-scale fishery known as "pirarucu" (*Arapaima* spp.) in the Amazon basin, even though these initiatives did not reach at national level.

It is self-evident that the domain of LEK requires a interdisciplinary approach to integrate natural and social sciences and a transdisciplinary involvement of non-academic experts, such as, fishers (Ruddle and Davis, 2013; Renck et al., 2023). This integration of natural and social science methodologies in conservation studies has become more prevalent over the past three decades, through the "citizen science" and the "ethnoscience" approaches (Berkes, 2017). Even though the acknowledgment of LEK for resource management has been hindered due to its difficulty of being translated into a form that can be applied to scientific endeavours. The development of systematic methods for the gathering and analysis of LEK, taking into account the cultural and ecological context, is essential to find a common ground between LEK and scientific knowledge (García-Quijano, 2007). Thus, Berkström et al. (2019) suggest that even though the LEK possessed by the fishers of Zanzibar led to a general understanding of connectivity rather than in-depth knowledge, which scientists possess, the LEK contains valuable information in fish ecology and behaviours which would be helpful for fisheries

management. Hence, considering a co-management approach and the incorporation of epistemological knowledge systems combining local and scientific ecological knowledge, would enhance the effectiveness of marine resource management.

1.5 Research objectives

Fishing activity and the protein obtained from it are essential for the society in many SIDS, but the lack of socio-ecological information on local fisheries, such as the goby-fry fishery, reduces the capacity to properly manage these marine resources and secure the food provision. Therefore, the main objective of this thesis is to characterize for the first time a goby-fry fishery located in the Gulf of Guinea, specifically in São Tomé and Príncipe, where it is locally known as the "peixinho" fishery, through an ecological and socio-economic perspective using the LEK from fishing communities. Additionally, it aims to identify and evaluate the ecosystem services provided by the "peixinho" and their importance for the riparian fishing communities. Based on previous studies Bell (1999), Castellanos-Galindo et al. (2011), Thomas (2017) in tropical areas with goby-fry fisheries, we hypothesise that the fishing tactics and techniques used will differ between areas due to social aspects such as gender or age. Furthermore, we expect that environmental cycles such as the lunar phases and wet and dry seasons will affect "peixinho" availability and will shape the fishing activity. Lastly, we will evaluate to what extent does the fishing communities of post-larval gobies depend on the "peixinho" as a primary source of livelihood, and how significant is this resource to their socio-economic well-being and cultural practices.

2. Material and Methods

2.1 Study area: São Tomé and Príncipe

São Tomé and Príncipe is a small island nation situated in the Gulf of Guinea, over 200 km off the coast of Gabon. As its name suggests, the country is comprised of two main islands: São Tomé and Príncipe, which are separated by 140 km. The archipelago encompasses a total land area of 1,001 km² and an EEZ of 160,000 km², which is approximately 160 times the size of its landmass (World Bank, 2021; De Labra et al., 2023).

São Tomé and Príncipe originated from volcanic origin, with sub-aerial formations estimated to be around 31 million years old for Príncipe and 15 million years old for São Tomé (Lopes, 2020). São Tomé is composed of steep slopes and mountainous systems, except for flatter regions in the northeast, where the highest point of the island, Pico de São Tomé, reaches 2,024 m, and several other peaks in the central region reach over 1,000 m. In contrast, Príncipe presents a plateau in the north and mountain systems in the south, with several peaks over 500 m, including Pico do Príncipe, which reaches 942 m (Ceríaco et al., 2022). Information on the terrestrial hydrography of the islands is limited. In both islands, the hydrographic structure is described as radial, from the central mountains to the coast, constituted for 116 river basins and 223 rivers and streams, from 5 to 27 km length (Ceríaco et al., 2022; da Costa et al., 2022; Sanitation and Water for All, 2022). The river network is evenly dispersed, flowing into the sea and forming small estuarine habitats or creating little waterfalls and cascades (da Costa et al., 2022).

The archipelago has oceanic equatorial climate, with mean temperatures higher than 25 ºC at sea level and decreasing with altitude. The year is divided between rainy and dry seasons, which is split into a long dry season, known as "gravana", from June to mid-September, and a shorter dry-season, the "gravaninha", which extents for few weeks that may occur anywhere between mid-December and mid-March (Lains e Silva, 1958). The seasons are determined by the Intertropical Convergence Zone, and the synergy of southern monsoon winds from the Atlantic Ocean and the northern dry harmattan winds from the Sahara (Ceríaco et al., 2022). The similar topography in both islands leads to a comparable distribution of climatic zones, where the elevated regions in the south and centre intercept the prevailing warm, moist south-westerly winds, which results in a significant north–south contrast in precipitation (Diniz and Matos, 2002). The southern region is "Super Humid" with annual precipitation above 3,000 mm, and even higher, increased by high humidity levels and low sun exposure. Then, in the north decreasing levels of humidity with decreasing latitude, there are the "Humid" belt with precipitation levels around 1,500 and 3,000 mm and the "Sub-Humid" belt, which receives between 1,000 and 1,500 mm of rain per year. And only in São Tomé Island, there is a "Semi-Arid" belt with precipitation levels around 600 and 1,000 mm in the flatter N-NE platform (Ceríaco et al., 2022).

The islands were uninhabited before the arrival of Portuguese settlers, and they became a biological laboratory for the acclimatization of economically interesting plants

and animals (Muñoz-Torrent et al., 2022). Until the 19th century, the main economic activities were related to the extensive exploitation of sugar and the slave trade, since the islands worked as a transit point for the transatlantic trade (Seibert, 2015). Furthermore, the economy was focused on coffee and cocoa production, becoming the world's largest producer of cocoa. São Tomé and Príncipe was an overseas province of Portugal until its independence of Portugal in 1975, after the Portuguese Revolution in 1974 (Seibert and Clarence-Smith, 2023). The São Tomean population comes from different ethnicities due to its colonial past. The main ethnic groups are the Forros (Portuguese for "freemen"), European and African descendants who gained freedom before the end of slavery, the Angolares, Angolean slaves' descendants, and Cape Verdean settlers (Eyzaguirre, 1989; Seibert and Clarence Smith, 2023). In recent decades, São Tomé and Príncipe has experienced significant population growth. For example, between 1991 and 2012, the population increased by 53.41%, nearly doubling since independence, and reaching 231,856 inhabitants in 2023 (Muñoz-Torrent et al., 2022; World Bank, 2024). This exponential growth of the population could result in a rapid degradation of natural resources in the islands due to increasing pressure on them, leading to deforestation, disappearance of beaches, gradual erosion of ecosystems and disappearance of endemic species (Muñoz-Torrent et al., 2022).

In this study, we focussed on 14 riparian fishing communities where the goby-fry fishery takes place (Figure 2.1). In São Tomé Island, in the western coast, there are Lembá, Santa Catarina, Paga-Fogo and Neves, and in the eastern coast, Santana, Ribeira Alfonso, Angra Toldo Praia, Iô-Grande, Praia Pesqueira, Monte Mario and Malanza. And in Príncipe Island, the fishing communities Praia Lapa, Praia Campanha and Budo-Budo were sampled.

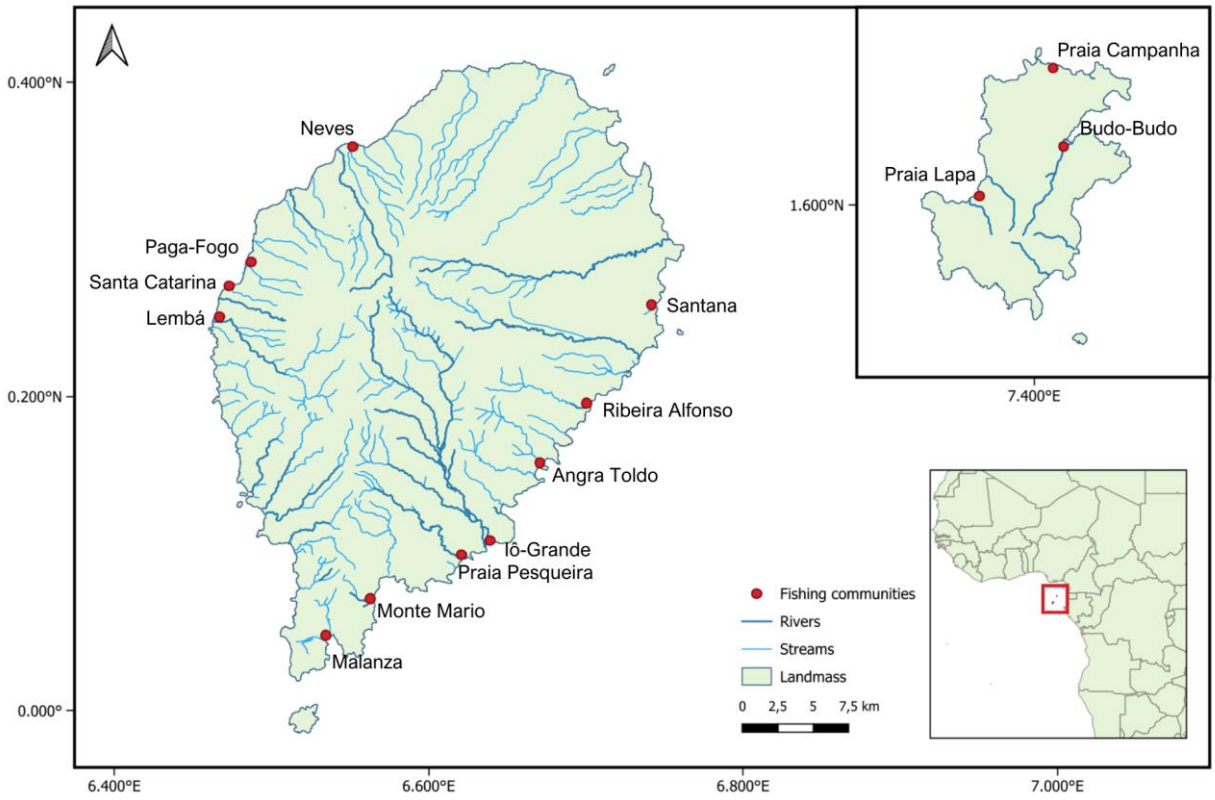

Figure 2.1. Map of the sampled fishing communities in São Tomé and Príncipe. Red circles indicate the locations of fishing communities involved in the "peixinho" fishery. Darker blue lines represent the main rivers, light blue lines indicate the streams in the archipelago, and light green represents the landmass. The inset map shows the location of the archipelago in the Gulf of Guinea.

2.2 Data collection

The data collection for this study was conducted in two phases between 2022 to 2024. During the first phase, in collaboration with students and professors from the University of São Tomé and Príncipe (USTP), semi-structured interviews were conducted face to face with various fishing communities involved in post-larval fishery activities on the islands of São Tomé and Príncipe.

In the second phase, conducted in 2024, after the initial results were analysed, a team of students and researchers from the USTP, the University of Algarve (UAlg), the Algarve Centre of Marine Sciences (CCMAR), and the Mar Ambiente e Pesca Artesanal (MARAPA) non-governmental organisation (NGO), provided feedback to the fishing communities. This phase also included the of additional field notes on fishing practices

and fishers' perceptions of the ecology of post-larvae. The findings were then cross-validated by members from both USTP, UAlg and CCMAR.

Hence, a mixed-methods approach was employed, integrating both quantitative and qualitative data drawn from the LEK from the fishing communities to achieve a comprehensive understanding of the "peixinho" fishery.

2.2.1 First phase: Fishing interviews

To collect local socio-ecological and economic data from the "peixinho" fishery semi-structured questionnaires were designed based on previous studies conducted in other African artisanal fisheries, specifically in Luanda Bay, Angola, including information on sociodemographic data, key species caught, fishing gears, seasons, and income (Faria et al., 2021). The questionnaires were collaboratively developed by researchers and professors from CCMAR, the Centre for Marine and Environmental Research (CIMA-UAlg), and USTP. They consisted of both closed and open-ended questions, allowing for the collection of semi-quantitative and qualitative data. This approach, often employed in conservation studies, offers a degree of flexibility while maintaining data quality (Young et al., 2014; Rose et al., 2018). After the questionnaire was designed, it underwent a pilot testing phase among colleagues to assess its duration and language appropriateness. The interviewers, who were USTP students, received training before conducting the actual interviews.

The questionnaires were structured into five sections and contained 45 questions with a mean duration of the interview of 20 minutes (see Annex): 1) sociodemographic characteristics of the fishers, including sex, age, educational level, and residency; 2) fishing gear and methods used in the "peixinho" fishery, detailing the types of gear employed, materials, fishery classification, fishing seasons, periods, and their relation to lunar phases; 3) information on "peixinho" catches, such as catch volumes over the past month, their highest catches or the prevalence of white or black post-larvae; 4) revenues from the "peixinho" fishery, including whether all the catches are sold, sales locations, and whether the revenues contribute to improving the fishers' livelihoods; 5) perceptions of fisheries management, such as, evaluations of the state of the goby-fry fishery, suggestions on who should be responsible for the management of the fishery, and potential management measures.

Fishing questionnaires were conducted across 14 fishing communities in the archipelago of São Tomé and Príncipe from July to November 2022. These communities were selected based on their apparently higher catch rates and their role in supplying the main markets where post-larvae are sold, as identified through the local expert knowledge of São Tomean researchers and technicians. The estimated number of fishers in each community ranged from 4 to 41. In total, 224 fishers were interviewed using semi-structured questionnaires.

