Fishermen's knowledge and conservation attitudes: focus on the great cormorant *Phalacrocorax carbo* (Linnaeus, 1758) in the Minho River, Portugal

Beatriz Vieite · Heitor O. Braga · Eraldo M. Costa Neto · Ulisses M. Azeiteiro

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Abstract Considerate the attitudes of traditional communities and their local ecological knowledge (LEK) can contribute to better policymaking and more appropriate management plans. Thus, this study strived to share the Minho River's fishermen LEK about great cormorant *Phalacrocorax carbo* (Linnaeus, 1758), as well as it exposes their conservation attitudes towards this species. We described and analysed interviewees' LEK qualitatively, while their attitudes were analysed quantitatively through

correlation with variables from fishermen's profile. Fishermen were able to identify cormorant's ecological characteristics like habitats, prey species, and foraging behaviour. They also exposed an overall moderate attitude towards the conservation of great cormorants. The LEK often was supported by published data, but we found diverse information in some themes, such as habitat and diet. We found a significant negative correlation between fishermen's age and attitudes ($p = 0.02$), and those fishermen who often fished contrasted significantly from those who rarely fished ($p = 0.02$). We lastly reaffirm the importance of the present study as background information regarding *P. carbo* in Minho River and of

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B. Vieite (✉) · H. O. Braga · U. M. Azeiteiro
Department of Biology and CESAM - Centre for
Environmental and Marine Studies, University of Aveiro,
Aveiro 3810-193, Portugal
e-mail: bea.vieite@ua.pt

H. O. Braga
e-mail: heitorob@ua.pt

U. M. Azeiteiro
e-mail: ulisses@ua.pt

H. O. Braga
CAPES Foundation, Ministry of Education of Brazil
(BEX:8926/13-1), Caixa Postal 250, Brasília,
DF 70040-020, Brazil

E. M. Costa Neto
Department of Biological Sciences, Feira de Santana State
University, Avenida Transnordestina S/N, Novo
Horizonte, Feira de Santana, BA 44036-900, Brazil
e-mail: eraldont@hotmail.com

ethnobiological studies as a tool for management plans.

Keywords Cormorant population control · Traditional knowledge · Wetlands · Ethno-ornithology · Stakeholders

Introduction

Over the past few decades, local ecological knowledge (LEK) has been proven to be a very functioning and accurate complementary tool to scientific data, filling in gaps and providing new information regarding the environment (Gilchrist et al. 2005; de Magalhães et al. 2012; Frans and Augé 2016; Alati et al. 2020; Cheng et al. 2021). Yet, even with several published works about local and traditional knowledge is noticeably being lost in a time when it is critically needed (Aswani et al. 2018; Ogar et al. 2020). Traditional communities also offer views, feelings, and attitudes towards the environment. Attitude has not a clear and unique definition, but according to Perloff (2020), it consists in a psychological construct around an object that has an effect on ways of thinking and actions. Studying attitudes can also bring insight into the existence, or not, of conflicts between stakeholders and wildlife (Vasudev et al. 2020), to the need of more educational programmes and awareness regarding the environment (Portman and Camporesi 2020), or to community-based conservation actions (Störmer et al. 2019).

In Portugal, several ethnobiology studies were published in the past 10 years, ranging from ethnobotany (Carvalho and Frazão-Moreira, 2011), to ethnoherpetology (Ceríaco, 2012), to ethnoichthyology (Braga et al. 2019, 2020), to ethno-malacology (Braga et al. 2022), to ethnomammalogy (Lopes-Fernandes et al. 2018), even to ethnobiological studies related to ecosystem services (Sousa et al. 2013) supporting a growing interest in this area. Stakeholders often participate and contribute to these works, namely fishermen, whose knowledge and perception cover not only commercial fish, but also sharks ecology and coastal management regulations (Barbosa-Filho et al. 2014; Liao et al. 2019; Morado et al. 2021). However, in Portugal only very few ethnobiology-related studies were made and most of them focus on species that are

relevant for fisheries (Braga et al. 2017a, 2017b, 2019, 2022).

Great cormorant *Phalacrocorax carbo* (Linnaeus, 1758) is a migratory and aquatic bird species and is considered a wintering species in Portugal (Aves de Portugal 2021). It is distributed worldwide, except in South America and Antarctica, and breeds in many countries from North America to Oceania (BirdLife International 2019). The breeding season can differ according to the geographical distribution, and consequently with the subspecies, counting with a peak in April and June in the Northern Hemisphere temperate regions (del Hoyo et al. 1992). Its diet is mostly based on fish, but it was also found that polychaetes, crustaceans, and amphibians can sometimes be a part of their meal (del Hoyo et al. 1992; Leopold and van Damme 2003). Yet, prey species, specifically fish species, appears to vary according to the location (Barrett et al. 1990; Carss and Marquiss 1997; Čech and Vejřík 2011; Gaye-Siessegger 2014).

Phalacrocorax carbo, currently, is considered a species of “Least Concern (LC)” in the IUCN Red List, both globally, with an increasing population trend (BirdLife International 2019). This resulted from making legislation to protect birds and their habitat, such as Council Directive 79/409/EEC (also known as The Birds Directive), that was amended in 2009—Directive 2009/147/EC—and Council Directive 92/43/EEC (also known as The Habitats Directive). Nevertheless, in 1997, it was removed from The Birds Directive because of its non-concerning conservation status (Kindermann 2008; European Commission 2021). To our knowledge, there is no legislation regarding great cormorants in the Iberian Peninsula.

