Effects of bird disturbance on the distribution of waterbirds on the Axe Estuary, East Devon

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Abstract

The Axe Estuary, East Devon, contains important estuarine habitats utilised by waterbirds. Seaton town alongside the estuary is being regenerated, which could increase recreational activities resulting in higher waterbird disturbance. The study investigated the temporal and spatial effects of human disturbance on waterbirds across three stratified habitat plots ($250m^2$); from Seaton harbour (Plot A), Axmouth (Plot B) and Colyford (Plot C) in the north. 96 surveys were conducted over the autumn/winter of 2017/2018.

Disturbance rates (combined 1.9 per hour, high tide, falling tide) of waterbirds decreased significantly over a south to north gradient. Disturbance events changed the abundance and distribution of birds, as disturbance levels increased there were highly significant negative correlations with reduced number of waterbirds. Walking activities on intertidal habitats and loose dogs significantly reduced the numbers of birds on Plot A and B, compared to significantly higher numbers of waterbirds on Plot C. Canoes and loose dogs also increased the probability of major flights in waterbirds on Plot A and B, comparable to the Exe Estuary study.

The construction of Seaton Quay will probably increase the levels of disturbance on Plot A and push more birds north, possibly leading to $250m^2$ of intertidal habitat being further underutilised.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

1.1 Introduction and aims

The Axe Estuary is a small estuary on the East Devon coast containing wintering waterbirds (BTO 2016). The estuary is a recommended Marine Conservation Zone (MCZ) with important habitats including, (intertidal mud, saltmarshes and saline reedbeds), which benefit waterbirds (DEFRA 2013). Seaton town alongside the estuary is being regenerated, which may increase recreational pressure on the estuary with more waterbird disturbance; smaller developments are of less obvious individual importance for birds but could have a significant cumulative impact (Hill 1997).

Human recreational activities are considered as potential threats to birds by altering the ability of animals to exploit important resources by directly restricting access to food supplies or roosting sites, or by altering the perceived quality of these sites (Gill 2007) and outside the breeding season, recreational pressure can reduce the use of wetland sites by birds (Hockin et al 1992).

By using a comparative site-based approach (Gill 2007) this study will compare disturbance rates and if numbers of waterbirds are reduced due to recreational pressure. Comparisons of temporal and spatial disturbance over three stratified habitat plots will show if abundance and distribution of water birds changes over a gradient from Seaton harbour in the south to Colyford in the north. Further analysis of disturbance observations will indicate the probability of what causes major flights.

1.2 Literature review

1.2.1 Effects of human disturbance on birds

Disturbance can be defined as any human activity that influences a bird's behaviour or survival (Liley et al 2011). There have been a wide variety of studies that have reviewed the effects of disturbance (Hockin et al 1992, Hill et al 1997, Gill 2007, Saunders et al 2000, Woodfield and Langston 2004).

Bird disturbance studies have examined behavioural effects such as changing feeding behaviour (Burger 1991, Fitzpatrick and Bouchez 1998), taking flight (Blumstein et al 2005), or being more vigilant (Randler 2006). There have been several research studies showing disturbance effects for a wide range of activities including aircraft (Drewitt 1999), traffic (Reijnen, Foppen & Veebbass 1997), dogs (Lord 2001, Banks & Bryant 2007). Other studies have focused on the effects of different types of water-based craft and the impacts from jet skis, kite surfers and windsurfers (Kirby et al 2004).

Variables such as habitat, flock size, cold weather, season and food availability can influence birds' abilities to respond to disturbance and scale of the impact (Stillman et al 2002). Also, birds can quickly become habituated to the effects or types of disturbance (Nisbet 2000, Rees et al 2005); the frequency and number of disturbance events can determine the extent to which birds can become habituated (Liley et al 2011).

