Filipa Santos Medinas Realinho da Silva

Food choices of the Yellow-legged Gull population of Barreta Island, on anthropogenic food sources from fishing ports, fishing vessels and landfills

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Declaração de autoria de trabalho

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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Index

Abstract

Human activities have caused changes in ecosystems and animal populations worldwide. These have been increasing with the human population growth and the consequent development of anthropogenic activities. One of the most affected groups of animals are marine birds yet, several opportunistic seagull populations have undergone a demographic explosion over the last decades. Gull species, such as the Yellow-legged Gull, owe part of their success to their great ability to exploit human-related food sources, namely fisheries discard and refuse dumps. The Yellow-legged Gull can widen or narrow its trophic niche according, for example, to temporal food availability. In fact, temporal fluctuations in food availability are one of the main factors shaping seabird population dynamics and foraging strategies. Understanding species' ecological responses to these fluctuations provides important information on gull populations dynamics and feeding ecology. Here, we report the food choices and foraging strategies of the Yellow-legged Gull population from Barreta Island, according to food availability at four different foraging sites in Algarve, Southern Portugal. Our results showed that the foraging strategies of this population go in line with the week/weekend cycles and precise timetable of fisheries activities and landfill-related work. This population can match its foraging schedules with human activity schedules, foraging at each study site not only when there are activities taking place and consequently food availability, but also when food abundance is higher. Furthermore, a significant proportion of individuals in this population seem to be able to predict food availability in space and time. Our results confirm the dependence of this population on fishery discards but point also to a relevant exploitation of food resources on the Sotavento landfill. These patterns of food dependency may lead to a decrease in this population after the implementation of European policies on fish discards and open-air landfill management.

Keywords: Food availability; Fisheries discards; Landfills; Yellow-legged Gull; Foraging strategies

Resumo

A crescente perturbação causada pelas atividades humanas na vida selvagem tem sido motivo de preocupação e investigação nas últimas décadas. A exposição a perturbações antropogénicas causa alterações comportamentais nas aves marinhas, tais como, modificações nos padrões de movimentação, procura de alimentos e escolhas alimentares, de forma a evitarem ou minimizarem os seus efeitos. No entanto, apesar de todas as ameaças a que estão sujeitas, as populações de grandes gaivotas (*Larus spp.*) sofreram um aumento populacional ao longo do último século na Europa, América do Norte e Austrália. No caso de algumas populações no Mediterrâneo, este aumento foi tão significativo que são mesmo consideradas uma peste devido aos seus impactos negativos nas atividades humanas e biodiversidade. Juntamente com medidas para proteção destas espécies e os seus dos habitats de reprodução, a causa de tal crescimento populacional tem sido atribuída ao aumento da abundância de fontes alimentares alternativas de origem humana, particularmente, rejeições de peixe provenientes das atividades pesqueiras e desperdícios alimentares disponíveis em lixeiras, que as gaivotas parecem conseguir obter com relativa facilidade.

As gaivotas têm estratégias alimentares bastante variáveis entre espécies e diversas mesmo dentro de cada espécie. A gaivota de patas amarelas é um excelente exemplo desta diversidade e o seu comportamento alimentar generalista e oportunista tem sido amplamente descrito. A sua elevada plasticidade no forrageamento permite-lhe procurar alimentos numa grande variedade de habitats, alterando os seus movimentos diários e distribuição para beneficiar do consumo de alimentos provenientes de atividades humanas, mantendo ainda assim o seu comportamento predatório. Para além disto, esta espécie consegue alargar ou estreitar o seu nicho trófico de acordo com as suas exigências nutricionais ao longo das estações, disponibilidade temporal de alimentos e distribuição espacial dos seus principais recursos alimentares. Desta forma, consegue evitar períodos de escassez alimentar, melhorar o seu rendimento reprodutivo e aumentar as taxas de sobrevivência.

A ecologia alimentar das gaivotas de patas amarelas varia significativamente entre populações de diferentes locais. Em zonas costeiras, as rejeições de peixe têm sido demonstradas ser a principal fonte de alimentação das populações, ainda assim as presas marinhas naturais continuam a ter uma elevada importância na dieta de algumas destas populações. Vários estudos sobre as escolhas alimentares desta espécie têm demonstrado que, para além das rejeições de peixe, a gaivota de patas amarelas é capaz de alimentar-se em lixeiras a céu aberto. No geral, a dependência desta espécie nos recursos alimentares disponíveis em lixeiras não é totalmente conhecida. Sabe-se que esta espécie não é especialista em

alimentar-se nestes locais, no entanto, ao longo da costa mediterrânica as populações de gaivotas de patas amarelas parecem ser fortemente dependentes deste recurso alimentar, especialmente em períodos de escassez de rejeições de peixe, normalmente associadas a períodos de reduzida atividade pesqueira. Quer as rejeições de peixe quer o desperdício alimentar em lixeiras, parecem ter uma elevada importância para consumidores oportunistas devido à sua renovação diária, previsibilidade e elevada abundância. As atividades humanas, tal como as pescas ou os trabalhos nos aterros têm horários de funcionamento precisos que deverão dar às gaivotas a possibilidade de aprender a antecipar a disponibilidade alimentar que delas proveem. Desta forma, as fontes alimentares alternativas de origem antropogénica parecem ser de elevada previsibilidade para as gaivotas, em comparação com os recursos marinhos naturais que são mais imprevisíveis e inconsistentes e consequentemente mais escassos para as gaivotas.

Para além da variabilidade de estratégias alimentares entre populações, alguns indivíduos de populações de gaivotas de patas amarelas têm variações na estratégia de procura de alimento e escolhas alimentares, especializando-se numa gama de recursos alimentares mais restrito. Apesar de ser um tema relativamente pouco estudado, pensa-se que a especialização individual acarreta benefícios, tais como, melhoramento do desempenho de reprodução, da aptidão individual e do esforço de procura alimentar. A especialização alimentar leva também a uma variação da largura do nicho trófico entre indivíduos, reduzindo a sobreposição na utilização de recursos e diminuindo a competição entre indivíduos da mesma espécie.

Estudos anteriores do comportamento alimentar da população de gaivotas de patas amarelas da Ilha da Barreta, revelaram a sua elevada dependência de rejeições de peixe, aumentando o seu consumo de presas terrestres e de alimentos disponíveis em lixeiras, essencialmente em caso de indisponibilidade de rejeições pesqueiras. A identificação das variações temporais nos habitats de procura de alimento e escolhas alimentares desta população é crucial para o conhecimento da dinâmica e distribuição da população, ecologia alimentar, causas de crescimento populacional e conservação da mesma. O presente estudo tem como objetivo avaliar as escolhas alimentares e estratégias de forrageamento da população de gaivotas de patas amarelas da Ilha da Barreta em fontes alimentares antropogénicas provenientes de portos de pesca, embarcações pesqueiras e lixeiras a céu aberto, de acordo com a sua disponibilidade. Esta investigação será baseada em duas questões principais: (1) as gaivotas de patas amarelas escolhem um dia ou hora específica para procurar alimento nos portos de pesca, embarcações pesqueiras e lixeiras? (2) Em que medida a abundância de gaivotas de patas amarelas em portos de pesca, embarcações pesqueiras e lixeiras, está relacionada com as operações a ocorrer nestes locais? Para além disto, haverão dois objetivos secundários: verificar (3) qual é o tempo de resposta entre um dado evento de disponibilidade alimentar e a chegada das gaivotas ao local, e (4) verificar as diferenças na abundância

de aves na colónia, portos de pesca, embarcações pesqueiras e lixeiras entre 2020 (com todas as restrições associadas com a pandemia mundial de SARS-CoV-2) e 2021.
Este estudo foi realizado no Algarve, sul de Portugal, em cinco locais de estudo distintos: Ilha da Barreta, porto de pesca de Olhão, porto de pesca da Culatra, aterro do Sotavento e a bordo de embarcações pesqueiras que operam ao largo do porto de pesca de Olhão. O trabalho de campo foi realizado mensalmente ao longo de um ano, entre junho de 2020 e junho de 2021, com o objetivo de estimar a abundância de indivíduos de gaivotas de patas amarelas em cada um dos locais de estudo. A metodologia de campo foi baseada na contagem e observação do comportamento das aves ao longo de transectos definidos, realizados por pelo menos dois observadores em cada dia de monitorização. Os dados recolhidos na colónia foram utilizados como uma medida da abundância populacional na área da Ria Formosa ao longo do ano, os dados recolhidos nos restantes quatro locais de estudo foram utilizados para obter informação sobre a ecologia alimentar, escolhas alimentares e dependência alimentar da população em fontes alimentares de origem antropogénica.
Os nossos resultados revelaram diferenças significativas na abundância de aves no aterro e porto de Olhão entre dias de semana e fim de semana. Em dias de maior abundância de aves no porto de pesca (dias de semana), a abundância foi menor no aterro, e vice-versa. Estes resultados revelam uma relação entre a abundância de aves nestes locais e as flutuações de disponibilidade alimentar, provocadas pelas diferenças nas operações a ocorrer entre dias de semana e fim de semana em cada local. Em relação à análise da abundância de aves ao longo das horas, no aterro do Sotavento foi verificado que as aves se alimentam quase exclusivamente no período da manhã. A razão para isto poderá estar no facto de uma grande de quantidade de lixo ser descarregada no aterro da parte da manhã ou no facto de as aves alinharem os seus horários de procura alimentar no aterro com aquelas que utilizam nas embarcações pesqueiras (recurso que exploram com maior frequência). No porto de Olhão, não parece existir uma hora ou período específico em que as gaivotas procuram alimento, os nossos resultados mostraram que abundância de aves neste local é bastante estável ao longo do dia. Isto pode estar relacionado com o facto de as gaivotas conseguirem encontrar outras fontes alimentares de origem humana nas imediações do porto, uma vez que se localiza numa zona urbana e bastante populosa. Assim, e de acordo com os resultados do nosso modelo, as gaivotas de patas amarelas parecem ter uma forte associação com este local de procura alimentar. Com este estudo conseguimos também verificar uma relação entre a presença das gaivotas em cada local de estudo e as atividades humanas a ocorrer (à exceção do porto da Culatra). No aterro do Sotavento, a abundância de aves em momentos com operações a ocorrer é superior aquela registada em momentos sem operações, no entanto, a abundância de aves em momentos sem operações

a ocorrer continua a ser elevada. Isto deverá estar relacionado com a estratégia alimentar adotada pelas aves no aterro, que ao contrário do observado em ambientes naturais, as aves parecem ficar a aguardar o próximo evento de disponibilidade alimentar em vez de continuarem a procurar alimento ativamente. Resumidamente, os nossos resultados parecem confirmar a forte dependência desta população de fontes alimentares de origem antropogénica. Apesar do que foi anteriormente descrito sobre o comportamento alimentar desta população, os nossos dados demonstram uma utilização mais extensiva dos recursos alimentares disponíveis no aterro mais próximo da colónia. A população de gaivotas de patas amarelas da Ilha da Barreta demonstrou não só ter a capacidade de fazer coincidir os seus horários de forrageamento com os horários das atividades humanas no aterro (tal como faz em interações com embarcações pesqueiras), mas também estratégias alimentares adaptadas ao tipo de atividades que lá ocorrem. Será, no entanto, importante ter em conta que esta investigação decorreu no período da pandemia mundial do vírus SARS-CoV-2, que levou a um longo período de quarentena nacional imposto pelo governo e que afetou fortemente várias atividades humanas incluindo as atividades pesqueiras. Esta redução nas atividades de pesca poderá ter tido influência no comportamento alimentar da população verificado neste estudo. Se os nossos resultados forem confirmados, será de esperar que esta população possa vir a ser fortemente afetada políticas Europeias previstas para regulamentação das rejeições pesqueiras, mas também pelo previsto encerramento das lixeiras a céu aberto.

