AN EXPLORATORY STUDY INTO THE BEHAVIOUR OF ATLANTIC PUFFINS *(FRATERCULA ARCTICA)* ON LUNDY

by

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ABSTRACT
The impact of sea conditions and weather on the behaviours of Atlantic Puffins (*Fratercula arctica*) have not previously been examined on Lundy therefore it was assessed in the current study. It was found that weather, swell size and group size had a significant effect on recorded behaviours, but not tide, wind or time of day. The current research provides insight into specific behaviours Puffins exhibit whilst on the water and the percentage of time spent performing them. The results could be useful for conservation, as well as to researchers and birdwatchers wanting to observe Puffins on the water.

Keywords: *Atlantic Puffins, Lundy, behaviour, environmental conditions, conservation*

INTRODUCTION

Atlantic Puffins *(Fratercula arctica)* breed in vast colonies off both coasts of the Atlantic Ocean (Harris, 1984). They are relatively small predatory seabirds, measuring up to 25 centimetres (Plate 1), and are omnivorous, largely hunting for small fish such as Herring *(Clupea harengus)* or Sand Eels *(Ammodytes tobianus)* in the open ocean or by the shore (Martin, 1989). As agile swimmers, they are able to dive to maximum depths of 60 metres for up to two minutes at a time to optimise foraging yield (Wanless *et al.*, 1988). Puffins are highly social animals, seemingly influenced by conspecific behaviour and activity (Ward & Zahavi, 1973). Furthermore, the

Plate 1: Puffins on Lundy.
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environment has an extensive impact on the birds' behaviours; Puffins have been found to adapt their breeding and hunting behaviours according to their environment, such as water temperature and altitude of the breeding site (Fayet, 2015). Puffins arrive at the island from March to nest in burrows on the west facing cliffs. Lundy was named due to the former high populations of Puffins on the island as the Icelandic word 'lundi' translates to 'Puffin' (Perry, 1940). They depart for the North Atlantic and Iceland in late July or August subsequent to breeding (Lock, 2006). Despite previously high numbers on the island, various factors over the years have led to population fluctuations, the primary factor being Rats *(Rattus rattus)* predating on pufflings and eggs in burrows. Numbers have been steadily decreasing from Perry's first estimate of 3,500 birds in 1940 to an estimate of 15 Puffins in 1996 (Price, 1996). This significant population decline to a low density is known as the Allee effect. It can arise for a number of reasons and can often be linked to changes in the environment (Roques *et al.*, 2008). However this number has since increased to 32 birds in 2010 (Saunders & Wheatley, 2012). Due to harsh winter storms in 2013/14 Puffin numbers drastically decreased on Lundy with few young birds surviving (Osthaus *et al.*, 2017). Currently, there is insufficient data on Puffin behaviour as research tends to focus on population estimates. Therefore, this study focuses on the behaviours of Puffins whilst on the water and the possible influence of sea and weather conditions.

Currently, Puffins are listed by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species as 'Vulnerable' (Birdlife International, 2016) and populations are in decline. Lundy is an important breeding ground for migratory Atlantic Puffins (Baldwin, 2009). Effective species conservation requires knowledge of natural behaviour such as migratory patterns, interactions with conspecifics and other species, foraging demands and reproductive behaviour (Slater *et al.*, 1997). This knowledge can enable the development of effective protection measures as accurate monitoring can aid conservation attempts (Nichols *et al.*, 2000). Therefore, increasing knowledge of Puffin behaviours may enable a further understanding including interactions and how these may relate to the Puffin population on Lundy, specifically Jenny's Cove.

