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TESI DI LAUREA

Intrinsic and extrinsic factors affecting foraging behaviour of breeding Mediterranean gull (*Ichthyaetus melanocephalus*)

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INDEX

1. SOMMARIO

I gabbiani sono un gruppo cosmopolita di uccelli marini, e come tali possiedono peculiari tratti biologici come riproduzione in colonia, elevate longevità, scarsa fecondità, cure parentali da entrambi I genitori, maturità sessuale raggiunta dopo diversi anni. Inoltre si distinguono per la loro natura generalista sia per quanto riguarda i metodi di locomozione (volo, cammino, nuoto) che per il comportamento alimentare e la dieta. Sono infatti degli opportunisti che essendo in grado di utilizzare sia gli habitat di terraferma sia quelli costieri e marini, costituiscono un collegamento tra le reti trofiche marine e terrestri. Non è raro inoltre che sfruttino le fonti di cibo derivanti da attività umane, come agricoltura e pesca.

In questo studio sono stati impiegati dispositivi GPS su adulti di gabbiano corallino *(Ichthyaetus melanocephalus)* per seguire i loro movimenti durante diverse stagioni riproduttive (2016, 2017, 2022), e in due diverse località a pochi km dalla costa dell'Emilia Romagna: la salina di Cervia e la zona umida dell'Ortazzo. È un approccio che non era mai stato usato in questa specie, che è meno studiata e conosciuta rispetto ad altre specie di gabbiani. L' obiettivo dello studio è valutare il tipo di comportamento alimentare di questa specie nel corso della riproduzione, e in particolare verificare da quali fattori esso venga influenzato. In questo studio ho analizzato alcune metriche dei viaggi di foraggiamento (massima distanza dal nido, durata) e il rapporto tra numero di posizioni in mare e in terra di ciascun viaggio, in relazione alle caratteristiche degli individui e ad alcune variabili meteo-marine.

I risultati mostrano che i maschi effettuano viaggi di lunghezza equivalente alle femmine, ma di maggiore durata, e che i genitori raggiungono, a parità di durata dei viaggi, distanze maggiori durante l'allevamento rispetto all'incubazione. La probabilità di foraggiare in mare è maggiore nei maschi, e aumenta con il passaggio dall'incubazione all'allevamento. Tale probabilità ha un picco nella tarda mattinata e risulta minore nelle restanti ore del giorno; inoltre risulta maggiore nei giorni lavorativi rispetto al fine settimana. I gabbiani corallini inoltre dimostrano di prediligere mare calmo e velocità intermedia del vento per recarsi in mare. La colonia di appartenenza non sembra invece avere un ruolo nel determinare il loro utilizzo del mare. La tattica di foraggiamento di questi individui è dunque determinata da una combinazione di fattori intrinseci (caratteristiche degli individui e fase della riproduzione) ed estrinseci (variabili ambientali).

Studi come questo sono importanti perché ampliando la nostra conoscenza sulle abitudini di questa specie permettono di ottenere informazioni utili alla loro

gestione e conservazione. La loro applicazione su altre specie di uccelli marini inoltre ha già dimostrato che studiando la loro ecologia è possibile ottenere indicazioni sulle condizioni dell’ambiente marino circostante, grazie al loro importante ruolo come organismi sentinella.

2. INTRODUCTION

2.1 Foraging in animals: strategies and shaping factors

Foraging affects animal's fitness because it plays an important role in the ability of an individual to survive and reproduce (Danchin et al., 2008). How the foraging behaviour of the animals respond to the environment where they live is described by the foraging theory, a branch of behavioural ecology. Optimal foraging theory predicts that the decisions that will be selected for and persist are those which maximize the payoff, where the payoff is the ratio of energetic gain per unit time during foraging (Hughes, 1989). To predict such decision, one can build a model that considers the different types of costs that the animal pays to forage or the constraints it meets, and the feeding system. There are different declinations of optimal foraging theory that try to predict the decisions animals will take in different situations:

- optimal diet model: it predicts that foragers choose the prey trying to balance the time required to find, capture, and consume the prey with the energy it provides (Danchin et al., 2008).
- patch selection theory: it seeks to find out how much time an individual will spend on one patch before deciding to move to the next one, depending on the travel time between patches and the energy gained from one patch versus another (Stephens et al., 2007) . This model is particularly suitable with central place foraging, that occurs when a forager must return to a particular place to consume food or to feed a mate and/or the offspring: the latter is the case, for instance, of breeding gulls (Corman et al., 2016) .

There are several factors that affect an animal’s ability to acquire profitable resources. One is the ability to learn, that means taking decisions relying on a previous experience in order to adapt to the continuous changes of the environment. An animal can learn whether a food item or a particular foraging technique are convenient (Hughes et al., 1992), but also learn when and where food is more available (Murphy, 2008). Foraging behaviour of individuals can also be influenced by their genotype, because there are genes associated with specific aspects of it, for instance onset of foraging behaviour and different task division and preferred prey by individuals in a group like in honey bees (Hunt, 2007). Some behaviours are more frequent than others because the allele that codifies for one behaviour is dominant over the other ones (Pereira, 1995). Other factors are the presence of predators and parasites, that induce animals to stop feeding and run away (Roch, 2018), or avoid areas where it is more likely to meet them. To prevent infections animals also avoid foods subjected to parasitic contamination, or include in the diet items that contain anti-parasitic properties (Hutchings, 2008).

Animals can forage alone or in a group: both tactics have their costs and benefits. Individuals foraging alone have the advantage to avoid local resource depletion and competitive interactions with conspecifics, and to be less conspicuous to predators (Le Roux et al., 2009). This strategy is usually chosen when the resources are abundant (Riedman, 1990). Solitary foraging behaviour can be characterized by the pattern of movement in “cruise searching”, when animals actively hunt for preys and “ambush searching” that means sitting and waiting that the preys passes by.

Group foraging, in contrast, can reduce predation risk by increasing the vigilance against predators or through dilution effect (Schreffler et al., 2010), allows to catch larger and dangerous preys (Packer et al., 1990) or to increase foraging efficiency, reducing energy expenditure (Schreffler et al., 2010) or creating aggregations of preys (Benoit-Bird and Whitman, 2009). Moreover, in social species some individuals can get information on novel foraging opportunities or techniques from others. Animals can actively form groups when group foraging is beneficial for the individuals (called aggregation economy) but may also be the consequence of individuals aggregating because they are attracted by the same resource, called dispersion economy. In this case social foraging is likely to be associated with costs, rather than benefits (Fretwell and Lucas 1970).

The foraging strategy of animals is therefore expected to be influenced by environmental conditions (such as the distribution and predictability of the prey, or the predation risk) and social conditions (such as population density).

2.2 The study of seabirds

A group of animals particularly suitable to study foraging behaviour and factors that affect foraging decisions is seabirds. These birds depend on marine environment for at least part of their life cycle and tend to present specific adaptations to forage in marine environments. Seabirds include almost 350 species that belong to 4 orders, the first two of which include only seabirds: Sphenisciformes, Procellariiformes, Pelecaniformes and Charadriiformes (Schreiber and Burger, 2002). Within these orders, some species (e.g. shearwaters and allies) forage exclusively in marine environments or in salty waters, whereas others are less specialized and can be found foraging both in marine habitats, freshwater habitats and on the land (typically gulls and terns).

2.2.1 Life history traits that make them unique

Despite the difficult categorization, there are still many features and life history traits that characterize seabirds.

Strictly marine species generally possess salt glands, that let them to excrete the salt they ingest (Schreiber and Burger, 2002). Procellariformes have tube-like structure enclosing the nostrils that in addition to prevent seawater from entering the lungs, may be involved in odour perception. Unlike the other birds in fact, petrels have a strong sense of smell, which is used to find food in the vast ocean (Lequette et al., 1989), and help distinguish familiar nest odours from unfamiliar ones (Bonadonna et al., 2003). Some seabird species fly vast distance to their feeding grounds, and undergo migrations that can go from one end of the globe to the other: they usually have narrow and long wings and are able to exploit a type of gliding flight called dynamic soaring to reduce the energetic cost of flying. In contrast, diving species have shorter wings and a bullet-shaped body. Also bills and feet show a vast array of adaptations to the different lifestyles (Schreiber and Burger, 2002). Seabirds are on average larger than other birds, and less colourful in plumage, a characteristic that is thought to be evolved for camouflage, both defensive and offensive.

An important characteristic is their tendency to breed in colonies: over 95% of seabirds are colonial, with colony sizes ranging from a few pairs to many thousands. Colonies can be widely spaced or densely packed. The term colony is restricted to breeding sites, while flocks refer to aggregations outside breeding site or period. Colonies and flocks differs also for the time individuals spend close to each other, that is usually much greater for the first. This implies that interactions that develop between individuals are more complex in colonies. These interactions can be by sight (panic flights), calls but also smell and sonar in some cases. Several different species can nest in the same colony, often exhibiting some niche separation. Many seabirds show remarkable site fidelity, returning to the same nest site for many years, and birds breeding for the first time usually return to their natal colony, nesting close to where they hatched: this tendency is known as philopatry (Coulson et al., 2002).

Regarding seabirds life history traits, they are the ones that characterize K-selected species: they are long-lived (usually they live between 20 and 60 years), with delayed sexual maturity (from 2 to 11 years), they usually have only one clutch a year, and for each clutch they lay one or two eggs in most of the cases, showing a low fecundity. Some species have a long chick rearing period, which requires a considerable effort by the parents. Most seabirds are monogamous, and share responsibility for nest defence, incubation and chick rearing (Hamer et al., 2002). Biparental care may be the consequence of the competition in the colony that requires constant nest defence, combined with the long flights to the foraging grounds. Possibly linked to monogamy is the limited sexual size and plumage dimorphism of seabirds (Coulson, 2002).

2.2.2 Importance of studying seabirds

Seabirds can be considered as sentinel organisms: a reduction in their numbers, health or breeding success provide an early signal that may indicate a problem in the surrounding marine habitat. Therefore, they are suitable to be bioindicators and biomonitors (Furness and Camphuysen, 1997), where a bioindicator is an organism that contains qualitative information on the status of the environment, while a biomonitor is a bioindicator that can give also quantitative information (Markert et al., 2003). They have several features that make them suitable for these roles, that often are related with their life history traits (Furness and Camphuysen, 1997). Their coloniality allows large quantities of data to be collected in a short period of time from a particular site, and to study large samples with a reduced effort, also because seabirds are conspicuous and can be easily censused. Furthermore, they are a group with a considerable public and scientific interest, so that there is an extensive availability of manpower to do the monitoring, including volunteers that allow to reduce the costs: for this reason there is now a detailed knowledge of seabird ecology. Finally, their being at the top of the marine food chain make them particularly appropriate as biomonitors of pollutants that are amplified in concentration through food chains. Among the aspects of the marine environment that they can help to describe, there are:

- Conditions of fish stocks (Furness and Camphuysen, 1997): both specialist fish predators and generalist seabirds are useful to this purpose: about the former, breeding success, activity budgets or, in some cases, breeding numbers may be monitors of changes in prey abundance, while for the latter diet composition can be used as an index of the relative abundance of prey stocks. In winter, mass strandings and large-scale fluctuations in wintering distribution of seabirds may be indicative of changes in prey stock abundance or prey availability .
- Fishing impact: The composition of the diet of species with a largely piscivorous diet is currently the most useful parameter in the assessment of the direct and short-term influences of fisheries activities (Einoder, 2009). The sampling of regurgitated pellets provides otoliths from eaten fish, which can be identified to species, measured to give fish size and sectioned to count annual layers to determine fish age (Alonso et al. 2013). However, also measures of foraging trip duration and energy acquisition rates have gained popularity in recent times. Breeding performance presents the most useful

indicator of longer term trends in the direct and indirect effect of fisheries on prey availability and ecosystem status (Einoder, 2009).

- Pollution (Furness and Camphuysen, 1997): Beached seabirds have been used for nearly a century to demonstrate the effects of oil pollution on the marine environment. If coupled with the chemical analysis of feather samples, they can be effective indicators of pollution of the seas by other lipophilic substances. An example is methylmercury, the organic and most toxic form of mercury, that is lipid-soluble and tend to biomagnify. For others metals instead feathers only can be used to estimate atmospheric contamination, while the ingested part requires the analysis of other organs to be revealed. Finally, seabirds are indicated also to detect other pollutants like organochlorines, because their concentration in seabirds vary less than in other organisms
- Climate change: Several studies have demonstrated that in addition to the more conspicuous effects of extreme climate change on adult survival, demographic parameters, such as recruitment and population trends, can be strongly correlated with large scale indices of ocean climate, such as the Southern Oscillation Index (Lee et al. 2007). Furthermore, changes in seabirds diet can reveal the influence of climate at many time scale, from seasonal to decadal (Piatt et al., 2007). Seabirds can be impacted also through match-mismatch effects: it means that their biological cycle doesn’t coincide anymore with the one of their preys, that has been modified by climate change (Bertram et al. 2001)

Apart from all these motivations, seabirds need to be studied also for their own conservation. Indeed, they are one of the most threatened group of birds. In the IUCN Red List, 31% of all seabird species are globally threatened (BirdLife International, 2018). The top three threats to seabirds in terms of number of species affected and average impact are identified in the invasive alien species, bycatch and climate change/severe weather, but overfishing, hunting/trapping, pollution and disturbance are also considered as major threats (Dias et al., 2019).