Fishers were interviewed following a snowball sampling method. The initial interviewers indicated the subsequent respondents. Both active or retired fishers who participate in the goby-fry fishery currently or in the past were included in the study. The answers were collected anonymously and individually, after the fishers' consent, and they were registered mainly in Portuguese, even though, in some cases, the interviews were carried out in their local languages, Forro and Angolar.

2.2.2 Second phase: Member checking with fishing communities and expert

Following Harvey (2015) and Young et al. (2018), the participants received the feedback from the main results of the semi-structured interviews in May of 2024, which was used simultaneously as a member check of synthesized analyzed data, following the Synthesized Member Checking methodology (SMC; Birt et al., 2016), providing the opportunity to triangulate data from initial collection. This method is used to validate the results by incorporating opposing perspectives (objectivism), while also fostering reflection on personal experiences and creating opportunities for additional data collection (constructivism; Birt et al., 2016).

We prepared a ten-slide presentation (see Annex) to return to the participants, which included synthesized data from the whole sample about the gender and fishing gears distributions in the fishing communities, the relationship of the "peixinho" fishery with the lunar phases and rainy and dry season. The two last slides presented the fishers' perceptions on the state of the "peixinho" fishery and the suggested possible management measures of the fishery, and through anonymized illustrative questions, participants were invited to comment mainly on the perception of the suggested management measures.

Due to the difficulty in accessing the fishing communities, the subsequent steps in the SMC methodology suggested by Birt et al. (2016), specifically, determining

participant eligibility to receive SMC and distributing the SMC report for feedback, were not feasible. Consequently, we directly gathered responses and supplemented data from fishing communities that had a high number of participants in the semi-structured interviews (Table 2.1). Therefore, a team of students and researchers from USTP, CCMAR, UAlg and MARAPA, discussed the main results with fishers from Praia Pesqueira (3) and Iô-Grande (4), where information which fishers considered relevant to share was collected. Furthermore, in the fishing community of Lembá, even though we could not discuss the main results, we collected the comments from fishers (2) about their perception of the state of the fishery and the selling price of "peixinho".

Table 2.1. Fishing communities of São Tomé and Príncipe interviewed, number of interviews compiled and communities where Synthesized Member Checking (SMC) was conducted.

Fishing communities	Number of people interviewed	SMC
Lembá	27	No
Santa Catarina	26	No
Paga-Fogo	5	No
Neves	5	No
Santana	8	No
Ribeira Alfonso	4	No
Angra Toldo Praia	34	No
Iô-Grande	41	Yes
Praia Pesqueira	15	Yes
Monte Mário	16	No
Malanza	21	No
Praia Lapa	5	No
Praia Campana	11	No
Budo-Budo	4	No

Additionally, we were able to carry out member check interviews with the main researcher in charge of gathering the interviews, who is considered an expert of this fishery. Firstly, the researcher was also invited to give their comments about the results of the perception of the state of the "peixinho" fishery and the possible management measures, as the fishers were. Then, the local names of the fishes captured with

"peixinho", which were identified throughout the interviews with the fishers, were revised in order to relate them to their scientific name. For achieving this, prior to the field trip, a research of the fishes common names in São Tomé and Príncipe was done, thereby, for each name was associated a picture, and in some cases few pictures, with their scientific names, to enhance the cross-validation between the results from the questionnaires, the expert's knowledge and the available data.

2.3 Data analysis

The questionnaires were translated and transcribed, and the open-ended questions were categorized into topics based on the participants' responses, creating a database (Microsoft Excel). All the analysis and visualization of the data were conducted using R software (R Core Team, 2024) and the packages "dplyr" (Wickham et al., 2023), "fmsb" (Nakazawa, 2024), "ggplot2" (Wickham, 2016), "networkD3" (Allaire et al., 2017), "readr" (Wickham et al., 2024), "tidyverse" (Wickham et al., 2019) and "ufs" (Peters and Gruijters, 2023).

The fishing effort of each fisher was estimated from the answers collected in the interviews, given that the total amount of catches during the last month they worked and the number of days they went to fish "peixinho" were compiled. The total amount of catches was given by cans, which were converted into grams, as previous studies standardized one can as equivalent to 300 g of "peixinho" (dos Santos, 2023). Additionally, some respondents provided the total amount in "jojos" or "bacias" units, which are containers holding 120 or 70 cans, respectively. Thus, the catch per unit effort (CPUE; kg/day) was calculated as:

$$CPUE = \frac{Total\ amount\ of\ cans \times 0{,}3}{Fishing\ days}$$

First, all the non-responses were removed, except in the case of fishers' perceptions of management measures. Quantitative results were presented with means ± standard error (mean ± S.E.), while qualitative variables were presented in percentages and/or counts. All statistical tests were conducted with a 95% confidence interval and a significance level of 0.05. Descriptive statistics and data visualization for all the questionnaire modules were calculated. As required, further analyses were achieved through the comparison of multiple variables by multiple testing.

Chi-square tests of independence were employed to assess the statistical significance association between fishing tactics and the geographical area (western and eastern coasts of São Tomé Island, and Príncipe Island), gender, and age. Additionally, Chi-square tests were used to evaluate the association between investment and gender, fishing category, outcome, and distribution chain, as well as the relationship between fishing category, commercial or subsistence fishing, and outcome, whether fishers sold their total catch or retained some for self-consumption. Crámer's V correlation statistic was calculated to determine the strength of association between two qualitative variables. The values range from 0 to 1, values close to 0 mean a weak correlation and values close to 1 indicate a strong correlation (Husson et al., 2011).

To understand whether the number of additional species caught varied by fishing tactic, and whether CPUE and highest CPUE varied by month, Kruskal-Wallis tests were carried out, as the data did not meet the assumptions of normality and homogeneity of variance. In the case of the fishing effort by months, a *post-hoc* Wilcoxon test was conducted to determine in which months the fishing effort differed.

2.4 Ethical aspects

The lack of clarity on ethical review is concerning, especially in biological-oriented review committees given that they had inadequate knowledge of human research techniques (St. John et al., 2014; Young et al., 2014). As a consequence, this project follows the recommendations suggested by St. John et al. (2016).

In all the research procedures, the local participants were informed about the research objectives and provided verbal consent at the beginning of each interview. Furthermore, the interview forms were revised by the Data and Privacy Protection Policy from University of Algarve and the National Institute of Statistics (INE) from São Tomé and Príncipe. And the ISE Code of Ethics has been followed through this study (International Society of Ethnobiology, 2006).

3. Results

3.1 Fisheries characterization

3.1.1 "Peixinho" fishers' profile

A total of 224 fishers of "peixinho" were interviewed across 14 fishing communities in the archipelago of São Tomé and Príncipe being the communities with more fishers identified, Iô-Grande (41), Angra Toldo Praia (34), Lembá (27) and Santa Catarina (26), accounting for 57% of the interviewed fishers.

The gender distribution of this fishery consists of 74% women (166) and 26% men (58). In some communities like Santa Catalina, Santana or Ribeira Alfonso, women are the only ones involved in this fishery. While this fishery includes participants from all age ranges, the majority are between 25 and 54 years old (61%) and have a basic level of education (53%), corresponding to the first cycle of primary school, from 6 to 14 years old (Figure 3.1). It is worth mentioning that half of the unschooled fishers are older women aged 55 to 65 and above (52%), whereas most fishers with higher education levels, such as secondary school studies, are young women aged 15 to 24 (59%).

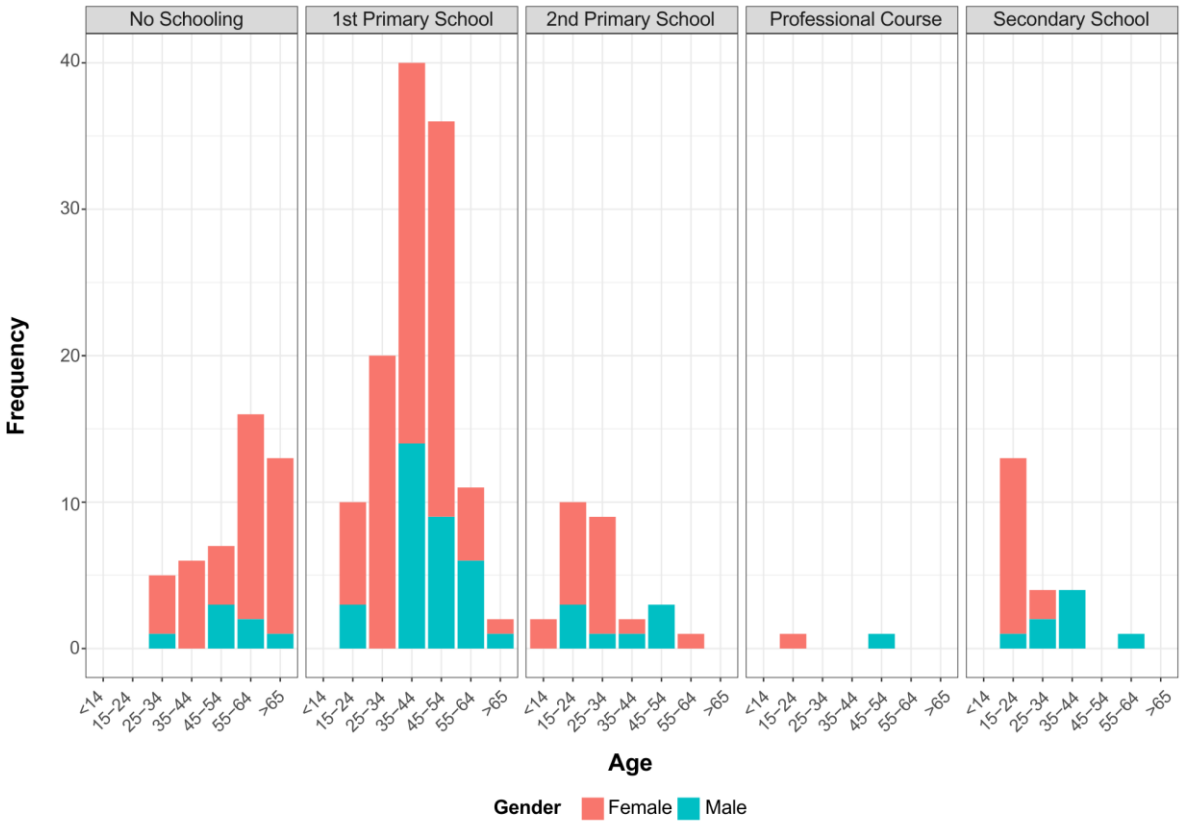

Figure 3.1. Distribution of fishers targeting gobiid post-larvae in São Tomé and Príncipe by age (under 14 years old, 15-24 years old, 25-34 years old, 35-44 years old, 45-54 years old, 55-64 years old, and 65 years old and above) and education level (no schooling, primary school from 1st to 6th grade, primary school from 7th to 9th grade, professional course and secondary school from 10th to 12nd grade). Female fishers are represented in red, and male fishers in blue.

3.1.2 Fishing tactics description

Based on the results of the semi-structured interviews the main fishing gears identified and used by fishers were the nylon net (35% of respondents), the "tchanga" (31% of respondents), a traditional basket made by vegetal fibers, the mosquito net (22% of respondents) and the cloth net (12% of respondents), a piece of clothing used as an improvised net (Figure 3.2). In case of the fishing nets, fishers typically work in groups of two to three people (85%), and with less frequent occurrences of larger groups from four up to eleven fishers (15%). In contrast, the traditional trap, known as "tchanga" tends to be used individually (92%; Table 3.1).

Figure 3.2. A) Fishers using a nylon net to capture "peixinho" and displaying the gobiid post-larvae in a plastic basin; B) Group of women using a mosquito net to catch a schooling of "peixinho" in the mouth of the river; C) Fisherwoman setting up the traditional trap or "tchanga" at the end of the funnel created with rocks and vegetal material in São Tomé and Príncipe. Source: LittleFish-STP project.

While 73% of "peixinho" fishers tend to use a single type of fishing gear, 27% of fishers employ multiple types of fishing gear, which is considered a multi-gear tactic. Eight distinct combinations of fishing gears for catching "peixinho" were identified. The most common combination involved using "tchanga" with nylon nets (43.33%), followed by "tchanga" combined with cloth nets (21.66%), "tchanga" with mosquito nets (13.33%), "tchanga" with both mosquito and cloth nets (8.33%), cloth and mosquito nets (6.66%), cloth and nylon nets (3.33%), "tchanga" with mosquito and nylon nets (1.66%), and cloth, nylon, and mosquito nets (1.66%).

The goby-fry fishery from São Tomé and Príncipe can occur during daylight (30%), at night (18%), or both (52%). However, the timing of the fishery varies depending on the fishing tactic used (Figure 3.3). During daylight, the most common fishing strategies are the "tchanga" (47.81%) and mosquito nets (34.32%). At night, fishers mainly use nylon nets (42.51%) or mosquito nets (22.49%). They also use lighting tools such as traditional oil lamp made from a bottle, locally known as "cafuca", or flashlights to identify post-larvae schooling and to attract them toward the nets (personal observation). When fishers operate both during the day and at night, they mainly use nylon nets (44%) or the multi-gear technique mentioned above (38.82%). Furthermore, when asked about their time preference for fishing, nearly 80% of those who fish during both daylight and night prefer to fish at night.

Table 3.1. Equipment and operating techniques by fishing gear, characteristics of the gears and number of fishers involved in each fishing technique in the goby-fry fishery from São Tomé and Príncipe.