Social interactions and information centres

Seminal research has indicated that Auk social behaviour and survival are closely linked (Darling, 1952) and other birds can significantly influence Puffins' foraging and general behaviour at sea. Therefore, social behaviours could impact on the survival of Puffins on Lundy. Research into Puffin interactions, particularly with other species, is currently lacking; consequently this study aims to investigate which behaviours Puffins exhibit on the water, looking particularly at social behaviours, such as interactions with other Auks and conspecifics. Puffins often share their habitat with a variety of seabirds, including Skuas *(Stercorariidae)* and Gulls *(Laridae)*. On Lundy, Puffins share their breeding grounds with Guillemots *(Uria aalge)* and Razorbills *(Alca torda)*, but there is limited research into interactions between the species. An observational study by Divoky (1982) found that although single Puffins often reside near Guillemot flocks on both land and sea, few interactions were observed between the species. Research suggests that living in close proximity to other species can promote intra-species as well as inter-species interactions, particularly in Horned Puffins *(Fratercula corniculata)* as they were found to be more social when in close proximity to another species (Bakhturina & Klenova, 2016). One social behaviour occasionally observed between two Puffins both on land and water is billing. It involves one bird nestling the other's breast and throat feathers. Billing can serve as a greeting or celebration following an aggressive encounter with a conspecific, but is mainly linked with courtship (Johnsgard, 1987). Billing has been found to be most commonly displayed during the early breeding season and is a group activity, with up to six birds billing in a group. This behaviour is proposed to be almost contagious, as new billing pairs were observed to begin billing near the originating pair (Conder, 1950). Understanding how Atlantic Puffins interact with conspecifics and other species can help conservation efforts; for instance, when Puffins begin to engage in billing behaviour in groups this may be an indicator that they will soon start to breed (Calvert & Robertson, 2002) and they benefit from limited human interaction.

It has been suggested that social interaction can lead to increased foraging success. Fisher (1954) proposed that living in social colonies can function to benefit feeding in birds. Ward and Zahavi (1973) found that birds congregate in so called 'information centres' to gain access and exchange information regarding the location and density of food sources. This was suggested as large groups of Puffins have been observed congregating outside of their colonies where they preen, rest or display prior to departing to forage (Ward & Zahavi, 1973). This is supported by research which found that food related grouping behaviour was proposed to enhance overall colony fitness (Beauchamp, 1998). Successful use of information centres has been observed in several bird species such as Great Blue Herons *(Ardea herodias)*, Great Egrets *(Ardea alba modesta)*, Carrion Crows *(Corvus carone carone)*, Hooded Crows *(Corvus carone cornix)* and Terns *(Lavidae)* (Mock *et al.*, 1988; Richner & Marclay, 1991; Waltz, 1987). All were observed departing with colony members, following congregation, and were found to have increased foraging success. Successful foragers then return to the 'information centre' and interact with unsuccessful foragers, which then are subsequently observed foraging with enhanced feeding success (Richner & Heeb, 1995). In the current study, it is hypothesized that Puffins will congregate in information centres, interacting with conspecifics or Auks prior to flying out to the open ocean to forage.

Impact of sea and weather conditions on behaviours

Environmental changes may significantly impact on species populations, therefore behavioural flexibility may be a key determinant in species success (Sol & Lefebvre, 2000), with individuals with more generalized adaptations being more flexible than specialists (Brashares *et al.*, 2000). Determining how behavioural shifts occur and are maintained may be essential for species conservation; for example, the Mauritius Kestrel *(Falco punctatus)* experienced a significant decline in population with the introduction of predators to nest sites (Temple, 1986). As a consequence, the remaining birds relocated from tree nesting to inhabiting cliffs; this habitat shift was maintained throughout generations demonstrating how changes in the environment may significantly impact on behaviour and influence population numbers. Understanding behavioural decisions made by individuals during certain environmental conditions can help to predict their behaviours in novel conditions, such as after harsh weather conditions. The consequences of habitat loss or change could then be predicted by behavioural models (Goss-Custard & Sutherland, 1997). Knowledge of Puffin behaviour on the water and the impact of weather conditions could increase investment in the continuation of Puffin populations on Lundy by facilitating both birdwatchers and researchers. Birkhead and Ashcroft (1975) proposed that there was limited information on how the sea conditions could influence diving behaviours in Auks. Therefore, this study aims to investigate the impact of various sea and weather conditions on Puffin behaviours on the water.