2.2.3 The use of GPS on seabirds

Marine biology was the first field of animal ecology using telemetry (Boyd et al. 2004). Biotelemetry is the instrumental technique for gaining and transmitting information from a living organism and its environment to a remote observer (Slater, 1965). Among the variables that can be measured for a free-living animal, its position in space allows intuitive and immediate ways to relate the animal to its environment. The advent of satellite telemetry allows remote tracking of animal positions and movements. Global positioning system (GPS), in particular, has several technical advantages, including the ability to determine position on the surface of the Earth (or in the air) with high precision and accuracy 24 h a day, with position updates available in rapid succession (Cagnacci et al, 2010). The first GPS receivers were developed in 1989 but they were impractical for animal applications due to their weight. Large commercial use have been responsible for the rapid advances in GPS receiver technology. GPS devices became smaller and more energy-efficient, until they became suitable also for tracking small mammals and birds. A contribute for the reduction of battery weight come from the use of solar panels to recharge the battery, even if it is still difficult to find a good compromise between device weight and operational life. Several systems to access the positioning data while the tag is still attached to the animal have evolved, including transmission through telephone network. Recent technological improvements like complete waterproofing have also allowed GPS applications in marine environment (Tomkiewicz et al., 2010). GPS devices can be associated to different types of sensors, like accelerometers and magnetic switches, that allow integrating different information. Together with GPS improvement, big datasets come out, that need to be managed and statistically analysed (Cagnacci et al., 2010).

Modelling animal movement is basic to understand different questions in animal ecology: how and why animals use specific resources, interact with conspecifics, compete and reproduce (Cagnacci et al., 2010). However, only location data are collected in many biologging studies because of the costs or the fact that the attachment of multiple sensor devices is often not possible, especially on small birds (Hawkins, 2004). This makes more difficult to understand the ecological significance of highly used areas in the absence of behavioural information, even if some assumptions can be made (Camphuysen et al., Le Corre et al., 2012).

About seabirds, GPS devices have shown to be a valid tool to discover information about their ecology and many of the aspects of the marine environment for which seabirds are a good indicator. Indeed biologgers including GPS demonstrate how seabirds adjust their foraging behaviour to fish stocks and distribution, providing new opportunities to use seabirds as indicators of marine food supply, to obtain early warning signal for its declining (Brisson-Curadeau et al., 2017). New models may be used on GPS data in order to determine foraging locations, patch use variation over time and, basing on this information, evaluate seabird responses to environmental change, identify candidate MPAs and inform marine infrastructural developments such as the positioning of offshore wind farms (Browing et al., 2018). GPS tracking, combined with other technologies, can be an instrument to study the interaction between individual seabirds and commercial fisheries, in order to evaluate the risk of entanglement or reliance on discards for food, and effects of changes in fishery management (Votier et al., 2010).

2.3 Factors affecting foraging in seabirds

The adoption of specific foraging tactics could be linked to individual characteristics (intrinsic drivers), but also to environmental variables (extrinsic drivers).

2.3.1 Intrinsic factors

- Age: a study on two species of Albatrosses (*Thalassarche melanophris* and *T. chrysostoma)* revealed that younger breeders of both species show improvements in foraging competency as years passed, reducing foraging trip duration until a certain age. Thereafter, there were signs of foraging senescence: older adults took gradually longer trips, narrowed their habitat preference (foraging within a smaller range of sea surface temperatures), made fewer landings and rested longer on the water. These age-related patterns in foraging behaviour are likely to have important consequences for the population dynamics of these threatened seabirds, as young or old individuals may be more vulnerable to worsening environmental conditions (Frankish et al., 2020)
- Sex: even small sexual size dimorphism can result in sex differences in flight efficiency and aerial agility, foraging areas and habitat (marine or terrestrial), foraging period of the day, diving depth, provisioning rate and preferred prey, ultimately affecting foraging behaviour. There are several examples of sexually dimorphic species in the literature where these differences have been demonstrated, both in species where males are bigger than females, like the Scopoli's shearwater *Calonectris diomedea* (De Pascalis et al., 2020), the Crozet shag *Phalacrocorax melanogenis* (Cook et al., 2007), the northern and southern giant petrels *Macronectes halli* and *M. giganteus* (Gianluca et al., 2019), and in species with reversed sexual dimorphism, like the red footed booby *Sula sula* (Weimerskirch et al., 2006). However, sex differences in foraging behaviour also occur in monomorphic seabirds, like the northern gannet *Morus bassanus* (Lewis et al., 2002). This indicates that physiological requirements and parental roles may also be important in shaping foraging tactics (De Pascalis et al., 2020).
- Breeding – non breeding season: Breeding is generally considered one of the most energy-consuming phase because of the high resource expenditure that it involves (egg production, nest attendance etc.) and the constraints that it generates. Pelagic birds are true sea wanderers during most of the year, but during the breeding season they become central place foragers that need to return to the colony regularly (De Pascalis et al., 2020). Therefore, during the

breeding phase, foraging trips parameters and feeding area choice will inevitably change. Moreover, usually seabirds migrate after breeding, therefore their foraging behaviour can differ from breeding season because of the different environmental conditions encountered during migration and in wintering areas. Even if wintering seabirds are not easy to study because of their low accessibility, it has been shown that they can change their diet or widen their trophic niche (Phillips et al., 2017).

- Breeding stage: a study on Scopoli's shearwater *Calonectris diomedea* revealed that trip duration, correlated with the farthest distance covered, decreased from incubation to the beginning of chick rearing stage, but then increased again as the chicks were growing. During the second stage, breeders alternated short trips for chick feeding with long trips for self-provisioning: this is called dual foraging strategy. Furthermore, during the incubation period individuals explored areas with higher values of primary production and shallower waters than during chick rearing. Chick rearing is therefore likely to constrain birds to use sub-optimal areas closer to their colony due to the intense pressures of chick provisioning. These data indicate that conservation efforts should therefore aim not only to protect the best foraging areas but also areas closer to the colonies, which will be profitable enough to provide adult birds with sufficient food for chick rearing (Cecere et al., 2013).

These factors should not be considered separately: for instance Frankish et al (2020) reports that some age-specific effects were apparent for the two Albatross species only in certain breeding stages, highlighting the complex interaction between intrinsic drivers in determining individual foraging strategies

2.3.2 Extrinsic factors

- Wind: Wind conditions encountered at sea have complex and contrasting effects on birds' activity and energy budgets. For purely flapping species like the black-legged kittiwake *Rissa tridactyla* and the little auk *Alle alle*, energy expenditure increased and food- provisioning rates of chicks decreased during strong winds. In contrast, higher average wind speeds led to enhanced foraging efficiency and breeding success in the wandering albatross *Diomedea exulans* which is able to use dynamic soaring. Northern gannets are able to buffer adverse effects of strong winds by reducing time spent drifting on water during trips and also by altering its flight height in relation to wind conditions, while the Brünnich's guillemot *Uria lomvia* and the black-legged kittiwake react switching to other food sources during windy days or increasing food delivery rates when weather improves. Such behavioural flexibility is likely to be critical to maintain fitness across variable environmental conditions encountered at sea (Lane et al., 2019).

- Weather: Among birds there are many examples of weather induced mortality, disruption of migration and breeding failure. Despite in some cases individuals may be affected directly by adverse conditions, most cases the effects occur indirectly through a reduction in feeding efficiency either by altering a bird's ability to detect and capture prey or by causing a change in the distribution or behaviour of the prey. A study on common guillemot *Uria aalge* demonstrate an increased foraging cost and a reduced energy intake of chicks during stormy weather. In fact adults have to stay longer away from the nest to forage, and to spend more time underwater to be able to catch the preys that, however were smaller than the ones they capture normally (Finney et al., 1999). Flexibility in foraging strategy with different weather conditions is important especially in a context of climate change: studies on movement and diet demonstrated that some seabirds species are able to modify their foraging routes and niche, while others are not, being more vulnerable (Kowalczyk et al., 2015).
- Period of the day: Most seabird species are visual predators and forage most actively during daylight hours, but several can forage also at night and some are exclusive nocturnal feeders (Brooke, 2002). Nocturnal feeders usually have eyes optimized for visual sensitivity, and some seabirds can rely on tactile or olfactory cues to forage at night. Diel patterns of foraging by seabirds may relate to predation risk (e.g. nocturnal behaviour of petrels, Mougeot, 2000), or to the behaviour and availability of preferred prey species: preys of nocturnal feeders usually are more likely to be available near the surface at night (Brooke, 2002). Such different conditions imply that, for a species with both nocturnal and diurnal foraging activity, feeding behaviour and techniques will be different. This is the case for instance of wandering albatross, which locate preys in flight during the day and employ a sit-and-wait technique at night (Weimerskirch et al., 1997). In the Eurasian oystercatcher *Haematopus ostralegus* the higher risk of clutch predation during the day is the reason why foraging trips at night are longer and the targeted sites are further away than those used during the day (Schwemmer and Garthe, 2011).
- Fishing activities: commercial fisheries have fundamentally altered marine ecosystems, transforming structure and function of marine food webs. Fishing discards provide large quantities of food to marine predators, and so the demography of their populations has been profoundly altered. For species that can compete effectively for discards, this food may be beneficial, since it is plentiful and easy to obtain, but for others it can represent an ecological

trap through a junk food effect (Votier et al., 2010). Long-term demographic studies show that seabird populations may suffer from competition with fisheries. This is the case for instance of the Peruvian booby *Sula variegata*, whose natural preys in fact are the same target of fishery (Bertrand et al., 2012). Fluctuations in discarding can have direct effects in term of foraging ecology, breeding biology and overwinter conditions on the species that rely on them, but also indirect effects that imply increased depredation of smaller seabirds by scavenger ones when they are facing a shortfall in their energy budgets (Votier et al., 2004). Several countries have implemented total or partial bans on at-sea dumping of fishery waste. A study on Cape gannets *Morus capensis* revealed that they revert to feeding on their natural prey as soon as it is available in sufficient quantities, and that their association with trawlers only lasts as long as pelagic fish biomass remains too low. However the seas are already so heavily overfished that several seabird species are likely to decline because of the bans (Tew Kai et al., 2013).

Extrinsic factors could affect individuals differently according to their intrinsic characteristics. For instance it has been argued that differences in wing loading between males/females and juveniles/adults drive variation in the at-sea distributions of wandering albatrosses (De Pascalis et al., 2020). In Scopoli's shearwater males are more prone to perform fine scale foraging trips than females, but both sexes shifted towards coarse scale trips with increasing wind intensity, probably to exploit the energetic advantages of dynamic soaring (De Pascalis et al., 2020). Another example for the same species is the different fishing attendance, greater for males than females, due to competitive exclusion of females from main feeding resources: this explain the male-biased bycatch ratio for this species (Reyes-Gonzales et al., 2021).

2.4 Gulls as generalist seabirds

Gulls (subfamily Larinae) are a cosmopolite group of seabirds that include about 50 species (Brooke, 2002). They vary in body mass from 100 g to 2 kg, have a stout, often colourful bill and webbed feet. They have long wings and, typically, their plumage shows some shades of grey or black in the upper parts of body and wings and white in the lower parts. Gulls occupy a large variety of habitats from the high Arctic and Antarctic to sea coasts, lakes, reservoirs, rivers, and cities. They are typical generalist seabirds, equally adept at flying, walking and swimming. Most species have a broad diet and are able to exploit various food sources, including those originating from human activities, like food waste and fishery discard (Cramp and Simmons, 1983).

2.4.1 Trophic niche

A study on herring gull *Larus argentatus* revealed sex differences in diet: females eat more earthworms and less garbage than males, and when the food availability dropped down, the difference between the two sexes increased because females were competitively excluded from the places where the colony used to forage (Pons, 1994). Another study including more species revealed that the difference in proportion of marine, terrestrial and anthropogenic resources between males and females is different among species (Washburn, 2013). The reasons at the base of this variation are thought to be related to different nutritional requirements, parental roles, foraging efficiency. The same study revealed also a variation of habitat use and food origin related to age possibly caused by the same factors.

A dietary switch coincident with the onset of chick provisioning has been observed in western (*L. occidentalis*) and herring gulls towards a major frequency of small fish, regardless of their previous diet (Annett and Pierotti, 1989; Pierotti and Annett, 1987). During the egg-laying and incubation phase gulls need food to be predictable in space and time due to the time constraints associated with brooding, while after hatching they have to match the food requirement of chicks, for which small marine fish are more likely to be a more suitable prey than terrestrial invertebrates (Isaksson et al., 2016). In the first days following hatching, the main constraint is the restricted capacity of ingestion of the small chicks. A study on herring gulls indeed found that small chicks are fed with earthworms, but as soon as chicks are able to swallow larger food items, parents preferentially feed them with refuse which constitutes a more predictable food supply (Pons, 1994).