Palavras-chave: Disponibilidade alimentar, Rejeições de peixe, Aterros, Gaivota de patas amarelas, Estratégias de forrageamento

List of figures

List of tables

List of annexes

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1. General Introduction

1.1 The effect of anthropogenic food sources on large seagulls *Larus sp*

Since the industrial revolution and the consequent increase in the world human population, anthropogenic activities have caused significant changes in ecosystems and animal populations (Garcês et al., 2019; Mendes et al., 2018; Oro et al., 2013). Currently, human-related disturbance of wildlife is stated as an issue of major concern related to biodiversity conservation and urban areas are known to be critical in anthropogenic pressures, where bird diversity decreases with expanding urbanization (Dias et al., 2019; Gill, 2007; Shochat et al., 2006). Global climate change, pollution, bycatch and resources overexploitation (predominantly from fisheries) are some of the stressors to which bird species are affected worldwide (Matos et al., 2018; Oro et al., 2013; Burthe et al., 2014). Their life history characteristics make seabirds among the bird groups most affected by these threats (Dias et al., 2019; González-Solís & Shaffer, 2009). Fishing activities promote a worrying pressure on marine populations as they are intrinsically linked to large-scale problems such as overfishing and bycatch (Matos et al., 2018; Oliveira et al., 2020). A reduction in available fish stocks, making natural food sources increasingly scarce for seabirds and, the death or injury of hundreds of thousands of seabirds every year due to their interactions with fisheries (during their feeding activities) are the two main consequences of these problems, respectively (Dias et al., 2019; Mendes et al., 2018; Weimerskirch, 2007). Previous studies have proven that large seagull species (*Larus* spp.) are among the species with the greatest interaction with fisheries, but not the most affected by by-catch (Barcelona et al., 2010; Calado et al., 2021). The same is not true for other seabird populations that have suffered a considerable decline due to this negative interactivity with fishing vessels (Oliveira et al., 2020; Rouxel et al., 2021). Increasing exposure to anthropogenic stressors causes behavioural changes in birds, such as modifications in movement patterns, foraging, or feeding choices to avoid or minimize their effects (Garcês et al., 2019; Mendes et al., 2018).

Despite all these threats, large seagull populations within Europe, North America and, Australia have undergone a demographic explosion over the last century (Alonso et al., 2015; Arizaga et al., 2013; Matias & Catry, 2010; Ramos et al., 2009a). In some colonies, this growth was so significant that has resulted in a large increase in intraspecific competition and predation of sympatric species, especially during periods when food resources from fishing activities are reduced or unavailable (Arizaga et al., 2013; Matias & Catry, 2010; Oro et al., 2005). In some cases, along the Mediterranean, overabundant

Yellow-legged Gull populations are even considered a pest, due to their impacts on human activities and biodiversity (Duhem et al., 2003; Ramos et al., 2009a). Among the impacts caused by this species, it is possible to highlight the damages on cities, airports and fisheries and, the strong negative impact on other protected bird species, decreasing their survival rates and fecundity, such as terns *Sterna* spp. (Oro et al., 2005; Pedro et al., 2013). To reduce these consequences, several overabundant seagull colonies were selected for population control management plans. However, these management plans did not work as expected and were mostly ineffective (Payo-Payo et al., 2015; Arizaga et al., 2013). An exception to this is the Yellow-legged Gull *Larus michahellis* (Naumann, 1840) population on Berlenga Island, Portugal. In 1994 it was estimated that this population comprised 45 000 individuals (Meirinho et al., 2014). This alarming number promoted the implementation of a series of measures to control population abundance and by 2016 the population numbers decreased to 10 693 individuals (Morais et al., 2016). Along with measures to protect the species and the corresponding breeding sites (Duhem et al., 2008; Pons & Migot, 1995), the increasing abundance of alternative food sources of human origin, particularly discards from fishing activities and food available in dumps was directly related with the exponential growth of seagull populations (Alonso et al., 2015; Arizaga et al., 2013; Duhem et al., 2008). While natural food resources are inconsistent in time and space over large areas and increasingly limited due to the rising pressure caused by anthropogenic activities (Mendes et al., 2018; Weimerskirch, 2007), food sources available in refuse dumps or fish discards represent a predictable and daily renewable aliment supply for opportunistic feeders (Mendes et al., 2018; Oro et al., 2013; Pedro et al., 2013). The increasing availability of anthropogenic food sources has also promoted an expansion in urban gull populations, that begin to potentiate conflicts between these species and humans, owing to socio-economic and sanitary problems (such as disease transmission) (Alonso et al., 2015; Matos et al., 2018).

1.2 The Yellow-legged Gull

The food choices and foraging strategies of birds can be highly variable across species and very diverse within each species (Ceia et al., 2014). The Yellow-legged Gull is a prime example of this diversity. This seagull has a highly plastic feeding behaviour that allows it to forage in a wide variety of habitats, altering its daily movements and distribution to take advantage of the demand for food sources from human activities as well as maintaining a predatory behaviour, to meet its energetic requirements (Ceia et al., 2014; Matos et al., 2018; Veríssimo, 2018). Thus, this species can feed on a considerable variety of food resources (natural and alternative) such as various fish species, pelagic crabs, insects and, food from anthropogenic waste (Meirinho et al., 2014).

The Yellow-legged Gull is long-lived and large-sized (body mass 800-1500g) when compared with other seagulls (Mendes, 2017; Calado et al., 2018). It breeds in colonies, sometimes of mixed species, from mid-March to April and lays up to three eggs (BirdLife International, 2021). According to the IUCN Red list, is evaluated as Least Concern (LC). This gull has an ample spatial distribution (Galarza et al., 2012) and the progressive colonisation of urban areas has led to an expanding of its distribution area (Meirinho et al., 2014). During the breeding season, it is spread over most of Southern Europe and North Africa (Alonso et al., 2015) while on the winter season, it can be found along all the European Atlantic and Mediterranean coasts (Meirinho et al., 2014). The Yellow-legged Gull has a markedly coastal distribution, and in Portugal, it occurs along almost the entire coast and nearly all islands (Meirinho et al., 2014).

The Barreta Island, also known as Deserta, is one of the five islands and two peninsulas comprising a barrier-island system that belong to the Ria Formosa Natural Park, Algarve, southern Portugal and separate the lagoon from the Atlantic Ocean (Ceia et al., 2010; Lopes et al., 2021; Mendes et al., 2018). This protected area is a large (around 55 km long) coastal lagoon system (Calado, 1996) with unique and highly changeable characteristics such as the tides, temperature, and salinity (Newton & Mudge, 2003). It is an ecosystem of great importance for hundreds of bird species (Newton & Mudge, 2003). The Barreta Island itself is a relevant breeding site for two species: the Audouin's Gull *Larus audouinii* (Payraudeau, 1826), which breeds in sympatry with the Yellow-legged Gull (Matos et al., 2018). The Barreta Island has lower tourist pressure compared to most of the Algarve coast and is characterized for its intense commercial fishing activity (Laranjeiro et al., 2020; Matos et al., 2018; Calado et al., 2017).

Fisheries activity are extremely important for this population which, according to various dietary studies, shows a preferentially marine feeding strategy rather than a terrestrial feeding strategy (Matos et al., 2018; Mendes et al., 2018). Nevertheless, in cases of reduced availability of marine food resources or adverse oceanographic conditions, this population seems to adopt a terrestrial feeding strategy, exploiting the closest landfill or other land related sources of food (Lopes et al., 2021; Mendes et al., 2018). The use of these anthropogenic food sources by this and other populations of Yellow-legged Gulls is also important, enhancing the fitness components and breeding performance of individuals, increasing their survival and favouring population growth (Lopes et al., 2021; Oro et al., 2013). According to Duhem et al. (2008), the existence and plenty of food from anthropogenic residues has such relevance for gulls that frequently determine their choice of nesting sites, diet, and wintering and breeding grounds. In the other hand, the consumption of anthropogenic waste entails some risks for these birds, increasing the probability of ingestion contaminants, poisoning and pathogen infections (Lopes et al., 2021; Sorais et al., 2020). These risks stem from the large amount of anthropogenic materials such as rubber, metal, glass and mostly plastic, that birds can ingest while foraging at landfills (Lopes et al., 2021).

1.3 European environmental measures and consequent impacts on gull populations

Environmental policies are being implemented throughout Europe to regulate human activities with impacts on ecosystems and species (Oro et al., 2013). The Common Fisheries Policy of the European Union (Calado et al., 2017) and the European Union Landfill Directive (European Commission 2016) have the goal of implementing two of the environmental measures imposed by European Union: A discard ban policy and the closure of open-air landfills, respectively. It is expected a significant decrease on the amount of predictable anthropogenic food subsidies when these measures start to be fully implemented (Payo-Payo et al., 2015). This foreseeable scarcity may result in a collapse of the populations using these food sources. According to Oro et al. (2013), there is a risk that the size of gull populations falls dramatically to even lower values than before the appearance of these food resources. Even so, due to their great adaptability, Oro et al. (1995) suggests that gull populations would move from one resource to another to avoid food shortages (Pons & Migot, 1995) that may arise after the definitive implementation of these measures. However, it is still uncertain how effective they would be in changing from a scavenger to an exclusive hunter (Bicknell et al., 2013). Thus, is crucial to maintain effective and long-term seabird monitoring, specially before and during the implementation of management alterations in fisheries and waste sectors to ensure that these populations are not adversely affected (Alonso et al., 2015; Calado et al., 2017).

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2 Manuscript

Food choices of the Yellow-legged Gull population of Barreta Island, on anthropogenic food sources from fishing ports, fishing vessels and landfills

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2.1 Abstract

Opportunistic gull species, such as the Yellow-legged Gull, owe part of their success to their great ability to exploit alternative food resources, including human-related food sources, namely fisheries discard and refuse dumps. This species can widen or narrow its trophic niche according, for example, to temporal food availability, avoiding periods of food scarcity. In fact, temporal fluctuations in food availability are one of the main factors shaping seabird population dynamics and foraging strategies. Understanding species' ecological responses to these fluctuations provides important information on gull populations dynamics and feeding ecology. Here, we report the food choices and foraging strategies of the Yellow-legged Gull population from Barreta Island, according to its availability at four different foraging sites: Olhão and Culatra fishing ports, Sotavento landfill and fishing vessels. Monitoring was conducted for one year on a regular monthly basis at all study sites. On each monitoring day, at least two observers recorded spatial data on transects, to estimate the abundance and behaviour of Yellow-legged Gulls at each foraging site. Our results showed that the foraging strategies of this population go in line with the precise timetables imposed by fishing activities and landfill-related work. This population can match its foraging schedule with the human activity schedule, foraging at each study site not only when there are activities taking place and consequently food availability, but also when food abundance at each foraging site is higher. Furthermore, a significant proportion of individuals in this population seem to be able to predict food availability in space and time. Finally, our results confirm the dependence of this population on fishery discards but point to a relevant exploitation of food resources on the landfill. This food dependency may lead to a decrease in this population after the implementation of European policies on fish discards and open-air landfill management.