Previous investigation into Auk behaviour whilst on the water indicated that Guillemots are active most of the time (64%) and spend only 13% of time resting. The remaining time was spent flying (11%) and diving (12%) (Tremblay *et al.*, 2003). Researchers also have explored whether sea state affects the performance of Auk behaviours. The state of the tide has previously been linked to seabird behaviour; research suggests that high tide causes prey to rise to the surface, resulting in increased diving activity in seabirds (Hunt Jr *et al.*, 1998). Therefore, Puffins may be more likely to be observed on the water and exhibit increased diving behaviours during high tide, as prey may be more plentiful. In addition, swell size could impact seabird activity; research suggests that diving behaviour in seabirds, including Auks, was significantly higher at high swell than at low swell (Burger *et al.*, 1977) suggesting that swell size may also impact on prey availability. Weather has also been found to impact food availability. Cimino *et al.* (2014) found that weather conditions can have an impact on Puffins prey species such as Krill *(Euphausiacea)* and smaller fish which in turn will impact Puffin behaviours; it may change foraging which would impact on Puffin location. Furthermore, studies on weather conditions and the impact they might have on seabirds was conducted on European Shags *(Phalacrocorax aristotelis)* (Bustnes *et al.*, 2013). The researchers found that unfavourable weather conditions in winter increased mortality rates of non-breeding Shags throughout all the age classes. On the other hand, research suggests that time of day does not affect Auk behaviour (Holm & Burger, 2002), although Corkhill (1973) found that Puffins generally forage in the morning or late afternoon. Daily feeding behaviours of Guillemots on the ocean frequently vary due to the changes in weather (Finney *et al.*, 1999). These studies indicate that weather could impact on the behaviours exhibited by other seabirds, including Puffins. Therefore, this study predicts that there is an impact of sea state and weather on the behaviour rates. Due to previous research into Auk behaviour it is also hypothesized that time of day will not significantly impact on Puffin behaviour.

METHODS

Location and subjects

The research was carried out on Lundy which lies in the Bristol Channel, 10 miles off the coast of North Devon, United Kingdom. The Puffins' nesting ground is typically found at Jenny's Cove which is on the west side of the island facing the Atlantic Ocean (Plate 2). The nesting ground is located on cliffs with the burrows situated near

Plate 2: Jenny's Cove, Lundy. © Peggy Liebig

the bottom. The Puffins were observed from a cliff opposite the nesting ground which provided a clear view of the sea using a spotting scope and two pairs of binoculars. Puffins are not sexually dimorphic, therefore a distinction between the sexes was not possible. Additionally, Puffins were easily distinguished from other auk species, Guillemots and Razorbills, by plumage and bill morphology (Plate 3). The Puffins were only observed while on the water at Jenny's Cove and not whilst they were at their burrow sites.

Plate 3: Distinction between Puffins and other Auks. © Peggy Liebig

Sampling method

Observations started at approximately at 8am and were discontinued after 3pm as Puffins were no longer visible on the water. The observations took place every day from 23-28 April 2017. The two observers used binoculars to observe the subjects. Distance observation sampling was conducted from approximately 200 metres from the focal cliff. Instantaneous focal animal sampling was utilised whereby one individual on the water was observed for a five minute period before changing to the next individual using the method of Altmann, (1974). Two teams observed two different animals, with one researcher constantly observing through binoculars and telling a second researcher the observations, who recorded those on a scoring sheet; the fifth researcher kept track of the time. Verbal communication between the two observers ensured they did not focus on the same bird at the same interval. When observing the same group, the observers would ensure during the first minute that they were watching different individuals. The tasks rotated after every interval to reduce observer fatigue. Inter-rater reliability was assessed by all researchers concurrently watching one individual and comparing recorded behaviours on the first day. The weather condition, wind, swell, tide state and Puffin group size were recorded for every time interval. The behaviours were recorded using an ethogram adapted from Camphuysen, Fox, Leopold & Petersen (2004) (Table 1).

Table 1: Ethogram to determine observed behaviours. Definitions adapted from Camphuysen *et al*. (2004) and the codes were used during observations

Behaviour	**Definition**	**Code**
Billing	Rubbing beaks with another individual	B
Diving	Whole bird under water	D
Flapping	Rapid up and down movement of the wings while on the water	F
Flying	Bird is in the air and moving	FY
Head dip	Head under water	H
Interaction with conspecific	Any contact with other Puffins; inspecting, playing with, grooming, nursing, hugging etc., except billing	IP
Interaction with other Auks	Any contact with other Auk species (Guillemots, Razorbills); inspecting, playing with, grooming, nursing, hugging etc.	IA
Interaction with Gulls	Any contact with predating species (Gulls); inspecting, playing with, grooming, nursing, hugging etc.	IG
Preening	Cleaning and positioning feathers of themselves with beak	P
Resting	Floating, inactive, not purposefully moving	R
Swimming	Moving on the water in a specific direction	S
Others	All other behaviours performed that are not listed above	O
Out of sight	Individual cannot be seen	OU