Considering the population growth and a fish-based diet, great cormorants began to clash with commercial fisheries (Kameda et al. 2003; Steffens 2010; Arlinghaus et al. 2021). Thus, by taking in account fishermen’s perceptions and beliefs towards great cormorants can help us to identify issues that might be occurring, or benefits that they can convey. This type of information will then complement the scientific data and can help evaluate its impact. The main goal of this study was to share the LEK and evaluate the degree of conservation attitudes towards great cormorant of fishermen in the main Portuguese villages of Minho River estuary: Valença, São Pedro da Torre, Campos, Vila Nova de Cerveira, Gondarém, Lanhas, Seixas, and Caminha. We described their

ethno-ornithological knowledge, such as folk taxonomy, population history, habitat and distribution, and diet and foraging habits. We also assessed the management of this species in the Portuguese side of the Minho River.

Materials and methods

Study area

Minho or Miño is a 300 km long transboundary river, located in Portugal and Spain, serving as a natural barrier between these countries in its last 77 km (Fig. 1). It is born in Serra de Meira (Spain), at 750 m of altitude, between Caminha (Portugal) and La Guardia (Spain). The hydrographic basin of the Minho River drains into the Atlantic Ocean and comprises an area of 17 080 km² (Oliveira et al. 2021). Part of Minho River (42.00°N, 8.39°W) is integrated in the Natura 2000 Network as a Site of Community

Importance (SIC: PTCON0019) situated in the Atlantic biogeographical region with a total area of 4 554 ha (Portaria n° 829/2007). Besides, it covers three types of habitat included in the Habitat Directive (Council Directive 92/43/ECC): Atlantic salt meadows (Habitat 1330), Coastal lagoons (Habitat 1150), and Mediterranean temporary ponds (Habitat 3170), in which the last two are considered high priority habitat types (Resolução do Conselho de Ministros n° 142/97). The Minho's estuary area is also considered an Important Bird Area (IBA), serving as place of passage for migratory birds, such as great cormorants. This is due to the fact that this region is constituted by saltmarshes, mudflats, and alluvial forests, as well as having an accentuated water salinity gradient (Bird-Life International 2021b).

In this region, there are two fishing associations: Fishermen's Association of Ribeira Minho and Association of Professionals of Fisheries of the River Minho and the Sea, with its headquarters located in São Pedro da Torre and Caminha, respectively.

Fig. 1 Map showing the location of the main fishing communities on the Minho River, Portugal

According to DGAM (2020), in International Minho River Estuary there are registered 196 local fishing boats, of which 134 have a licence for local fishing.

Data collection

In seeking to understand the attitudes and local ecological knowledge (LEK) of fishermen about the great cormorant (*Phalacrocorax carbo*), we applied individual semi-structured interviews (Albuquerque et al. 2014). We performed this study in eight Portuguese fishing communities along the Minho River estuary that are considered the most critical sites for fishing in this region, such as Valença, São Pedro da Torre, Campos, Vila Nova de Cerveira, Gondarém, Lanhas, Seixas, and Caminha (Costa et al. 2001), during September and October 2020. Establishing a safe and trustworthy environment was a very important feature that was achieved by temporarily living in a locality near the fishing villages, as well as visiting places frequented by fishermen regularly (Brook and McLachlan, 2008). Fishermen were approached and interviewed individually to avoid any interference of other fishermen that may be around.

To sample the fishermen, we used the fishing Minho River's social media and snowball sampling (Bailey 2008), where one respondent successively recommended another fisherman. Before the interview, the participant's prior consent was requested through the statement of informed consent. This document also contained the objectives, data from the institution, and the researcher responsible for the study. The questionnaire consisted in three parts: (1) fishermen's profile, (2) fishermen's LEK of great cormorant, and (3) their attitudes towards its conservation (Supplementary information 1). Fishermen's profile contained information about their social-demographic characteristics (age, locality and time of residence, education, number of children, income, and access to the Internet) and their fishing activity (if they still fishing, fishing experience, fishing time, fishing effort, fishing sites, fishing gear, and target species).

Fishermen's LEK concerning great cormorant included a projective test (Costa Neto et al. 2009) where we showed an illustrative image of a specimen of *P. carbo* to see if fishermen were able to recognize and identify it, as well as multiple questions about our target species' ecology (staying period and preferred

sites in Minho River, preference for prey species and size, daily food intake, foraging behaviour), fisherman's personal opinion about *P. carbo* and beliefs or taboos towards it.

For their attitudes towards conservation of great cormorants, we explored matters like the need (or not) for population control and the impact of these birds in fishing activity and commercially important fish species. In addition, this process followed the ethics code of the International Society of Ethnobiology (ISE 2006). In the present study, we formulate the concept of attitudes as tendencies that are expressed by judging a certain entity in a position of some agreement or disagreement (Bogardus 1924; Eagly and Chaiken 1993; Crano and Prislin 2006). Furthermore, because we were still facing the COVID-19 pandemic, we established a minimum of 30 interviews, since that is considered an adequate sample size for publishing articles (Dworkin 2012).

Data analysis

Qualitative analysis

Data obtained from the interview transcript allowed us to share and access fishermen's LEK about great cormorant's ecology. Fishermen's knowledge was analysed through an emic-etic approach, where both emic and etic methods coexist. It means that we integrated both cultural-specific and cultural-comparative (universal) elements, respectively. This allowed us to overcome the restrictions of each approach, by combining them to acquire a more sensible perception (Cheung et al. 2011). In this study, such method reflects on gathering local knowledge and scientific knowledge to assess data regarding cormorant's ecology. Education levels were divided into three classes according to the Portuguese system: low level (no education and 1 s cycle of primary school—1st to 4th grade), basic level (2nd and 3rd cycles of primary school—5th to 9th grade), and intermediate (secondary school or higher—10th and above). All scientific names mentioned were described according to the Catalogue of Life database (COL 2020), except for one species, that we followed the BirdLife International database (BirdLife International 2021a).