There have been several studies examining the temporal and spatial effects of waterbird disturbance at a site-based scale (Belanger and Bedard 1989, Klein et al 1995, Lafferty 2001, Burton et al 2002, Ravenscroft et al 2007, Liley et al 2011). Gill (2007) recommends site-based studies are useful to assess the effects of human disturbance and comparisons or spatial and temporal data can yield information on the distribution of waterbirds; high levels of human activity may result in long term avoidance of an area.

1.2.2 Human disturbance effects on wintering waterbirds

During the non-breeding season the main impacts on waterbirds are interrupted foraging and roosting, linked to flight events (Woodfield and Langston 2004). There may be a seasonal variation in responsiveness to disturbance as individuals trade-off between increased predation risk (tolerating disturbance) and the increased risk of starvation (avoiding human presence) (Stillman & Goss-Custard 2002). Ravenscroft et al 2007 found shorebirds to be highly susceptible to disturbance due to their quick flight responses to humans and because they are exposed to high levels of recreational pressure on coastal habitats.

Disturbance can have a negative effect on the distribution of waterbirds especially on estuarine sites. Burton et al 2002 found four species of birds (brent goose *Branta bernicla*, shelduck *Tadorna tadorna*, dunlin *Calidris alpina* and redshank *Tringa totanus*) decreased in numbers closer to coastal footpaths. Brent geese and shelduck feeding on mud in Langstone Harbour were found to take flight when humans approached on foot at 200m (Martin 1973). Also, Ravenscroft et al 2007 found walkers were the most common potential disturbance event recorded in a study on two Suffolk estuaries.

A wintering bird disturbance study on the Exe Estuary found evidence bird distributions are related to access, parts of the estuary with the lowest levels of access are linked to the highest bird counts (Liley et al 2011). Birds were more likely to take flight when recreational activities took place on the intertidal or on the water. Bait digging, dog walking on mudflats and kitesurfing were activities which accounted for the majority of major flight events. Water-based recreation has been shown to affect the distribution of some species of ducks (Tuite et al 1984). The species most effected were teal *Anas crecca* and shoveler *Anas clypeata* with the greatest impacts caused by power boating, coarse fishing, sailing and rowing.

1.3 Research questions

The study investigated spatial and temporal effects of waterbird disturbance on three stratified habitat plots, located on a gradient south to north of the estuary. Little is known about the effects of recreation on waterbirds on the Axe Estuary and the intensity of these activities is expected to increase with further residential development.

RQ1: Are there different temporal disturbance rates of waterbirds within/between the three plots (A: south Seaton harbour, B: mid-Axmouth, C: north Colyford). Are these temporal disturbance rates different between plots, tides, season (autumn/winter)?

RQ2: What recreational activities (walkers, dogs, boats/canoes, trams) affect waterbird abundance within/between the three habitat plots?

A: Do different types mean recreational disturbance levels correlate negatively with mean avian species abundance on spatial habitat zones on the three plots?

B Do different types of mean recreational disturbance levels correlate negatively with conservation target species (black-tailed godwit *Limosa limosa*, curlew *Numenius arquata*, lapwing *Vanellus vanellus*) mean abundance on the three plots?

RQ3: What different disturbance events increase the probability of major bird flight responses on the three plots?

2 METHODOLOGY

2.1 Study location

The study was conducted on the Axe Estuary, East Devon (GR 25338 90515), a small intertidal estuary located alongside the town of Seaton. The estuary is connected to Lmye Bay in the south and is a recommended Marine Conservation Zone (0.33 km^2) with important priority mudflat and saltmarsh habitats (DEFRA 2013). The estuary is linked to the River Axe SAC in the north; Seaton Wetlands, Black Hole Marsh and Colyford Common Local Nature Reserves adjoin the estuary to the west (Seaton Bay 2018). The nearest mudflat and saltmarsh habitats are the Otter Estuary SSSI 19.1km west, the Exe Estuary Special Protection Area (SPA) 26.6km west and Chesil Beach and the Fleet SPA 31.5km further east (Figure 2.1).