Statistical analysis

The intervals were re-coded for statistical analysis; the time of day was divided into three categories; early morning (8am-10am), late morning (10am-noon) and afternoon (noon-3pm). Weather was coded as either sunny or cloudy, since it did not rain during the observation period. Tide was coded as low tide or high tide. The swell was recorded as wave height in metres, which ranged between no swell and two metres during the observation period. Tide times, wind and swell estimates for each day were obtained from the BBC weather website. All the behaviours were coded as separate variables as well as the group size, which was defined as the number of individuals around the focal Puffin. It was then analysed whether the Puffins exhibited a specific behaviour more frequently per observational period than another. Therefore, this study looked at rates of the behaviour, rather than frequencies (Altmann, 1974). Multiple multivariate analysis of variances (MANOVA) were used to examine the effects of tide, time of day, weather, swell, group size and wind, which were included as independent variables, on all of the observed behaviours which were entered as the dependent variables.

The data was analysed with IBM SPSS Statistics 24. Results were considered significant when $P<0.05$ with a confidence interval of 95%. Data were checked for normality and homogeneity and initial analyses indicated that the data was normally distributed. Additionally, there were no significant outliers found in the data.

RESULTS

A principal component analysis indicated that the behaviours did not correlate significantly with each other therefore the behaviours were not grouped together for further analysis.

All mean rates per observed times, standard errors as well as the minimum and maximum observed rates for each scale variable were calculated (Table 2). Resting behaviour was exhibited most often and interaction with Gulls was the least often.

Grouping the active behaviours together (billing, flapping, head dip, interactions and preening), descriptive statistics show that Puffins were active the majority of the time whilst on the water (65.82%) and spent the remaining time resting (27.98%), flying (3.32%) and diving (2.88%). (Figure 1).

Social interactions and information centres

To investigate how sociable the Puffins on Lundy are, two new variables were computed. The first variable was called 'interactions' and consisted of billing, interactions with other Puffins, Auks and Gulls. The second variable was called 'single behaviours' and consisted of diving, flapping, flying, head dipping, preening, resting and swimming. Puffins spent only 10% of the observed time interacting with Gulls and Auks and 90% performing other behaviours independently. The most commonly performed behaviour was interacting with conspecifics ($N=246$). They were observed less often interacting with other Auks ($N=36$), billing with Puffins ($N=13$) and, the least, interacting with Gulls ($N=1$).

Looking at all behaviours individually, group size had a significant effect (MANOVA Pillai's $V=1.089$, $F(143,1980)=1.522$, $P<0.001$). Puffins swam more frequently in groups between three and five ($F(11,182)=2.760$, $P=0.002$). Group size also affected

Table 2: Descriptive statistics including mean, standard error, minimum and maximum of the observed behaviours from the ethogram, as well as group and swell size

Variables	Mean	Standard Error	Minimum	Maximum
Group size	3.50	0.19	1	17
Swell size	1.02	0.06	0	2
Billing	0.07	0.03	0	5
Diving	0.44	0.08	0	8
Flapping	1.89	0.18	0	24
Flying	0.51	0.05	0	4
Head dip	2.76	0.30	0	27
Interaction with conspecific	1.26	0.12	0	9
Interaction with Auk	0.18	0.04	0	4
Interaction with Gull	0.01	0.01	0	1
Preening	0.69	0.09	0	6
Resting	4.28	0.27	0	24
Swimming	3.17	0.24	0	16
Others	0.04	0.02	0	2
Out of sight	0.38	0.04	0	1