Quantitative analysis

We developed 10 questions with a three-point Likert scale to assess fishermen's attitudes. Although the most common variation of the Likert scale is the five-point scale (Bertram 2006), we decided to use a three-point scale to avoid misperception in differentiating a scale from another. To analyse attitudes quantitatively, we followed the methodology presented in both Braga and Schiavetti (2013) and Braga et al. (2018). Hence, we converted the three-point Likert scale into scores from 0 to 1 (unfavourable attitude = 0, moderate attitude = 0.5, favourable attitude = 1). Attitudes were considered favourable when fishermen showed no conflict with cormorants, moderate when showed indifference or unfavourable when showed conflict. To evaluate the individual mean index of attitudes, we calculated the average score for each fishermen. Then, we obtained the overall mean index of attitudes by calculating the average of individual mean indexes of attitudes, to understand the general perception of Minho River's fishermen. The mean index of attitudes was then classified into three classes (0–0.33: negative attitudes; 0.34–0.66: moderate attitudes; 0.67–1: positive attitudes).

For statistical analysis, we tested the normality of our data through the Shapiro–Wilk test. We then used the Spearman's rank correlation coefficient to test correlation between the mean index of attitudes and fishing experience, average fishing time, fisherman's age, and number of children. To analyse significant differences between the mean attitude's index and fishing effort, education level, and income, we performed the Kruskal–Wallis H test and or the Mann–Whitney U test, depending on the number of independent groups. Thereafter, for the variables that showed significant differences, we performed the post hoc Dunn test with Bonferroni adjustments to understand which groups of that variable were significantly different from another. We also tested the reliability of our semi-structured interview by applying the Cronbach's alpha coefficient (Cronbach 1951). All analyses were carried out through R version 4.0.3, using packages from R Studio Version 1.4.1103 library—*dplyr*, *rstatix*, *corrplot*, *ggplot2*, and *psych* (R Core Team 2013; RStudio Team 2020).

Results

Fishermen's profile

We managed to interview a total of 50 fishermen in Minho River's fishing communities (Valença, $n = 6$; São Pedro da Torre, $n = 5$; Campos, $n = 5$; Vila Nova de Cerveira, $n = 7$; Gondarém, $n = 3$; Lanhelas, $n = 5$; Seixas, $n = 4$; Caminha, $n = 15$), which allowed us to have more diverse and complete data. All interviewees were men and older than 33 years old, and most of them ($n = 33$; 66%) have or had other jobs other than fishing (e.g. construction work) (Supplementary information 2). Almost half ($n = 24$; 48%) of the interviewees had basic level of education (5 to 9 years of education), and 42% of fishermen ($n = 21$) claimed that they earn between 601 and 1200 euros (€) monthly. Also, most interviewees ($n = 38$; 76%) had access to the Internet.

Currently, most respondents ($n = 43$; 86%) still practise fishing activity (Supplementary information 3). We were able to question fishermen with little experience (e.g. 6 years of fishing experience) to plenty of experience (e.g. more than 60 years of fishing experience). Almost all fishermen ($n = 43$; 86%) went fishing 5 to 7 days a week. However, no fisherman claimed to fish 7 days a week, often mentioning that fishing activity is closed between 11 pm on Saturday and 11 pm on Sunday.

Great cormorant's folk taxonomy

When the projective test was applied, all fishermen ($n = 50$; 100%) recognized the target species when shown the images. *Corvo-marinho* was the most mentioned ($n = 47$; 94%) common name used to identified *P. carbo*. Other common names given by the interviewees were *pato-funduche* ($n = 3$; 6%), *cormorante*, *garça*, and *flamingo* ($n = 1$; 2% each).

Abundance

Seven fishermen (14%) noticed an increase in great cormorant specimens, compared to the past, and four fishermen (8%) said they only appeared recently. One of the four fishermen added that was an exponential growth of population about 20 to 30 years ago. On the other hand, two fishermen (4%) claimed that nowadays they sight great cormorants much less often. One

of the two fishermen pointed out the construction of walkways as the leading cause.

Habitat and distribution

Temporal distribution

When questioned about great cormorant's staying period on Minho River (Fig. 2), more than half of the fishermen ($n = 31$; 62%) alleged that this bird appears all year, of which some ($n = 4$) even mentioned that, nowadays, it does not migrate, and it is a resident species.

However, two other fishermen claim they observe a greater abundance between January and May because of the fishing season and, consequently, fishermen go to the river more often. The remaining fishermen ($n = 19$; 38%) mentioned several periods when it came to temporal distribution of great cormorants in Minho River, including other answers such as winter ($n = 3$; 6%), autumn ($n = 1$; 2%), and warmer seasons, when the water is hotter ($n = 1$; 2%). Only one fisherman (2%) could not answer.

Spatial distribution and habitat

Fishermen's answers allowed us to gather information not only about the great cormorant's geographical distribution but also about its habitat (Table 1). The

Table 1 Great cormorant's spatial distribution and preferential habitat, according to fishermen ($n = 50$).