2.2 Introduction

Food availability is one of the main factors shaping seabird population dynamics and foraging strategies (Mendes et al., 2018; Pons & Migot, 1995). Variations in food resources usage, either according to resource availability or individual preferences, provide important information for understanding the feeding ecology of seabird populations (Alonso et al., 2015; Ceia et al., 2014). This knowledge is of particular interest when it comes to opportunistic gulls species (*Larus* sp.), as their success is based on their great ability to rapidly shift their diet, exploiting different food resources (Alonso et al., 2015; Ceia et al., 2014). Thus, these species can avoid periods of food scarcity, improve its breeding output, survival rates, recruitment and population growth (Pedro et al., 2013; Weimerskirch, 2007).

The generalist and opportunistic feeding behaviour of the Yellow-legged Gull *Larus michahellis* are long known and has been widely described (González-Solís et al., 1997; Oro et al., 1995; Mendes et al., 2018; Cama et al. 2012; Matos et al., 2018; Egunez et al., 2018; Duhem et al., 2008). This species is able to broaden or narrow its trophic niche according to its energetic requirements throughout the seasons, temporal availability and spatial distribution of its main food sources (Pedro et al., 2013). The Yellow-legged Gull has a great plasticity in food demand, exploiting anthropogenic food resources including refuse tips and fisheries discards (Ceia et al., 2014; Duhem et al., 2003; Mendes et al., 2018). Both sources have great importance for opportunistic feeders due to their daily renewable, predictability and abundance (Duhem et al., 2003). Despite its opportunistic feeding behaviour, the Yellow-legged Gull maintains its predatory and competitive behaviour (Oro et al., 2005; Pedro et al., 2013). One of its favourite natural preys on the Atlantic coast is the Henslowi's swimming crab *Polybius henslowi*, which according to Alonso et al (2015), is of great importance for the Yellow-legged Gull breeding population at Berlenga Island, the largest in Portugal (Calado et al., 2021).

The Yellow-legged Gull feeding ecology varies substantially among populations of different localities (Ramos et al., 2009b). Several dietary studies, based on stomach contents analysis, stable isotope analysis, or direct observation were conducted with the aim of analyse the consumption of discarded fish and refuse tips by Yellow-legged Gull (Alonso et al., 2015; Ceia et al., 2014; Matos et al., 2018; Ramos et al., 2009; Calado et al., 2018). In coastal areas, fishery discards have been shown to be the main food resource chosen by populations of Yellow-legged Gull (Matos et al., 2018). Yet, natural marine prey remains an important part of the diet of some of these populations (Alonso et al., 2015; Moreno et al., 2010). In agreement with Matos et al. (2018), the consumption of land-based or refuse prey by the Yellow-legged Gull population of Barreta Island, increases when fishing activity decreases however, not remarkably. In general, the dependence of Yellow-legged Gulls on food from refuse dumps is not fully understood. It is known that this species is not a specialist in foraging exclusively at refuse dumps, even so various studies across the Mediterranean coast have proven that these populations rely heavily on this alternative food source, especially in periods of scarcity of food from fisheries discards (Duhem et al., 2003; González-Solís et al., 1997; Ramos et al., 2009a).

In addition to variability in food choices among populations, certain individuals within Yellow-legged Gull populations have variations in foraging, and feeding strategies, specialising in a narrower range of food resources (Cama et al., 2012; Ceia & Ramos, 2015; Patrick & Weimerskirch, 2014; Weimerskirch, 2007). This strategy may bring advantages for individuals such as maximising energy input per unit time while reducing foraging effort, as well as predation risk (Catry et al., 2014; Ceia & Ramos, 2015). Individual specialization can result in inter-individual niche width variation, limiting the overlap and therefore reducing intraspecific competition among individuals (Bolnick et al., 2003; Ceia & Ramos, 2015; Patrick & Weimerskirch, 2014). The reason why individuals of generalist species use a different food strategy from their conspecifics, and the consequent ecological implications at the individual and population level is not fully known (Ceia & Ramos, 2015). It is expected that individual specialisation leads to improvements in ecological characteristics such as the breeding performance, individual fitness, or foraging effort (Bolnick et al., 2003; Ceia & Ramos, 2015). However, although some previous studies have confirmed this hypothesis (Golet et al., 2000; Tinker et al., 2008), other studies found no significant differences in ecological performance between specialists and generalists (Ceia & Ramos, 2015; Dornhaus, 2008; Woo et al., 2008). Individual dietary preference is probably related to resource abundance and resource traits (Bolnick et al., 2003). Woo et al. (2008) proposed that temporal fluctuations in resource availability, along with resource predictability may be key factors for variations in individual specialisation.

The Yellow-legged Gull, like other gull species, is thought to be able to predict or anticipate resource availability in space and time (Cama et al., 2012; Oro et al., 2013). Fisheries and landfills-related works usually have a precise daily and weekly operating schedule, leading to the possibility that gulls learn to anticipate the availability of these food sources (Oro et al., 2013). For this reason, these alternative food sources of anthropogenic origin appear to be of high predictability and abundance compared to natural marine food sources, which, according to Weimerskirch (2007), are inconsistent and unpredictable in time and space over large areas and consequently scarce for seabirds. The knowledge of the location of energy-profitable and predictable food sources brings to this species the advantage of optimizing its energetic costs, skipping foraging activities when food resources are not available, and reducing foraging times and foraging range (Cama et al., 2012; Oro et al., 2013; Weimerskirch, 2007). Weimerskirch (2007), states that the predictability of available prey should increase foraging site fidelity. Also, increasing abundance of anthropogenic food waste is expected to reduce competition and may promote strong effects on population dynamics and structure (Matos et al., 2018; Oro et al., 2013).

Identifying temporal variations in food choices and foraging habitats of the Barreta Island Yellow-legged Gull population is crucial for understanding population dynamics and distribution, feeding ecology, causes of population growth (Duhem et al., 2008), for controlling population abundance and, for protecting the species (Alonso et al., 2015; Arizaga et al., 2013). Understanding the dependence of the Yellow-legged Gull at individual and population level on each available anthropogenic food resource brings essential information for management in an ecosystem-based approach (Bicknell et al., 2013), as well as to understand to which level this population may be affected with the implementation of European environmental measures on human activities in fisheries and dumps (Alonso et al., 2015; Bicknell et al., 2013; Lopes et al., 2021). Overall, these measures should be implemented progressively to give this population the possibility to adapt, and simultaneously, implement and maintain the monitoring of this population, in order to control the breeding success, foraging activity, population numbers, as well as the impacts on other species (Alonso et al., 2015; Matos et al., 2018).

The present study aimed to evaluate the food choices and foraging strategies of the Yellow-legged Gull population breeding at Barreta Island on anthropogenic food sources on fishing ports, fishing vessels, and refuse dump, according to their availability. This research will be based on two main questions: (1) do Yellow-legged Gull choose a specific day/time to forage on the refuse dump, fishing ports, and fisheries discards? and (2) how the abundance of Yellow-legged Gull on fishing ports, fishing vessels, and refuse dump is related to the operations occurring at these sites. In addition to this, there will be two secondary objectives: assess (3) what is the response time between a given food availability event and the arrival of the seagulls at the site, and (4) assess the differences in the abundance of birds on the colony, fishing ports, fishing vessels, and refuse dump between 2020 (with all the restrictions linked with the SARS-CoV-2) and 2021. Taking into consideration that the availability of anthropogenic food resources at the different study sites depends on the operations that take place there (at fishing ports and fishing vessels when there are fish discards occurring and at the landfill when rubbish is dumped), and that gulls move to the different sites in search of food, is predictable a relation between the abundance of birds at the different sites and the operations that take place there. Anthropogenic activities schedules vary according to weekday/weekend cycles. Although fishing-related work has a precise schedule during the week, on weekends the overall fishery activity decreases (Matos et al., 2018), leading to reduction or no availability of discarded fish in the ports. On the other hand, activity at the Sotavento landfill is not interrupted on a weekly basis. For this reason, even during weekends, anthropogenic food resources are available at the landfill with the same abundance and predictability. Consequently, we expect that, on days of low fishing activity, the abundance of Yellow-legged Gull individuals at fishing ports will be reduced and greater at the landfill. According to Cama et al (2012), time of day is a critical element in determining whether gulls can anticipate food availability and benefit from this predictable source. It is expected that, if gulls are foraging at the same sites on a regular day/time basis, as well as anticipate the time of first operations at foraging sites and arrive at the sites very quickly after these events, or even arrive before the first activity event, this should indicate that they can anticipate/predict food availability at these sites.

2.3 Material and methods

2.3.1. Study sites

This study was carried out at Algarve, southern Portugal. The field work was performed at five distinct study sites: Barreta island, Olhão fishing port, Culatra fishing port, Sotavento landfill, and on-board fishing vessels operating off Olhão fishing port (Figure 2.1). The Barreta Island (36°58′N, 8°02′W to 37°03′N, 7°32′W) is a natural breeding colony of Yellow-legged Gull in Ria Formosa Natural Park, a protected area that covers an area of about 18,000 ha (Mendes et al., 2018). Is a small (about 7 km long) and uninhabited sandy island that hosts a population of around 500 breeding pairs of Yellow-legged Gull, 4000 of Audouin’s Gull, and few pairs of Lesser Black-backed Gull (V. Paiva pers. comm.). It is located around 5.5 km from the populated urban centres (Lopes et al., 2021). Olhão fishing port (37º1'30"N; 7º50'30"W) is a local main port (Matos et al., 2018) located at Olhão, Faro, Portugal. It is characterized by a high historical and present fishing activity, and is located about 8 km from the breeding colony (Matos et al., 2018). Culatra fishing port (36°58′54.53” N; 07°49′59.78” W) is a smaller port located on Culatra Island, one of the barrier islands of Ria Formosa Natural Park. This island (artificially separated from Barreta Island to ensure navigation of fishing boats to the Olhão fishing port (Filipe Rafael Ceia et al., 2010)) has a closer location to the colony under study. One of the two existent landfills operating in Algarve region is the Sotavento landfill, located at Cortelha, Loulé (37°16'13''N 7°58'35''W). Algar (the entity responsible for the two landfills in the region) deposited 281,960 t of waste directly into landfills in 2020. Of this, 47% was deposited in the Sotavento landfill (Algar relatório e contas 2020). The types of debris the dump receives are very diverse including paper, rubber, metal, glass, plastic, large items (such as mattresses), and organic waste. All type of debris are landed together with no spatial or temporal segregation. This study site is 30 km apart from the colony (Matos et al., 2018). Finally, the fieldwork was also carried out on board fishing vessels operating gillnets and purse-seines off Olhão fishing port.