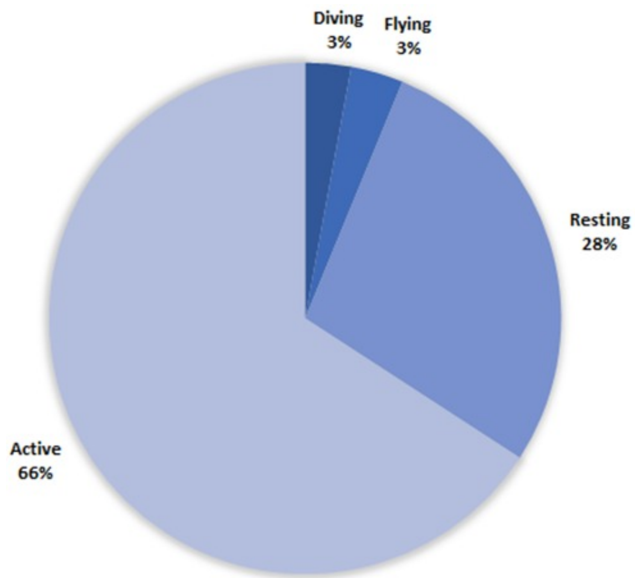

Figure 1: Percentages of Puffin activity on the water
Active behaviours were grouped to include: billing, flapping, head dipping, interactions and preening. Puffins were active the majority of the time whilst on the water, excluding diving and flying. They were found to spend just over one quarter resting whilst on the water

Puffins' interactions with Auks (F(11,182)=2.549, P=0.005) where they preferred to interact with Auks when alone or up to a group of 10 Puffins. Puffin-Puffin interactions were also affected by group size (F(11,182)=5.385, P<0.001). These interactions were highest when group sizes were between two and 10 individuals. Further analysis revealed that group size affected the performance of billing behaviour (F(11,182)=3.422, P<0.001) where a group size of six was the preferred size (Figure 2).

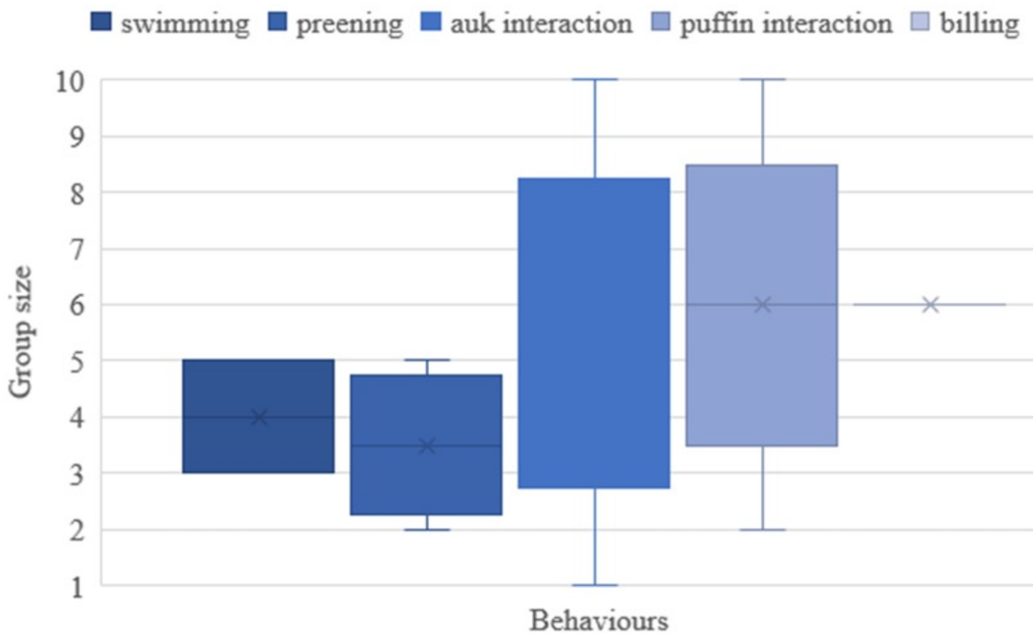

Figure 2: Group size correlating with significant behaviours
Puffins were found to swim more frequently when in groups between three and five. They also preferred to preen in group sizes ranging from one to four Puffins. Puffin-Puffin interactions were highest when group sizes were between two to 10 individuals, furthermore interactions with Auks were most frequent when the Puffins were alone or up to a group of 10 Puffins. Billing behaviour occurred most often in a group size of six

Another new variable was computed, using Auk interaction and Puffin interaction, called 'interaction 2', to determine whether Puffin-Puffin interactions or Puffin-Auk interactions led to Puffins flying off to the ocean. A linear regression analysis was performed with flying as dependent variable and the interaction as independent variable. Puffin-Puffin and Puffin-Auk interactions did not significantly predict flying (F(1,193)=0.041, P=0.839).