Fishing gear	Gear description	Method of operation	Nº of people involved
Cloth net	Piece of fabric or clothing used as improvised net to catch the post-larval schooling.	Fishers recognize the schooling of post-larval individuals, the nets are submerged in the water and lifted once they have their catches. During the night, they use oil lamps ("cafucas") to locate the schoolings and attract them to the nets.	2-3
Mosquito net	Net made from fine mesh fabric designed to prevent mosquitoes from passing through, which it is used to catch the post-larval schooling.	Two people hold opposite ends of the mosquito net and sweep it through the water. Or using an "scooping" technique, as the net moves through the water, it catches the schooling. During the night they use torches to detect and attract the post-larvae.	2-3
Nylon net	Nets made by synthetic fibers of nylon. The size can be of 3 meters of length and 1,5 meters of width (dos Santos, 2023)	A group of people hold the extreme of the net, once they locate the schooling they move the net through the water capturing the schooling. During the night, they attract the fish with oil lamps or flashlights, and then, they capture them.	2-3
Basket ("tchanga")	Trap made by vegetal fibers united by a plastic band creating a cilindrical basket with a wider entrance. The end of the trap is closed by a thin rope locally known as "congo".	With pebbles and vegetal material, they create channels to guide the post-larval gobies towards the baskets, where they are captured. The "tchanga" has a funnel opening which avoid that the post-larvae turn around.	1

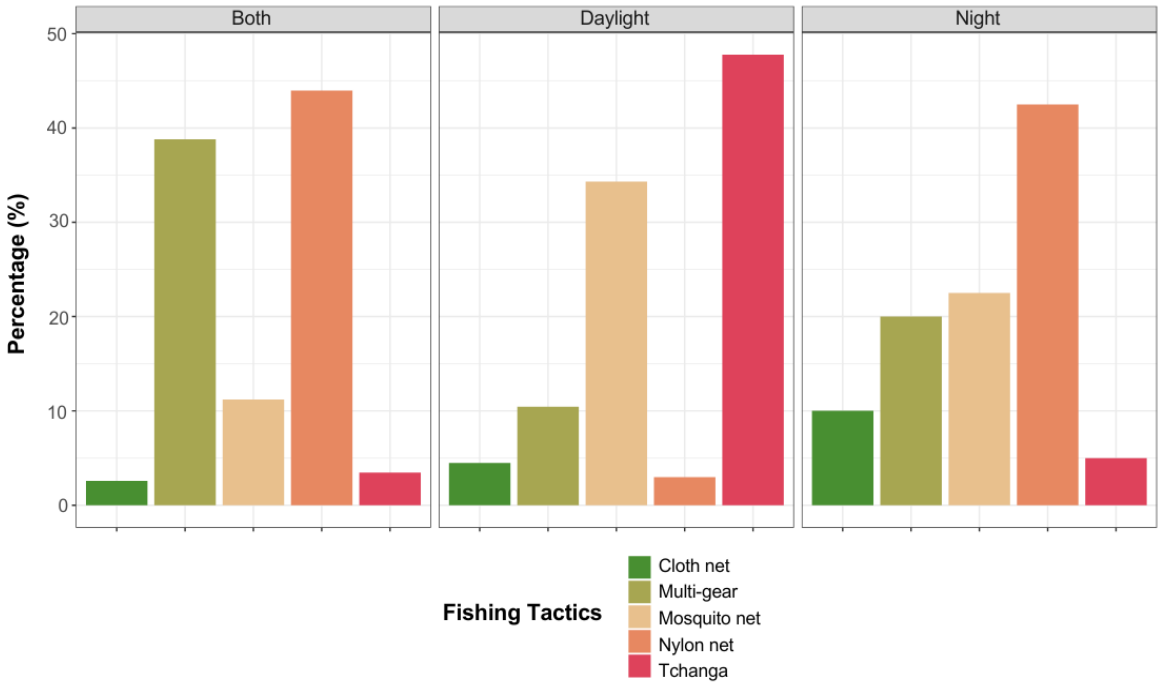

Figure 3.3. Distribution of the fishing tactics (cloth net, multi-gear, mosquito net, nylon net, and "tchanga") used during both day and night, daylight, and night in the goby-fry fishery from São Tomé and Príncipe. The bar plot represents the percentage of each fishing technique used in different time periods, daylight, night and both.

Regarding the fishing periodicity, 70% of the fishers reported that they do not fish every month (151), furthermore, 95% indicated that they do not fish throughout the entire month either (211). Hence, the average number of days spent fishing is 12 ± 5.97 days per person per month. In the open-ended question, fishers provided explanations for the limited number of fishing days. Of these responses, 56% were associated with the life cycle of the amphidromous post-larvae. Statements included observations such as "the "peixinho" stops swimming up the rivers" and "it is only during these days that it is captured". Whereas 34% of the answers were related to the livelihood of the "peixinho" fishers, with comments like "there is no other option" or "lack of job opportunities". Furthermore, 2.59% of respondents attributed their limited fishing days to lunar phases. Additionally, fishers were asked about their tendency to fish "peixinho branco" and/or "peixinho preto," which correspond to different post-larval stages. About 87% of fishers reported targeting "peixinho branco" more frequently. Furthermore, when "peixinho preto" appears in their catches, 83% of fishers continue capturing it, while 17% stop their fishing activity. The main reasons for continuing this behaviour are related to their livelihoods, with 50% indicating necessity or economic return ("it gives money back

too"). Other reasons include no perceived difference between different post-larval stages (12%) or simply because the post-larvae swim up the river (7%).

3.1.3 Fishing tactics depending on the area

When examining spatial differences in fishing tactics, it was observed that on the western coast of São Tomé Island, which includes Lembá, Santa Catarina, Paga-Fogo and Neves, fishers tend to use mainly the single traditional basket technique, "tchanga" (52.38%), followed by the multi-gear technique (22.22%), nylon net technique (22.22%) and mosquito net technique (3.17%; Figure 3.4). For instance, in the fishing community of Santa Catarina, the "tchanga" is the only fishing technique employed. Whereas in the eastern coast, with fishing communities such as Santana, Ribeira Alfonso, Angra Toldo Praia, Iô-Grande, Praia Pesqueira, Monte Mario and Malanza, they tend to use mainly the nylon net technique (39.57%), the multi-gear technique (32.37%), mosquito net technique (17.26%), cloth net technique (7.19%) and "tchanga" technique (3.59%). In some fishing communities like Praia Pesqueira, the nylon net is the only fishing tactic used. Finally, in Príncipe Island, fishers only followed the mosquito net technique (100%). The relation between the fishing tactics, specifically, multi-gear fishing technique, "tchanga", nylon net and mosquito net techniques were compared between the western and eastern coast of São Tomé Island and their association is statistically significant and reasonably strong ($X\text{-squared} = 69.37$, $df = 4$, $p\text{-value} < 0.001$, $Cramer\text{-}V = 0.57$).

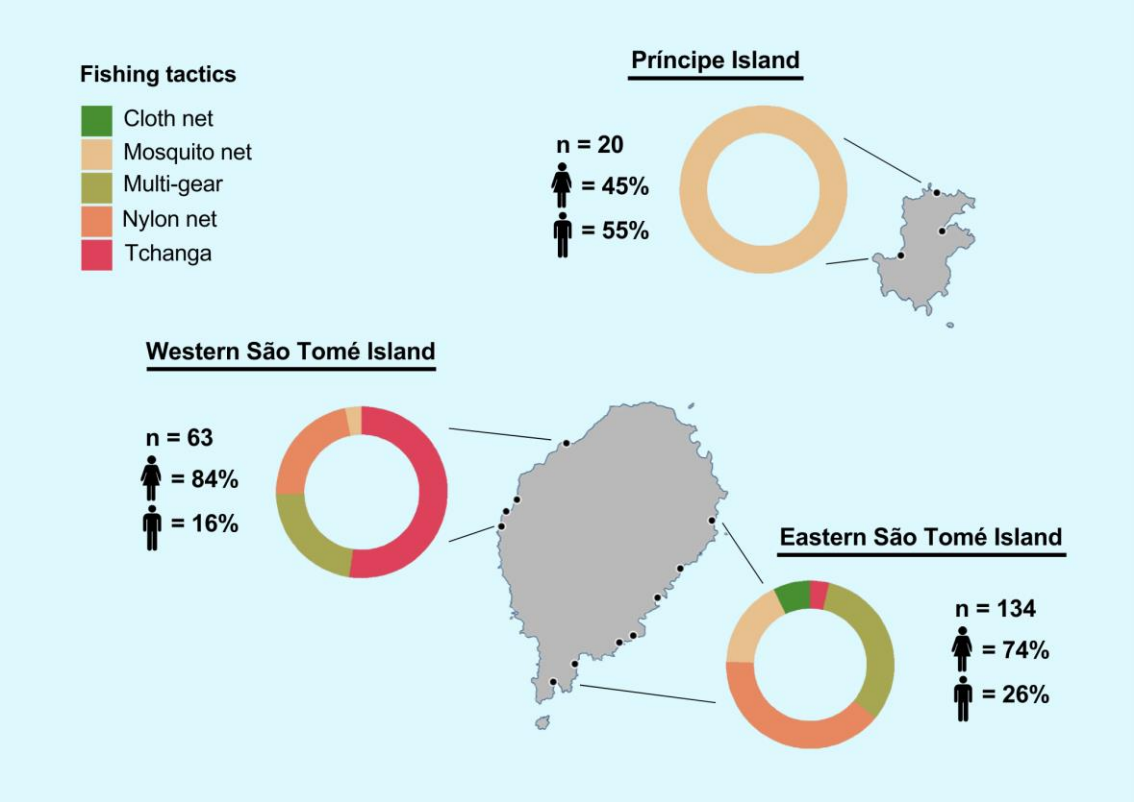

Figure 3.4. Map of São Tomé and Príncipe Islands showing "peixinho" fishing tactics and gender distribution across regions. Three areas are represented, Western São Tomé Island, Eastern São Tomé Island and Príncipe Island. The pie charts indicate the types of fishing techniques used in each region, including cloth nets, mosquito nets, multi-gear, nylon nets, and "tchanga". For each region, the number of fishers and the gender related to the fishing tactics are displayed.

The relation between gender and fishing tactics depending on the area was studied. In the eastern coast, women tend to follow the nylon net (36.36%) and multi-gear technique (32.32%), and men mainly use the nylon net technique (48.57%). The association between gender and fishing techniques in the eastern coast is not statistically significant either (X-squared test with Yates' continuity correction = 0.04, df = 1, p-value = 0.84). Meanwhile, in the western area, the "tchanga" technique is used mostly by women (62.26%), whereas most of the men use the nylon net technique (70%), but the association between gender and fishing tactics was not statically significant (X-squared test with Yates' continuity correction = 4.56×10^{-31}, df = 1, p-value = 1).

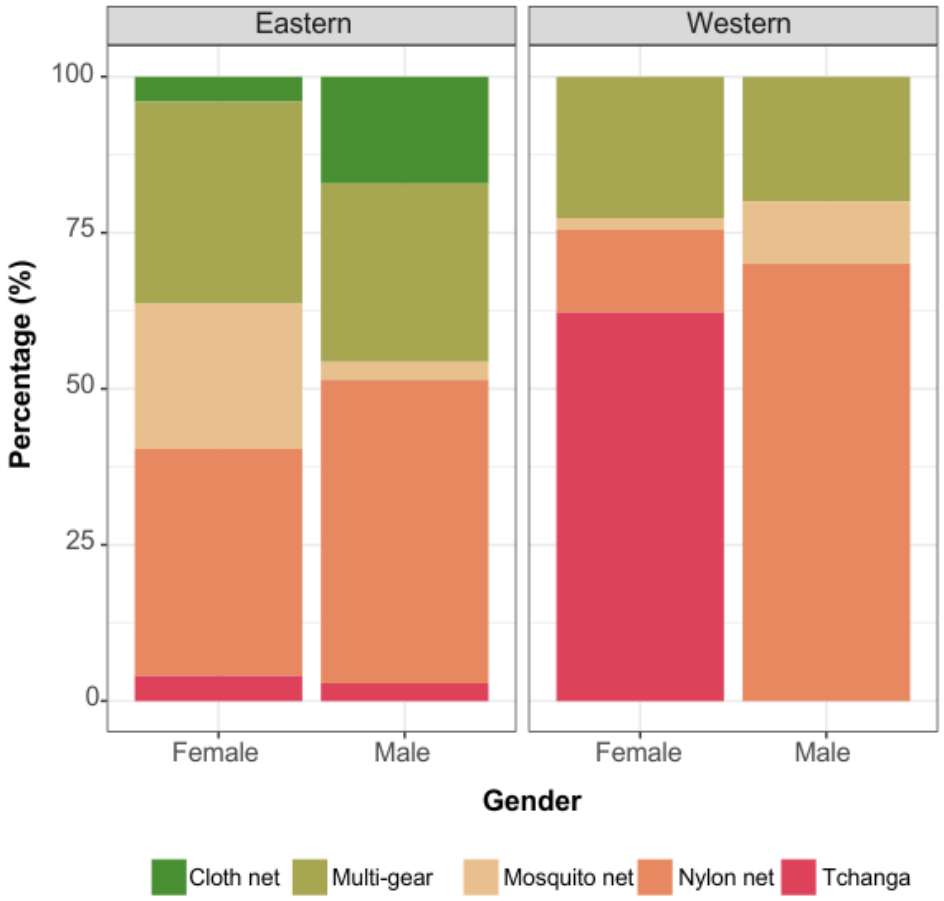

Figure 3.5. Distribution of fishing tactics of the "peixinho" fishery by gender in Eastern and Western São Tomé Island. The bar plot shows the percentage of females and males using different fishing techniques, including cloth nets, multi-gear, mosquito nets, nylon nets and "tchanga".