Gulls are characterized by a great foraging flexibility and as a result their diet can vary seasonally and annually according to the availability of prey. The diets of sympatric gull species often differ, whereby larger gull species typically feed at higher trophic levels, but gull diets can also vary among colonies. In fact gulls, being typically generalist seabirds, during breeding season may adjust their diet according to the prey types available within their ranges. For example, gulls breeding on multi-species seabird colonies often feed on seabird eggs, chicks, and even adults. Both inter-colony and inter-specific difference has been demonstrated in the diet of great black-backed gull *L. marinus* and herring gull breeding on inshore and offshore colonies. These differences are related to diet specialization and trophic level, evaluated through analysis of δ15N, δ13C and isotopic niche breadth (Maynard and Davoren, 2020)

The extended use of anthropogenic resources raises the question as to whether urban gulls can be completely independent from the sea. A study on yellow-legged gull *L. michahellis* (de Faria, 2021) studied diet and isotopic niche of adults and chicks from urban and natural colonies and fatty acids (FA) composition of fledglings. The results show that adult urban gulls consume considerably lower proportions of marine prey, but they fed their younger chicks mostly with fish, while refuse items were mostly delivered to chicks older than 20 days. Fledglings from the most urbanized colony presented overall higher FA concentrations and diversity, but they were lacking some omega-3 FAs relevant to their physiology. This is in line with other studies on gulls that show that a decrease in marine preys in the diet has led to breeding costs such as decrease in chick weight and egg quality. Therefore, marine resources are still important in the diet of urban gulls, particularly during early chick rearing.

2.4.2 Foraging behaviour

Population level plasticity can be observed in gulls not only for diet, but also for foraging behaviour. They can use different foraging methods, like diving, picking prey from the surface, “dipping”, but they also perform aerial pursuit of prey, kleptoparasitism (food theft), and scavenging (Shealer 2002). Gulls also show specialization among individuals or across populations on habitat use and foraging trip patterns: this can reduce niche overlap, thereby decreasing competition, and may ultimately facilitate adaptation to changing environmental conditions. For instance variation in foraging behaviour was revealed for western gulls between an offshore colony and a coastal one, with the foraging range of the offshore colony being larger. These differences determine a greater absence from the nest in the offshore island which, combined with larger breeding colony size, may contribute to the observed lower productivity at the offshore island through higher predation risk (Shaffer et al., 2017).

Both sexes of lesser black-backed gull *L. fuscus* reduce their searching effort doing shorter and more frequent foraging trips and visiting repeatedly the same few sites during the breeding season. However females, as opposed to males, show pronounced shifts in their habitat use and strongly specialised on urbanised foraging habitats. They are in fact smaller than males and consequently outcompeted by them for the most profitable marine food resources and therefore rely on a resource that is more predictable and ubiquitous (Baert et al., 2021). Larger individuals of herring gulls tend to be more site faithful. However, since this species is sexually dimorphic, it is difficult to disentangle size factor from sex. This could have to do with the ability to defend specific foraging patches or the necessity to reduce the costs of flying that are more important on bigger individuals (Van Donk et al., 2020).

As the diet switch already mentioned suggests, a drastic change in habitat use can be found. In lesser black-backed gull, while during the incubation stage terrestrial foraging is frequent, after hatching its proportion decreases in favour of marine foraging (Isaksson et al., 2016).

The same study also demonstrated the role of other, extrinsic factors, like weather: terrestrial foraging trips occur more frequently when there is greater cloud cover and rainier conditions. Cold and wet conditions in fact have previously been associated with greater soil invertebrate activity as well as with more terrestrial feeding by other species of gulls. Another variable is the height of vegetation: gulls preferentially forage in fields where it is shorter. In fact gulls need to be able to walk and see sufficiently in order to forage on fields and this becomes more difficult with higher vegetation.

Gulls are particularly able to exploit anthropogenic resources: indeed it is not rare to see flocks of gulls in mainland following tractors ploughing fields or at sea near fishing vessels feeding on fishery discard. Increased availability of fish discards has been correlated to increases in the number of breeding individuals at colonies, while the removal of fish discards changes their foraging behaviour to exploit alternative and sometimes lower quality food sources, and can lead to populations decline (Wilhelm et al., 2016). The influence that fishery has on the foraging behaviour of gulls is confirmed also by its spatio-temporal pattern: during workdays gull distribution at sea fully matched with fishing activities, avoiding areas under moratorium, while on weekends they made a lesser use of sea (Becares et al., 2015).

Fishing is not the only human activity that was proved to match in space and time with foraging gulls. This was found to be true also for schools and waste centres. The temporal predictability of the food sources from these human activities seems to have resulted in a change of feeding strategy of gulls, that adopt a sit-and-wait approach instead of actively search for food (Spelt et al., 2021). Temporal patterns were observed also for rural or natural resources: number of herring gulls in pasture fields are highest around dawn (Sibly and McCleery, 1983), and terrestrial foraging trips are more frequent than marine trips around sunrise in lesser black-backed gull (Isaksson et al. 2016). A reason could be the presence of earthworms, that are of great importance to gulls and are known to be abundant during early hours of the day (Spelt et al., 2021).

Although gulls are considered diurnal birds, many species can be active and forage also at night: a reason could be to integrate food when it is insufficient or to compensate for the less time available to forage during reproduction (Burger and Staine, 1993; Garthe and Huppop, 1996) .

3. AIMS AND HYPOTHESES OF THE STUDY

My study focuses on foraging behaviour of breeding Mediterranean gulls, inferred from movement data obtained from GPS-equipped birds. Using gulls as study species can provide insights into the potential ability of diet-generalist animals to adapt their foraging schedule to temporal patterns in food availability (Spelt et al., 2021). Although this species is quite common in southern Europe, its biology and ecology are still poorly understood as compared to other gulls species. GPS tracking has never been used in detail before on this species (but see Meneghini, 2017 for preliminary analyses of the movements of this species), and can provide an opportunity to increase our knowledge of Mediterranean gull's habits.

The aim of the study is to assess whether intrinsic (i.e. individual characteristics and reproductive phase) and extrinsic factors (i.e. weather and environmental) have a role in shaping the foraging behaviour of Mediterranean gulls during incubation and chick rearing phases. Specific factors and relative hypotheses based on literature are:

- <u>Sex:</u> the hypothesis is that being males, on average, slightly larger than females, they are more competitive and therefore able to forage in the nearest foraging sites while females are forced to travel further. This difference in foraging trip length has been demonstrated for instance on black-tailed gull *L. crassirostris* (Kazama et al. 2018). However, considering that sex dimorphism is limited in Mediterranean gull, we do not expect marked sexual differences in this aspect of their foraging behaviour.
- <u>Breeding phase:</u> we expect foraging trips length to decrease after hatching because of the need of chicks to be fed frequently during the first days, and to increase again as the chicks grow up. This has been demonstrated for instance on lesser black-backed gull (Baert et al., 2021). Moreover, as Isaksson et. al. (2016) reports on the same species, we expect sea trips to be more frequent during chick rearing, because fish digestibility and nutritional properties make it particularly suitable for chicks.
- <u>Wind and sea waves:</u> strong wind conditions might make foraging at sea more difficult, because the sea surface is rippled by the waves and the visibility is low, but also because flying in strong wind conditions is energy demanding. Therefore, we expect that gulls forage mainly on land (where wind speed is usually lower than at sea) during strong winds and high waves, as reported for yellow-legged gull (Zorrozua et al., 2020). When on land, in fact, gulls forage walking and pecking, likely with no influence of wind.

- Rainfall: according with what has been found for lesser black-backed gull (Isaksson et al., 2016), we expect that birds forage more on land in rain conditions, which likely decrease the visibility on sea surface. On the contrary, wet grounds might make invertebrates more accessible to gulls foraging on land.
- Fishery: gulls that are particularly able to exploit anthropogenic resources are expected to follow the temporal patterns of fishing activities. Therefore, we expect that their presence at sea is greater during weekdays, when fishing boats are active, than during weekends. This has been demonstrated for instance for Audouin's gull *Ichthyaetus audouinii* (Becares et al., 2015).

4. STUDY SPECIES

4.1 Morphology

The Mediterranean gull (*Ichthyaetus melanocephalus,* Temminck, 1820) is a small- to medium-sized seabird (215-350 g). It shows some degree of sexual dimorphism in size, but not in coloration: adult males are on average slightly larger than females, but with considerable overlap in size. In some populations, sex identification via morphometric measurements is possible (Dubiec et al. 2015).

Back and upper wing-coverts appear pale blue-grey, while its abdomen, underwing and wing tips are white. Outside the breeding season, the adults have a white head with variable black patch around and behind the eye. Bill and legs are usually deep-red or blackish, and the bill shows a dusky subterminal band. During the breeding season, they show a completely black hood that contrasts with prominent white crescents below and above the eye, that is surrounded by a red orbital ring. Legs and bill take a brighter red (Cramp and Simmons, 1983).

Juveniles have wide brown areas especially on the back and upperwing where they show a scaling pattern. Wing tips are dark brown, and the tail present a subterminal brown band. Bill and legs are dark. After the post-juvenile moult, they become more similar to adults and with the first pre-breeding moult in their second calendar year they start showing the nuptial coloration, but they can still be distinguished by the black points on the wing tips (Cramp and Simmons, 1983).

***Figure 1**: Mediterranean gull in nuptial plumage (https://ebird.org/species/medgul1)*

***Figure 2**: Mediterranean gull in winter plumage (https://www.vogelwarte.ch/it/uccelli/uccelli-della-svizzera/gabbiano-corallino)*

4.2 Distribution and movements

The species counts a population of 236,000-656,000 mature individuals that breeds (or is resident) in a surface of 7,780,000 km^2 (Birdlife International,2022). The distribution of Mediterranean gulls covers most of the European continent, from the Mediterranean to Denmark and from the Atlantic to all the Black Sea, but also the coasts of Middle East and Northern Africa.

Mediterranean gulls breed almost entirely in Europe. Originally they bred only on Black Sea coasts, but since the '80s also Northern-middle Europe started to be colonized, even if 90% of the European population still nests on the original area (Nardelli et al, 2016). Since the 2000s, the rate of expansion has slowed down considerably and the species has ceased to increase the boundaries of its breeding range (Carboneras, 2015). Apart from the Black Sea, the other reproductive sites are fragmented and many are situated inland.

Conversely, wintering areas are concentrated on the coasts, confirming their more marine habits outside the breeding season (Nardelli et al., 2015). They maintain strongly gregarious habits also during this period, in which they form dense flocks of usually 400-1000 individuals. The increase of the wintering range in the past years was much more moderate than that of breeding range (Carboneras, 2015).

Most populations of this species are fully migratory and travel along coastlines between their breeding and wintering areas, although a minority travel inland across Asian Turkey or follow major river valleys through Eastern and Central Europe (del Hoyo *et al.* 1996, Snow and Perrins 1998, Olsen and Larsson 2003). Adults migrate to reach their breeding colonies from late-February to early-April (Birdlife International 2022); post-reproductive migration is between August and November (Brichetti and Fracasso, 2006).

Mediterranean gulls bred for the first time in Italy in 1978 in the "Valli di Comacchio", a system of brackish lagoons in Emilia Romagna Region. In the following years the breeding population increased and colonized other wetlands on the Adriatic coast in Emilia Romagna, Veneto and Puglia. The current Italian nesting population is estimated to be 5000-8000 mature individuals (Nardelli et al., 2015). The Italian population, thanks to colour ring data is believed to winter mainly on the Mediterranean and Atlantic coasts of Spain and Portugal, but a fraction winters in Italy and is distributed in all the Italian regions (Nardelli et al., 2016).

4.3 Breeding biology

Mediterranean gulls breed on the Mediterranean coast at lagoons, estuaries and coastal saltmarsh, and even inland on large steppe lakes and marshes in open lowland areas (del Hoyo *et al.* 1996, Snow and Perrins 1998). The reproductive season lasts from early-May, when they begin to nest, to July, when the juveniles disperse.

The species breeds usually in dense colonies that can be mono or plurispecific. In the latter case, they can associate with other small gulls, for instance black headed gull *Chroicocephalus ridibundus* and slender-billed gull *C. genei*, or terns like the common tern *Sterna hirundo* (Fasola and Canova 1991). Colonies generally have less than 1000 pairs, with neighbouring nests situated about 60 cm apart, and occasionally in single nests among colonies of other species (del Hoyo et al., 1996).

I. melanocephalus forms monogamous pair bonds, whose duration however is unknown. At least in some cases, pair-formation occurs before arrival on breeding grounds (Cramp and Simmons, 1983). They make their nest on bare ground (but usually not sand) or in low halophytic vegetation near water. The nest is constituted by a shallow depression, lined with grass and some feathers, and it is built probably by both sexes. The female lays up to three eggs with an interval of about 24 hours between them. There is only one brood, but a replacement clutch can be laid if the first clutch is lost. The incubation lasts 23-25 days and it is carried out by both parents that alternate for this task. Hatching is nearly synchronous within a colony. The chicks are precocial and semi-nidifugous: they may leave the nest and hide at short distances after a few days. They are brooded for and fed by regurgitation by both parents. Fledging occurs at 35 to 40 days of life, and chicks become independent soon after (Cramp and Simmons, 1983).

In this species individuals typically reach sexual maturity at the age of three years, while they can live up to 22 years (Fransson et al., 2010).