Areas	<i>n</i>	Habitat	<i>n</i>
Through all Minho River	18	Margins	23
Fort of Insua	4	Sandbanks	4
Isle of Boega	3	Trees	2
Islets	3	Deeper waters	1
Mouth of Minho River	3	Reeds	1
Isle of Canosa	2	Riverbed	1
Lanhelas	2	Rocks	1
Gondarém	1	Shallower waters	1
Isle of Amores	1	Stream entrances	1
Isle of Areeiro	1	Stream exits	1
Monção	1	Surf zone	1
Mota Quay (Gondarém)	1		
São Pedro da Torre	1		
São Sebastião (Seixas)	1		

most common answer for the distribution of *P. carbo* was through all Minho River (including the estuary) (18 citations). Some interviewees identified Fort of Insua, Isle of Amores, Isle of Areeiro, and Monção as dormitories for great cormorants. One fisherman also referred that cormorants rest on the eucalypts, specifically on the Portuguese margin. Another fisherman explained that cormorants often choose areas with a

Fig. 2 Great cormorant's (*Phalacrocorax carbo*) temporal distribution on Minho River, according to fishermen. Other answers include answers that were not specific, such as seasons

Table 2 Conservation status of the species mentioned by fishermen as prey of great cormorants in the Minho River region, Portugal (Cabral et al. 2005; Froese and Pauly 2020; Guterres 2019, Aquamuseu do Rio Minho 2020)

Common/Local name	Scientific name	Red Book of Vertebrates in Portugal	IUCN Red List (Global)
Bogardo [pt]	<i>Achondrostoma arcasii</i>	Endangered – EN	Vulnerable – VU
Allis shad [en], Sável [pt]	<i>Alosa alosa</i>	Endangered – EN	Endangered – EN
European eel [en], Enguia-europeia [pt] ^(a)	<i>Anguilla anguilla</i>	Endangered – EN	Critically Endangered – CR
Goldfish [en], Pimpão [pt]	<i>Carassius auratus</i>	Not available	Least Concern – LC
Thicklip grey mullet [en], Negrão [pt]	<i>Chelon labrosus</i>	Not available	Least Concern – LC
Common carp [en], Carpa [pt]	<i>Cyprinus carpio</i>	Not available	Vulnerable – VU
European seabass [en], Robalo [pt]	<i>Dicentrarchus labrax</i>	Not available	Least Concern – LC
Thinlip grey mullet [en], Mugem [pt]	<i>Chelon ramada</i>	Not available	Least Concern – LC
Largemouth black bass [en], Achigã [pt]	<i>Micropterus salmoides</i>	Not available	Least Concern – LC
Flathead grey mullet [en], Tainha [pt]	<i>Mugil cephalus</i>	Not available	Least Concern – LC
Sea lamprey [en], Lampreia-marinha [pt]	<i>Petromyzon marinus</i>	Vulnerable – VU	Least Concern – LC
Flounder [en], Solha-das-pedras [pt]	<i>Platichthys flesus</i>	Data Deficient – DD	Least Concern – LC
Northern straight mouth nase [en], Boga [pt]	<i>Pseudochondrostoma duriense</i>	Not available	Vulnerable – VU
Atlantic salmon [en], Salmão-do-Atlântico [pt]	<i>Salmo salar</i>	Critically Endangered – CR	Least Concern – LC
Brown trout [en], Truta [pt]	<i>Salmo trutta</i>	Critically Endangered – CR	Least Concern – LC
Common sole [en], Linguado [pt]	<i>Solea solea</i>	Not available	Data Deficient – DD
Iberian chub [en], Escalo-do-norte [pt]	<i>Squalius carolitertii</i>	Not available	Least Concern – LC
Mussels [en], Mexilhões [pt]	Mytilidae	Not available	Not available

higher abundance of flounders *Platichthys flesus* (Linnaeus, 1758). Two other fishermen (4%) also claimed cormorants rest on the margins. Another fisherman (2%) said cormorants look for islets (like the Isle of Amores, the Isle of Boega, and the Isle of Canosa) to dry their wings to be more protected.

For the habitat, fishermen often mentioned the margins of the river. Two fishermen (4%) justified the presence of great cormorants in the margins because there is a higher abundance of European eel (*Anguilla anguilla*) in those spots. According to one of the two fishermen, it is due to whirlpools at the bottom of the river. Two other fishermen (4%) pointed out that cormorants look for isolated locations, and one of the two added they go away when anyone gets closer. Two fishermen (4%) also claimed that the accumulation of great cormorants' droppings in Fort of Ínsua killed all the specimens of Hottentot-fig (*Carpobrotus edulis* (L.) N. E. Br.), and another one (2%) mentioned the same type of situation in a tree where the fisherman often spotted great cormorants. At last, two fishermen (4%) who sighted great cormorants through all Minho

River added that this species goes after spots where more fish is available.

Diet and foraging behaviour

Prey

Most fishermen ($n = 37$) reported great cormorants preyed fish species that are also targets of fishing activity, which includes, *Anguilla anguilla* (Linnaeus, 1758) in the stage of glass eel, *Alosa alosa* (Linnaeus, 1758), *Dicentrarchus labrax* (Linnaeus, 1758), *Petromyzon marinus* Linnaeus, 1758, *Platichthys flesus* (Linnaeus, 1758), *Salmo salar* Linnaeus, 1758, and *Salmo trutta* Linnaeus, 1758 (Table 2). The most cited fish species as prey of great cormorants were *A. anguilla* (37 citations) and *P. flesus* ($n = 31$). Other prominent preys include *P. marinus* (18 citations), *A. alosa* (15 citations), *D. labrax* (9 citations), *Pseudochondrostoma duriense* (Coelho, 1985) and *S. trutta* (7 citations each), and *Chelon ramada* (Risso, 1827) (6 citations).