Regarding the relation of age and the fishing tactics depending on the area, in the western coast, the relationship was moderate and statistically significant (X-squared = 21.49, df = 3, p-value < 0.001, V-Cramer = 0.56). Fishers aged between 14 and 34 years old use mainly the nylon net technique (66.66%). However, older fishers, from 35 to more than 65 years, use the "tchanga" technique, representing the 63.04% of the most preferred technique through this age class. However, in the eastern coast, fishers tend to use more different fishing nets, and despite there is a statistically significant relationship, the correlation was weak (X-squared = 32.78, df = 8, p-value < 0.001, V-Cramer = 0.35). Specifically, for each age class the most used technique is mosquito net (54.54%) for fishers from 14 to 24 years old; nylon net technique (46.87%) for 25-34 years; multi-gear tactic (57.14%) for 35 to 44 years; nylon net (51.85%) for 45 to 54 years; and multi-gear (36%) and nylon net technique (32%) for 55 to more than 65 years old class.

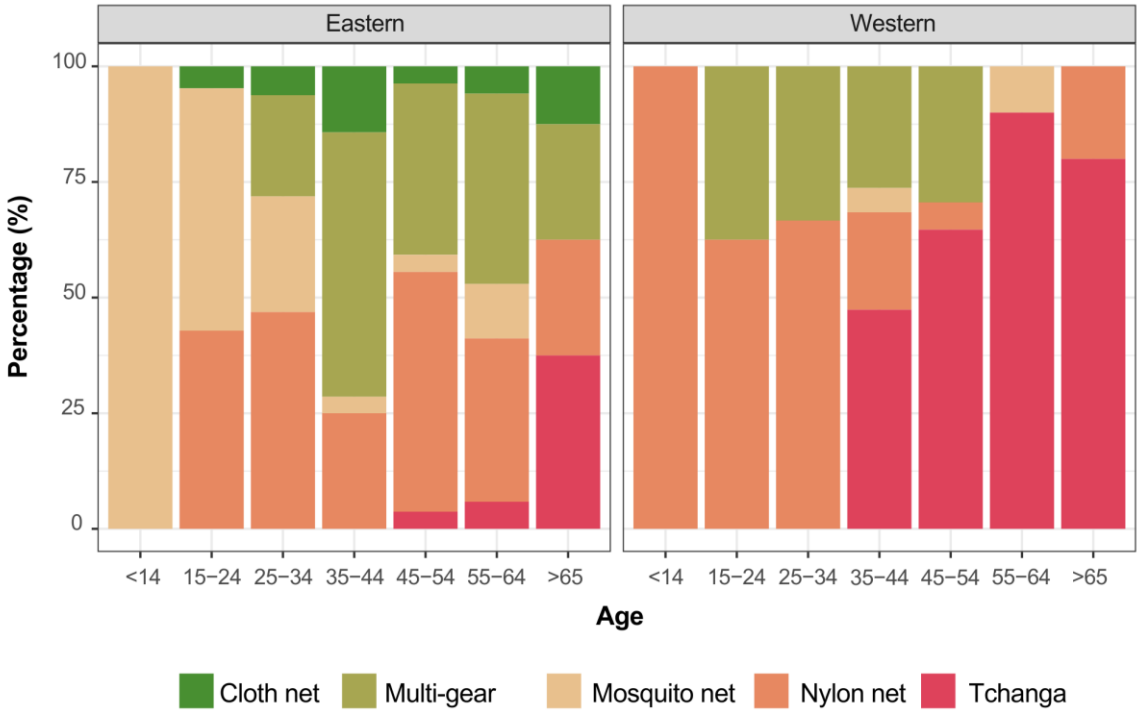

Figure 3.6. Distribution of fishing tactics of the "peixinho" fishery by age in Eastern and Western São Tomé Island. The bar plot shows the percentage of seven age class (under 14 years old, 15-24 years old, 25-34 years old, 35-44 years old, 45-54 years old, 55-64 years old, and 65 years olds and above) using different fishing techniques, including cloth nets, multi-gear, mosquito nets, nylon nets and "tchanga".

3.2 Ecological aspects of the fishery

According to the knowledge of fishers, the post-larval fishery is highly related to the lunar phases and the wet and dry seasons, since 88% of the fishers indicated that there is a relation between the "peixinho" fishery and the lunar phases, being the new moon (37%) and last quarter (40%), the phases with higher catches of post-larval gobies. Furthermore, most of the fishers (86%) indicated that during the wet or rainy season they catch "peixinho" with higher frequency.

Additionally, accidental catches of other species were reported in this fishery. Each fisher indicated the additional species captured with the "peixinho" catches with their common name. Later, through the member-checking with the expert, we were able to relate the common name with their scientific name at species or genera level. We calculated the frequency of occurrence based on the common names (Table 3.2). Within the catches of "peixinho", frequently, were reported species locally known as "camarões", which are decapods of the genera *Macrobrachium* and *Atya*, or "klacá", which

corresponds to the post-larvae of these species. Other species reported to be captured with the schooling of "peixinho" are the "concovado", *Caranx* sp., and the "charroco", it is suspected to be from the genera *Eleotris*.

Based on the frequency of common names provided by the fishers, we analysed the number of additional species or by-catch observed across different fishing strategies (Figure 3.6). Fishers using nylon nets reported the highest number of additional species (3.79 ± 1.76), followed by those using multi-gear techniques (3.5 ± 1.55), cloth nets (3.12 ± 0.84), mosquito nets (2.97 ± 1.18), and the traditional basket, "tchanga" (2.82 ± 1.01). However, statistical analysis revealed no significant differences in the number of additional species reported among the different fishing strategies (Kruskal-Wallis chi-squared = 8.52, df = 4, p = 0.07).

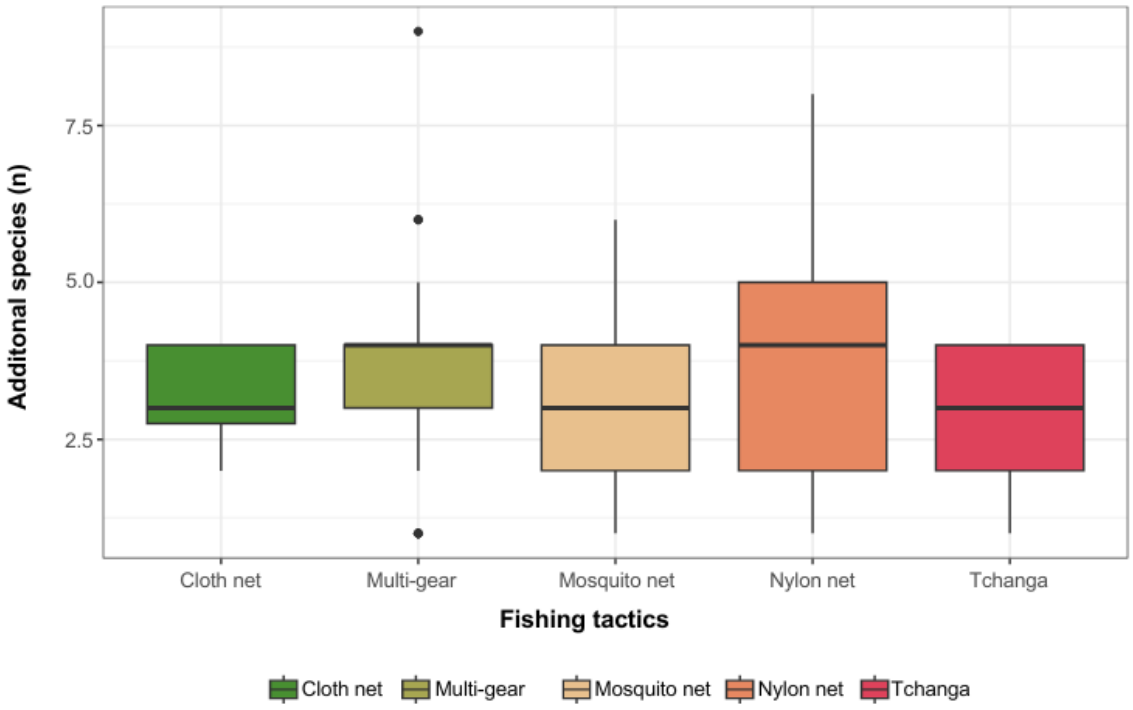

Figure 3.7. Distribution of additional species caught with the "peixinho" by different fishing tactics (cloth net, multi-gear, mosquito net, nylon net, and "tchanga") in São Tomé and Príncipe. The box lengths represent the interquartile range (IQR), the bars show the full range of data, and the horizontal lines indicate the median values. Black dots represent outliers.

Table 3.2. Frequency of occurrence of additional species caught in the goby-fry fishery of São Tomé and Príncipe, with their local name and scientific name.

Common name	**Scientific name**	**Frequency of occurrence (%)**
Concovado, comcom do rio ou cococcó	*Caranx* sp.	15.71
Camarão (adult) or klaclá (post-larvae)	*Macrobrachium* sp. *Atya* sp.	15.52
Charroco	*Eleotris* sp.	11.49
Tainha congo	*Mugil curema*	10.73
Parente	*Parakuhlia macrophthalmus*	10.35
Barbudo	*Galeoides decadactylus*	9.58
Corvina	*Lutjanus goreensis*	9.20
Roncador	*Pomadasys jubelini*	6.13
Sardinha	*Sardinella* sp.	2.49
Caranguejo	*Potamonautes* spp.	2.30
Papê or tilapia	*Oreochromis mossambicus*	1.53
Moreia	*Muraena robusta*	0.96
Pata-pata	*Alectis alexandrina*	0.96
Zamvé	*Sardinella* sp.	0.77
Bonito	*Caranx crysos*	0.57
Sopa or maiâ	*Kyphosus* sp.	0.57
Cozinheiro or San Cluso	*Drepane africana*	0,38
Azno	*Acantharus monroviae*	0.19
Linguado	*Bothus* sp.	0.19
Colombeta	*Coryphaena equiselis*	0.19
Tchintchin	*Holocanthus africanus*	0.19

3.3 Catch-per unit effort (CPUE)

During the interviews, fishers were asked about their total catches from the last month of fishing and their highest catches since they began to fish. The average total catches were 17.13 ± 33.47 kg per month, while the highest catches averaged 39.45 ± 37.29 kg per month. To study the effect of the seasonality on the CPUE, assumptions for multisampling tests were not met, thus non-parametric test were carried out (Figure 3.8).

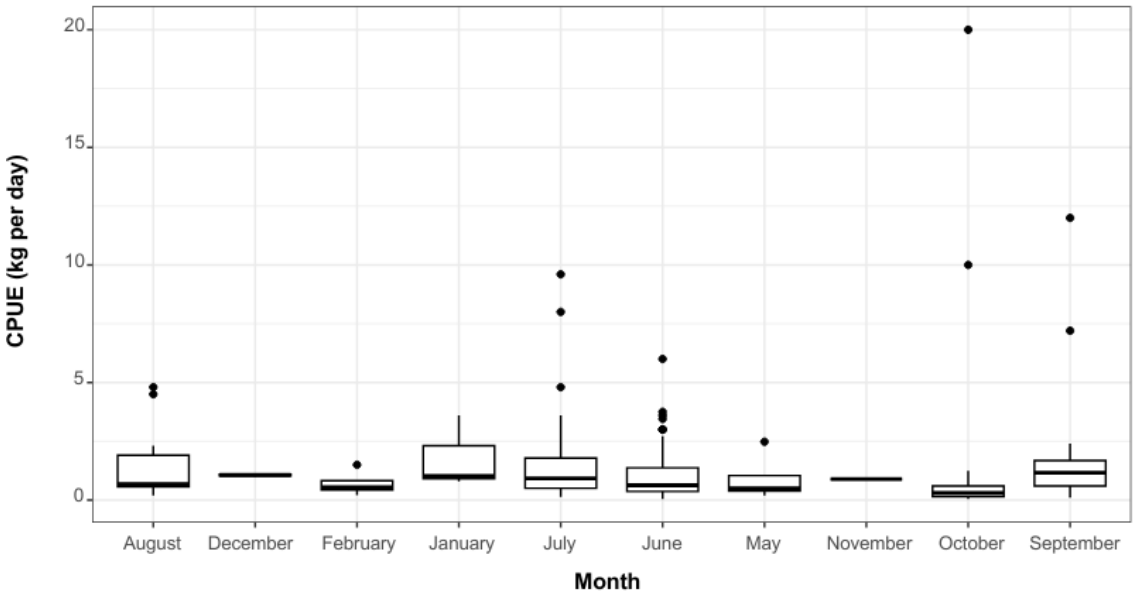

Figure 3.8. Monthly distribution of the CPUE (kg per day) of the goby-fry fishery of São Tomé and Príncipe. The boxplots display the interquartile range for each month, with the horizontal line representing the median and the bar length represents the range. Black dots are outliers.

Significant statistical differences between the CPUE depending on the months were found (Kruskal-Wallis chi-squared = 19.38, df = 9, p-value = 0.02). Then, a Wilcoxon test, or *post-hoc* analysis for non-parametric data, was carried out demonstrating that there are statistical differences in the means of the fishing effort of October and June (p-value = 0.01), October and July (p-value < 0.001), October and August (p-value = 0.003), October and September (p-value = 0.003) and October and January (p-value = 0.04; Table 3.3).