4.4 Foraging behaviour

The Mediterranean gull, as other gull species, is a versatile forager. The range of terrestrial preys on which it relies on include earthworms, spiders, myriapods and insects like beetles, moths and butterflies, locusts and grasshoppers, mole-crickets, bugs, ants, flies, caddisflies, lacewings, and also vertebrates like lizards and voles. Aquatic preys include molluscs (gastropods, bivalves and also cuttlefish), crustaceans, small fishes and frogs. Moreover, like other gulls, they also feed on other birds' eggs and chicks (Cramp and Simmons, 1983). Finally, they have been also reported to eat plant material like seeds of barley, wheat, sunflower, grain and olives. However, vegetal food is not the preferred one by gulls, as their digestive system is not well suited to digest seeds: therefore these cases can probably be explained by a high availability of this type of food at the expense of others in some particular regions and periods (especially winter) (Milcher et al., 2004).

Diet and foraging habits of Mediterranean gulls differ considerably among different geographical areas, but also among years in the same region (Goutner, 1994). Within year, there is a diet change between the breeding season and the wintering period: in the second one, marine fish and offal prevail in their diet, along with occasionally rubbish and sewage (Cramp and Simmons, 1983). However, they differ by other gull species for the lower extent they use garbage resources (Burger et al., 2015).

Regarding the diet of the nestlings, a study that analysed stomach content of dead chicks and regurgitation revealed that adults feed them with gastropods, insects, annelids, fish, and human refuses. Wheat grains were found in dead chicks without injuries and not in regurgitations, suggesting that they could be the reason of death (Goutner et al., 1994).

Along with the variety of prey, they also use different foraging techniques. The most used in Greece during the winter are pecking, neck and head dipping and probing (Dies and Dies, 2017), while the most used in Spain during the breeding season are walking and pecking, then surface grabbing and scavenging, for instance in harbours or on rubbish dumps (Liordos, 2010). They also use to follow fishing vessels or tractors ploughing fields (Cramp & Simmons 1983)

Like other gulls and seabirds in general, they are primarily flock foragers. However, they are not cooperative foragers, they do not search for food in groups, suggesting that flock formation is a consequence of recruitment to prey patches following the initial discovery by individual foragers (Shealer, 2002).

4.5 Conservation status, threats and protection

The species is evaluated as at Least Concern by the IUCN red list, as it has a very large range and population size. However its current overall population trend is estimated to be decreasing. It was classified with the same category by the Italian Red List, that has defined its population trend in Italy as stable, despite colonies showed large fluctuations in number. In Cervia, for instance they nest in some years while in others they do not, showing a discontinuous presence (Nardelli et al., 2016).

The major threat to this species appears to be predation at colonies, by invasive non-native species or problematic native ones, but also egg collection and illegal hunting by humans (Burger et al. 2017; James 1984; European Commission, 2016). Other threats, in Italy in particular, are related to salt work operations and abandonment of saltpans, and more in general the management of water levels and vegetation for saltpans, fish farms and lagoons where they nest (Nardelli et al., 2015). The concentration of nesting pairs in very few breeding sites in Italy makes the species very vulnerable to single negative events. In fact these gulls are subject to large scale nest desertion in response to disturbance by tourists at breeding colonies (James 1984, Burger et al. 2017), or extreme weather events. Pollution of surface waters, of any origin, can also represent a problem. In their wintering period, when they become more pelagic, they can be affected by the fishing discard management (Nardelli et al., 2015) and by oil pollution (Birdlife International, 2017).

The species is listed on Appendix II of the Bern Convention and on Annex I of the EU Birds Directive. It is present also in the Appendix II of the Convention on Migratory Species (CMS or Bonn Convention) and is covered under the African Eurasian Waterbird Agreement (AEWA). It is indicated as occurring within 127 Important Bird Areas, and in the EU, within 424 Special Protection Areas.

A conservation scheme for the protection of gull and tern breeding colonies in coastal lagoons and deltas (e.g. Po Delta, Italy) should include protection from human disturbance, prevention of erosion of islet complexes, habitat maintenance and the creation of new islets for nest sites (Fasola and Canova 1996). Artificially constructed nesting sites in coastal locations such as beaches of bare shingle and islands or rafts covered with sparse vegetation are successful in attracting breeding pairs of this species (Burgess and Hirons 1992).

5. MATERIALS AND METHODS

5.1 Fieldwork

The fieldwork where I participated was carried out in the site of Ortazzo in 2022, but in my study I also used the data collected in Salina di Cervia in 2016 and 2017. Both the sites are located in the province of Ravenna (Emilia Romagna Region).

The site of Ortazzo is located almost entirely in the Regional Park of Po river Delta, and shows a great environmental diversity. It is composed by two main wetlands: the mouth of the river Bevano, with the wetland Ortazzino behind it, and the valley of Ortazzo, bounded by river Bevano and the canal Fosso Ghiaia, further inland. The first is a brackish area close to the shoreline that shows ponds, reeds, dunes with Mediterranean vegetation and coastal pine forests. The second was an ancient fresh water valley, obtained by the reconversion of previous paddies, now subject to brackish influxes from the aquifer: it appears like a wide system of ponds, characterized by halophile vegetation like those of genus *Juncus* and *Puccinellia*. To the west, the wetland is bordered by the wide Pine forest "Pineta di Classe", a Site of Community Interest and Special Protection Area. The site includes the Oasis of protection "Ortazzo and Ortazzino" (800 ha), the Natural Reserve of "Duna e foce Bevano" (172 ha), and a wetland of international importance under the Ramsar Convention (430 ha). The area is important for the migration and wintering of water birds, and a nesting site for different Charadriiformes species, besides gulls.

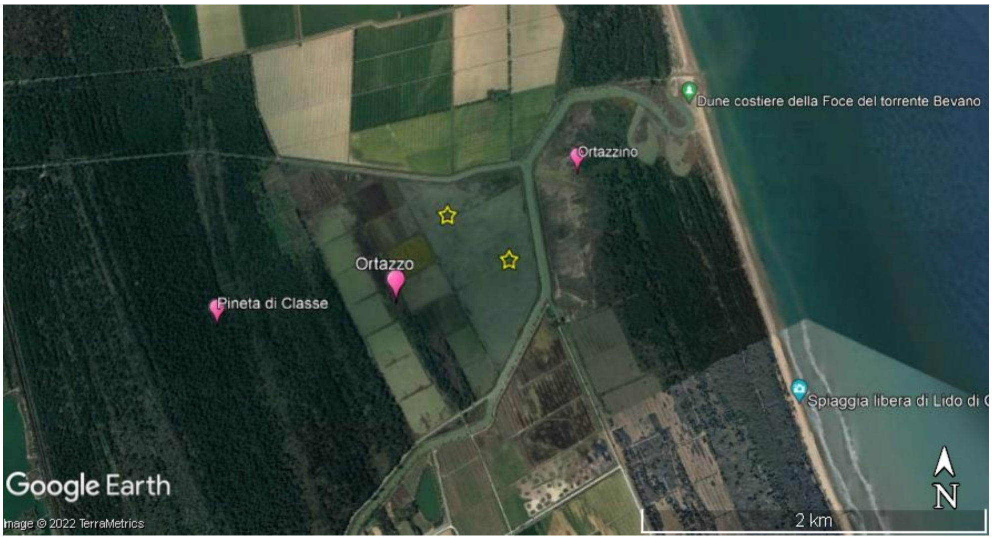

Figure 3: *Map of the site of Ortazzo. Yellow stars indicate the position of the 2 clusters of Mediterranean gull nests in 2022*

Salina di Cervia is enclosed in the Regional Park of Po river Delta, and like Ortazzo, it is a wetland of international importance under the Ramsar Convention, as well as a Site of Community Interest and a Special Protection Area. It is an ancient saltpan of 830 ha, constituted by 97 basins, divided by a net of low embankments characterized by highly hydrophilic vegetation. The inflow and outflow of marine waters are regulated by artificial channels linked with the sea, that is about 2 km distant by the site. The salinity becomes higher while the water is moving from one basin to the following by gravity, and the salt is collected at the end of summer in some dedicated basins. The site hosts one of the largest populations of breeding *I. melanocephalus* in Italy, as well as the ones of many other waterbird species, both wintering and nesting.

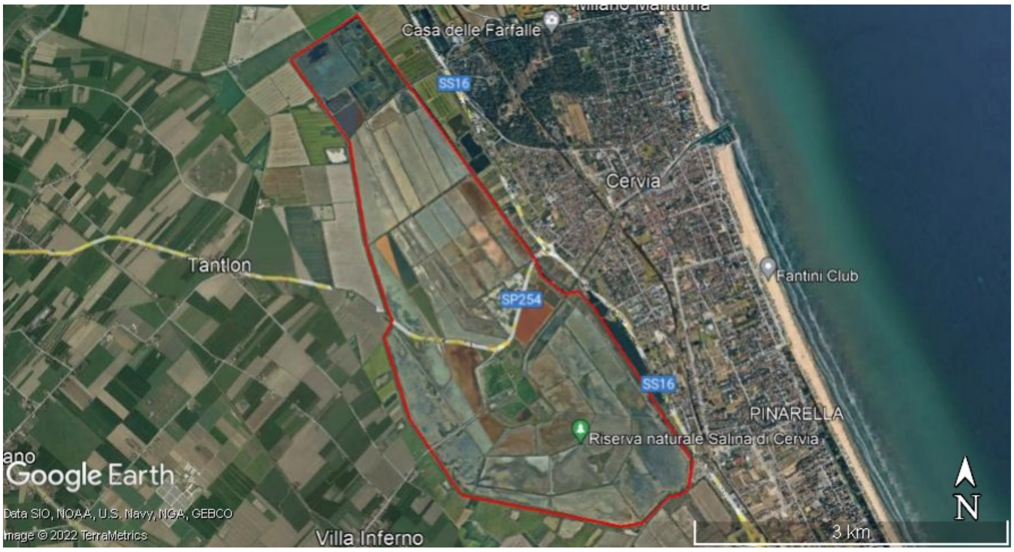

Figure 4: *Map of Salina di Cervia. The boundaries of the saltpan are represented with a red line*

Inside the valley of Ortazzo, two clusters of the Mediterranean gull nests were individuated: one was on an embankment and included about 137 nests, the other one was in a small islet in one of the ponds and included about 98 nests. These clusters were 500 m away from each other. We saw some individuals of black headed gull flying in the area, and in fact some nests of this species were present, but the majority of them were of Mediterranean gull, recognizable by position and morphology: they were laid on the bare ground, closely spaced and the shape was not elaborated.

Ten incubating individuals were captured at the nest between 19 May and 01 June 2022 using two types of traps: one is a wired net cage whose door closes through a snap mechanism when the individual sits on the nest; the second one, called spring trap, is a soft net that close over the individual when it is triggered remotely through a remote controller. Nests for trap placement were chosen randomly, favouring those with 3 eggs because they had higher probability of reproductive success. Seven out of ten captured individuals belonged to the embankment-cluster, while the other three belonged to the islet-cluster.

In Salina di Cervia, 25 individuals were captured in 2016, and 21 in 2017.

Figure 5: *A trap positioned on a nest in Salina di Cervia. (Photo by A.Pesce)*

We marked each nest where we captured an individual with a stake reporting a different letter or number, and we put a camera trap attached to a pole in a way that it framed the nest and the stake, at a distance of around 2 meters from the nest. After the capture and before the following operations the gulls were kept in soft cloth bags to reduce stress. The colony was left as soon as possible and the operations with the captured individuals took place out of sight of gulls to avoid disturbance of the colony.

Each gull was marked with a metallic and a colour ring, both reporting a unique code for the identification. Then the animal was weighed with a dynamometer (accuracy ± 1g), and a series of measurements were taken with a caliper: tarsus, sternum, bill length, length of head + bill, bill height at the gonys, (± 0.1mm), and wing length (± 1mm). Some feathers were taken from the breast of each animal for sex determination through genetic analysis, and a picture of the opened wing was taken too to calculate the wing loading, that is the ratio between the weight of the animal and its wing area. Finally, the bird was equipped with a GPS device.

At the end the animals were set free immediately. We tried to reduce the time of handling as much as possible, and it usually did not exceed 20 minutes.

***Figure 6**: A Mediterranean gull with the GPS device. (Photo by J. Cecere)*

***Figure 7**: Handling of a Mediterranean gull during the fieldwork (Photo by A. Pesce)*

5.2 GPS data loggers

GPS-GSM (“OT-9 3G” model by Ornitela) are the devices used to track the animals in 2022. These devices were able to transmit data using GSM (“Global system for mobile communication”, i.e. the mobile phone network), in a way that it is possible to download them directly with a computer or a smartphone upon access to the site of the manufacturer. They differentiate in this way from the GPS-UHF (Ultra High Frequency) data loggers, that transmit a radio signal that is captured, when in proximity, by a base station on the field. GPS-UHF (“Sterna” model by Ecotone Telemetry) are the type that have been used in 2016 and 2017. All the devices we used were waterproof and powered by a battery recharged by a photovoltaic panel present on their top.