Behaviours and environmental factors

Tide state did not have a significant effect on overall behaviours. Although time of day was non-significant on the behaviours overall, it had a significant effect on diving (F(2,191)=3.358, P=0.037). A post-hoc pairwise comparison revealed that the Puffins preferred to dive in the late morning (N=76) than early morning (N=52).

Swell size had a significant effect on the performance of the behaviours overall (Pillai's V=0.587, F(52,720)=2.382, P< 0.001). Individually, swell size had a significant effect on diving (F(4,189)=3.336, P=0.011). Post-hoc pairwise comparisons (Tukey's method, with overall α=0.05) suggested that the Puffins preferred to dive when swell size was between zero and one and a half metres. Swell size also significantly predicted interactions with other Puffins (F(4,189)=3.273, P=0.013) and other Auks (F(4,189)=4.256, P=0.003); Puffins interacted more with other Auks in higher swell sizes, between one and a half and two metres. Swell size significantly affected preening behaviour (F(4,189)=6.009, P<0.001). A post-hoc revealed that the Puffins preferred to preen when there was a one to two metre swell compared to other swell sizes. Swimming was also significantly affected by swell size (F(4,189)=4.078, P=0.003), suggesting that they swam more in one and two metre swells (Figure 3).

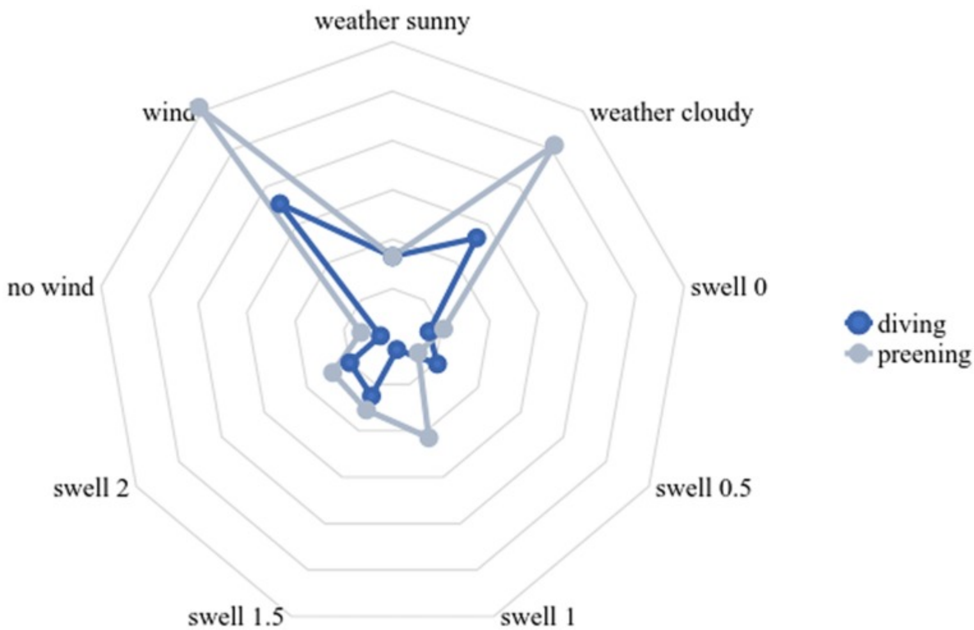

Figure 3: Diving and preening rates performed during different sea and weather conditions Puffins preferred to dive when there was a 1.5 metre swell and when it was cloudy and windy. They also were observed to preen more in one metre swell, when it was cloudy and windy

Weather was found to have a significant effect on the performance of the behaviours (Pillai's V=0.228, F(13,179)=4.072, P<0.001). Wind was not significant on behaviours overall, but results suggest the Puffins were flapping more in windy conditions (F(1,191)=4.223, P=0.041). They were observed to fly more when it was sunny compared to when it was cloudy (F(1,191)=4.530, P=0.035). They also were observed to preen more when it was cloudy (F(1,191)=11.948, P=0.001) and windy. Puffins had more interactions with other Auks in cloudy weather (F(1,191)=9.844, P=0.002). (Figure 3).