Table 3.3. Pairwise Wilcoxon rank-sum test for comparison of fishing efforts across different months of the goby-fry fishery of São Tomé and Príncipe. The values represent the p-values from the pairwise Wilcoxon tests. Significant differences are highlighted with * ($p < 0.05$). "NA" indicates months for which comparisons could not be made.

	August	*December*	*February*	*January*	*July*	*June*	*May*	*November*	*October*
December	0.65	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
February	0.29	0.53	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
January	0.33	1.00	0.23	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
July	0.66	0.89	0.26	0.51	*NA*	*NA*	*NA*	*NA*	*NA*
June	0.29	0.49	0.74	0.22	0.08	*NA*	*NA*	*NA*	*NA*
May	0.43	0.57	0.90	0.39	0.33	0.76	*NA*	*NA*	*NA*
November	0.88	0.66	0.80	1.00	0.86	0.82	1.00	*NA*	*NA*
October	**0.003***	0.11	0.29	**0.04***	**0.0002***	**0.01***	0.27	0.27	*NA*
September	0.76	0.82	0.28	0.75	0.94	0.16	0.29	0.80	**0.003***

The highest CPUE was evaluated based on the maximum catches reported by fishers, along with the corresponding month of capture. Since the assumptions for a parametric test were not met, a non-parametric test was conducted (Figure 3.9). However, no statistically significant differences were found (Kruskal-Wallis chi-squared = 17.21, df = 11, p-value = 0.1). January and February show the highest CPUE with greater variability, while other months have more consistent CPUE patterns.

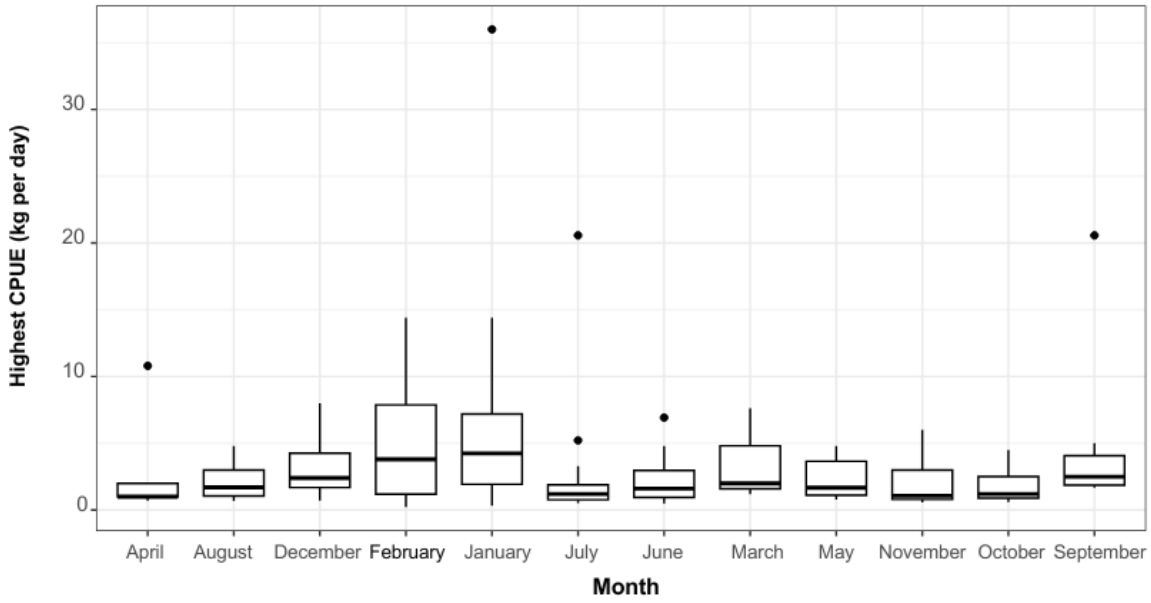

Figure 3.9. Monthly distribution of the highest CPUE (kg per day) of the goby-fry fishery of São Tomé and Príncipe. The boxplots display the interquartile range for each month, with the horizontal line representing the median and the bar length represents the range. Black dots are outliers.

3.4 Socio-economic aspects of the fishery

The first price for two "canecas" of "peixinho" reported by the interviewed fishers corresponds to 25 DB (1.01 €), 1.68 € per kg. However, the respondents also reported that, along the day, the price can be reduced reaching to the point of 17 DB for two "canecas" at the end of the day (1.15 € per kg).

Most of the revenues obtained from selling "peixinho" are invested mainly in household expenses (72%) and animal husbandry (28%), specifically in breeding pigs (Figure 3.10). Fishers who preferred invest their money in household expenses, they invested mainly in school material (32%), such as school uniforms or school enrolments, in food (18%), in clothing (18%), in building materials (6%), in electronical devices (6%), such as TVs, radios or mobile phones, in kitchen items (5%), in hygienic products

(0.88%), in fishing material (0.88%), in energy supplies and power units (0.66%), and in medicines (0.22%). Even though, the relation between the fishers investments and the factors such as “Gender” (X-squared = 0.98, df = 1, p-value = 0.32), “Fishing category” (X-squared = 0.004, df = 1, p-value = 0.95) and the “Distribution chain” (X-squared = 4.67, df = 3, p-value = 0.19) were no statically significant, it was found a statistical significant relation between the “Outcome” and the “Investments”, although it is considered a low association (X-squared = 5.46, df = 1, p-value = 0.02, Cramer-V = 0.16).

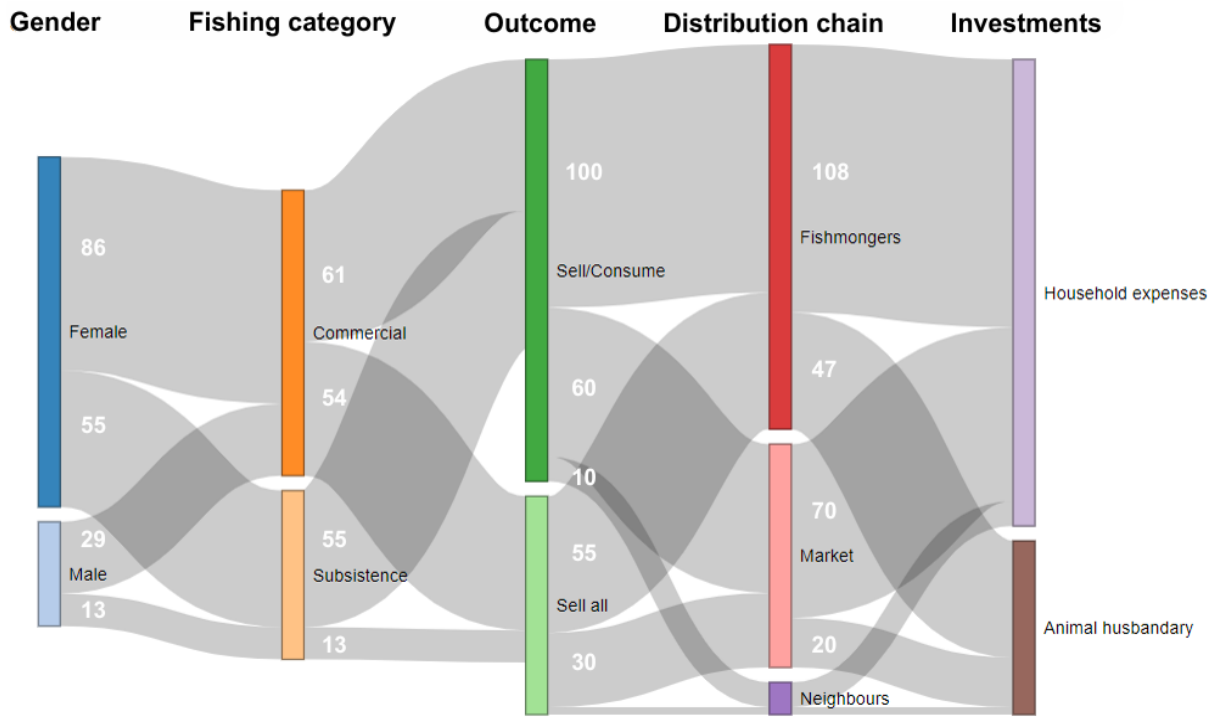

Figure 3.10. Sankey diagram illustrating the flow of the “peixinho” fishery activities in São Tomé and Príncipe by gender, fishing category, outcome, distribution chain, and investment choices. The width of the flows corresponds to the number of individuals in each category, with the counts (n) represented.

Even though, 63% fishers considered the goby-fry fishery from São Tomé as a commercial fishing activity, 33% of them reported that they do not sell all their catches. The relation between the variables “Fishing category”, how fishers considered their fishing activity, “Outcome”, the final outcome with the catches, if they are selling everything or not, was statically significant (X-squared with Yates' continuity correction= 13.09, df = 1, p-value < 0.001, V-Cramer = 0.27). The fishers usually sell their catches directly to the fishmongers from the community, commonly known as “palaiês” (58%),

however some of them sell directly in the fish market from São Tomé or district markets (37%) or even to the members of their community or neighbours (5%).

Additionally, only 36% (80) of fishers have experienced an accident or illness during their fishing activities, being rheumatism on of the main illnesses suffered by the fishers (45%), and, wounds made by seashells (42%).

3.5 Management measures perception

In the last part of the interview, fishers were asked about their perception about possible management measures to the "peixinho" fishery. Most of the fishers, 90%, indicated that the state of the fishery is worse in the present than when they started fishing, 6% expressed that the state of the fishery has remained the same, and 4% considered that the state of the fishery improved (Figure 3.11). Even though the majority considers that the fishery has worsen, the 66.07% of the fishers think that the "peixinho" will not disappear in front of the 25.44% which consider that this resource could disappear from their community. Regarding the perception of the management measure, 52.68% agreed with applying management measures, in front of 45.98% of fishers which believed that management measures are not needed. Consequently, most of the fishers did not indicate any possible fishing measure (55.05%), and the most common fishing measures proposed were to avoid cleaning items with toxic products in rivers (20.21%) and cleaning banks of rivers and beaches (17.43%).

Additionally, when they were asked about who should create the management measures, most of them pointed out that it should be the community (46.15%) or they did not give any answer (40.89%).

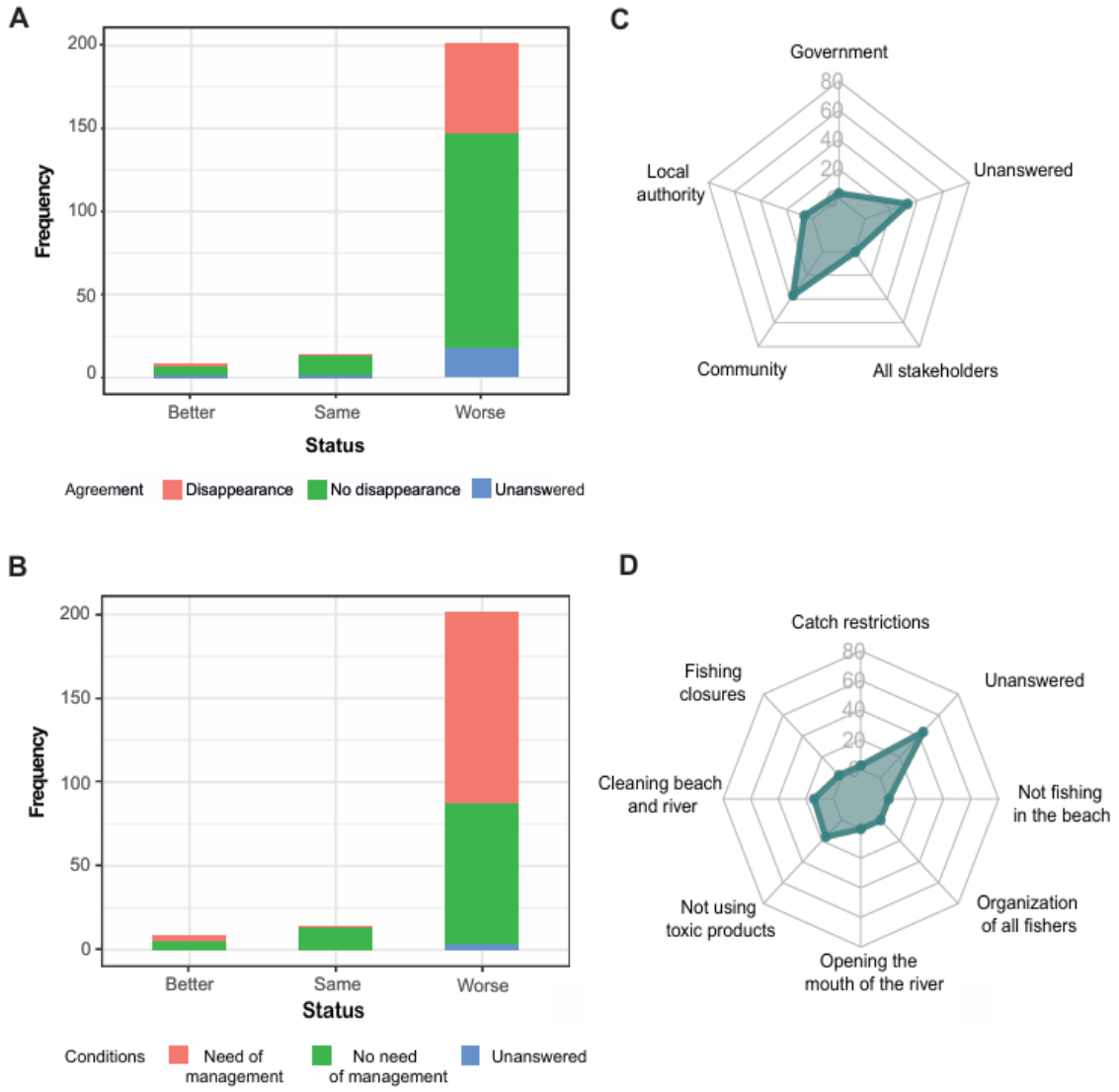

Figure 3.11. A) Distribution of the fishers' perception regarding the status (better, same and worse) and the future presence of gobiid post-larvae in the "peixinho" fishery of São Tomé and Príncipe, non-responses were considered; B) Distribution of the fishers' perception regarding the status (better, same and worse) and the need of management measures of the "peixinho" fishery of São Tomé and Príncipe, non-responses were considered; C) Contribution to the creation of management measures, non-responses were considered; D) Preferences for possible management measure, non-responses were considered.