Yet, some fish species were mentioned only once or twice—*Achondrostoma arcasii* (Steindachner, 1866), *Chelon labrosus* (Risso, 1827), *Mugil cephalus* Linnaeus, 1758, and *Squalius carolitertii* (Doadrio, 1988) (2 citations each); *Carassius auratus* (Linnaeus, 1758), *Cyprinus carpio* Linnaeus, 1758, *Micropterus salmoides* (Lacepède, 1802), *S. salar* and *Solea solea* (Linnaeus, 1758) (1 citations each). One fisherman added cormorants eat not only fish, but also mussels (Mytilidae). When questioned about *P. carbo* preferences regarding prey's life stage/size, nineteen fishermen (38%) told it does not have a preference, claiming it feeds on what is available. However, 28% of interviewees ($n = 14$) claimed cormorants prefer smaller/juvenile fish. Six fishermen (12%) said these birds hunt both larvae and juvenile fish, while seven other fishermen (14%) mentioned they prefer both juvenile and adult fish.

In terms of fish consumption, 24% of all fishermen ($n = 12$) were not able to tell great cormorant's daily food intake (DFI), that is how many kilograms (or grams) great cormorants eat per day. The lower value mentioned by fishermen was 0.150 kg, and the higher value was 10 kg, resulting in an average of $1.96 \pm 1.86 \text{ kg day}^{-1}$ ($\pm \text{sd}$). Also, for those who could name a value for great cormorant's DFI, the mode was 1 kg day^{-1} .

Foraging habits

About cormorants' foraging habits, interviewees, for the most part, claimed this species hunt alone ($n = 44$; 88%) or, sometimes, in pair ($n = 2$; 4%) (Fig. 3). However, few said they hunt in a group ($n = 3$; 6%), while one fisherman (2%) mentioned they both hunt alone and in groups. When questioned about what time of the day they saw cormorants feeding, the most common answer was that cormorants forage both in the morning and in the afternoon ($n = 23$; 46%). When hunting in the morning (including "mornings only" and other answers that include this time of day), according to six fishermen (12%), *P. carbo* is usually seen at the break of day and early morning. One of these fishermen even pointed out that it happens because there is too much movement after those hours, which scares away the cormorants. Furthermore, some of the fishermen who deny that cormorants hunt in the evening ($n = 3$; 6%) stated they collect for sleeping upstream and cannot locate the prey at night.

However, some fishermen ($n = 9$; 18%) responded that it does not depend on the time of the day but the tides. One fishermen pointed out that hunting in lower tides facilitated predation, since fish get stuck in small wells. On the other hand, two fishermen said that hunting in high tides creates more opportunity for predation, since that is when fish start entering the river.

Conservation attitudes

Data analysis

The average value of the attitudes' index was 0.64 ± 0.27 ($\pm \text{sd}$), which suggests a moderate attitude of fishermen towards great cormorants, when classified according to the defined classes. Index of attitudes ranged from 0.15 to 0.95. The Cronbach's alpha for the part of the questionnaire that concerns the conservation attitudes' questions was 0.89, counting with a 95% confidence interval. On the other hand, a significant and negative correlation was found between the age of fishermen and their conservation attitudes ($r_s = -0.34$, $p = 0.01$) (Fig. 4). Hence, in this study, older fishermen tended to have more negative attitudes towards the conservation of great cormorants in Minho River.

Moreover, Kruskal–Wallis H test's results showed significant differences between the median of groups A, B, and C, regarding the index of attitudes ($\chi^2 = 5.81$, $\text{df} = 2$, $p = 0.05$) (Fig. 5). No other differences among groups were significant. Then, the pairwise post hoc Dunn test with Bonferroni adjustments, at a significance level of 5% ($\alpha = 0.05$), revealed only significant differences between individuals who fish 1 to 2 times a week—group A—and those who fish 5 to 7 times a week—group C ($p = 0.02$). Therefore, other comparisons did not show different behaviours in attitudes' index.

Ultimately, no significant correlations were found between attitudes and other variables in fishermen's profile—fishing experience ($S = 25,652$, $p = 0.11$), average fishing time per trip ($S = 20,471$, $p = 0.91$), number of children ($S = 18,359$, $p = 0.41$), education level ($\chi^2 = 1.90$, $\text{df} = 2$, $p = 0.39$), income ($\chi^2 = 0.13$, $\text{df} = 2$, $p = 0.94$), and access to the Internet ($W = 200$, $p = 0.53$).

Fig. 3 Fishermen's answers regarding the cormorant's foraging habits ($n = 350$). Other answers include during "early morning and sunset", and "the entire day". The bar for the answer "Tides" include two citations of "high tides" (black rectangle) and seven citations of lowering tide (grey rectangle)

Discussion

Great cormorant's folk taxonomy

Corvo-marinho was the common name of *P. carbo* most cited by fishermen of Minho River. In both national and international databases (Aves de Portugal 2021; Avibase 2021), the target species is commonly designated, in Portuguese, as *corvo-marinho-de-faces-brancas*. However, Avibase repository displays other synonyms such as *corvo-marinho* and *corvo-marinho-comum*. Fishermen also cited names such as *pato-funduche*, *cormorante*, *garça*, and *flamingo*. *Pato-funduche* can be translated to *funduche* duck, alluding to a duck that dives deep/to the bottom. This nomenclature may be due to fishermen claiming great cormorants dive deep and the fact they may think cormorants and duck look alike. Also, *cormorante* is very similar to the English common name—great cormorant (Avibase 2021). Thus, *cormorante* and *pato-funduche* could be possible new folk names. On the other hand, *garça* and *flamingo* are already associated with Ardeidae (Herons) and

Fig. 4 Significant and negative correlation between the mean index of attitudes and fishermen's age (years) ($p = 0.02$)

Phoenicopteridae (Flamingos), respectively (Avibase 2021). Therefore, those common names do not seem appropriate for *P. carbo*.