DISCUSSION

Currently there is limited research into Puffin behaviour, therefore little is known about how their behaviour changes with differing environmental conditions such as sea state and weather. Due to the increasing population size, studies of Puffin behaviour on Lundy may become more achievable now than they were previously. Having sufficient data on their behaviours can assist various organisations to design relevant conservation projects and help conservationists predict behavioural change (Goss-Custard & Sutherland, 1997). This study focused on Puffin behaviour while on the water; results showed the similar distribution of performed behaviours as previous research on Guillemots (Tremblay *et al.*, 2003). It was found that there was a significant impact of most recorded environmental factors; however Puffins were not found to congregate in information centres, as found in the study conducted by Ward and Zahavi (1973).

Social interactions and information centres

Seminal research indicated that Puffins are highly sociable (Darling, 1952); however, during this study, Puffins spent only 10% of the observed behaviours interacting with other birds. During observations, it was noticed that Puffins frequently interacted with conspecifics and other auks. Puffins appeared to use other auks as a shield towards predatory Gulls by placing their burrows amongst other auks. This could be to avoid having their food taken by the Gulls, as it was found that the arrangement of nests in relation to conspecifics can significantly reduce food theft (Pierotti, 1983). Previous researchers have suggested that interactions with other birds are more frequent if breeding grounds are shared (Grant, 1971). However, on Lundy, although Puffin populations are outnumbered by auks and gulls and they nest in the same vicinity, the Puffins still did not spend significantly more time interacting with other auks. Consequently, this study supports the results found by Divoky (1982) who observed few interactions between Puffins and Guillemots. The current research also does not seem to support the notion that interactions increase with proximity (Bakhturina & Klenova, 2016). The lack of interactions between Gulls and Puffins could be as research was conducted early in the breeding season, therefore Puffins were not bringing fish back to their offspring at the nesting grounds (Pierotti, 1983), therefore the gulls would not have been able to intercept this transportation and steal the fish. This could be an area considered for future research as interactions between Puffins and other sea birds may increase later in the breeding season. Furthermore, the observation of interactions between Puffins and other species, such as Gulls, could aid conservation efforts as Gulls have been observed predating on Puffins and stealing their fish during the breeding season (Pierotti, 1983). Conservation efforts for the Puffin population could aim to monitor and potentially regulate Gull populations on Lundy to protect vulnerable pufflings.

Additionally, information about social behaviours and interactions could aid conservation as restrictions could be placed on the visiting tourists; for instance, not allowing them to go within a specific proximity of the potentially breeding pairs as soon as billing is observed (Calvert & Robertson, 2002). This study confirms Conder's (1950) findings as it was observed that Puffins performed billing behaviour in the early breeding season in groups of up to six individuals. Understanding the behaviours which suggest that the Puffins may be preparing to breed could lead to more successful breeding and rearing of the pufflings and overall increases in populations as human impact could be reduced.

Regarding the information centre hypothesis, there was no correlation found between interaction with conspecifics and increased flying. To support the information centre hypothesis, it would be expected that interactions would lead to an increase in flying behaviour, with Puffins congregating to access information regarding food location, then flying out to forage out in the open ocean (Ward & Zahavi, 1973). However, Richner and Heeb (1995) propose that this information centre hypothesis is redundant and an alternative hypothesis based on individual selection could more successfully serve as an explanation for the observed behaviour. In order to further explore the use of information centres in Puffins, it would be necessary to code the behaviours in the order they occurred, as this research was only able to explore the association rather than the direction. This study also was not designed to look whether Puffins went out to the ocean to forage after interactions occurred; this could be another area for further study.

Behaviours and environmental factors

Although previous literature suggests that time of day does not affect Auk behaviour (Holm & Burger, 2002), the results of the current study found that Puffins dive more frequently in the late morning compared to the early morning or afternoon. This could be explained by the timings that the Puffins were observed; recorded observations did not take place before 8am as the observations made before this time indicated that Puffins were not visible on the water. Additionally, observations did not take place after 3pm because Puffins were again not visible. One could speculate that during these times the Puffins were out foraging and therefore they were not observable on the water. Corkhill (1973) suggests that Puffins usually forage in the morning and late afternoon which coincides with this explanation. Because of this, it could be argued that Puffin behaviour does vary throughout the day; however, the current study could not investigate this due to the constraints of the observation area.