4. Discussion

Globally, goby-fry fisheries have been underestimated and insufficiently studied, mainly due to their specific characteristics. These fisheries are classified as artisanal and local scale and their target species have not attracted that much attention, like "valuable" diadromous fish, such as lampreys, salmons or eels (McDowall, 2007; Sánchez-Garcés et

al., 2011). Most of the recent studies based on amphidromous gobies are focused on its ecology and taxonomy (Rodríguez-Machado et al., 2021; Heim-Ballew et al., 2024; Sahami et al., 2024), while few studies have documented the fishery itself and its influence on local communities, such as in the cases of Colombia (Sánchez-Garcés, 2017), La Réunion Island (Thomas, 2017) or Philippines (Vedra and Ocampo, 2014).

In the current study, we characterized the goby-fry fishery of São Tomé and Príncipe, locally known as the "peixinho" fishery, using LEK obtained from fishers through semi-structured interviews. This information was cross-checked with fishing communities and a recognized expert using a member-checking approach. The results indicate that this fishery is mainly conducted by middle-aged women who employ four distinct types of fishing gear: the traditional basket or trap (commonly known as "tchanga"), the nylon net, the mosquito net, and the cloth net. The fishery runs for nearly two weeks each month and at any time of day. Fishers indicated a correlation between higher catches and certain lunar phases, specifically, between the last quarter and the new moon, as well as with seasonal patterns, specifically, during the rainy or wet season. However, these associations could not be completely confirmed based on the CPUE data collected during the interviews. Additionally, the "peixinho" fishery is an important part of the livelihood of the fishing communities, who are aware of the degradation of their resources, but remain hesitant about the implementation of fishing regulations.

The "peixinho" fishery is likely to be one of the oldest fisheries in the archipelago of São Tomé and Príncipe. In 1877, Ribeiro reported the "peixinho" as part of the popular diet of São Tomé and detailed the traditional capture method: "... *pegam n'um panno bastante comprimido, que emergem na agua, e esperam os cardumes, e quando estes passam por cima do panno levantam-no, colhendo assim milhares de peixinho. Isto repete-se por centenares de vezes e em quasi todos os rios.*" ("... they fish with a tightly stretched cloth, which they submerge in the water and wait for the schools of fish. When the fish pass over the cloth, they lift it, catching thousands of little fish. This is repeated hundreds of times in almost every river", in English). Similarly to São Tomé and Príncipe, La Réunion Island was uninhabited until the arrival of the first settlers in mid-17th century and has a goby-fry fishery, known as "pêche des bichiques". This fishery dates back to the period of slavery, since the first slaves likely introduced the fishing tradition from Madagascar, and, the post-larvae were considered poor man's dish, caught and consumed by slaves (Thomas, 2017). It is suspected that the origin of the "peixinho" fishery in São

Tomé and Príncipe could also date back to the island's history of slavery. Although further research is needed to confirm this, historical archives can provide useful information to create more comprehensive management decisions in fisheries management, redefining and broadening the focus on what is relevant for the fishing communities in managing their fisheries, and to construct their cultural heritage (McClenachan et al, 2024).

More than a century after the Ribeiro (1877) fishery description, fishers are still using the same technique, although modern materials such as the mosquito nets and nylon nets have been adopted, apart from the improvised net made from a piece of cloth. Mosquito nets are distributed for malaria protection by NGOs, foundations, trusts and philanthropists, however growing evidence indicates that fishing is their main use (Short et al., 2018; Jones and Unsworth, 2020). In this study, we differentiated between the mosquito net and the nylon net, since the mosquito net can be a bed net treated with insecticide, while the nylon net is often recycled from window screens. Fine mesh sizes (usually $\leq$ 3mm) are essential to avoid mosquitos, but they are unselective of small fish (Short et al., 2018).

The traditional basket or trap, known as “tchanga”, requires a different technique. Fishers create channels from pebbles and vegetal materials at the river mouths and place the traps at the end of this rocky funnel to guide the post-larvae towards the trap. The use of mosquito nets and baskets made of vegetal fibers were found in other goby-fry fisheries. Thomas (2017) reported the use of mosquito nets and traditional baskets, locally known as “vouves”, in the goby-fry fishery from La Réunion Island. As in the goby-fry fishery of São Tomé and Príncipe, these traditional baskets are used with the same technique, creating pebble channels to lead post-larvae towards the traps in rivers or streams. However, in La Réunion Island, during the last years the basket made by vegetal fibers has been replaced by metal material, and fishers add mosquito nets to the back of these metal traps, to ensure the post-larvae do not escape. Additionally, they count with open sea fishers, who are displaced to sea with masks, fins, buoys and larger mosquito nets by freediving, and the mosquito nets are used by groups from six to ten fishers. In Colombia, Castellanos-Galindo et al. (2011) and Sánchez-Garcés (2017) documented small groups of two to three fishers working with mosquito nets from beaches, where they locate the shoal, submerge the net and lift the catch from the beach, although, there are still some indigenous communities which catch the post-larvae still with traditional baskets made by vegetal fibers. Similarly, Bell (2009) described the use of mosquito nets

and traps in the goby-fry fishery from Dominica, which previously relied on traditional basketwork traps, however, currently, they use fertilizer bags or woven bags stabilized and fixed with stones to capture post-larvae during their benthic phase.

In the goby-fry fishery of São Tomé and Príncipe, fishing tactics vary depending on both region and age. On the western coast, older fishers typically use the traditional trap known as “tchanga”, while on the eastern coast, younger fishers tend to use different types of fishing nets, even though older fishers prefer the “tchanga”. Consistent with our results, variations in the fishing tactics in Colombia and Dominica have been reported before, and these regional differences were linked to differences in river basin substrates (Bell, 2009; Sánchez-Gárces, 2017). Which may explain why fishing techniques differ by area in São Tomé and Príncipe. Setting up the "tchangas" requires a riverbed with pebbles to assemble the channels that guide the gobiid post-larvae toward the trap, whereas in sandy river mouths, the traditional trap is less effective, leading the fishers to use a variety of fishing nets instead. However, in this study the geomorphology of the fishing grounds was not considered, in future studies in the area, a characterization of the riverbeds could be implemented to understand the regional differences in fishing nets used in São Tomé and Príncipe.

Our findings also reveal a higher number of fishers using the fine mesh sizes nets, particularly nylon nets, in the goby-fry fishery of São Tomé and Príncipe. For instance, in Iô-Grande, a fishing community where nylon nets and cloth nets are the main fishing gears for capturing "peixinho," fishers reported being unable to afford traditional traps (personal communication). This economic barrier is not unique to São Tomé and Príncipe, on La Réunion Island, “bichiques” fishers explain that maintaining traditional fishing methods is challenging, since a metal trap costs around 100 euros, while a traditional trap ranges from 300 to 450 euros (Thomas, 2017). The durability, lightweight and easy accessibility of mesh mosquito nets make them a convenient alternative for fishers (Jones and Unsworth, 2020). However, the shift from traditional traps made from biodegradable materials to net traps can increase the fishing pressure, as it has been observed in La Réunion Island or Salomon Islands, where it led to a decline in fish stocks, and became a source of plastic pollution (Locke et al., 2017; Thomas, 2017).

The fishing periodicity of the goby-fry fishery is closely linked to the recruitment phase of amphidromous goby migration. After being in the sea, gobiid post-larvae

respond to the colonisation cues, although the signal has not been determined yet, it is suspected to be related to the new moon and heavy rainfalls, particularly on La Réunion Island for *Sicyopterus lagocephalus* (Delacroix, 1987; Keith et al., 1999; Hoareau, 2005; Keith et al., 2008). However, in some locations, such as Dominica, other factors such as timing, competition, abundance and seasonality, may have greater influence on the recruitment than the lunar phases (Bell, 2009).

Most fishers from São Tomé and Príncipe report that the highest catches of "peixinho" occur during the wet or rainy season, and between the last quarter moon phase and the new moon, with a fishing period around 12 days per month. These findings align with the goby-fry fishery of La Réunion Island, where the catch intensity also varies throughout the lunar cycle, being highest between the last quarter moon and new moon, with 8 to 12 days of fishing activity per month (Thomas, 2017). Similarly, in other goby-fry fisheries locations, such as Cuba, Dominica, Puerto Rico and Jamaica, fishers capture mainly post-larvae during the last quarter moon phase (Bell, 1999; Bell, 2009; Rodríguez-Machado et al., 2021). However, in the Philippines and Taiwan, the highest appearance of post-larvae is observed around the full moon (Manacop, 1953; Shiao et al., 2015). Bell (2009) suggested that the lunar response mainly facilitates the synchronization of post-larvae as a predatory swamping strategy. In places like Dominica, where tidal ranges are small and tidal currents are reduced by water depth, reversing currents in open water would require vertical migration through most of the water column, making it less effective in deep waters. Bell (2009) also considered that if the lunar phases were a determinant factor for the recruitment of amphidromous gobies, there would be no global variations in the lunar phase. However, Tomas (2017) considered that the recruitment in La Réunion Island occurs between the last quarter and new moon, consistent with most locations where goby-fry fisheries are found, contradicting Bell (2009), who considered that the recruitment in La Réunion Island took place around the full moon. Since tidal ranges are larger between the last quarter moon and the new moon, as well as between the first quarter moon and the full moon, the recruitment of "bichiques" is likely to be more successful when the tidal range is greater, and nocturnal luminosity is lower (Thomas, 2017).

There is greater consensus when it comes to the seasonality of goby-fry fisheries. Most studies from Ecuador (Jiménez-Prado, 2014), La Réunion Island (Thomas, 2017), Philippines (Manacop, 1953) and Colombia (Sánchez-Garcés, 2017), are in agreement

with the “peixinho” fishers from São Tomé and Príncipe who stated that the highest catches occur during periods of increased precipitation or the rainy season.

The high variance in catches could be attributed to the influence of seasonality and lunar phases on the migration of amphidromous gobies (Bell, 1999). However, it was not possible to demonstrate the links between the differences in the CPUE throughout the seasons and lunar phases. Our findings indicated only statistically significant differences in the CPUE between October (wet season) and June to September (dry season, also known as "gravana"). Differences were also found between October and January, which includes a brief dry period known as "gravaninha". However, the CPUE from the rest of the months did not show differences. Furthermore, no clear relationship between CPUE and lunar phases could be established in the goby-fry fishery from São Tomé and Príncipe. The implementation of biological monitoring programs in the goby-fry fishery of São Tomé and Príncipe could improve the assessment of the influence of lunar phases and other environmental variables on the distribution and life cycle of the gobiid post-larvae. These efforts should focus on rivers where the fishing effort is more pronounced and taking into account the effects of climate change in the life cycle of gobiid post-larvae, since future scenarios predict a combination of longer dry seasons and increased precipitation intensity, apart from a delay in the rainy season in São Tomé and Príncipe (Kniveton et al., 2009; Thomas, 2017; Chou et al., 2020).

Similar to other goby-fry fisheries, fishers reported that when the “peixinho” migrates upstream in schools, it is accompanied by post-larvae of other species, such as "kclacá" and "charrocos" (personal communication). As Bell (2009) documented, the upstream migration includes not only gobies but also eleotrids, gastropods, and decapod shrimps and have been reported in Dominica, in Colombia, where they are locally known as the “viuda” in the north, and “chaupisa” in the south (Sánchez-Garcés, 2017), and in the Philippines (Vedra et al., 2013). These events hold cultural significance, such as the Santa Ipon Festival in Philippines or “La viuda” in Colombia, given that these migrations provide a unique opportunity for fishing communities to gather and interact outside their domestic environments (Blanco-Libreros, 2015). In the fishing community from Iô-Grande, in São Tomé Island, some fishers mentioned a ritual where the community leader, known as “mêce”, is the first to catch post-larval gobies, then this initial catch is distributed within the community, and the leader’s approval is required to continue the fishing activity.

Although the total number of fishers engaged in the "peixinho" fishery remains unknown, this fishery is predominantly carried out by women, with most fisherwomen using the traditional trap in the western coast of São Tomé Island. Comparably to other goby-fry fisheries a gender segregation related to the fishing techniques was observed. Whereas in Dominica, men are in mainly in charge of the beach seiners and women operate with traps, in Colombia, the post-larval fishery has been considered a women activity until recently (Bell, 2009; Blanco-Libreros et al., 2015). Although women account for 40% of the small-scale fishing workforce, their contribution has long been overlooked (FAO, Duke University and WorldFish, 2023; Chambon et al., 2024). This oversight hinders a comprehensive understanding of small-scale fisheries dynamics, leading to consequences for fisheries management and food security, since women's catches can represent up to 50% of the fish and seafood consumed in fisherwomen-headed households, such as those in coastal areas of Kenya (Chambon et al., 2024).