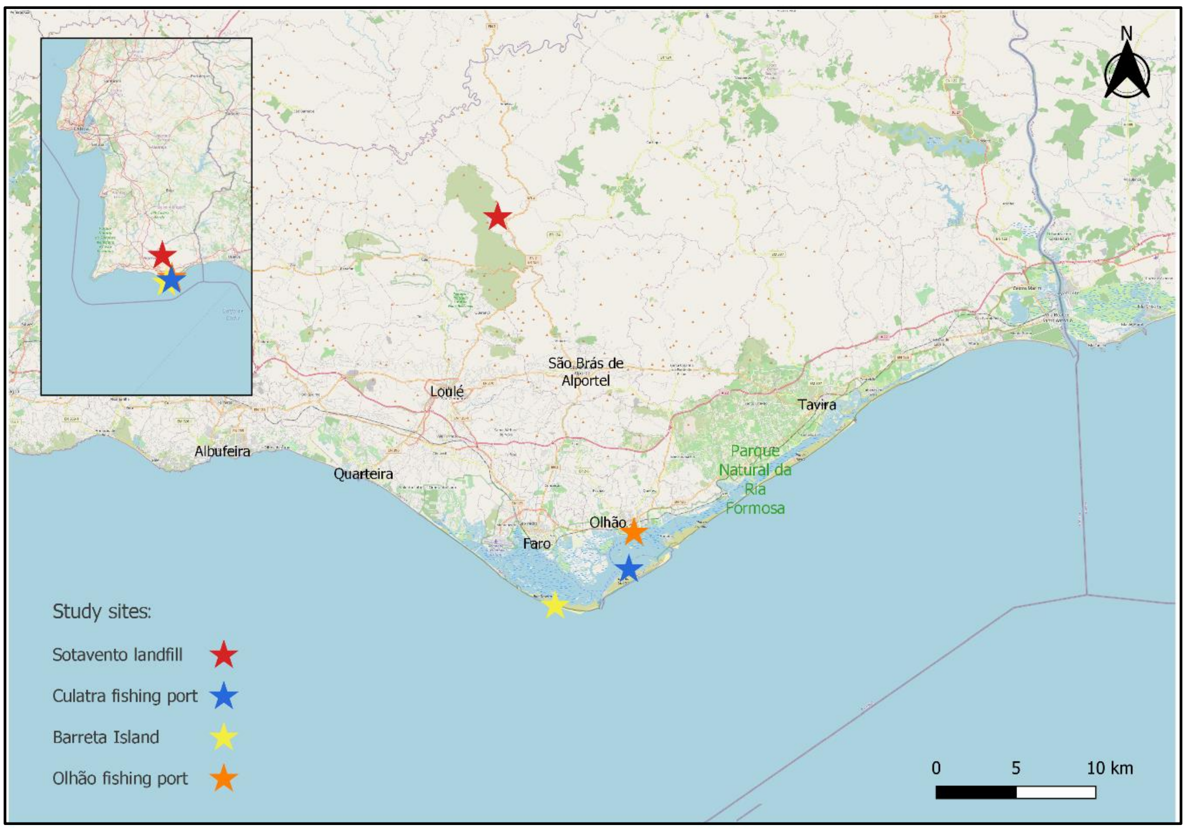

Figure 2.1 Geographical location of the four onshore monitoring sites. Sotavento landfill (red star), Culatra fishing port (blue star), Barreta island (yellow star), and Olhão fishing port (orange star).

2.3.2 Monitoring

A total of 141 monitoring days and 18,364 counts (Annex 3) have been carried out between June 2020 and June 2021 on a monthly regular basis in all study sites to estimate the abundance of Yellow-legged Gull individuals. The monitoring was based on two main techniques, bird counting and behaviour observation (Annex 7). Bird counting to record the total number of individuals in a population or population sample in a specific area is a useful and relatively simple method used to monitor changes in population size, abundance, and distribution (Hussel et al., 1998; Link et al., 1998; Ralph, 1981). Systematic monitoring was performed over time to acquire robust and reliable data on population's foraging strategies and resources dependence (Ramos et al., 2009b).

2.3.3 Fishing ports and landfill

In the fishing ports of Olhão and Culatra, at least two observers recorded spatial data on transects covering the whole area, conducted within one hour, with one hour interval between transects (each monitoring day had a minimum three transects). Counts were conducted at different times of the day throughout the months, to sample the whole daylight and thus the different phases of activity in the fishing port.
At Sotavento landfill, counts were conducted by at least two observers, from vantage observation points (counting points), every hour throughout the day, with a minimum of seven hours from sunrise. Monitoring at both fishing ports and landfill was carried out at least two days per month, one weekday and one weekend day, so that it was possible to evaluate whether differences in the abundance of birds on the landfill could be related to differences in fishing effort during the week and weekend. Aerial photographs with grid division (Annex 1; Annex 2) of each study site were used to record the specific grid (spatial position) of each observed bird. Other records made during monitoring at the fishing ports and landfill were species identification, number of birds, age (adult, immature, juvenile), behaviour observed (feeding, flight, grounded), time of observation, start and end time of the transect, and operation phase. In fishing ports, the operation phase was recorded as no activity or discharge of fish, while in the landfill was recorded as no activity, waste dump occurring or compacting machine working.

2.3.4 Fishing vessels

On board fishing vessels, seabird observations were carried out every 15 min, starting as soon as the vessel leaves port until its return, except in situations where visibility does not permit observation, in this case observations start as soon as the visibility conditions improve. Birds around the boat were observed, giving priority to the area where the fishing gear was located. Number of birds, behaviour observed (feeding, flying, grounded), time (start and end time of each monitoring and time of each count), operations occurring in the vessel, and different fishing moment (net setting, hauling, discards) were the records made by one observer per boat. The observer registered also the GPS coordinates and type of fishing gear used (in case of a fishing event taking place). In the fishing vessels activity is recorded as fishing and no activity is recorded as navigation.

2.3.5 Barreta Island

Monitoring on Barreta Island was carried out in transects covering the area of each colony by at least two observers. In this study site, transects were conducted once a month and observers recorded species identification, number of birds, age (adult, immature, juvenile), behaviour observed (feeding, flight, grounded), time of observation, start and end time of the transect, spatial position of the bird observed (grid), colony under monitoring and GPS coordinates.

In addition, extensive work on reading Yellow-legged Gull individual ring-tags was performed during the monitoring in the fishing ports, landfill, and colony, with the aim of evaluate individual specialisation.

Data collected on monitoring the colony, at Barreta Island was used as a measure of population abundance throughout the year in the Ria Formosa area. Data collected at the other four study sites on the abundance and behaviour of Yellow-legged Gull were used to obtain information on their feeding ecology and food choices, as well as temporal dependence on each anthropogenic food resource (alternative food).

2.3.6 Data analysis

The mean bird abundance (± SD) was calculated for all the variables and categories, per site. Subsequently, two Generalised Linear Models (GLMs) with a negative binomial distribution to count over dispersed data (conditional variance exceeds the conditional mean) were performed. The first model was used, to test the effect of (1) year (2020/2021), (2) study site (Sotavento landfill, Olhão fishing port, Culatra fishing port, fishing vessels), (3) time, (4) days of the week (week days, weekend days), (5) operation phases (With activity, without activity), and (6) different fishing moments (AL: hauling/ RJ: Discards/ LG: net setting) on Yellow-legged gull abundance. The second model was used to test the effect of (1) study site, and (2) food availability event (first food event, first hour after first food event, and second hour after first food event) on Yellow-legged gull abundance. Culatra fishing port was not included in the second model, because after initial analyses, it did not appear to be an actual fish discharge port. GLM models use a reference category against which the remaining data is compared, so the following categories were assigned as reference for each of the variables, (1) year: 2020, (2) study site: Culatra fishing port for the first model and fishing vessels for the second model, (4) day of the week: weekday, (5) operation phase: without operations, (6) moment description: AL, and (7) food event: first food event. GLMs with negative binomial distribution were performed using "gml.nb()" function from "MASS" package. Post-hoc comparisons were performed using estimated marginal means and Tukey's p-value adjustment with the "emmeans" package. All analysis were performed in Rstudio software version 4.0.1 (R Core Team), and significance was set at alpha = 0.05.

2.4 Results

According to the results of the first GLM, all the factors included in the model (except the category "net setting" of the factor fishing moment) are statistically significant associated with bird abundance at the significance level of 0.05 (all $p < 0.05$; Table 2.1). Year (β= -0.06 ± 0.02; $p < 0.05$), day of the week (β= -0.14 ± 0.02; $p < 0.001$), time (β= -0.01 ± 0.004; $p < 0.05$), are negatively correlated with bird abundance. On other hand, operation phase (β= 0.33 ± 0.06; $p < 0.001$) is positively correlated with bird abundance. Study site was the factor with strongest effect on bird abundance (Table 2.1).

2.4.1 Comparing bird abundance between study sites

Bird abundance at Sotavento landfill (18.48 ± 29.17) was significantly higher compared to Olhão fishing port (2.19 ± 4.35; β= -1.95 ± 0.06), Culatra fishing port (3.14 ± 9.19; β= -1.55 ± 0.06), and fishing vessels (5.19 ± 7.30; β= -1.05 ± 0.13) (all p <0.001). Sotavento landfill had a greater effect on bird abundance compared to the other study sites (Table 2.1).

2.4.2 Comparing bird abundance between days of the week and throughout the day, per site

Yellow-legged Gull abundance at the Sotavento landfill was significantly higher during the weekend (22.65 ± 34.80) compared with weekdays (13.47 ± 19.34; β= 0.14 ± 0.02; $p < 0.001$; Annex 5). Bird abundance on weekdays was significantly higher in Culatra fishing port (3.22 ± 5.19) and Olhão fishing port (2.47 ± 5.50; β= 0.14 ± 0.02; $p < 0.001$; Figure 2.2) than during the weekend. Weekdays had a greater effect on bird abundance than weekend (Table 2.1).