The logger was attached to the gull’s back with a body harness made of Teflon strings. The harness was of “backpack” type, with the strings around the wings. Birds apparently were not disturbed by it while walking or flying. The harness was custom fitted directly on each animal, tight enough to stay in position and avoid loss of the device, but loose enough to prevent any harm to the gull.

On average, devices put in 2022, harness included, weighed 10.7 g, which represented 3 to 4% of the body mass. The ratio for devices used in 2016-2017 did not exceed 3.1%. Studies utilizing biologging technologies typically apply a general rule that this ratio should be less than 5% to minimize the impact of the device (Portugal and White, 2018), but it has been proposed also a more conservative 3% rule (Kenward, 2001). However, according to other authors there is little evidence suggesting that adverse effects intensify between 3% and 5% (Barron et al., 2010).

The GPS loggers were set to record, every 15 minutes, the following information: date, time, position (latitude, longitude and altitude), instant speed, direction and acceleration in the three spatial components (x,y,z). Collected data were transmitted by the device once a day. For each bird, data collection covered on average the second half or 2/3 of the incubation period, and all the chick rearing period and beyond. At the end of the breeding season loggers were not removed from birds, because the idea was to continue the study through the next years. However, for the present study we only considered, for each bird, the period from the day after GPS-tagging until the date on which we assume the chicks have fledged to focus only on the reproductive season.

5.3 Observations

Camera traps we put in front of the nests were set to take a picture every 2 hours. They were essential to discover how many eggs hatched and the exact date of hatching. In fact, in Ortazzo it was hard to follow the situation at the nests with direct observations: the nests were so close to each other that it was frequent to see broken eggs on the ground that were difficult to assign to a specific nest, and the chicks began to walk around soon so it was virtually impossible to understand where they came from. However these observations were useful to discover that 2 individuals that we tracked failed soon: their nests disappeared just a few days after we captured them.

Even with binoculars and a telescope we could not learn much more because we had to lurk far from the colony not to alarm the gulls as there were no trees to hide behind. Moreover, one of the clusters was on an islet far from the shore of the pond. Therefore, we used them only to understand if the traps had sprung when we captured the individuals.

From the camera traps we could ascertain that, in 2022, in two nests the eggs successfully hatched (with three chicks for both nests), while other four nests failed because the eggs were broken, or they slid away from the nest and then were abandoned by the parents, or because they did not hatch for unknown reasons. It is hard to say what happened exactly: the presence of other predators was not recorded in the photos, but since they were taken every 2 hours this is not a proof that they were not actually present. The eggs could also be broken accidentally because of the high density of gulls and the nests in a vulnerable position on the ground, or be preyed upon by other gulls of the same species. Another aspect is that some of the gulls who failed left the nest unattended almost every night, suggesting they were inexperienced birds.

About the two remaining nests, no photo was available, either because the camera trap did not work, or because the SD card was damaged. However, we presume that one of the two nests failed because looking at the movements of the tracked individual we know that it left the nest and never came back. About the other one, the frequency at the nest of the marked gull was high and constant during the period considered for the other individuals, so we presume that its eggs successfully hatched.

5.4 Molecular sexing

Molecular sexing consists in the research for a particular sequence (CDH gene) from the DNA extracted from tegumentary cells attached to the calamus of the feathers. This is done through PCR amplification of the specific locus whose length differs between the two sex chromosomes. Products are analysed using electrophoresis: males show only one band, while females have two. This is due to the fact that in birds males are the homomorphic sex, while females have two different sexual chromosomes.

5.5 Statistical analysis

The following analyses were performed using R (version 4.05, R Core Team, 2021) and QGIS (version 3.22.9, QGIS.org, 2018) software.

5.5.1 Dataset preparation

The tracking datasets from successful individuals (i.e., individuals whose nest did not fail soon after capture) of 2016, 2017 and 2022 were merged together, visually inspected and cleaned from spatio-temporal duplicates or abnormal speed values using “SDLfilter” package (Shimada et al., 2021). The data from the day of tagging were removed, since they could reflect some abnormal behaviours due to handling (the data started at 24:00 UTC of the day following tagging for each bird). The foraging trips performed by each individual were identified using R *tripSplit* function from “Track2KBA” package (Beal et al., 2021). A foraging trip was defined as a movement outside a 500 m buffer from the colony lasting at least 30 minutes, and fixes inside the buffer were removed, since they reflect colony-based behaviours. We then removed the incomplete foraging trips (i.e., the foraging trips not returning to the colony) and foraging trips with gaps >2 hours (due to device malfunctioning), as well as foraging trips that started in a day and ended in the following one (N = 28), since they include fixes at roosting site and can affect the estimation of points on land and sea (see below). For each fix, we identified if it occurred during day- or night-time based on astronomic twilight, calculated via the “suncalc” package (Thieurmel and Elmarhraoui, 2019), and we removed all the fixes during night-time. We also removed all the fixes in a buffer of 700 m from the coastline, since Mediterranean gull often perches on piers and breakwaters, and these behaviours are unrelated from the actual foraging tactic selection. Finally, we

calculated for each foraging trip, the number of fixes falling on land or on sea. We then identified if each foraging trip occurred during incubation or chick rearing, based on observations from camera traps, and we considered a period of 25 days after hatching as the chick rearing period. For each foraging trip we associated a set of environmental variables measured at the time of trip departure (at the nearest hour or 30 mins, see below for temporal resolution of environmental variables). The environmental variables were measured by the Regional Agency for Environment and Energy of Emilia Romagna (Agenzia regionale per la prevenzione, l'ambiente e l'energia dell´Emilia-Romagna, ARPAE, see https://www.arpae.it/it/temi-ambientali/meteo/dati-e-osservazioni for a description of data and hydrometeorological measuring instruments used) and are available from https://simc.arpae.it/dext3r/. We selected the control units closest (1-10 km) to the colonies, and for sea condition we used data from the regional wave buoy “Nausicaa-II”, located off the coastline of Cesenatico.
Specifically, we used:

- Accumulated precipitation (measured hourly, kg m^2)
- Mean wind speed at 10 m height (measured hourly, m s^{-1})
- Significant wave height (measured every 30 mins, m)

Ultimately, we identified if the foraging trip occurred during days of the working week (or weekdays Monday to Friday) or during the weekend (Saturday and Sunday). In 2022, we considered as weekend a period ranging from the 23rd of May until the 5th of June, since there were no fishing boats at sea due to a strike of fishermen.

5.5.2 Description of trip metrics

We calculated two foraging trip metrics:

1. Foraging trip duration (hours): the duration of a foraging trip, calculated from the departure to the arrival at colony.

2. Maximum distance reached (km): calculated as the maximum linear distance from the colony reached during a foraging trip.

We then calculated mean and standard deviation for the two variables, separately for males and female, and for incubation and chick rearing. Finally we performed a t-test to assess differences in trip metrics between sexes and between breeding stages.

5.5.3 Drivers of foraging tactics

To investigate the drivers of foraging tactic adoption (marine vs terrestrial) we used a Generalized Linear Mixed Model framework, fitted via the package “glmmTMB” (Brooks et al., 2017). The number of points at sea and on land for each trip was fitted as dependent variable using *cbind*, and precipitation, wind speed, wave height, weekday/weekend (two levels factor), sex (two levels factor), year (three levels factor), breeding stage (two levels factor) and hour of the day (at the minute) were fitted as explanatory variables. Hour of the day and wind speed were also included in the model with a quadratic term, since we hypothesized a possible non-linear effect of such variables. All the biologically meaningful first-order interactions between variables were tested and discarded when not significant. Bird identity was included in the model as a random effect, to avoid pseudoreplication issues. We used a betabinomial error distribution instead of a binomial one to prevent overdispersion (dispersion parameter $\varphi = 1.2$), and all the variables were scaled prior to model fitting, to help convergence. We tested for zero inflation model with the “DHARMa” package (Hartig, 2022), and we did not detect zero inflation ($P = 0.4$). We used a full model approach, and all the variables (apart from the interactions) were retained in the final model. Significant effects were plotted using the “visreg” package (Breheny and Burchett, 2017).

6. RESULTS

6.1 Molecular sexing

We successfully sexed 9 individuals out of 10. We were not able to assign the sex to the remaining individual because no clear results were obtained with the procedure. Regarding the individuals captured on 2016-2017, for all of them sex was known. The final sample consisted of 5 males and 12 females

6.2 Dataset preparation

From the original sample of 46 individual tagged during the 3 years, many of them were excluded from the analysis, either because they left the colony soon, or because molecular sexing failed, or because the hatching date was unknown. Overall, we retained in the final dataset for analyses 1442 foraging trips belonging to 17 individuals. Among these, 4 individuals were tagged in 2022, performing 352 trips, 10 were tagged in 2016 with 852 trips, and 3 were tagged in 2017 with 238 trips. Among the 14918 total fix, 3520 are at sea (23,6%), while 11398 on land (76,4%). As figure 8 shows, a large part of foraging trips are entirely on land (without fixes at sea), while other values of proportions of fix at sea are evenly distributed. Foraging trips performed in the three years are plotted in figure 9.

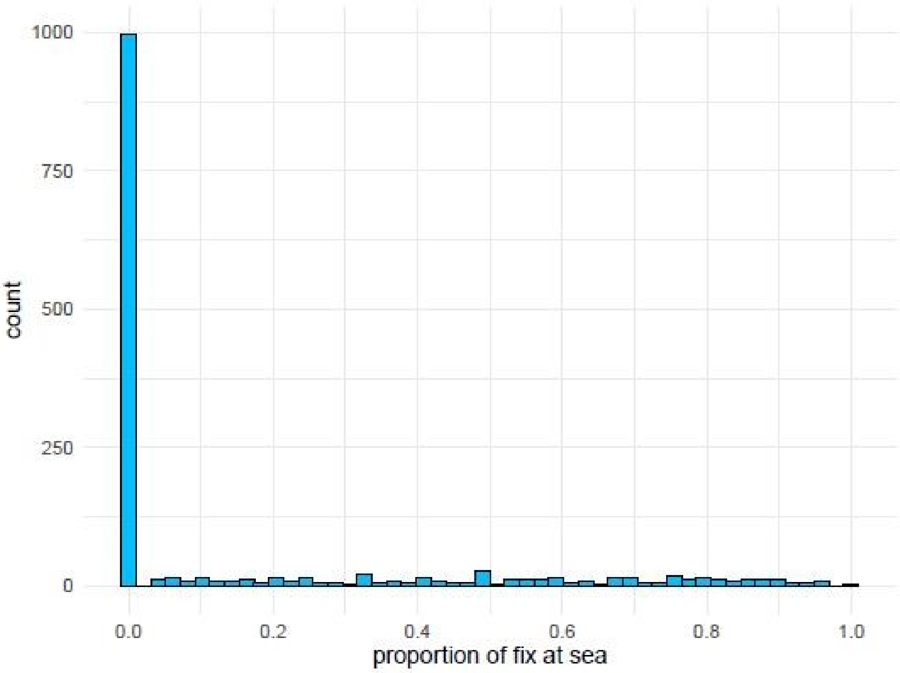

Figure 8: *Histogram representing the frequency distribution of proportion of fix at sea in each foraging trip.*