Seaton (8,413 residents, Office for National Statistics 2011) is a small seaside town being regenerated, including a Tesco superstore, Premier Inn and Bovis residential estate. Seaton Quay, a development of 90 properties has been granted planning permission and will be based directly alongside the south-west wall of the estuary opposite intertidal mudflats, Planning Application Reference 16/0503/MRES, (Seaton Quay 2018).

Figure 2.1: Map showing location of Seaton/Axe Estuary (central) and wider mudflat (brown) and saltmarsh (green) habitats across Lyme Bay with SPA designations (blue) © Magic Maps

2.2 Site extent and characteristics of the study site

The Axe estuary bird surveys were conducted over three stratified intertidal 250m^2 plots, method recommended by (Bibby et al 1992, Klein et al 1995). The plots covered suitable intertidal habitat selected on a spatially uniform gradient (500m distance between plots to separate areas) from Seaton southern harbour to Colyford Common in the north of the estuary (Figure 2.2, Appendix 1 Field Plot Maps).

Further details of the plot areas are provided in Table 2.2. Permission to conduct the surveys on Seaton Wetlands were provided by James Chubb East Devon District Council Countryside Team Leader (Sites) (Appendix 2).

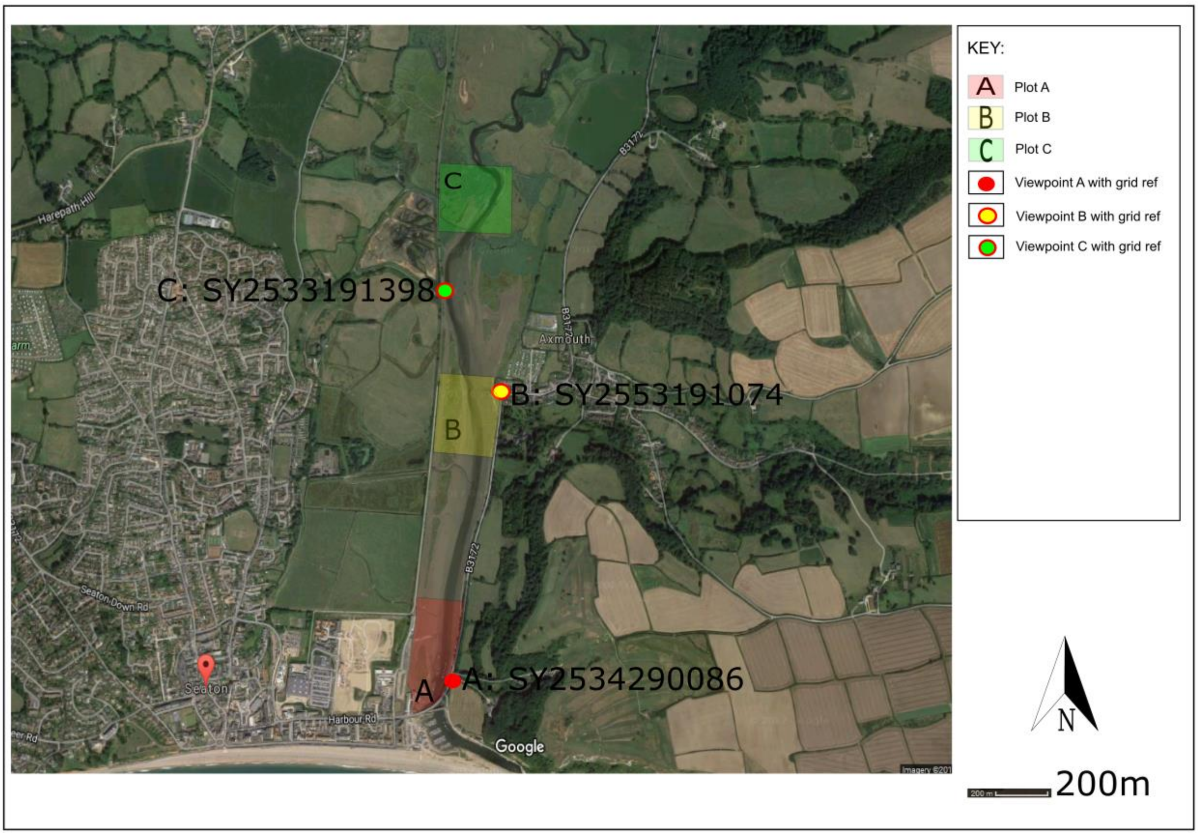

Figure 2.2: Map showing the location of the three study plots on the Axe Estuary © Google Maps

Table 2.2: Size, habitats and British National Grid Coordinates for the three study plot locations, + = UK BAP habitat types determined © MAGIC maps

Plot	Size (Ha)	UK BAP Priority Habitat types +	BNG Coordinates
A - Southern Harbour	250m^2	Intertidal mudflats, coastal saltmarsh, rivers/water	SY2532490086
B – Mid-Axmouth	250m^2	Intertidal mudflats, coastal saltmarsh, rivers/water	SY2553191074
C – North Colyford	250m^2	Intertidal mudflats, coastal saltmarsh, rivers/water, coastal and floodplain grazing marsh, reed beds	SY2549591685

2.3 Surveys (bird counts and human activity/disturbance surveys)