Fig. 5 Comparison of the index of attitudes and fishermen's fishing effort. A = 1 to 2 times a week; B = 3 to 4 days a week; C = 5 to 7 days a week. Group A and Group B are significantly different ($p = 0.02$). The thick black line represents the median

Abundance

The last survey we came across on the wintering *P. carbo* population in Portugal was in 2013 and counted with 15 000 specimens (Leitão et al. 2013 in Meirinho et al. 2014). Nevertheless, Costa and Rufino (1996) found that the national wintering population of great cormorants increased fourfold between the 1980's and the 1990's, counting with 4.000 individuals. This could be a result of the adoption of The Birds Directive (Council Directive 9/409/EEC) in 1979, and, nationally, Decreto-Lei n° 75/91. Starting to ban dichlorodiphenyl-trichloroethane (DDT) in the 1970's can also be a promoter of the increase in great cormorant's population, since this pesticide is responsible for affecting birds' reproduction success and their feeding behaviour (Mitra et al. 2011). These data coincide with those fishermen who noticed the increasing trend of great cormorant's population, especially with the exponential population growth 20 to 30 years ago mentioned by one fisherman.

Yet, few interviewees declared they do not see cormorants very often nowadays, which one of them blames the construction of walkways. Bötsch et al. (2018) found that recreational trails had a negative impact on forest birds. They also concluded that the main source of disturbance was not the process of

construction, but the presence of humans. The same situation might be happening in Minho River in certain locations, scaring cormorants away to other areas.

Habitat and distribution

Temporal distribution

It is known that *P. carbo* does not breed in Portugal and stays in this country from September to April, which makes it a wintering species. Nonetheless, there are a few specimens who are resident in Portugal, such as immature and non-breeding individuals (Bregnballe et al. 2014; BirdLife International, 2019; Aves de Portugal, 2021). Most fishermen ($n = 31$, 62%) affirmed great cormorants appear in Minho River throughout the entire year, and, also, some ($n = 4$; 8%) told this species is resident. Therefore, it is possible that the specimens sighted by fishermen between May and August were non-breeding or even immature. However, a study by Almeida (2008) found one couple of great cormorants breeding for the first time in Portugal, in a colony of herons in Dejebe Creek. In the following year, three couples were found again breeding nearby the previous location, nesting in aspen trees (*Populus* sp. L.). Even though this location is far away from our study site, it allows the possibility of similar events occurring in the future in other regions of this country.

Spatial distribution and habitat

Wetlands are the main type of ecosystem inhabited by *P. carbo*, and it is present in the Minho River region (Sousa et al. 2008; Meirinho et al. 2014). Also, this species is often associated with habitats such as sandbanks, rocks, large lakes, and trees near to a water mass (Nicolai et al. 2001; Svensson et al. 2017). Sandbanks, trees, and rocks were a few habitats also mentioned by our interviewees (Table 1). Reeds were also cited by one fisherman and are typically found in wetlands. Shallow waters are also mentioned by one fisherman, and are considered favourable for hunting (Musil et al. 1995; Johansen et al. 2001). No published data showed any evidence of deeper waters, riverbeds, and surf zones to be a preferential habitat for cormorants. Great cormorants are spotted in streams, without any specification about being particularly present in their entrances or exits (Sutter, 1995).

Minho River's fishermen often mentioned margins as cormorants' main habitat. Throughout the course of the river, margins are mostly composed by trees and riparian vegetation, an important type of vegetation in wetland ecosystems (Nilsson et al. 2010). Therefore, the concept of margin may not be the actual privileged habitat for great cormorants, but the vegetation associated with it.

Regarding the distribution of *P. carbo* in Minho River, there is not any literature to corroborate the fishermen's LEK. However, according to observation reports registered on eBird (2021), great cormorants are spotted all through the Minho River, like fishermen revealed in the present study (Table 1). It is also shown a higher number of observations in the mouth of the river, as well supporting our data. These records depend only on people registering observations, meaning it does not represent the entire distribution of a species.

Diet and foraging behaviour

Prey species

Fishermen of Minho River reported great cormorants' prey on some fish species fished by them. Allis shad (*A. alosa*), European eel (*A. anguilla*), sea lamprey (*P. marinus*), Atlantic salmon (*S. salar*), and brown trout (*S. trutta*) are not only both fishing targets and great cormorant's prey, according to the interviewees, but are also endangered, vulnerable or critically endangered in Portugal (Cabral et al. 2005; Appendix 3). If *P. carbo* feeds on these fish species and their conservation statuses can reflect smaller population size, it could lead to a conflict between fishermen and cormorants.

In Portugal, there are few studies regarding great cormorant's diet (e.g. Dias et al. 2012; Catry et al. 2017). Dias et al. (2012) showed that Cyprinidae, Mugilidae, and Pleuronectidae (e.g. *P. flesus*) were the most frequent fish families consumed by *P. carbo* in Minho estuary. Likewise, *P. flesus* was also one of the most cited preys in our study. In parallel, Catry et al. (2017) found that mullets (Mugilidae) were *P. carbo*'s most common prey in Sado estuary, followed by seabreams (*Diplodus* sp.), toadfish (*Halobatrachus didactylus* (Bloch & Schneider, 1801)), and soles (*Solea* sp.). Both studies of great cormorant's diet in Portugal showed that the most found prey species were

not exactly the same, when compared to the present work and to each other. Consequently, *P. carbo* appears to have a very diverse diet. This suggests that great cormorants take advantage on what fish is available, implying they are opportunistic and generalist feeders, which as be proven to be true previously (Carss, 2003; Kirby et al. 1996; Dias et al. 2012; Catry et al. 2017).