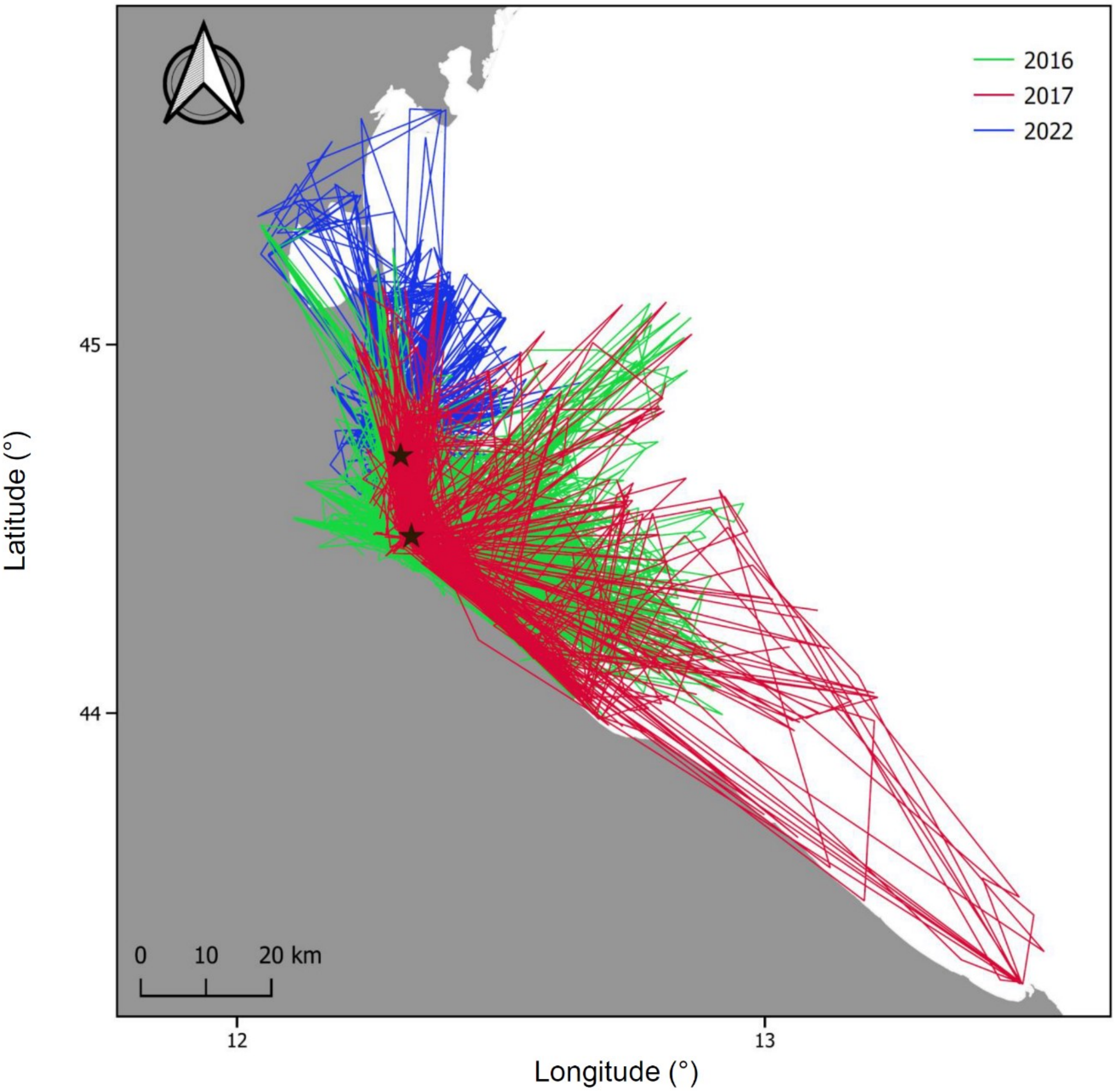

Figure 9. *Mediterranean gull foraging trips used in this study from two colonies in the North Adriatic. Foraging trips are coloured according to the year (2016, 2017 or 2022) and the location of the two colonies are indicated with stars. The northernmost colony corresponds to Ortazzo, while the other one corresponds to Salina di Cervia.*

6.3 Description of trip metrics

Foraging trip duration and maximum distance from the colony for each sex and breeding stage are shown in Table 1 and plotted in Figure 10 and Figure 11. Overall, foraging trip metrics were similar between groups, with foraging trips from males reaching slightly, but not significantly, further distances from colony and lasting longer time than females, and trips during chick rearing reaching further distances but lasting similarly than trips during incubation. The t-test revealed that the differences between trip duration in males and females, and between maximum distance during incubation and chick rearing were both highly significant, ($P<0.001$). Maximum distance from the colony turned out to be positively correlated with the proportion of fix at sea ($r = 0.66$)

Table 1: *Foraging trip metrics from Mediterranean gulls considered in this study. Mean and standard deviation and sample size (number of trips) are reported for each sex and breeding stage. P-values of the t-tests are indicated, significant values are in bold.*

Trip metric	Females	Males	t	P	Incubation	Chick rearing	t	P
Duration (h, mean ± SD)	2.2±1.8	3.0±2.6	**-6.11**	**<0.001**	2.5±2.4	2.4±2.1	-0.31	0.76
Max. distance (km, mean ± SD)	16.5±25	17.8±22.4	-1.05	0.29	12.2±19.7	18.9±25.0	**5.42**	**<0.001**
Sample size (N° of trips)	917	500			449	993		

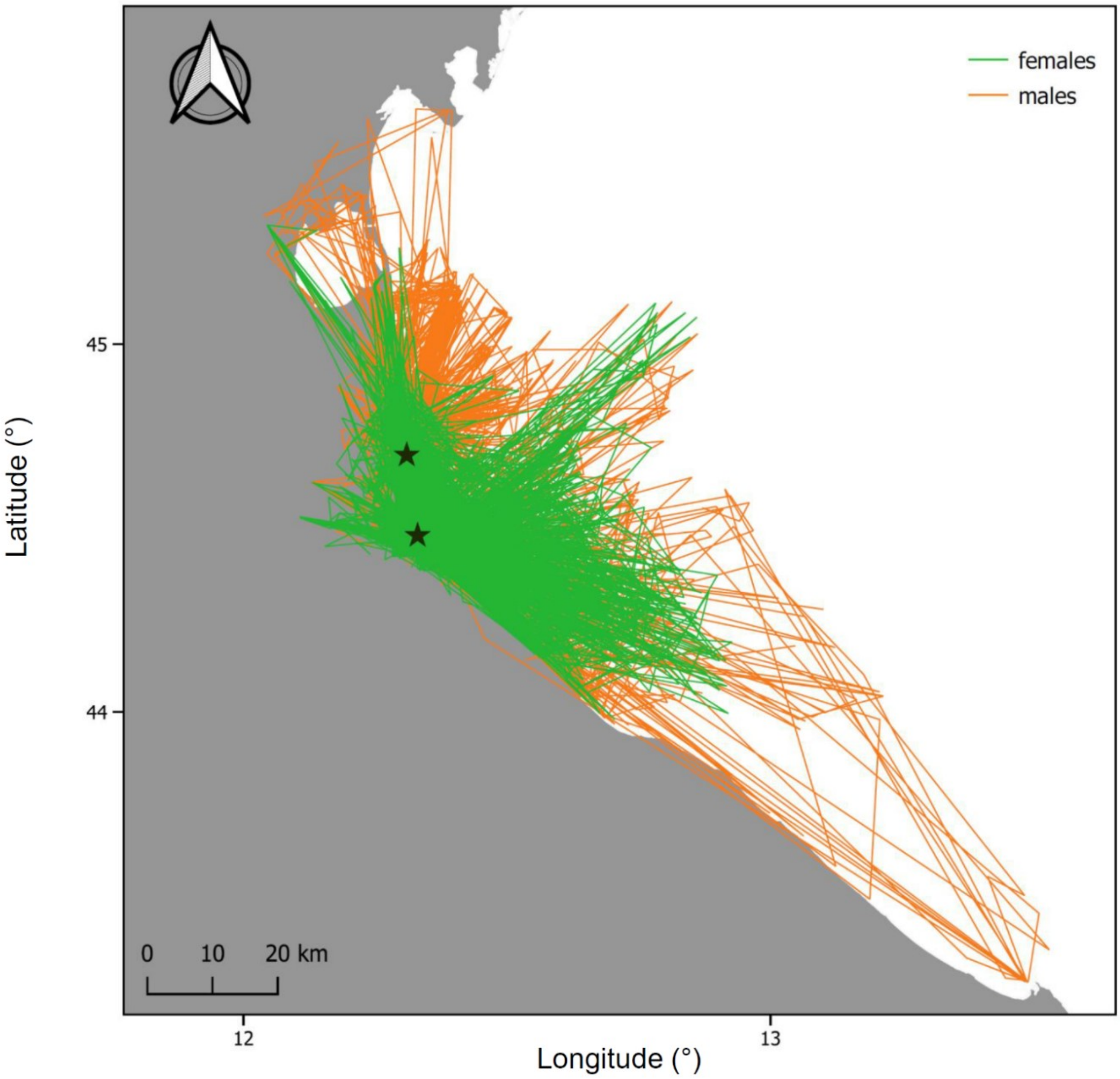

Figure 10. *Foraging trips of Mediterranean gulls coloured according to sex. Foraging trips from females are shown in green, while foraging trips from males are in orange. The location of the two colonies is indicated with stars.*

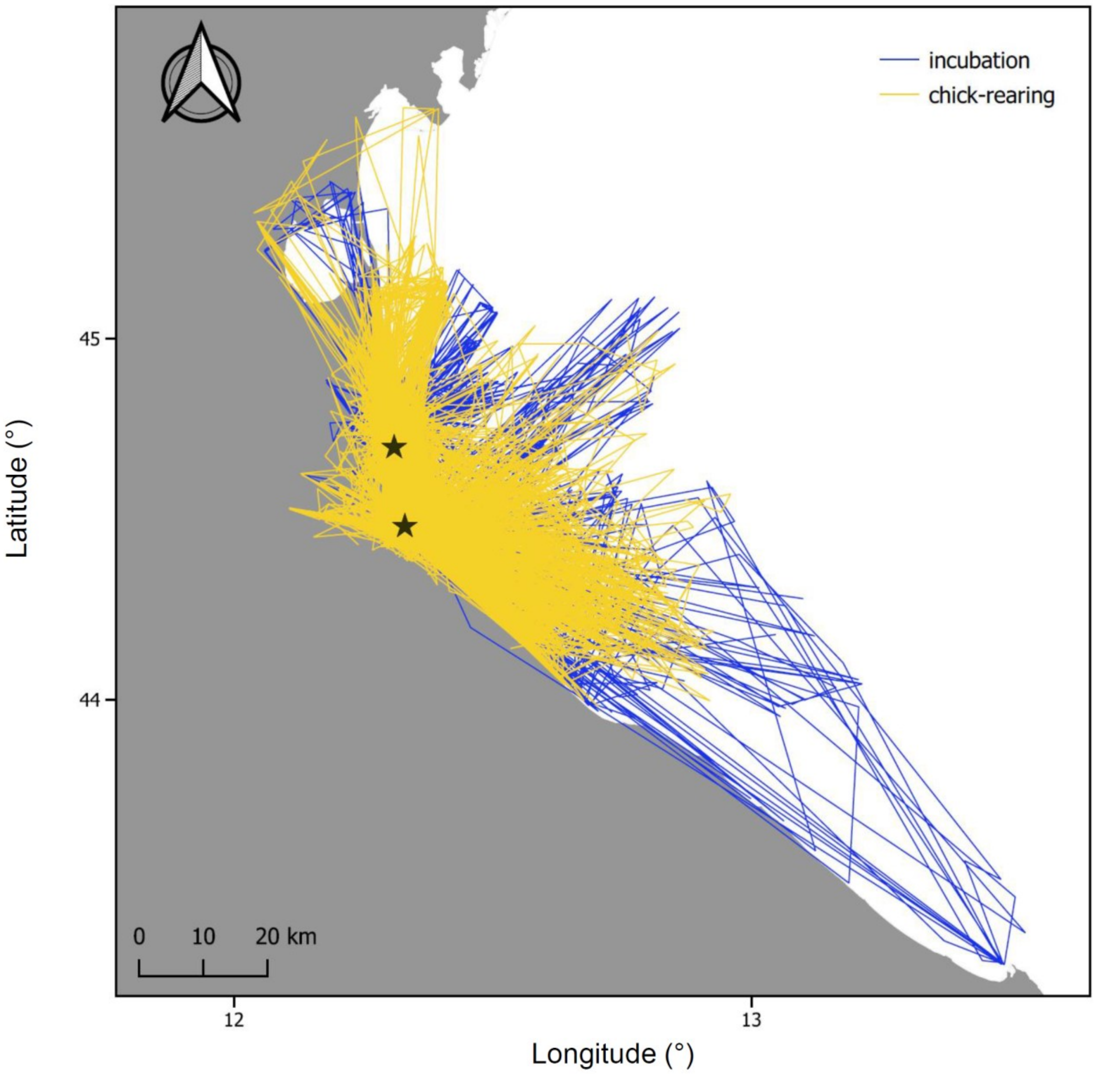

Figure 11. *Foraging trips of Mediterranean gulls coloured according to breeding stage. Trips during incubation are shown in blue, while trips during chick rearing are shown in yellow. The location of the two colonies is indicated with stars.*

6.4 Drivers of foraging tactics

Overall, the selection of a marine foraging tactic was a function of different intrinsic and extrinsic factors (Table 2). Individuals were more likely to forage at sea during chick rearing (Figure 12) and during working days of the week (Figure 13). Moreover, males were more likely to perform foraging trips at sea (Figure 14). The hour of the day showed a non linear effect (Figure 15), with individuals more prone to forage at sea during the late morning (08:30 UTC). Similarly, wind speed had a quadratic effect on the probability to forage at sea (Figure 16), with moderate wind speed driving the choice of a marine foraging tactic. Finally, wave height played an important role, with individuals choosing to forage at sea when the sea was calm (Figure 17):

***Table 2**. Betabinomial generalized linear mixed model testing the effect of intrinsic and extrinsic factors on the likelihood of performing marine foraging trips. The dependent variable was the number of points at sea for each trip c-binded with the number of points on land of the same trip. The model included bird identity as random intercept effect. The model was not overdispersed (ϕ = 1.2).*

Predictors	**β ± SE**	***Z***	***P***
Precipitation	-0.13 ± 0.07	-1.9	0.057
Stage (incubation)	-0.32 ± 0.13	-2.4	**0.02**
Hour of the day	-16.1 ± 2.77	-5.8	**< 0.001**
Hour of the day^2	-17.28 ± 2.70	-6.4	**< 0.001**
Wind speed	0.33 ± 0.09	3.6	**< 0.001**
Wind speed^2	-0.14±0.05	-3.0	**0.002**
Wave height	-0.31±0.07	-4.5	**< 0.001**
Sex (male)	0.67±0.32	2.1	**0.03**
Year 2017	-0.37±0.44	-0.8	0.4
Year 2022	-0.13±0.37	-0.35	0.7
Weekend	-0.65±0.13	-5.1	**< 0.001**