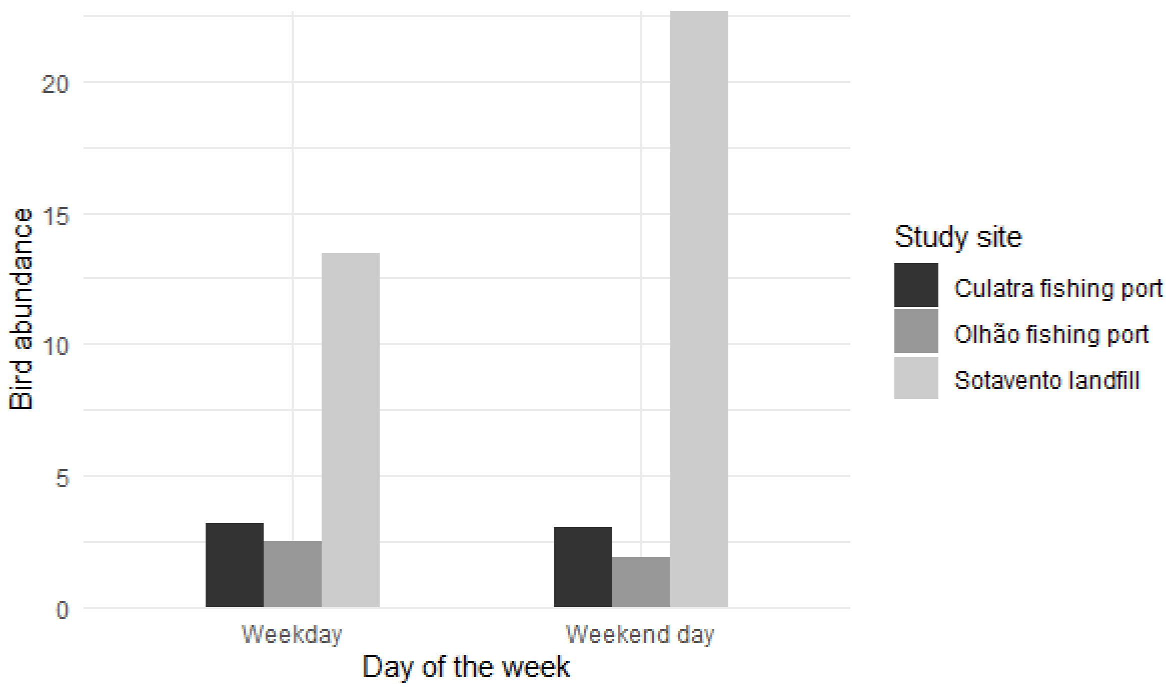

Figure 2.2 Average bird abundance between days of the week (week versus weekend days) in the different study sites: Culatra fishing port, Olhão fishing port and Sotavento landfill

In relation to bird abundance throughout the day, at the Sotavento landfill bird abundance was significantly highest in the morning (between 7am to 11am), reducing by about half after 12pm (Figure 2.3). From 15pm onwards the abundance decreased sharply, and after 16pm the abundance of birds reached zero (Annex 4). In the fishing port of Olhão the abundance of birds is relatively stable throughout the day (from 6am to 19pm) without notable differences between morning and afternoon. It can be noted that

between 9am and 2pm bird abundance was slightly higher compared to the rest of the day and reached the highest abundance at 10am (3.05 ± 6.14) (Annex 4). In Culatra fishing port, Yellow-legged abundance was higher between 11am and 17pm. In the fishing vessels, bird abundance was highest between 7am to 11am and reached a peak of abundance at 10 am (Annex 4).

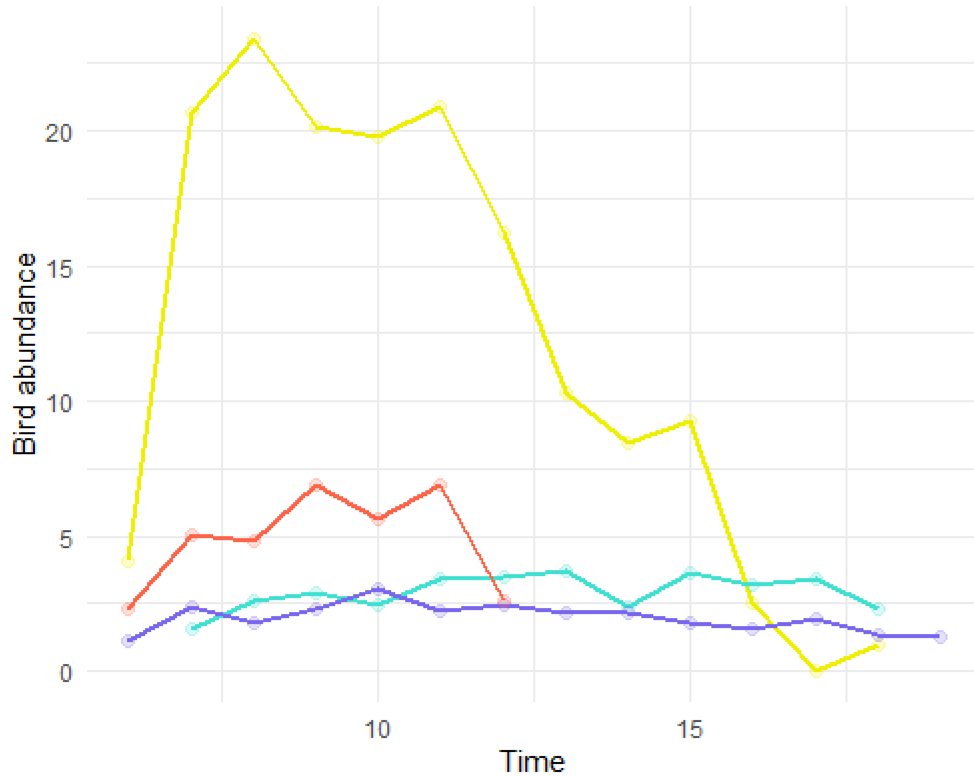

Figure 2.3 Average bird abundance throughout the day in the different study sites: Culatra fishing port (turquoise line), Olhão fishing port (purple line), Sotavento landfill (yellow line) and fishing vessels (orange line).

2.4.3 Comparing bird abundance between operation phases/fishing moments, per site

Unexpectedly, bird abundance on fishing vessels was significantly higher in the moments with no activity (6.88 ± 8.658) than in moments with activity (4.91 ± 7.02; β= -0.33 ± 0.06; $p < 0.001$; Annex 5; Figure 2.4). At all the other study sites, bird abundance in times with activity occurring was significantly higher than at times with no activity ($p < 0.001$). Times with operations occurring had a higher effect on bird abundance than times with no operations occurring.

During fishing moments on the vessels, bird abundance was significantly higher when fish discards (RJ) were occurring (8.29 ± 13.04) compared to hauling (AL) (4.95 ± 7.41; β= -0.70 ± 0.2; $p < 0.05$) and net setting (LG) (4.94 ± 4.11; β= -0.70 ± 0.2; $p < 0.05$) occurring. Hauling is not significant in bird abundance ($p > 0.05$) and moments with discards occurring had a strongest effect on bird abundance compared to the other fishing moments.

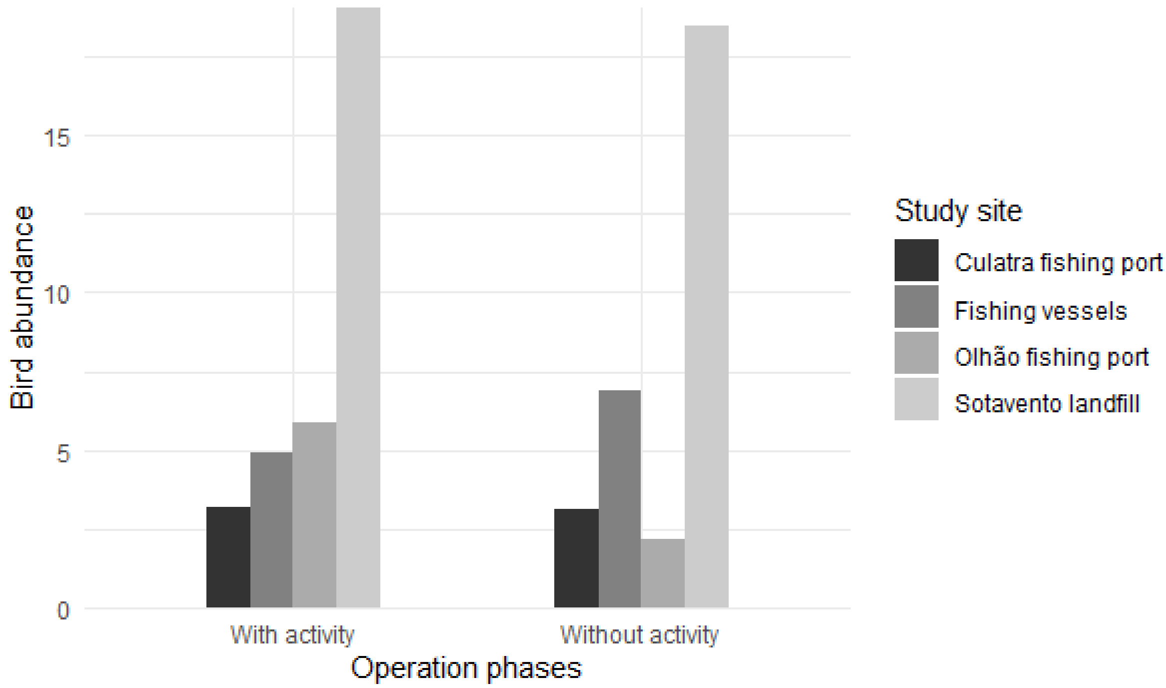

Figure 2.4 Average bird abundance between operation phases (moments with and without activity) occurring at the different study sites: Culatra fishing port, Olhão fishing port, Sotavento landfill, and onboard fishing vessels.

2.4.4 Comparing bird abundance between 2020 and 2021, per site

Yellow-legged Gull population abundance in the colony was higher in 2021 (71.56 ± 250.46) than in 2020 (33.03 ± 58.58). The abundance of birds in 2020 was significantly higher in Olhão fishing port (2.44 ± 3.67) and fishing vessels (6.35 ± 8.65) than in 2021 (Annex 5). On the other hand, the results revealed that Yellow-legged Gull abundance was significantly higher in 2021 at Sotavento landfill (19.53 ± 28.73) and Culatra fishing port (3.42 ± 10.85) compared to 2020 (Annex 5). 2020 had a higher effect on bird abundance than 2021 (β= 0.06 ± 0.02; p <0.05).

According to the results of the second model (food event*study site), the differences in bird abundance over the hour of the first food event availability and the two subsequent hours were significant (all $p < 0.05$). Food event had a significantly effect in bird abundance at Sotavento landfill (β= 1.64 ± 0.83; $p < 0.05$), but not in Olhão fishing port and fishing vessels. Food event is negatively correlated with bird abundance, while study site as positive correlation with bird abundance. Study site had a stronger effect on bird abundance than food event (Table 2.1).

2.4.5 Comparing bird abundance during the hour of the first food availability event and two subsequent hours, per site

Yellow-legged abundance at the Sotavento landfill was significantly higher in the first hour after first food availability event (63.38 ± 90.93), followed by the second hour after first food availability event (47.38 ± 88.19), finally during the hour of the first food event availability bird abundance was lower (35.67 ± 46.50; all $p < 0.05$). In Olhão fishing port, results revealed that bird abundance was significantly higher during the hour of the first food event availability (20.4 ± 54.75; $p < 0.05$), followed by the second hour after the food event (10.4 ± 26.11; $p < 0.05$), when compared to the first hour after the food event (5.6 ± 17.55; $p > 0.05$). On board fishing vessels, bird abundance was significantly higher during the hour of the first food event (4.95 ± 17.44) than during the first (1.21 ± 4.44) and second (1.09 ± 1.95) hours after the food event availability. The post hoc test showed that there are no significant differences in bird abundance over the hour of the first event and the two subsequent hours on the fishing vessels (all $p > 0.05$; Annex 6). For Olhão fishing port there are significant differences in the abundance of birds between the hour of the first food event, and the first hour after the first food event (all $p < 0.05$), but not in the second hour after the first food event ($p > 0.05$). In relation to Sotavento landfill, bird abundance differences over the hour of the first event and the two subsequent hours are significant (all $p < 0.05$). Sotavento landfill is the study site with higher effect on the model.

Table 2.1 Coefficients (±SD), p value, and effect of each variable included in the first GLM, calculated relative to their reference category. Day of the week (Weekday, weekend), Operation phase (With activity and no activity), Year (2020, 2021), fishing moment (hauling, discards, and net setting), Time, and Study site (Olhão fishing port, Sotavento landfill, and fishing vessels).