Prey size

Some studies revealed that *P. carbo* prey on juvenile and smaller fish, which can affect the recruitment, and lead to a decreasing population trend (Källo et al. 2020; Mustamäki et al. 2014; Troynikov et al. 2013). According to Gagliardi et al. (2015), cormorants seemed to select smaller-sized fish (fish with body mass below 0.110 kg). However, the same study showed that our target species consumed burbot *Lota lota* (Linnaeus, 1758) of different life stages. This could suggest that great cormorants may not select fish according to its life stage, but according to its size. Our results are partially supported by published data, since 28% of fishermen claim that great cormorants prefer smaller/juvenile fish. However, 38% of fishermen say cormorants prey on what is available and have no preference. We mentioned before that *P. carbo* is an opportunistic feeder, which can indicate that they do not necessarily have a preference. A possible explanation is that they often prey on smaller fish, because it could be an easier catch. Ovegård et al. (2017) mentioned that cormorants often suffocate while trying to swallow bigger fish, sometimes resulting in death, and showed a case where a cormorant was strangled by an eel. Therefore, bigger fish can be harder to swallow and more resistant.

Daily food intake (DFI)

There is not a precise number when it comes to great cormorant's daily food intake, since it can vary according to different parameters, such as body mass, time resting, time in water, and water temperature (Grémillet et al. 2003). Grémillet (1997) revealed that the mean DFI for great cormorants was 0.828 kg day⁻¹, whereas Čech and Vejřík (2011) obtained a mean DFI of 0.397 kg day⁻¹. Alternatively, Grémillet et al. (2003) modelled the daily food intake for *P. carbo* through published data and data

obtained from captive cormorants, resulting in a mean DFI of $0.672 \text{ kg day}^{-1}$. According to the Minho River fishermen, cormorant's daily food intake was, on average, 1.96 kg day^{-1} . Although the mean DFI that we found much higher than the studies previously mentioned, some fishermen ($n = 10$; 20%) revealed values that agree with those previous studies. Also, the most mentioned value by fishermen was 1 kg day^{-1} , which is similar to the results found in Grémillet (1997). Therefore, it is important to understand that published data can support some of the answers from fishermen.

Foraging habits

Phalacrocoracidae is considered gregarious, but *P. carbo* may not always be a social species (Heinzel et al. 1995). On one hand, Lekuona and Campos (1996) found that cormorants hunt solitarily most of the time, but they also observed social hunting in 33% of the time. On the other hand, van Eerden and Voslamber (1995) proposed that our target species changed from foraging alone to foraging in group, as an adaptation to water turbidity. In Minho River, we also obtained various types of information, even if most fishermen (88%; $n = 44$) alleged that *P. carbo* hunts alone. Thus, we suggest that solitary foraging could be the most common behaviour in great cormorants, which can be altered due to adaptation to external factors, like water turbidity in van Eerden and Voslamber (1995).

White et al. (2007) found that great cormorants have very poor visual performance for a predator, especially when compared with terrestrial birds. Grémillet et al. (2005) revealed that light conditions did not interfere with cormorants' daily activities during Polar night, maintaining their diving behaviour, which usually occurred between 5am and 8 pm. Yet, Johansen et al. (2001) showed that *P. carbo* fed mainly in the morning and afternoon but concluded that was due to metabolic demands and length of the day. That is, poor insulation and shorter days resulted in less foraging sessions. In our study, almost half of the fishermen observed the same results as the last-mentioned study—hunting bouts in the morning and afternoon. Fishermen were also supported by published records when saying cormorants feed at the break of day. However, three interviewees said that these birds cannot locate the prey at night, which

proves to be false, according to Grémillet et al. (2005). When it comes to the fact that foraging depends on the tides, there is no evidence. Although, it has been proven that *P. carbo* seems to prefer hunting in shallow waters (Musil et al. 1995; Johansen et al. 2001). Nevertheless, one fisherman pointed out that cormorants prey on fish stuck in wells during low tides, which can be an interesting predation strategy to analyse in the future.

Conservation attitudes

The Cronbach's alpha value is considered “good”, according to rules of thumb provided by George and Mallery (2003), which indicates that our interviews were consistent internally and reliable to analyse fishermen's attitudes. Fishermen in Minho River showed an overall moderate conservation attitude towards great cormorants, while half of them showed a positive attitude. However, in other studies, fishermen seem to have a more unfavourable perception towards this bird, blaming it for depredating the environment and supporting its extermination (Pyrovetsi and Daoutopoulos, 1989; Daoutopoulos and Pyrovetsi, 1990; Peeva et al. 2017).

Besides, we found that younger fishermen tended to have more positive attitudes towards the conservation of our target species. The same relation was found in Braga et al. (2017b), where older fishermen lean towards a more negative conservation attitude towards the European sardine *Sardina pilchardus* (Walbaum, 1792). Shuib et al. (2012) also found that age was associated with attitudes towards the conservation of the deltaic mangrove forest areas, where the younger generation had more positive attitudes. However, Allendorf et al. (2006) did not notice a significant relationship between age and attitudes towards protected areas in Myanmar.