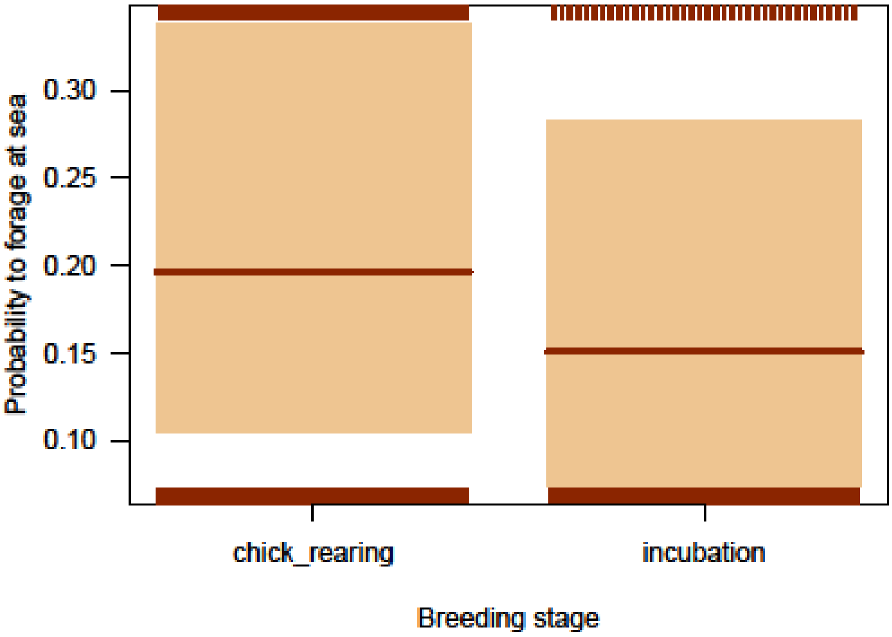

Figure 12. *Probability of foraging at sea according to breeding stage. Predicted probabilities (bold lines) and 95% confidence intervals (shaded areas) for each breeding stage were derived from the fitted model reported in Table 2.*

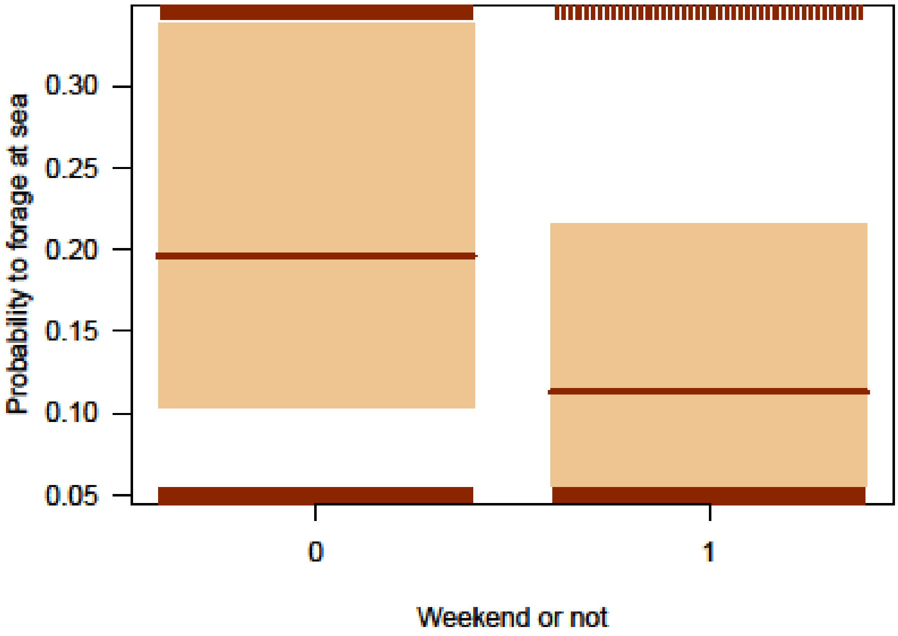

Figure 13. *Probability of foraging at sea according to day of the week. Week days are coded with 0, weekends are coded with 1. Predicted probabilities (bold lines) and 95% confidence intervals (shaded areas) for each category were derived from the fitted model reported in Table 2.*

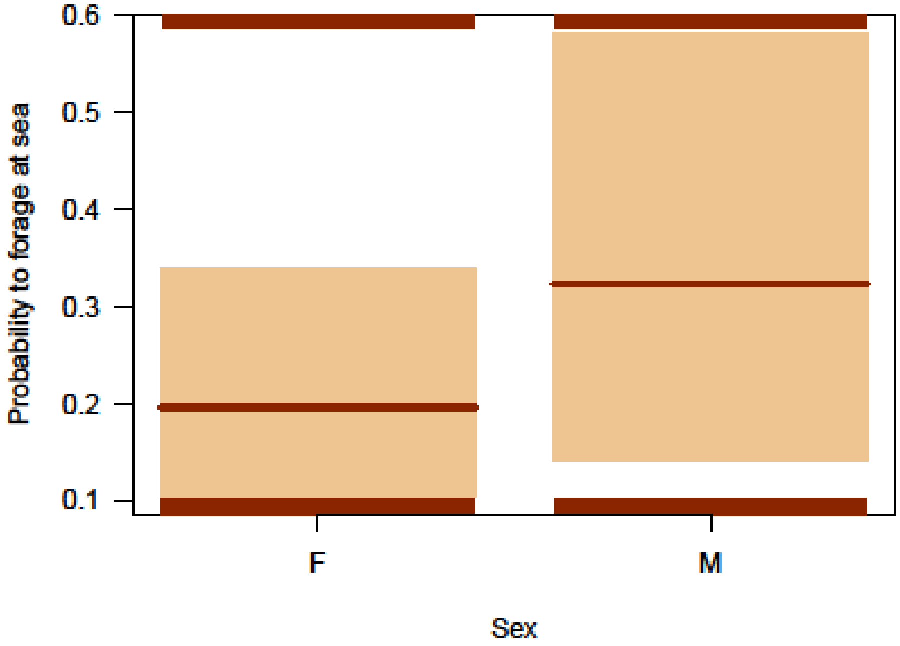

Figure 14. *Probability of foraging at sea according to sex. Predicted probabilities (bold lines) and 95% confidence intervals (shaded areas) for each sex were derived from the fitted model reported in Table 2.*

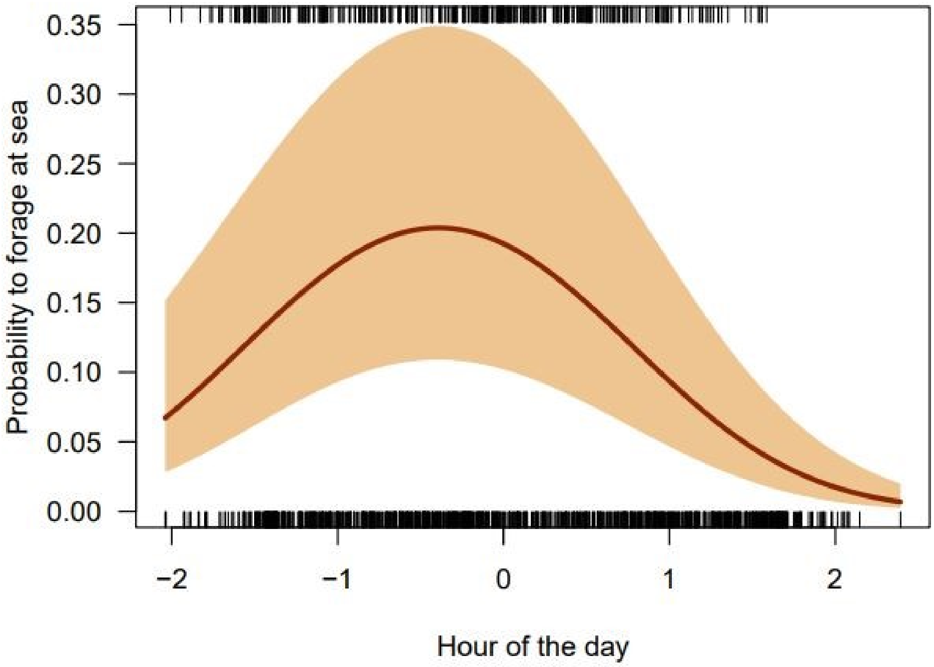

Figure 15. *Probability of foraging at sea according to hour of the day at departure. Values on the x-axis are scaled, in a way that "-2" ,"0" and "2" corresponds to about 0:15 UTC, 10:30 UTC and 20:40 UTC. Predicted probabilities (bold lines) and 95% confidence intervals (shaded areas) during the day were derived from the fitted model reported in Table 2.*

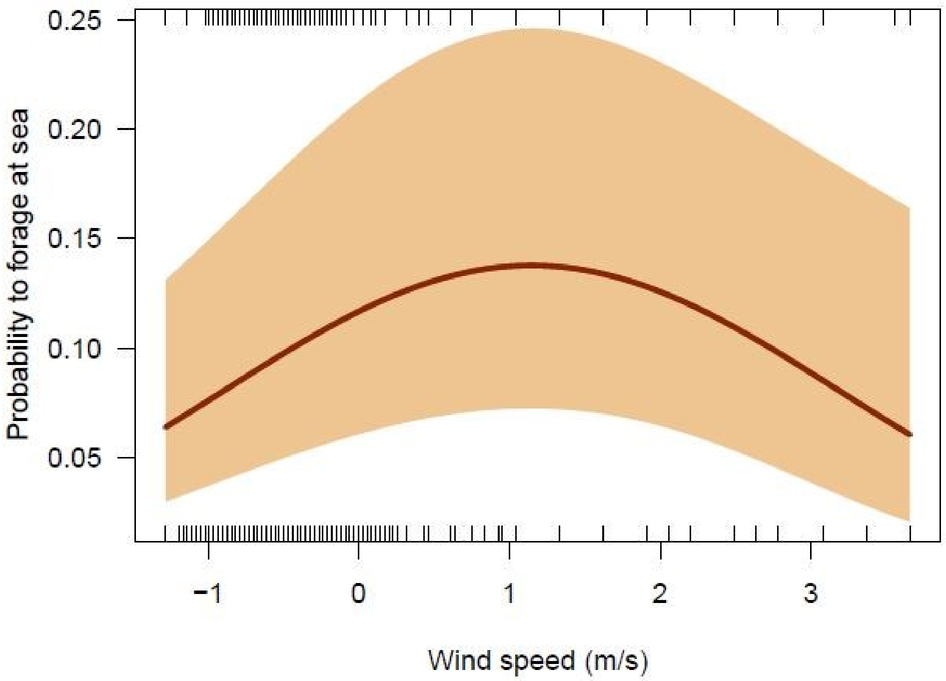

Figure 16. *Probability of foraging at sea according to wind speed at departure (values on the x-axis are scaled). Predicted probabilities (bold lines) and 95% confidence intervals (shaded areas) for different values of wind speed were derived from the fitted model reported in Table 2.*

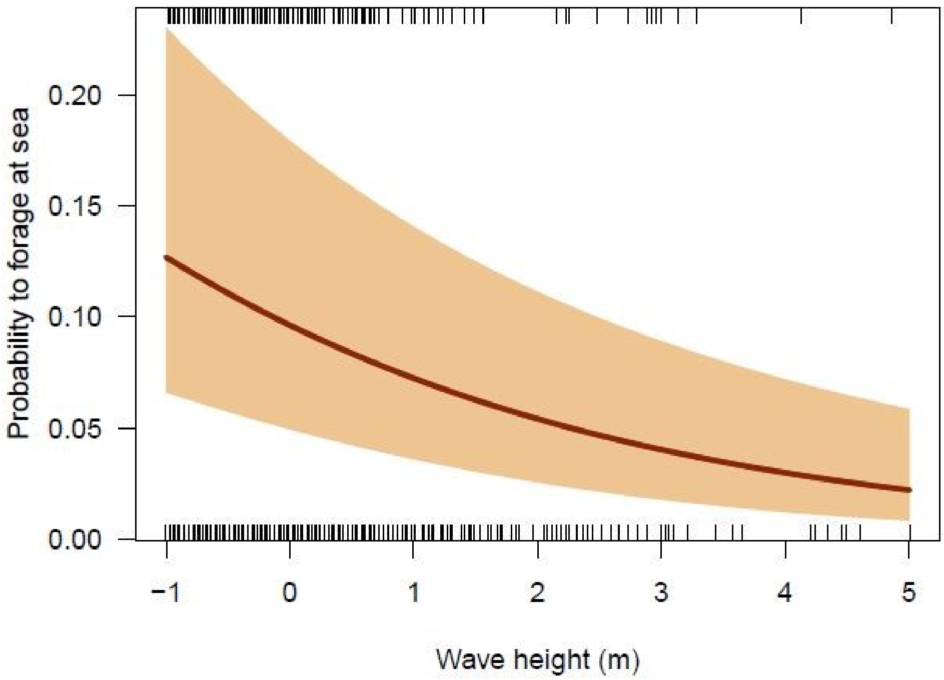

Figure 17. *Probability of foraging at sea according to wave height at departure (values on the x-axis are scaled). Predicted probabilities (bold lines) and 95% confidence intervals (shaded areas) for different values of wave height were derived from the fitted model reported in Table 2.*

6. DISCUSSION

The use of GPS devices on Mediterranean gulls allowed us to find out that trip metrics vary with sex and breeding stage, and that both intrinsic and extrinsic factors contribute to determine a marine or land based foraging tactic during breeding season.