Variables	***Categories***	**β ± SE**	**Z**	***p***	**Effect**
Day of the week	Weekend	-0.14 ± 0.02	-5.74	**< 0.001**	Weekday > Weekend
Operation phase	With activity	0.33 ± 0.06	5.35	**< 0.001**	With activity > No activity
Year	2021	-0.06 ± 0.02	-2.53	**< 0.05**	2020 > 2021
Fishing moment	Discards	0.71 ± 0.20	3.50	**< 0.001**	Discards > others
	Net setting	-0.002 ± 0.14	-0.01	> 0.05	
Time	-	-0.01 ± 0.004	-2.73	**< 0.05**	-
Study site	Olhão fishing port	-0.40 ± 0.03	-15.8	**< 0.001**	Sotavento landfill > others
	Sotavento landifll	1.54 ± 0.06	25.69	**< 0.001**	
	Fishing vessels	0.49 ± 0.12	4.28	**< 0.001**	

Table 2.2 Coefficients (±SD), p value, and effect of each variable included on the second GLM, calculated relative to their reference category. Study site (Olhão fishing port, and Sotavento landfill), and Food availability event (first hour after first food event, and second hour after first food event).

Variables	*Categories*	β ± SE	Z	p	Effect
Food event	First hour after first food event	-1.43 ± 0.70	-2.02	**< 0.05**	Second hour after first food event > others
	Second hour after first food event	-2.08 ± 0.72	-2.898	**< 0.05**	
Study site	Olhão fishing port	1.42 ± 0.76	1.88	> 0.05	Sotavento landfill > others
	Sotavento landfill	1.64 ± 0.83	1.98	**< 0.05**	
*Food event*Study site*	First hour after first food event*Olhão fishing port	0.13 ± 1.07	0.124	> 0.05	-
	Second hour after first food event*Olhão fishing port	1.40 ± 1.08	1.3	> 0.05	-
	First hour after first food event*Sotavento landfill	2.34 ± 1.17	2	**< 0.05**	-
	Second hour after first food event*Sotavento landfill	2.70 ± 1.18	2.3	**< 0.05**	-

2.5 Discussion

2.5.1 Weekday or weekend visitors?

Our results on the abundance of Yellow-legged Gull during the days of the week between Olhão fishing port and the Sotavento landfill are in line with the temporal fluctuations in food availability imposed by week/weekend cycles on fishing activities and landfill-related work (Spelt et al., 2021). On days with higher abundance of birds in the port (weekdays), abundance is lower in the landfill, and vice versa. The higher abundance of birds in the port during weekdays compared to weekend, is probably related to the greater food availability there, as consequence of a higher occurrence of fish discards associated with fishing activities. Therefore, when fish are available in the harbour, gulls seem to preferably choose to forage there. On the other hand, in low fishing activity periods, fish discards are not available (or available in reduced quantities), therefore bird abundance on the landfill increases, where the likelihood of birds finding alternative food resources is high or almost certain. In general, Yellow-legged gulls should give preference to feed on fish over alternative food sources. Fish is a nutrient-rich food and a good source of energy (Carmona et al., 2021), compared to the low-quality food that gulls find in landfills (Real et al., 2017). In addition, the location of the colony seems to have an influence on the preference of birds to feed on discarded fish. According to Matos et al (2018), the relatively high amount of fishing activity in the vicinity of the colony is likely to be one of the factors justifying the dependence of this population on this food resource, specially across the breeding season. During this period, the association of breeding birds with the colony is high and, consequently, birds spend more time around the colony. This restriction in the choice of foraging areas causes birds to use available food resources closer to the colony, such as fish discards and natural marine prey (Ceia et al., 2014). Even the older individuals, according to Arizaga et al (2013), remain near their breeding sites across the year. Nevertheless, exploitation of alternative food resources either because its first-choice food source is not available, or the atmospheric conditions are not favourable, is an expected behaviour for a generalist species, like the Yellow-legged Gull (Alonso et al., 2015; Ceia et al., 2014; González-Solís et al., 1997). One noteworthy example, is the decrease in consumption of the Henslow's swimming crabs (main prey) and sharply increase in refuse consumption in June 2011 by the Yellow-legged Gull population on Berlenga island, when the swimming crabs population decreased around the colony (Alonso et al., 2015).

Although our results were in line with the expected generalist and opportunistic feeding behaviour of this population, they also revealed another interesting feeding behaviour. Even though in reduced numbers, this population forage on the Sotavento landfill during weekdays and in Olhão fishing port during the weekend. These results allow us to discuss two main ideas. First, some birds do not choose the landfill to feed exclusively when discarded fish are not available but choose to forage in this habitat rather than foraging in harbours and fishing vessels, specialising in it (Ceia & Ramos, 2015). Similarly, some individuals may not make use of the alternative food sources available at the landfill, specializing in forage at the ports. However, it should be taken in consideration that gulls, especially in the non-breeding period, may not need to feed every day and may manage their foraging activity days according to the greater availability of their first-choice food resource. Second, the presence of some birds in the fishing port during the weekend should be related to the likelihood of birds finding alternative food sources, even in periods of low fishing activity. The mechanisms driving a change in feeding behaviour at the individual level in a generalist population are probably related to a combination of several factors. The reason for individuals to specialise in foraging at the landfill should be strongly associated with the high abundance, predictability, and renewability of food, which should justify the high abundance of birds even on weekdays. Indeed, foraging at the landfill can have advantages for birds. The Sotavento landfill is about 30km away from the colony (Matos et al., 2018). According to Weimerskirch (2007), birds are less likely to forage in areas distant from colonies, however, taking in consideration that the landfill is a profitable and predictable foraging ground, the high energy costs of flying to the landfill compared to the energy costs of flying to ports must be offset. Moreover, the high abundance and predictability of food on the landfill should also decrease intra- and interspecific competition (Matos et al., 2018), which is identified as an important factor promoting individual specialisation (Catry et al., 2014).

The fishing port of Olhão is located in a populated urban area where birds should be able to find other human-related food sources, such as waste in the rubbish bins or food scraps left by people in restaurants and cafes. Thus, birds may not be exclusively dependent on fish discards at this port. In fact, according to our model results, the study site had a greater effect on bird abundance compared with the other factors, which allows us to predict that birds may have a greater association with this foraging site than with a specific type of food they can find there. This seems to justify the fact that the abundance of birds is still considerable at weekends in this port. Thus, based on optimal foraging theory, it is possible to predict that some birds are specialised in feeding at one of these foraging sites, becoming more efficient in exploiting the food resources present there and less efficient in exploiting other food resources (Catry et al., 2014).

2.5.2 The influence of time in foraging activities

In Olhão fishing port bird abundance throughout the day was quite stable yet, there was a slight increase in abundance between 9am and 2pm. This increase was expected to be related to the presence of fishing vessels in the port. According to our data, the first boats arrived at the harbour between 7am and 8am, but in fact there are boats landing at this harbour over the day. This availability of fish throughout the day together with, as discussed above, the possibility of gulls feeding on alternative food sources in the immediate vicinity of the harbour, should motivate the presence of birds in this port, without major changes in abundance over the day.

The results on bird abundance throughout the day at the Sotavento landfill were quite enlightening and are opposite to the results for the fishing port of Olhão. This population forages at this site almost exclusively in the morning, regardless of whether it is weekdays or weekends. Rubbish collection in the cities takes place during the early hours of the day, and the transport to the landfill begins in the morning. According to our data, although there is dumping of waste at the landfill over the day, a large amount of waste is discharged at the landfill in the morning. Thus, morning must be the most profitable time window for birds foraging on this anthropogenic food resource (Yoda et al., 2012). This seems to be a strong reason why gulls forage on the landfill almost exclusively in this period of the day. Beyond this, it may be possible to predict that gulls align their foraging schedule on the landfill with the foraging schedule on the fishing vessels. However, there may be a reason why gulls forage further away from the colony in the morning than in the afternoon.

The first daily waste discharges at this landfill take place between 7am and 8am, which reveals a relation between the arrival time of most gulls at the site and the first daily food availability event. These results may indicate that the birds are able to anticipate food availability at this location (Cama et al., 2012). The regular day/time foraging behaviour that the population shows on this foraging habitat seems to reveal that gulls predict the availability of food in space and time and match their foraging schedule with the activity that takes place on the landfill, as shown by the results of Spelt et al (2021). In fact, the mechanised work related to the landfill, such as the precise working schedules and the repetition of events through the day (arrival of the truck at the landfill > rubbish landing > rubbish spreading > rubbish compaction), should promote a quicker understanding by the birds of the best times of the day to forage at this site, according to food availability. The acquired ability to predict food availability in time and space should be advantageous as it allows birds to increase foraging efficiency by reducing the time and energy spent in search for food (Cama et al., 2012; Spelt et al., 2021) (Annex 8).

As the fishing activity of the sample vessels took place exclusively during the week and in the early morning/ middle morning, data were collected on board fishing vessels only on this specific period. For this reason, it was not possible to carry out the same analysis of bird abundance on the different days of the week and throughout the day for these data. Although it is not possible to compare the abundance of birds across the day as for the other study sites, it was possible to verify that the abundance of birds interacting with fishing vessels increases greatly by 7am in relation to the start time of fishing activities (6am), and remains high in all subsequent hours, decreasing again to about one third by 12pm. It is known that this population rely heavily on fish, mainly demersal fish species that these gulls can obtain through fisheries discards (Calado et al., 2018). These results, support once again that this population match its foraging schedules with fishing activities, taking advantage of this abundant food source.

2.5.3 Is the presence of gulls associated with the operations taking place?

Considering that food availability in anthropogenic habitats depends on the operations that take place there, our results for the landfill go in line with what was expected. The mean abundance of birds in times with rubbish discharge, spread or compaction taking place was higher than in moments with no operations. It should be noted that bird abundance at times when operations are not in progress is still quite high. This is likely to be related to birds staying on site between times of activity (waiting for the next food availability event). The same behaviour was verified by Spelt et al (2021), in the waste centres gulls have been observed waiting for food to become available. According to our results, it is possible to predict that this population, when foraging at this study site, will adopt a sit-and-wait strategy rather than continuing to actively forage (Spelt et al., 2021). Consequently, the high abundance at times when no operations are taking place is related to the feeding strategy adopted by the population, increasing the residence time in this foraging ground (Yoda et al., 2012).

The abundance of birds at the Olhão fishing port when fish discards are taking place is higher than when no activity is registered, as the occurrence of fish discards should attract birds to this site. Although, as discussed above, the presence of birds at this site does not appear to be exclusively related to fish availability, birds are more abundant when fish landing take place. As at the landfill, it is possible to predict that, at fishing ports gulls adopt a feeding strategy based on waiting for the next food availability event, however our results show a greater discrepancy in abundance values between moments with and without operations, so gulls should not use this strategy so extensively, opting also for actively forage between food availability events.