Contradictory to past studies (Hunt Jr *et al.*, 1998), there was no effect of tide found on any of the behaviours including diving. This unexpected result could be related to the location in which the Puffins were observed, as observations were made in the bay and the Puffins may go further out to sea to forage; therefore, there may be less need for the Puffins to dive as food is scarce in the bay. Puffin prey, such as Sand Eels and Herrings, are usually found in the open water (Wright & Begg, 1997), thus the swell observed in the bay may not significantly impact on diving behaviours as these behaviours may be more linked to the open ocean.

Diving was performed more frequently when there was a swell up to one and a half metres. This supports previous research which suggested that diving behaviour in seabirds increases at times of high swell compared to low swell (Burger *et al.*, 1977). Puffins exhibited more preening behaviour when the swell size was one metre high and during cloudy and windy weather. They also displayed preference to preen when there was a group size of one to four individuals. Preening has been associated with enhancing the waterproof quality of feathers in seabirds, by using the oils and waxes that secrete from the preen gland (Chiale *et al.*, 2014), therefore this increase in preening behaviour during cloudy conditions could be a result of the increased diving behaviour seen. This maintenance could be more important in cloudy and windy weather conditions, because feathers may be increasingly ruffled due to the wind. Additionally, increased preening in larger social groups could also be explained by the contagious effect, as found previously with billing (Conder, 1950). As weather conditions were found to significantly impact on Puffin behaviour at Jenny's Cove, knowledge of how behaviour may be impacted by the environment may assist conservationists and help to increase the currently low numbers of Puffins around the British shores.

As considered earlier, environmental conditions have been found to impact behaviours. In the research previously discussed conducted by Temple (1986), the Mauritius Kestrel population was reduced to only two breeding pairs; similar population decline was also found with Puffins on Lundy, with a significant decline from early estimates of 3,500 (Perry, 1940) to an estimate of 15 Puffins (Price, 1996). This Allee effect can be due to various reasons, partly because of environmental factors (Roques *et al.*, 2008); the storms on Lundy were linked with the significant decrease in Puffin population (Lock, 2006). Climate fluctuations have been found to be a key factor in breeding success for a variety of bird species, including Puffins (Durant *et al.*, 2004). Therefore, it is important to study sea and weather conditions in relation to Puffin behaviour to help conservation efforts to determine which conditions are favourable for the successful breeding of Atlantic Puffins and in which conditions the populations may suffer. This is particularly important in current times due to the results of climate change and its possible impact on the environment. Environmental changes may not only influence the populations of the Puffins on the island, but also the behaviours as demonstrated by this observational study (Goss-Custard & Sutherland, 1997). Behavioural changes may link to the rate of reproductive success and survival, thus may impact on populations. As there is limited information on the behaviours of Atlantic Puffins, the insight into the effect of the environment on Puffin behaviour provided by this study may enable further efforts into the conservation of this currently 'Vulnerable' seabird species (Birdlife International, 2016).

CONCLUSION

In conclusion, this research gives further insight into Puffin behaviours, specifically the range of behaviours they display on the water. The first prediction was found to be supported, as the sea state and weather was found to have a significant influence on a variety of behaviours. However, time of day did impact on the frequency of diving behaviours, with Puffins diving more frequently in the late morning. The second prediction was found to not be supported, as Puffins did not necessarily use information centres as they were not observed congregating in meeting places, interacting with conspecifics and/or Auks prior to flying out.

Further research should include the order in which the behaviours occurred which would allow for a closer look into foraging behaviour after interactions took place. Understanding the way in which Puffin behaviour changes in different environmental conditions could be useful to researchers and birdwatchers wanting to observe Puffins on the water; this would also aid conservationists as Puffin behaviours could be predicted during specific environmental conditions, including the impact of harsh weather. Additionally, little has been documented on the behaviours of Atlantic Puffins specifically whilst they are on the water; therefore, this study provides some insight into what behaviours the birds are likely to perform.

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