In our analysis we did not isolate, within a trip, the sites of foraging activity from the sites that are only covered by relocation, so we do not exactly know which resources breeding gulls used. However, we can still use the proportion of fix at sea and land as an indication of their use of land and sea habitat to forage.

Generalist seabirds that use both sea and land to forage have to cope with different challenges given the differences between these two habitats. Marine resources are often unpredictable and patchily distributed from the point of view of a seabird (Weimerskirch 2007). This can be a reason why, as a general rule, tagged individuals showed more terrestrial habits than marine during the reproductive season. In fact, the total number of fixes at sea were only the 23.6 % of the total number of fixes. Regarding the foraging trips, the histogram shows that even if almost all proportions of fixes at sea are represented in the sample between 0 and 1, as many as 1000 trips over 1442 do not include fixes at sea at all. Therefore, given the opportunistic nature of gulls, they likely decided to rely mainly on terrestrial resources that are more predictable and available.

However, sometimes also marine resources can be predictable and easy to obtain: this is the case of fishing discards. Tagged individuals seem to be aware of this resource and to exploit it to some extent. In fact, their presence at sea was greater during weekdays, when fishing activities take place, than during the weekend when they stop, as we hypothesized. Maybe this reliance on fishery could be the reason for the long trips along the coast that are visible on the figure 9. Optimal foraging theory in fact suggests that animals should choose to do a long travel only if they are certain to obtain high quality resources that compensate for the energy expenditure the travel implies. Another factor that suggests that they follow fishing vessels is the fact that a high proportion of fix at sea seems to be associated with a higher maximum distance reached during trips. Comparing gull movements with the route of fishing vessels would be the way to prove unequivocally that our hypothesis is true.

The probability to forage at sea varies, other than during the week, also during the day: it assumes the shape of a bell, which peak approximately corresponds to 8.30 UTC (10.30 local time). Overnight trips (that started and ended in different dates, and that were eliminated) were only a few, and the same was true also for trips that started during the night but after midnight (so that departure and return date coincide) that were retained in the dataset. This can be noticed by the rugs (little vertical bars on x-axis which represent observations) that are rare in the tails of the “Hour of the day” graph (Figure 15) and that correspond to night hours. This indicates that Mediterranean gulls are much less active at night thereby confirming it as diurnal species, at least during the breeding season. Trips that start during the night and end the morning after are therefore probably directed toward roosting sites. The variation of their presence at sea during the day is coherent with the fact that environmental variables such as wind speed and wave height are not constant as the hours go by. Usually the early morning is the time of the day when the sea is more calm, while in the afternoon wind blows stronger and waves are higher. However, Pearson’s correlation coefficient is low (r = 0.23) between the variable time of the day and wind speed, and negligible (r = 0.05) between time and wave height. This is probably due to a higher weather variability across the study period, than within a day. Moreover, since the peak of the curve (higher probability of foraging at sea) does not coincide with early morning, hours probably exert an influence on the behaviour of gulls that is independent by weather conditions. Visibility for instance, probably clearer when the sun is higher, can be a factor at play. In addition, although some fishing vessels come back to the harbour at sunrise, some come back also later in the morning, and this could be another reason explaining gull presence at sea. Again, the knowledge of the schedules and routes of fishing activities would be instrumental to confirm this hypothesis. Finally, there is another factor that could explain a less frequent presence at sea in some periods of the day, that is the existence of a terrestrial resource more available during those periods. An example is earthworms, that are of great importance to gulls and are known to be abundant during early hours of the day (Spelt et al., 2021), when gulls indeed are not so present at sea.

Gulls have shown to be affected by weather conditions in their choice to forage at sea. Wind speed and wave height are significant predictors in the model. There is an inverse proportionality between wave height and probability to forage at sea, so that this probability is high when the sea is completely calm, but it rapidly decreases as the sea becomes more and more rough. In presence of high waves the visibility is indeed worse, and it becomes more difficult to individuate a prey, but also to dive and catch it. Wind instead was included in the model with its squared term, since we suspected the response to this predictor not to be linear. In fact a model with just the linear component of wind has a lower fit and wind effect was less significant than in the former case. Gulls preferred to go to the sea when wind speed was moderate. A strong wind becomes an obstacle to gulls not only because it is usually associated with a more rippled sea surface, but also because it makes flight more difficult. Therefore, the fact that gulls avoid to face the sea with these conditions confirm our initial hypothesis. On the other hand, the lower likelihood of birds presence at sea with a weak wind can be explained by the fact that gulls are flight generalists (they do both flapping and gliding, Rayner, 1988), therefore a tail wind that drives them ahead is useful and can reduce energy expenditure, as it was found for other seabirds like the Murphy's petrel *Pterodroma ultima* (Clay et al., 2019).

The last variable in the model related to weather is rainfall. We found a negative relationship between probability to forage at sea and rainfall amount, confirming our hypothesis that, with abundant rain, the worsening of visibility at sea and the increase of some terrestrial preys are an incentive to a shift toward terrestrial foraging. This predictor resulted, however, not significant, but with a p-value just above the threshold. This result is probably related with the fact that summer seasons of the study years have been particularly dry. Therefore, the scarce representation of rainy days in our sample is supposed to lower the power of our analysis, making the effect not significant.

We decided not to include temperature in the model because was correlated with the hour of the day, and therefore it was not a factor that, independently, explained a part of the variability in the use of sea.

The attendance of gulls at sea varies also because of intrinsic factors. Males in fact were more likely to go to the sea than females. Differences between sexes in the habitat use, as well as for other aspects of foraging behaviour, have been already demonstrated in other gulls and seabirds. These differences can be a result of a different morphology, and consequently different physiology and energetic requirements. This hypothesis has been proposed to explain sex differences in habitat use on Audouin's gull, although the results were the opposite: females are the ones that have a more intense use of sea than males, because of the need to restore calcium levels after laying (García-Tarrasón et al., 2015). Even if our hypothesis that females make longer trips than males due to competitive exclusion is not confirmed by the results, the higher presence of males at sea can still be explained by competition. In fact there is a great intra- and inter-specific competition to feed on fishery discards, which are a high-energy resource limited in space and time. In this context, a larger size is important and we expect males to get the better for this reason. This was found for instance on lesser black-backed gull (Camphuysen et al., 2015). This partial specialization in habitat use can be a way to solve inter-sexual competition on foraging, and could be the reason why females are not forced to travel further. Apart from sexual dimorphism, males and females could also show differences in their role during incubation and chick rearing, even if in this species, like for seabirds in general, both sexes give their contribution, alternating in these tasks. Males indeed make trips of longer duration, and this could be a consequence of the fact that a more assiduous presence at the nest is part of the role of females. The literature shows contrasting results about this topic: a tracking study on lesser black-backed gull reports longer nest attendance of males (Camphuysen et al., 2015), while direct observation studies report that both western gull and great black-backed gull females spend more time incubating, however while males of western gull feed chicks more often than females (Pierotti et al., 1981), for the other species the effort is the same in the two sexes during chick rearing (Butler and Butler, 1983).

Finally, also breeding stage proved to affect the probability to forage at sea of breeders, that is higher during chick rearing. This shift reflects the different nutritional requirements that chicks have with respect to their parents, that for this reason apply a dual foraging strategy, with trips of different length and destination. The result confirm our hypothesis: parents probably prefer to feed chicks with fish, which likely meets better their nutritional and digestibility requirement than terrestrial organisms or waste items (Isaksson et al., 2016). Another confirmation comes from the metrics of the trips: during chick rearing gulls make trips that reach greater distances but which duration doesn’t differ from incubation trips. This means that during this breeding stage gulls apparently headed toward a safe source like fishing discards, but also that they increased their efforts. This means that fish is a good resource for chicks and it's worth the effort. Our hypothesis that parents do shorter trips during chick rearing because they need to feed them frequently is not confirmed, likely because the quality of food is more important. Another explanation could be resource depletion: with the progression of the breeding season, since there are a lot of individuals that search for food in the same areas at the same time, resources around a seabird colony become more and more scarce, and therefore animals could be forced to go further to forage. This phenomenon was demonstrated around a colony of double crested cormorants *Phalacrocorax auritus*, where the transepts more visited by the birds showed a lower density of fish (Birt et al., 1987). Resource depletion is the reason why in smaller seabird colonies individuals do shorter trips but also can show lower energy expenditure and higher nest survival, as it was found on masked booby *Sula dactylatra* (Oppel et al., 2015). A shift toward sea use during chick rearing could be also explained by a seasonal change in abundance, quality and prey availability of both habitats. This is the case of black-headed gull, for which marine habitat (in terms of biomass of macro-benthic community and mass gain of individual benthic organisms) results a better choice than the terrestrial one (because of high vegetation that hide soil invertebrates) as the breeding season progresses (Schwemmer and Garthe, 2008).

We included in the model also the year in which individuals were tracked, to investigate if any unexplored variability among years (in terms of environmental characteristics or resource availability) and especially differences between colonies we sampled those years, could be factors that determine another part of variability that was not explained by the other selected variables. It turned out that this was not the case, as year is not a significant factor in the model. Therefore, taking into account all the environmental variables included in the model, foraging tactics were not different from one year to another, or from Cervia to Ortazzo. Probably the fact that the two sites are situated at the same distance from the sea is the reason why the probability to forage at sea doesn’t differ between individuals of the two colonies. Cervia and Ortazzo are similar in their landscape, but differ in the surrounding environment: while around Salina di Cervia there is a human-modified landscape, with streets and cultivated fields, the area around Ortazzo is much more natural, with the pine forest behind and the dunes ahead. Therefore there could be other differences on aspects of foraging behaviour that we did not analyze in detail, for instance the resources they fed on. An analysis of the foraging sites would be the way to answer to this question.

Generalist species like gulls are able to switch to alternative available resources within their foraging range. For instance, herring gulls breeding in colonies closer to built-up areas use more terrestrial resources, while individuals from colonies located in areas with sheltered coastlines, forage more on intertidal resources (Hanlon et al., 2017). On the other hand, Schwemmer and Garthe (2007) observed that, among three black-headed gull colonies, the one whose individuals were expected to make greater use of terrestrial resources due to its position, relied unexpectedly more on marine food. This shows that not only the relative vicinity with resources, but also their quality (in terms of abundance of prey and lack of inter-specific competition) make the difference. However, even for species that have the ability to switch between marine and terrestrial habitat, this may come at a cost of lower breeding success. For instance herring gulls raise smaller broods in colonies where they consume a lower proportion of intertidal resources (Hanlon et al., 2017), and a wide ranging decline of black-headed gulls in many countries of northern Europe have been explained by food shortages (Schwemmer and Garthe, 2007).

Overall, the results shown here provide new knowledge about the foraging behaviour of Mediterranean gull, which is poorly known compared to other gull species, and for which only a few, dated, information on behaviour and ecology is available. This is in fact the first study that applies the use of GPS on this species (but see Meneghini 2016-2017 for preliminary results of the same study project). Further research could be carried out to assess fine-scale foraging habitat selection during breeding period (Meneghini 2016-2017 described main used habitats by observing on the field the characteristics of foraging hotspots identified with GPS fixes, but a more thorough study could be achieved through habitat maps using satellite imagery), and foraging behaviour during the non-breeding period.

Even if Mediterranean gulls have demonstrated to have mainly terrestrial habits during the breeding season, marine resources seem to be important to them during chick rearing. Moreover, they could show a shift to a marine lifestyle in the winter, based on what Cramp and Simmons (1983) and Nardelli et. al. (2015) report. This means that Mediterranean gulls could still be affected by the conditions of the Adriatic sea, that is the most exploited basin of the Mediterranean Sea. There are multiple pressures that afflict this basin, such as nutrient enrichment and pollution from large rivers, climate change, invasive species, overfishing, habitat destruction by anthropogenic activities (Barausse et al., 2011). As a result, 98% of traditional marine resources are depleted to less than 50% of former abundance, and functional extinctions have altered and simplified food-web structure over time, with a shift to more fecund, smaller and earlier-maturing species (Lotze et al., 2011). This situation will get worst in the future if the pressures persist. In this scenario, the study of foraging behaviour of Mediterranean gulls during winter would be useful to assess to which extent they will be impacted by the depletion of marine resources.

Studies on foraging behaviour like this are important they offer crucial information on the pressures that the species is facing, and that can be used to improve its management and conservation. These pressures can act in terms of resource availability, but also in terms of climate change. In fact we have seen that weather variables have an important influence on foraging tactics, and in a future with decreasing rainfall and a higher number of extreme bad weather events, investigations should be focused on assessing the extent to which change in habitat use may negatively impact reproduction and, hence, demography (Zorrozua et al., 2020). Another important aspect is that the relative importance of different resources for a species is an index of their abundance and quality in the environment around the colony, and by comparing this kind of data for several years we can obtain long term trends of habitat and resource conditions.

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