Contrary to our expectations, on fishing vessels, bird abundance was higher when the vessels were in navigation than when fishing was taking place. This can be related to two main conditions, firstly the number of attracted birds should increase over the course of the fishing activity. Bearing in mind that the initial navigation (between the port and the fishing area) is not usually monitored, since is carried out at night, the whole monitoring period of navigation should correspond to the return trip to the port and some short trip between fishing areas. In other words, navigation coincides with the final period of the fishing day. Secondly, fishermen usually sort fish, clean fish, and wash the decks during the trip back to port. During these activities several discard events occur (often almost continuously, or at least not one-off events), which attracts even more birds to the vessels. Thus, given that most of our data recorded like navigation, corresponds simultaneously to these continuous or more frequent discarding events, we would expect a higher bird abundance when the vessels are in navigation than when fishing is taking place. In addition, it is important to take in account the activity of other fishing gear that may attract more birds at certain times of the day, such as trawling. It is expected that if there are one or more trawlers cleaning nets in a nearby area, birds will be more attracted to them than to the boats operating the nets. As expected, our data reveal that, at times of fishing taking place, bird abundance was higher when fish were discarded than at any other operation time. These discards are recorded during fishing activity and are usually quite visible and considerable. Confirming once again that the interactions of birds with fishing vessels are intrinsically related to the food availability events that occur there.

2.5.4 Can Yellow-legged Gull predict food availability?

Our results revealed that at the time of the first feeding event a significant number of birds were already on the landfill, but the abundance rises in the second hour after the first feeding event. This may indicate that some individuals, probably older or specialists, can predict food availability in this foraging area and arrive just before the first food availability event, while others arrive at this foraging site after the first food availability event. Juvenile individuals are less experienced in foraging habits and behaviour and therefore may not be as effective as adults in predicting food availability at the landfill. Thus, these individuals are likely to be attracted by the behaviour of more experienced individuals rather than to the availability of food at the landfill, justifying their arrival at the landfill after food availability events had begun to occur (Franks & Thorogood, 2018). However, there may be other unknown factors dictating

the different arrival times of birds at the landfill.
On fishing vessels, bird abundance is significantly higher at the time of the first food availability event, decreasing strongly in the second and third hour after the fish discards occur. Also, in the fishing port of Olhão, the highest abundance of birds occurs at the time of the first food event, which may be related to the fact that this population has a strong association with fish discards. As the population is dependent on this food resource, it is expected to show a better ability to predict its availability and a greater efficiency in its use (under conditions of normal food availability).

2.5.5 Differences in the abundance of birds between 2020 and 2021

The fishing industry was heavily affected in Portugal due to the SARS-CoV-2 global pandemic. In 2020 there was a decrease in the total fishing effort since the national quarantine imposed by the government early in the year (DGRM/INE report on fisheries statistics 2020). Fishing continued, as a food supply industry, but closure of all restaurants implied less demand. Consequently, the availability of fish discards available to the gulls was likely to have been much reduced compared to the usual abundance coming from the high fishing activity that characterises the Algarve coast. This limitation on the abundance of the main food source of this population, gave us the opportunity to verify its effects on the feeding ecology of birds.
Our results revealed that in Olhão fishing port and fishing vessels the abundance of birds was higher in 2020. On the other hand, at Sotavento landfill and Culatra fishing port, bird abundance was higher in 2021. The higher abundance of birds in Olhão fishing port and fishing vessels seem to indicate that this population maintained the use of fish discards in 2020. This rises the hypothesis that, the transition from fish discard use, a food source that this population makes extensive use, to foraging at the landfill was a gradual process like all adaptation processes. After a longer period of low fishing activity, birds must have started to anticipate the decrease in food availability and consequent increase in foraging competition at the fishing port and vessels, and started to forage in alternative food sources. Since this population was already making habitual use of the landfill for foraging, we would expect an increase in bird abundance by 2021 at this site, as our data confirm. In fact, an opportunistic gull population will be expected to alter its foraging habitats if the availability of its main food source is scarce. Oro et al (1995) investigated in the Ebro Delta, the effects of a trawling moratorium on a population of Yellow-legged Gulls. such as the Yellow-legged Gull population from Barreta Island, this gull population depends

heavily on fish discards from the intense fishing activities that occur along the Mediterranean coast. However, according to Oro et al (1995) results, this population did not significantly increase the consumption of refuse during this period. These results were attributed to the fact that there was low availability of refuse tips in this population foraging area.

Our results showed a significant difference in the abundance of birds in the colony between 2020 and 2021, revealing that the Yellow-legged Gull abundance in the Ria Formosa area in 2021 was more than the double of 2020. Such a marked difference in abundance may indicate that the birds were more concentrated on land during 2020.

2.5.6 The Culatra fishing port

After initial analyses and according to what was observed during the fieldwork, the fishing port of Culatra does not appear to be a real fish landing port. During one year of monitoring, few records of activity and consequent fish discards were recorded here. At this study site, mainly small quantities of fish are discharged by fishermen for locals' own consumption. As these discharges are not representative of a true availability of fish for gulls, due to their small quantity and frequency, the results for this port will be discussed separately from all other study sites.

Despite what has been concluded above, gulls can find food on this island from other sources, although in smaller quantities. Firstly, fishermen clean and repair their nets in this port. During this work, the fishermen end up rejecting small quantities of fish on which the gulls feed. Secondly, seagulls may find food of anthropogenic origin in the vicinity of this port. This island, inhabited by a population of about 1000 people (Silveira, 2020), receives a daily significant number of tourists in Summer. For this reason, as well as in the port of Olhão, although in much smaller quantities, the gulls can feed on food scraps left by humans in rubbish bins and restaurants. Finally, this population maintains its predatory behaviour despite the use of human-related food sources, so it is expected, due to the privileged characteristics of the Ria Formosa islands, that the gulls have a relatively high availability of natural prey in the vicinity of this harbour.

The first results that support the idea that the presence of birds in this port is not exclusively related to fishing activities and consequent fish discards, are the abundance results between the different days of the week. There was a slightly higher abundance of birds during the weekend compared to weekdays. Bird abundance was higher between 11am and 5pm on this port, which appears to be inversely related to

the abundance of birds on the landfill. At the same time abundance starts to decrease at the landfill, it starts to increase in this port.
Our results on the abundance of birds between periods with and without discards taking place showed that, in moments when small amounts of fish are being discharge, bird abundance is slightly higher compared to moments with no discards, but not notable. Consequently, although these results do not seem to fully explain the presence of birds in the port, they do show that the abundance of birds is related to the reduced operations that take place there. Finally, the total abundance of birds recorded at this port was slightly higher than at Olhão fishing port.

The reason for the high relation of this population to this fishing port remains to be clarified, however, there are some reasons that we can hypothesise. This port is very close to the colony, and as discussed earlier, the proximity to the colony seems to be a preponderant factor in the choice of foraging sites, especially during the breeding season (Ceia et al., 2014). In addition, the reduced food availability at this port compared to the port of Olhão should be offset by the low energy costs of flying to this port. In sum, our results are not conclusive about the strong relationship of this population with this fishing port, more research is needed to explain it.

2.5.7 Limitations

A relevant limitation to discuss on our study is the fact gulls fly to the landfill in large groups (Annex 9), sometimes of mixed species. Due to of this fact, and because the weather conditions at the landfill can be challenging (such as heavy fog and strong wind that makes visibility difficult), species identification and counting the number of individuals was sometimes difficult. Birds were identified down to the genus when species identification was not possible, consequently this data were omitted in data analysis. Thus, the differences in bird abundance for the analyses at the landfill would be greater than those shown if these data were used. In addition, the fact that it was not possible to monitor the fishing ports throughout the entire day made it impossible for us to record all the first feeding events. Therefore, analysis of bird abundance during the hour of the first feeding event and the following two hours was limited.

2.5.8 Yellow-legged Gull feeding behaviour and European management policies: a matter of

conservation

As shown by this study, the Yellow-legged Gull population from Barreta Island seems to be moderately adaptable, able to choose the most suitable food resource and forage habitat according to food availability. However, its dependence on anthropogenic food sources, especially on fish discards, could make this population susceptible to environmental management plans (Alonso et al., 2015; Matos et al., 2018). The measures envisaged by the European Union (discard ban policy and the closure of open-air landfills), may drastically reduce the availability of anthropogenic food resources from fisheries discards and waste in the landfill (Payo-payo et al., 2015). In the North Sea, Mitchell et al (2004) confirmed a decline in a population of Herring Gull *Larus argentatus*, after the implementation of discards management. It is therefore predictable that the Yellow-legged Gull population from Barreta Island will be affected by these measures and may decline sharply (Bicknell et al., 2013). Given the generalist and adaptable behaviour of this population, it is likely that a discard ban policy would promote a more terrestrial foraging behaviour by this population, with increased exploitation of food on the landfill and other human-related food resources. On the other hand, the closure of the Sotavento landfill is probable to lead gulls to start exploiting the nearest landfill (Barlavento landfill), as verified by Arizaga et al (2014), leading to a change in the movement patterns of the population. The consequences of these European measures would not only affect the population under study. Although it is a species with distinct feeding strategies (Calado et al., 2018), the food shortage caused by these measures could lead to increased competition with the Auduin's Gull population on Barreta Island and increase predation of young Auduinis gulls by Yellow-legged Gulls (Oro et al., 2013). However, these policies can also have benefits for birds, such as reducing the risk of bycatch, reducing injuries during landfill feeding, and reducing the ingestion of toxic materials such as plastics, which are extremely abundant in landfills (Bicknell et al., 2013).

It is essential to implement these European management plans gradually. Maintain constant monitoring of this population of Yellow-legged Gull (considering individual specialisation) and monitor disturbance of Yellow-legged Gull on other sensitive species to ensure that these populations are affected to the least extent possible. Although the Yellow-legged Gull is an adaptable species, seabirds' biological characteristics make them a vulnerable group (Oliveira et al., 2020), in terms of conservation.

2.6 Conclusion

2.6.1 Final remarks

This work provided relevant insights into the food choices and feeding strategies of the Yellow-legged Gull population from Barreta Island, according to temporal fluctuations in food availability. Most dietary studies previously conducted on this population have shown that this population is highly dependent on fish discards, exploiting alternative food sources mainly when fishery discards are not available. However, the present study reveals that this population makes extensive use of the food available at the landfill nearest the colony. This population showed not only the ability to match their foraging schedules with the human activities on the landfill (as for fishing activities) but also feeding strategies specialized to the type of activities taking place at this foraging site. It is important to bear in mind that the fact that this research work took place during a global pandemic, that strongly affected human activities such as fisheries, may have influenced the feeding behaviour of this population, leading to an increase in terrestrial feeding strategy. Additionally, our results confirmed the idea that the presence of this population at the different foraging sites (except for Culatra fishing port) is strongly related to the human activities taking place there and the consequent food availability, confirming the dependence of this population on human-related food sources. Our results also pointed to the possibility that some individuals in this population adopt a specialist dietary strategy, however, further studies should be conducted to confirm this hypothesis.

It is important to analyse the feeding behaviour of this population with the normal availability of fish discards, to confirm its link with the food sources available at the landfill. If our results are confirmed, this population may be not only strongly affected by European policies on the management of fisheries discards but also by open-air landfills management policies. In addition, the effect of increased feeding by this population on low-quality food, available at the landfill, should be analysed.

The general reduction in natural marine resources and the increased availability of alternative food sources of anthropogenic origin, together with the opportunistic feeding behaviour of this species, have led to the changes in feeding behaviour currently observed. It is now crucial to invest in conservation of the ecological equilibrium between these species and other components of the ecosystem.