The goby-fry fisheries are characterized by their informality. In La Réunion Island fishers occupy public rivers and maritime domains illegally; however, the fishing activity has been tolerated due to its cultural heritage value. With the introduction of mosquito nets during the 1970s, the goby-fry fishery was transformed from a recreational and subsistence fishing into a "profession", creating a significant underground economy. Currently, it is considered a recreational and subsistence-based fishery (Thomas, 2017). Similarly, a large proportion of "peixinho" fishers consider their fishing activity as commercial, with a distribution chain consisting of local fishmongers, locally known as "palâies". These fishmongers sell the catches in the main market of the capital city of São Tomé or in district markets, where the price of the "peixinho" fluctuates throughout the day from 1.68 euros per kg to 1.15 euros per kg at the end of the day. In contrast, the price of gobiid post-larvae in the goby-fry fishery of La Réunion island reached 80 euros per kg in 2016 (Thomas, 2017). Fishers also sell directly to members of their communities or neighbours. However, they admit that they do not sell all their catches, indicating that this fishery still has a significant subsistence component, as part of the catch is kept for their own consumption. Post-larval gobies are an important alternative of animal protein at local level (Carvajal-Quintero, 2011; Sahami et al., 2024). Almost the same number of small-scale fishers participate in subsistence fishing at some point during the year as those employed in commercial fisheries, given that subsistence fishing serves as a crucial safety net for livelihoods, helping to combat poverty, malnutrition, and gender inequality among

communities that rely on aquatic foods around the world, often in areas where people are highly vulnerable to the impacts of climate change (Virdin et al., 2023).

Regarding the goby-fry fisheries considered in this study, only the "bichique" fishery from La Réunion Island and the "ipon" fishery from Philippines are regulated, in both locations, fishing closures have been defined (Republic Act No. 614, 1970; Lagarde et al., 2023). The goby-fry fishery from São Tomé and Príncipe is not regulated by any organization or state administration. Although most of the "peixinho" fishers were hesitant to give their own opinion about possible management measures, they suggested that these measures should be defined by the fishing communities themselves. Ostrom (1988) described a fishing community in Alanya, Turkey, where fishers developed a self-managed system of lotteries and rotations, assigning themselves to different fishing locations and moving daily to new sites in line with fish migrations. This system provided equal access to the stocks, limited fishing effort, and helped to prevent the degradation of marine resources. Community-based collaborative approaches are often presented as a universal solution, panacea (Conley, 2003). However, Ostrom et al. (2007) cautioned against falling into the "panacea traps", the belief that all resource governance issues can be addressed by a single model of linked social-ecological systems, providing a general solution to resource overexploitation. Additionally, Berkes (2007) argued that for community-based conservation to be effective, it must address the multilevel nature of linkages and multiple partners, with institutions that connect the local level to higher levels of social and political organization, since on a practical level, multilevel management may affect transaction costs, such as those associated with research, monitoring, and decision-making. Furthermore, the "peixinho" fishers showed their support towards management measures mainly related to the reduction of pollution in rivers and beaches by using less toxic products and cleaning the beach and rivers. Fishers themselves expressed their worry about insecticide from the impregnated mosquito nets, apart from cleaning products from their household activities (personal communication). Most of the mosquito nets are treated with Permethrin, a water-soluble insecticide, and its long-term effects on fish population and ecosystems are unknown (McLean et al., 2014; Short et al., 2018). In São Tomé and Príncipe, impregnated mosquito nets were distributed by organizations, such as the World Bank Group, to prevent the proliferation of malaria, for instance, in 2019, 63% of the population under 5 years old were using insecticide-treated bed nets (World Bank, 2011; World Bank, 2019). Furthermore, in the

goby-fry fishery from São Tomé an intentioned exposure to toxic chemicals to increase the catches has not been reported, however in La Réunion Island, Thomas (2017) outlined the use of bleach from part of the fishers to increase the catches of "bichiques".

5. Conclusions and recommendations

In conclusion, our findings indicate that the goby-fry fishery of São Tomé and Príncipe is mostly carried out by middle-aged fisherwomen, with fishing techniques variations based on the location and age of the fishers, which have evolved in materials since the 19th century. Furthermore, fishers present a broad knowledge about the ecological migration of gobiid post-larvae, especially in the lunar phases and seasonal patterns, as well as in the possible impacts of pollution in rivers, providing an important baseline for future research. Additionally, the goby-fry fishery is also part of the cultural heritage and economy of the riparian fishing communities of the archipelago, and despite its significant role in the livelihood of "peixinho" fishers, it still maintains a considerable subsistence component.

In comparison to the goby-fry fishery on La Réunion Island, which has similar fishing techniques and cultural backgrounds, the fishing gear has evolved less in São Tomé and Príncipe. Thereby, it is possible that the "peixinho" fishery will continue to increase its fishing effort through the use of mosquito or nylon nets, leading to conflicts over water and resource sharing, to the detriment of the environment and culture. Furthermore, fishers are already aware of the declining of the "peixinho" catches, and even though they remain indecisive about the application of management measures, they are inclined towards community-based management processes. Therefore, considering that most of the fishers acknowledge the worsening of the fishery and support the creation of management measures by the community, we propose a participatory approach involving all the stakeholders, including the "peixinho" fishers, the MARAPA NGO and the Directorate of Fisheries and Aquaculture. This collaboration could be a first step to discuss and agree on management options with the best scientific advice available, while securing equitable participation of the fishing community in the decision-making process. LEK gathered in this study is the first step leading to more comprehensive research, allowing us to identify the knowledge gaps in this fishery and facilitating the collaboration among different stakeholders to initiate the participatory approach.

6. References

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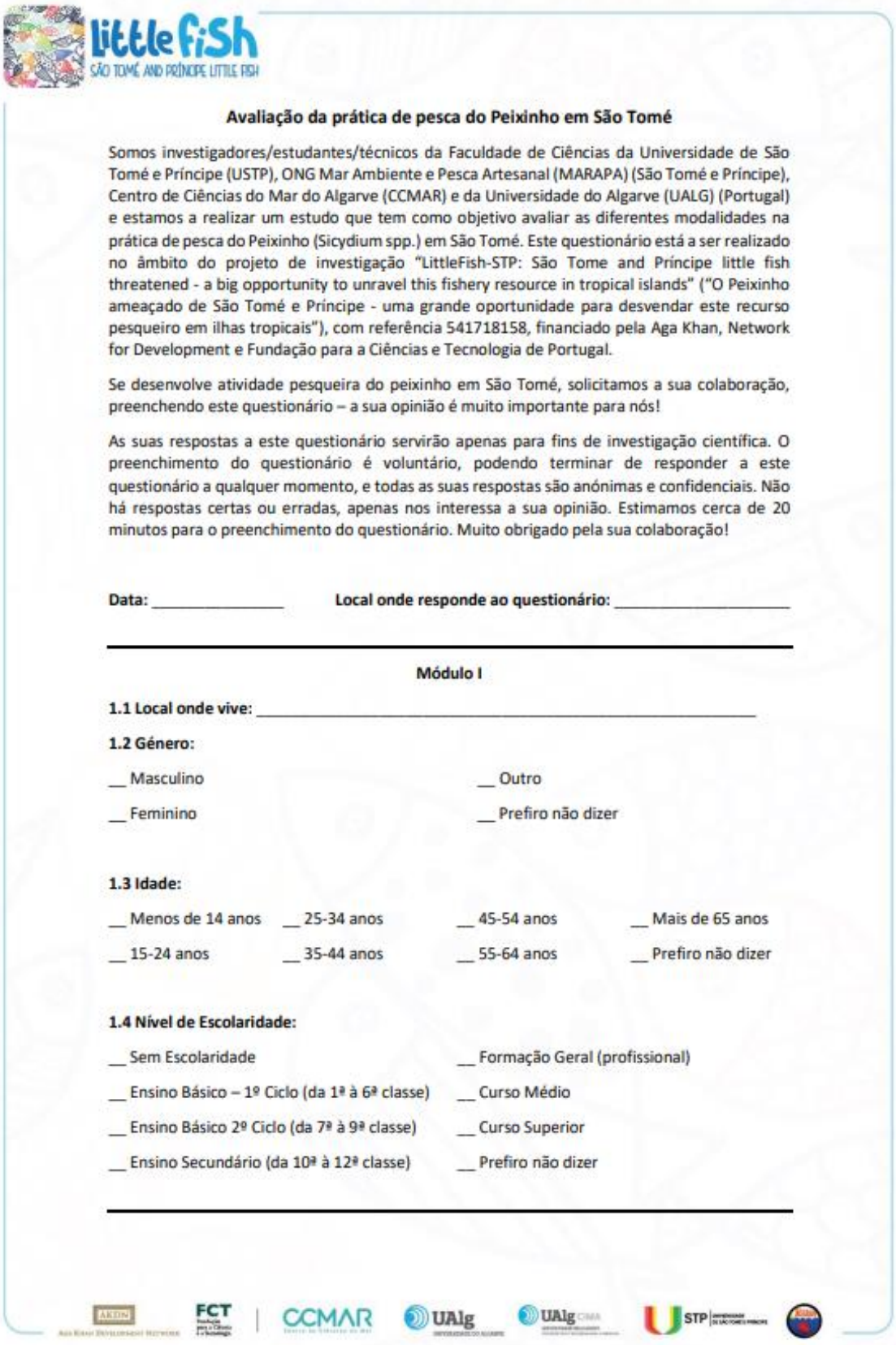
7. Annex

7.1 Fishing interviews

Annex Figure 7.1. LittleFish-STP member interviewing a fisherwoman in the fishing community of Iô-Grande in August of 2022.

Example of semi-structured interview guide:



littleFiSh
SÃO TOMÉ AND PRÍNCIPE LITTLE FISH

Avaliação da prática de pesca do Peixinho em São Tomé

Somos investigadores/estudantes/técnicos da Faculdade de Ciências da Universidade de São Tomé e Príncipe (USTP), ONG Mar Ambiente e Pesca Artesanal (MARAPA) (São Tomé e Príncipe), Centro de Ciências do Mar do Algarve (CCMAR) e da Universidade do Algarve (UALG) (Portugal) e estamos a realizar um estudo que tem como objetivo avaliar as diferentes modalidades na prática de pesca do Peixinho (Sicydium spp.) em São Tomé. Este questionário está a ser realizado no âmbito do projeto de investigação "LittleFish-STP: São Tome and Príncipe little fish threatened - a big opportunity to unravel this fishery resource in tropical islands" ("O Peixinho ameaçado de São Tomé e Príncipe - uma grande oportunidade para desvendar este recurso pesqueiro em ilhas tropicais"), com referência 541718158, financiado pela Aga Khan, Network for Development e Fundação para a Ciências e Tecnologia de Portugal.

Se desenvolve atividade pesqueira do peixinho em São Tomé, solicitamos a sua colaboração, preenchendo este questionário – a sua opinião é muito importante para nós!

As suas respostas a este questionário servirão apenas para fins de investigação científica. O preenchimento do questionário é voluntário, podendo terminar de responder a este questionário a qualquer momento, e todas as suas respostas são anónimas e confidenciais. Não há respostas certas ou erradas, apenas nos interessa a sua opinião. Estimamos cerca de 20 minutos para o preenchimento do questionário. Muito obrigado pela sua colaboração!

Data: _____ **Local onde responde ao questionário:** _____

Módulo I

1.1 Local onde vive: _____

1.2 Género:

__ Masculino __ Outro

__ Feminino __ Prefiro não dizer

1.3 Idade:

__ Menos de 14 anos __ 25-34 anos __ 45-54 anos __ Mais de 65 anos

__ 15-24 anos __ 35-44 anos __ 55-64 anos __ Prefiro não dizer

1.4 Nível de Escolaridade:

__ Sem Escolaridade __ Formação Geral (profissional)

__ Ensino Básico – 1º Ciclo (da 1ª à 6ª classe) __ Curso Médio

__ Ensino Básico 2º Ciclo (da 7ª à 9ª classe) __ Curso Superior

__ Ensino Secundário (da 10ª à 12ª classe) __ Prefiro não dizer

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Módulo II – Conhecimento sobre as artes de pesca