We propose three reasons for our results. The first one is that the younger fishermen might be more aware of environmental issues and the importance of conserving biodiversity. Since all the fishermen we interviewed are older than 30 years, different interviewed cohorts were educated under different educative, socio-environmental (namely under different environmental pressures), socio-cultural and socio-political scenarios (namely under different management, conservation, and governance scenarios). Also in 1986, Portugal became part of the European Union,

which led to a greater focus on conservation programmes (European Union, 2021). The second one is that, in the past when older fishermen were more active, the same environmental issues were not such a priority, and, therefore, there were probably less environmental restrictions. At last, if great cormorants have a considerable impact on fish stocks, their recent increase in abundance can be another reason for older fishermen have had unfavourable attitudes towards this species.

Fishing effort was also correlated with fishermen's attitudes, particularly fishermen who went fishing very often (5 to 7 days a week) tended to have more positive attitudes than fishermen who went fishing less often (1 to 2 times a week). To our knowledge, this is the first time that was found a relationship between the number of fishing trips and fishermen's attitudes. A possible reason for that can be that fishermen who spend more time in the river can be more accustomed to the presence of great cormorants.

One interesting point we noticed throughout some interviews was a change of a pre-conceived thought. At the beginning of the projective test, where fishermen tried to identify *P. carbo*, some often mentioned this species was “the destroyer of the river”, “the biggest predator of the river”, that it “ate all the fish”, among other variations of these negative claims. Nonetheless, during the rest of the interview, some ($n = 10$) ended up showing a moderated attitude towards the presence of great cormorants in Minho River. This suggests that interviewees may have shaped their perceptions by reflecting on our questions. Nevertheless, attitudes are mouldable, but it takes time and effort to change a perception (Pickens 2005). Thus, it might be ambitious to claim that they in fact changed perceptions that quickly. Perhaps those comments were an instant reaction, coming from a stigma around cormorants, and then when asked particular questions fishermen were able to answer with their own observations.

Almost half of fishermen ($n = 21$; 42%) revealed they believe that the population of great cormorants in Minho River should be controlled. Some propositions for control methods include hunting in certain periods of the year, “scientific methods” and the method that was used in yellow-legged gulls (*Larus michahellis* J. F. Naumann, 1840) in the Berlenga Island (that was referred as “chemical system”). Yet, this last proposition was not a chemical procedure, but a birth

control. In Berlenga Island, Portugal three methods have been tested throughout the years: destruction of eggs, egg-oiling, and egg puncture (SPEA 2019). However, this methodology it is not appropriate for this study area, since it implies that great cormorants nest in Minho River, which has not yet been proven.

Local control of these birds is being attempted in few locations, although it is legal to only kill a low number of cormorants, when compared with the total number of individuals (Volponi et al. 2005; Chamberlain et al. 2013). Therefore, it is not significantly affecting the population, and proves not being effective on population level in the following winter (Volponi et al. 2005; Chamberlain et al. 2013). Yet, Kindermann (2008) proposed the European Cormorant Management Plan (2008/2177(INI)), and it was approved. That is, a community plan for the management of great cormorant populations. It pretends to monitor cormorant population across Europe, to understand the populations' structure and size, and supporting and financing the fishery sector.

The question remains: is it necessary to control the population of great cormorants in Minho River? It is not possible to answer now. The lack of current and updated scientific data is an obstacle in the progress of establishing a management plan. The present study establishes a base on the LEK of Minho River's fishermen and their perceptions on great cormorants. Even if presenting an overall moderate attitude, some fishermen agree that there should be a population control, and few do attribute all the culpability to cormorants. Some mention pollution and even over-fishing as reason for decreasing fish stocks. Thus, sharing this knowledge with the scientific community brings the attention to issues that need to be addressed. It also allows to create a baseline information concerning the population of great cormorant in Portugal, to motivate and guide possible future studies.

Conclusion

This was the first study in Portugal related to the local ecological knowledge and conservation attitudes towards *Phalacrocorax carbo*. Minho River's fishermen showed knowledge about this species and brought up the need for more information about wintering cormorants in Portugal. Their conservation attitudes

towards this bird were moderate, unlike other studies on the same subject. Yet, older fishermen tended to show more negative attitudes. Significant differences were also noticed between those who fish very often (group C) and those who fish more rarely (group A). That is, those who went fishing frequently are inclined to have more positive attitudes.

In addition to previous ethnobiology-related studies, we express the importance of local ecological knowledge and community's attitudes to the environment. The gap in updated ecological and biological information about *P. carbo* can be complemented by LEK, but we reinforce the need for more studies regarding population structure nationally. Only then, it is possible to merge both scientific knowledge and traditional knowledge to form a plan that regards the fishing community preoccupations and needs. Hence, this work plays a very relevant role by serving as background information for other researchers studying *P. carbo* in this area.

In parallel, educational programmes using the information that is currently available for our target species can be useful. It has been shown that greater knowledge can reflect on more positive attitudes (Kuentzel et al. 2012). Addressing other issues like pollution and its impact on fishing activity and fish stocks can also be relevant. At last, since Minho River is an international river, ethnobiological studies regarding the great cormorant can also be important to understand Spanish fishermen's perceptions towards this species. Subsequently, their findings can be compared with our results, in order to better assess the conflict in both margins.

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Data availability All data resulting from this study are stored in the Department of Biology at University of Aveiro and available for consultation for a 5-year period, in case of a justifiable request to the corresponding author.

Declarations

Conflict of interests The authors have no relevant financial or non-financial interests to disclose.

Data statement The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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