2.6.2 Work developed and techniques acquired beyond this research

Throughout this year of work I participated in monitoring at four of the five study sites, at the fishing ports, at Barreta Island and at the landfill. I worked in collaboration with several volunteers and Spea workers to collect data used in this research. Data on board fishing vessels was collected by a team of specialist fisheries observers from the University of Algarve. In addition to all the work carried out to collect specific data for this study, I also had the opportunity to participate in other field tasks related to the LIFE Ilhas Barreira project. These included ringing juvenile yellow-legged gulls on Barreta and Culatra Islands and monitoring for data collection of other seabird species. In addition, during this year, extensive work was also carried out on read bird rings at the various study sites in which I also had the opportunity to participate. In addition, I helped on the reported of part of the bird rings that were sighted during this year of work. The reading and reporting of ringed birds are an important source of information on the distribution, and movement patterns of birds.
Developing my thesis in a multidisciplinary project environment gave me the chance to develop diverse techniques and work with different professionals who gave me the opportunity to acquire very important knowledge for my future professional life.

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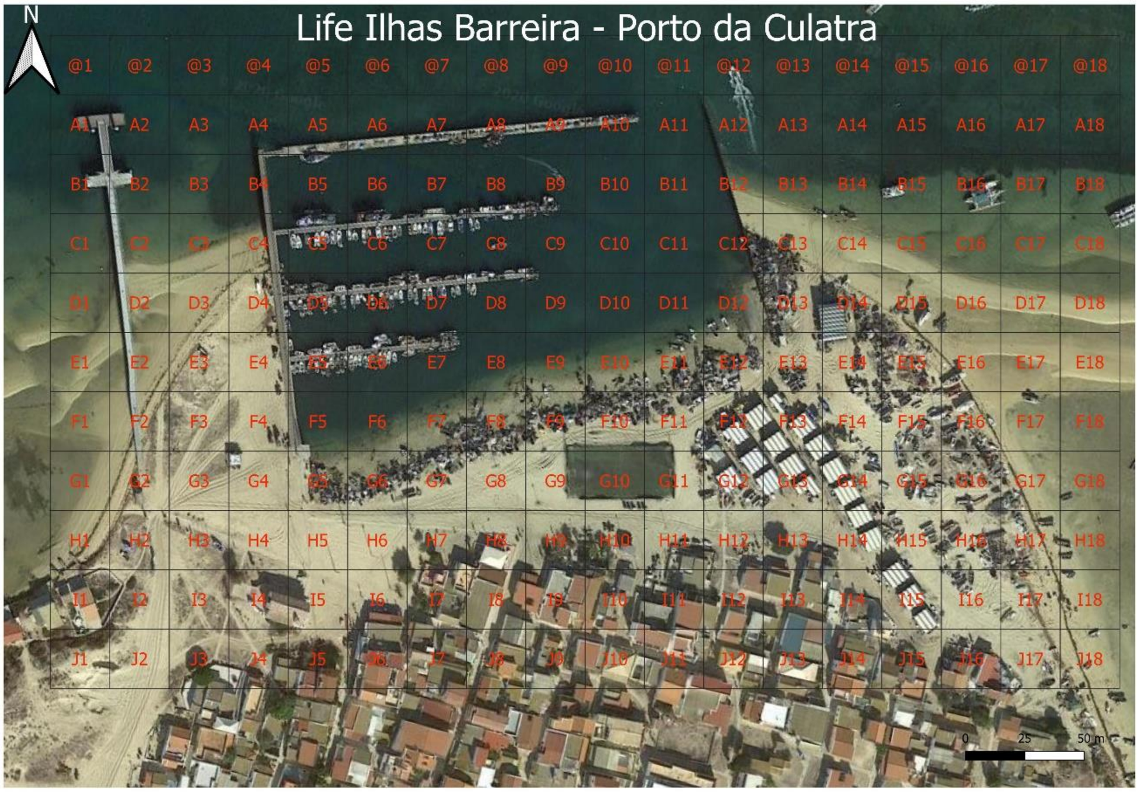
3. Annexes

Annex 1 Aerial photograph of Olhão fishing port with grid division, used on the monitoring in this port to record the specific spatial position of each observed bird. – Source Google Maps elaborated by Nuno Oliveira, SPEA



Annex 2 Aerial photograph of Culatra fishing port with grid division, used on the monitoring in this port to record the specific spatial position of each observed bird. – Source Google Maps elaborated by Nuno Oliveira, SPEA

Study site	Total nº of counts	Total nº of counts in which I participated
Barreta Island	770	95
Olhão fishing port	7850	2462
Culatra fishing port	6118	1148
Sotavento landfill	1815	584
Fishing vessels	1811	0
Total	18364	4289

Annex 3 Total number of counts performed during monitoring, total number of counts in which I participated during monitoring and respective totals, per site.

Variables	Categories	Abundance per site				
		Sotavento landfill **μ ± SD**	*Culatra fishing port* **μ ± SD**	*Olhão fishing port* **μ ± SD**	*Fishing vessels* **μ ± SD**	*Barreta Island* **μ ± SD**
Day of the week	Weekday	13.47 ± 19.34	3.22 ± 5.19	2.47 ± 5.50	-	-
	Weekend	22.65 ± 34.80	3.06 ± 12.02	1.88 ± 2.38	-	-
Operation phase	With activity	19.04 ± 28.86	3.2 ± 2.86	5.85 ± 21.41	4.91 ± 7.02	-
	No activity	18.48 ± 30.39	3.13 ± 9.89	2.17 ± 3.44	6.88 ± 8.66	-
Year	2020	16.09 ± 30.03	2.54 ± 3.49	2.44 ± 3.67	6.35 ± 8.65	33.03 ± 58.58
	2021	19.53 ± 28.73	3.42 ± 10.85	1.99 ± 4.83	3.82 ± 4.95	71.56 ± 250.46
Fishing moment	Hauling	-	-	-	4.95 ± 7.41	-
	Discards	-	-	-	8.29 ± 13.04	-
	Net setting	-	-	-	4.94 ± 4.11	-
Time	6am	4.07 ± 4.53	-	1.15 ± 0.48	2.30 ± 2.49	-
	7am	20.69 ± 28.70	1.55 ± 1.35	2.38 ± 10.11	5.06 ± 7.85	-
	8am	23.45 ± 32.75	2.63 ± 3.60	1.80 ± 2.41	4.84 ± 6.72	-
	9am	20.16 ± 26.87	2.9 ± 4.32	2.29 ± 3.07	6.92 ± 9.84	-
	10am	19.81 ± 26.71	2.44 ± 3.44	3.05 ± 6.14	5.61 ± 4.88	-
	11am	20.92 ± 37.23	3.41 ± 18.18	2.26 ± 4.42	6.93 ± 6.55	-
	12pm	16.24 ± 34	3.47 ± 5.08	2.44 ± 3.40	2.6 ± 1.2	-
	13pm	10.28 ± 15.63	3.75 ± 5.72	2.15 ± 2.85	-	-
	14pm	8.43 ± 11.70	2.36 ± 2.97	2.16 ± 2.98	-	-
	15pm	9.25 ± 13.91	3.62 ± 6.04	1.82 ± 2.21	-	-
	16pm	2.5 ± 1.5	3.18 ± 4.29	1.6 ± 1.4	-	-
	17pm	0	3.4 ± 8.8	1.92 ± 2.19	-	-
	18pm	1 ± 0	2.28 ± 2.51	1.37 ± 0.76	-	-
	19pm	-	-	1.29 ± 0.70	-	-
Food event	First food event	35.67 ± 46.50	-	20.4 ± 54.75	4.95 ± 17.44	-
	Fisrt hour after first food event	63.38 ± 90.93	-	5.6 ± 17.55	1.21 ± 4.44	-
	Second hour after first food event	47.38 ± 88.19	-	10.4 ± 26.11	1.09 ± 1.95	-

Annex 4 Mean bird abundance (±SD) for each variable and respective categories: Day of the week (weekday, weekend), Operation phase (With activity, no activity), Year (2020, 2021), Fishing moment (Hauling, discards, and net setting), Time (6am to 19pm), Food event (First food event, first hour after first food event, and second hour after first food event), per site.

Variables	***Contrast***	**β ± SE**	**df**	**z.ratio**	***p***
Year	2020-2021	0.06 ± 0.02	Inf	2.53	**< 0.05**
Day of the week	Weekday- Weekend	0.14 ± 0.02	Inf	5.74	**< 0.001**
Operation phase	With no operations- With operations	-0.33 ± 0.06	Inf	-5.35	**< 0.001**
Fishing moment	AL - LG	0.002 ± 0.14	Inf	0.01	> 0.05
	AL - RJ	-0.71 ± 0.20	Inf	-3.50	**< 0.05**
	LG - RJ	-0.71 ± 0.24	Inf	-3.01	**< 0.05**
Study site	Culatra fishing port - Fishing vessels	-0.49 ± 0.12	Inf	-4.28	**< 0.001**
	Culatra fishing port - Olhao fishing port	0.40 ± 0.03	Inf	15.84	**< 0.001**
	Culatra fishing port - Sotavento landfill	-1.55 ± 0.06	Inf	-25.69	**< 0.001**
	Fishing vessels - Olhao fishing port	0.89 ± 0.11	Inf	7.82	**< 0.001**
	Fishing vessels - Sotavento landfill	-1.05 ± 0.13	Inf	-8.27	**< 0.001**
	Olhao fishing port - Sotavento landfill	-1.95 ± 0.06	Inf	-32.89	**< 0.001**

Annex 5 Post hoc Tukey test results of the first model performed, for the variables and respective categories: Year (2020, 2021), Day of the week (weekday, weekend), Operation phase (With activity, no activity), Fishing moment (Hauling, discards, and net setting) and Study site (Olhão fishing port, Culatra fishing port, Sotavento landfill and fishing vessels). Significant effects are highlighted in bold.

Variables	***Contrast***	**β ± SE**	**Df**	**Z**	**p**
Food event	Fishing vessels - Olhão fishing port	-1.88 ± 0.45	Inf	-4.20	**< 0.001**
	Fishing vessels - Sotavento landfill	-3.51 ± 0.49	Inf	-7.16	**< 0.001**
	Olhão fishing port - Sotavento landfill	-1.62 ± 0.51	Inf	-3.15	**< 0.05**
Study site	First hour after first food event	0.98 ± 0.47	Inf	2.07	> 0.05
	Second hour after first food event	1.08 ± 0.47	Inf	2.28	> 0.05
	First hour after first food event - Second hour after first food event	0.1 ± 0.47	Inf	0.21	> 0.05

Annex 6 Post hoc Tukey test results of the second model performed, for the variables and respective categories: Food availability event (hour of the first food event, first hour after first food event, and second hour after first food event) and Study site (Olhão fishing port, Sotavento landfill and fishing vessels). Significant effects are highlighted in bold.

Annex 7 Photograph showing the use of telescope, one of the field techniques used to count birds, read bird rings and behavioural observation, at Sotavento landfill. Source Maria Ruiz, SPEA

Annex 8 Photograph showing the great abundance of birds feeding on the waste pile, and in interactions with the working machinery at the Sotavento landfill - Source Maria Ruiz, SPEA

Annex 9 Photograph showing a large group of gulls of mixed species and ages, at the Sotavento landfill – Source Maria Ruiz, SPEA