2.1 Há quantos anos pratica a pesca do peixinho?

__ Menos de 5 anos __ 10-14 anos __ 20 ou mais anos

__ 5-9 anos __ 15-19 anos

2.2 Como classifica esse tipo de pesca?

__ Subsistência __ Outra: (qual?) _____

__ Comercial

2.3 Quais são os tipos de arte de pesca que utiliza?

__ Rede mosquiteira

__ Armadilhas com cesto (Tchanga)

__ Armadilhas com panos

__ Armadilhas com rede de nylon que se coloca nas janelas e nas portas das casas

__ Outras: (quais?) _____

2.4 Quais os tipos de materiais que utiliza para a prática da pesca do peixinho?

__ Rede mosquiteira __ Pano branco

__ Rede de nylon __ Outros: (quais?) _____

2.5 A pesca do Peixinho é realizada em grupo ou individualmente? _____

2.6 Caso seja em grupo, quantas pessoas participam? _____

2.7 Sempre usou a mesma arte para apanhar peixinho? __ Sim __ Não

2.8 Sempre apanhou peixinho nesta comunidade? __ Sim __ Não

2.9 Se respondeu que não, por favor indicar outros locais: _____

2.10 A pesca é feita em que período do dia?

__ Durante a noite até de madrugada __ Tanto de dia como de noite

__ Durante o dia até ao final da tarde

2.11 Se for à noite, quais são os materiais de iluminação usados?

__ Lanterna __ Lampião

__ Candeeiro de petróleo __ Outros: (quais?)_____

2.12 Caso a pesca ocorra tanto de dia como de noite, quando é que costuma pescar mais?

__ Dia __ Noite

2.13 Normalmente pesca Peixinho todos os meses? __ Sim __ Não

2.14 Se não, com que frequência pesca peixinho?

__ Mês sim mês não __ Meses da gravana

__ De dois em dois meses __ Outras: (quais?) _____

__ Meses de chuvas

2.15 Pesca Peixinho durante todo o mês? __ Sim __ Não

2.17 A pesca do peixinho está relacionada com a fase da lua? __ Sim __ Não

2.18 Se sim, em que fase da lua costuma pescar com maior frequência?

__ Lua cheia __ Quarto crescente

__ Lua nova __ Quarto minguante

2.19 Quando o Peixinho aparece, quantos dias pesca o mesmo? _____

2.20 Porquê? _____

_____

2.21 Que outras espécies (ex., peixes, camarões, etc.) costumam ser capturado com o Peixinho? _____

_____

Módulo III – Conhecimento sobre a quantidade de Peixinho pescada

3.1 Qual foi o último mês em que apanhou Peixinho? _____

3.2 Qual foi a quantidade de Peixinho que apanhou nesse mês? _____

3.3 Qual foi a maior quantidade de Peixinho que já apanhou desde que começou a pescá-lo?
_____

3.4 Em que mês e ano ocorreu? _____

3.5 Costuma apanhar mais Peixinho branco ou Peixinho preto? _____

3.6 Quando aparece mais Peixinho preto, normalmente continua com a captura ou esta é interrompida? _____

3.7 Porquê? _____

_____

3.6 Qual a época do ano que pesca mais Peixinho? _____

Módulo IV – Conhecimento sobre contrapartida financeira

4.1 Onde costuma vender o Peixinho que apanha?

__ Mesmo na comunidade para as palaiês __ Na cidade do distrito

__ Na cidade capital __ Outros: (quais?) _____

4.2 Normalmente costuma vender todo o Peixinho que apanha? __ Sim __ Não

4.3 Qual o valor médio diário que consegue com a venda do Peixinho? _____

4.4 Com a venda do Peixinho consegue adquirir alguns bens materiais? __ Sim __ Não

4.5 Se sim, quais?

__ Construção de casa __ Material escolar para os filhos

__ Televisor __ Porco para criação

__ Rádio __ Outros: (quais?) _____

4.6 Alguma vez sofreu algum acidente durante a pesca do Peixinho? __ Sim __ Não

4.7 Se sim, qual? _____

Módulo V – Perceção sobre as medidas de gestão

5.1 Como compara a situação da pesca do Peixinho atualmente em relação à época em que começou a pescar?

__ Melhor __ Pior __ Igual

5.2 Acha que deviam haver medidas para gerir a pesca do Peixinho?

__ Sim __ Não

5.3 Quem acha que devia definir essas medidas?

__ Estado
__ Poder Local
__ Comunidade
__ Todas as partes interessadas
__ Outros: (quais?) _____

5.4 Acha que o Peixinho pode vir a desaparecer nesta comunidade? __ Sim __ Não

5.5 Se sim, o que acha que devia ser feito?

__ Limites nas quantidades pescadas
__ Proibição de pesca em alguns períodos
__ Limpezas constantes nas margens dos rios e nas praias
__ Evitar lavagem de artigos com produtos tóxicos nos rios onde se captura peixinho
__ Outras: (quais?) _____

5.6 Conhece algum rio ou local onde antes se pescava Peixinho, e agora já não tem este recurso? __ Sim __ Não

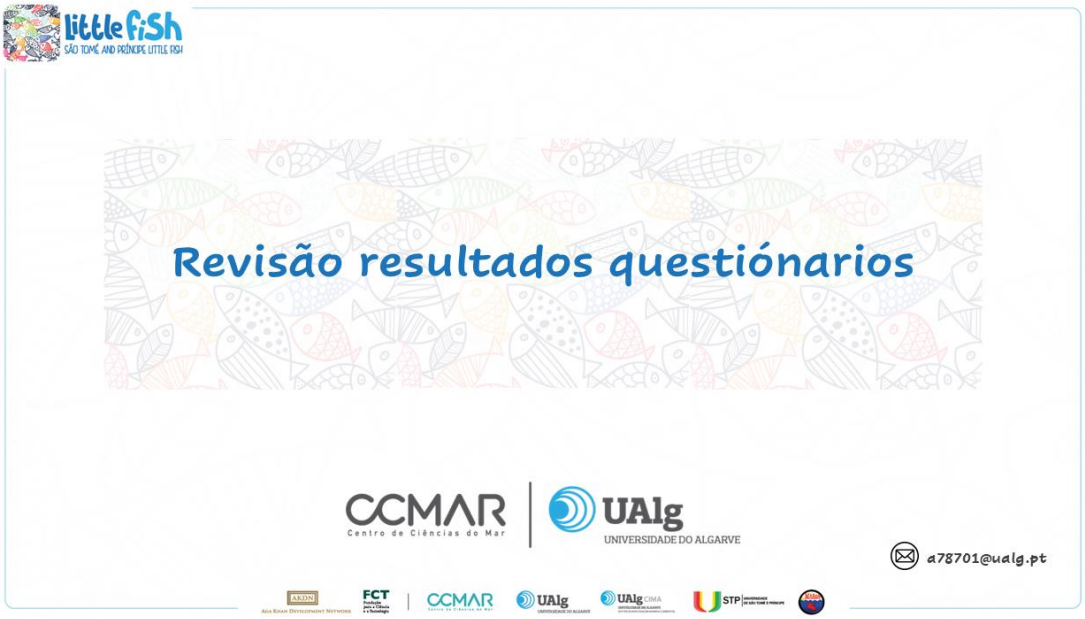
5.7 Se sim, qual ou quais? _____

7.2 Member checking with the fishing communities and expert

Annex Figure 7.2. LittleFish-STP project members during the SMC with the “peixinho” fishers from Praia Pesqueira fishing community in São Tomé and Príncipe in May of 2024.

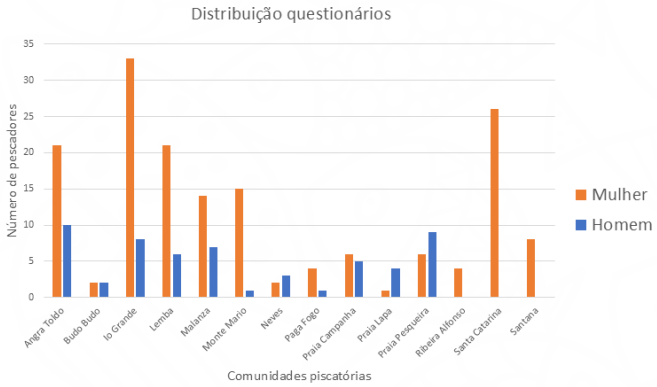
Annex Figure 7.3. LittleFish-STP project members cross-checking the results at University of São Tomé and Príncipe in May of 2024.

Example of a presentation used during the member checking with the fishing communities:

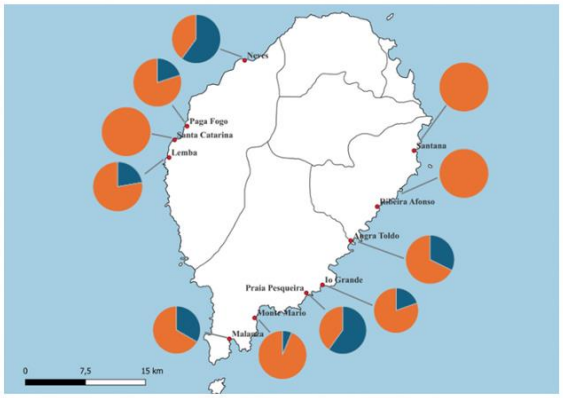


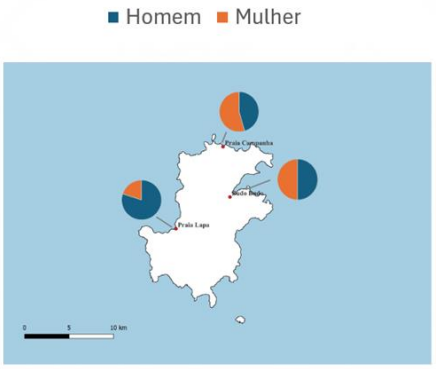
Questiónarios

- 124 questionários
- 74% mulheres
- 26% homens



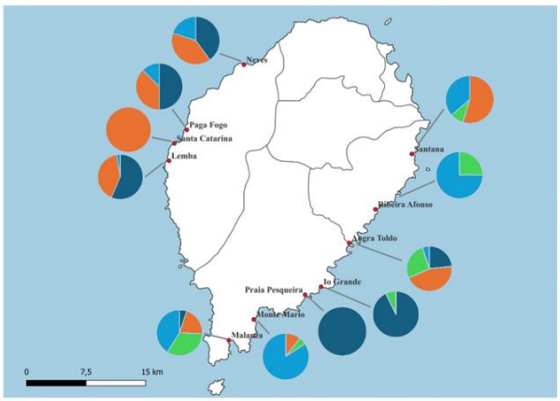
Pesca do peixinho e o género

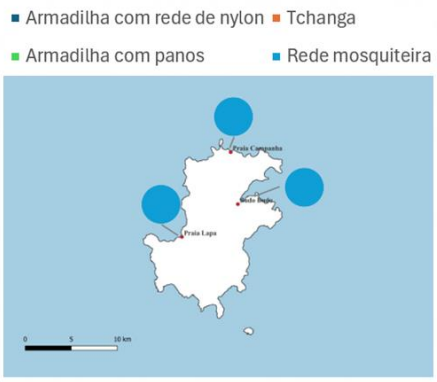




Artes de pesca

Em geral: → 35% armadilha com rede de nylon
→ 31% tchanga
→ 12% armadilha com panos
→ 22% rede mosquiteira



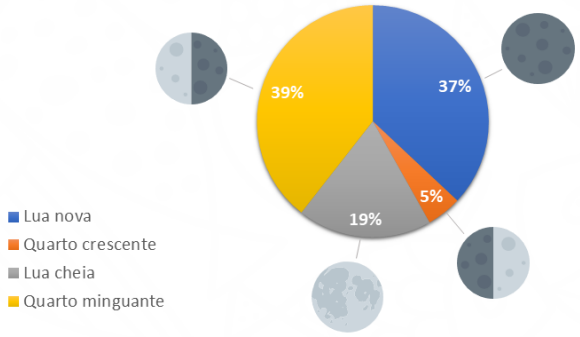


Pesca do peixinho e a lua

Em que fase da lua costuma pescar com mais frequência?

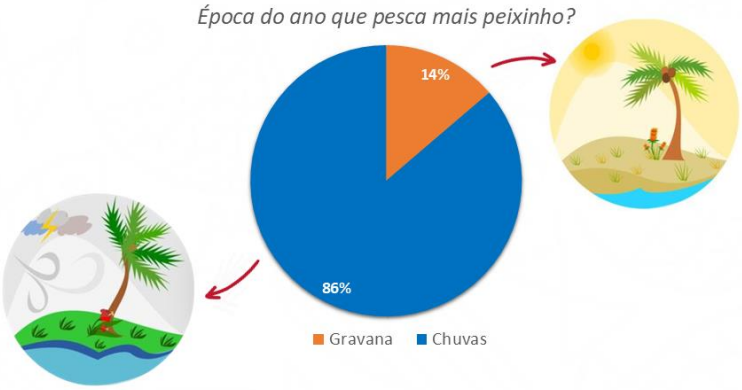
A pesca do peixinho está relacionada com a fase da lua?

- **89% acham que há relação**
- **11% acham que NÃO há relação**



Pesca do peixinho e época do ano

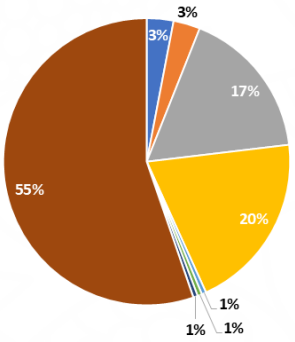
Época do ano que pesca mais peixinho?



Sugestões de medidas de gestão do peixinho

Se o que acha que devia ser feito para ter peixinho no futuro?

- Limites nas quantidades pescadas
- Proibição de pesca em alguns períodos
- Limpezas constantes nas margens dos rios e nas praias
- Evitar lavagem de artigos com produtos tóxicos nos rios onde se captura peixinho
- Abrir boca do rio
- Organizar todos os pescadores de peixinho
- Evitar lançamento de rede no mar
- Sem resposta



Sugestões de medidas de gestão do peixinho

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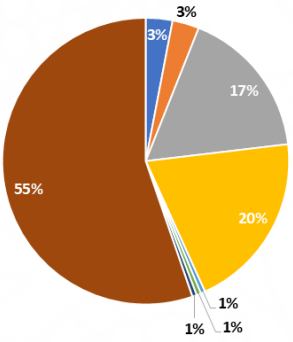
- Organizar todos os pescadores de peixinho
- Evitar lançamento de rede no mar
- Sem resposta



littlefish
O PEIXINHO DE SÃO TOMÉ E PRÍNCIPE

Obrigada

@LittleFishSTP
@littlefishstp
littlefishstp.com/

a78701@ualg.pt

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