Bird counts and bird disturbance surveys were conducted systematically each week from October 2017 to February 2018 (Appendix 3). Surveys for each plot were conducted over an even range of tides (high, falling, low and rising), covering weekdays/weekends over suitable weather conditions (Appendix 6). Eight surveys per plot/per tide were conducted for statistical comparison (96 surveys). Disturbance events were recorded over 60 minutes and counts of water birds were recorded at the end of each survey, as recommended by (Liley et al 2011).

All human activity/disturbance surveys and bird counts were recorded on separate data sheets (Appendix 4 and 5) with protocol (Appendix 6).

2.4 Data management and analysis

Data was summarized and analysed using Microsoft Excel 2018 (Microsoft), QED Statistics v.1.5, (Pisces Conservation Ltd.) and SPSS 2018.

Following unsuccessful data transformation, F-tests for equal variance and large variation in counts of birds (unequal variance), non-parametric statistics are mostly used for analysis: Mann Whitney *U* tests for the comparison of two samples, and Kruskal Wallis (*H*) tests for comparison of several samples, Spearman Rank Correlation Coefficient (r_s) for correlations of different categories of disturbance (mean scale) and numbers of birds present (mean count). Binary Logistic regression (assumptions passed) was used to determine what event observations increased the probability of waterbirds flying.

Only significant statistical test screen shots are provided in the appendix for evidence (Appendix 7) and standard errors (±SE) with appropriate data.

3 RESULTS

3.1 RQ1: Are there different temporal disturbance rates of waterbirds within/between the three plots. Are these temporal disturbance rates different between tides, season (autumn/winter)?

3.1.2 Event rates

Events occurred on all three plots, nine of the 96 counts recorded no activity (9.4%). Plot A recorded no activity on only one count (3.1%, n = 32), Plot B two counts (6.3%, n = 32), Plot C six counts (19%, n = 32).

Out of 208 events the total mean site activity rate was (2.2±0.16 per hour, n = 96). Activity rates on Plot A (89 events) were higher (2.8±0.32 per hour, n = 32), slightly lower on Plot B (66 events) (2.1±0.22, n = 32) and lower on Plot C (53 events) (1.7±0.24, n = 32).

There was no significant difference in number of events between Plot A/B (*U = 404.5, n1= 32, n2 = 32, P = >0.05*) and B/C (*U = 409.5, n1 = 32, n2 = 32, P = > 0.05*). There was a significant difference in number of events between Plot A/C (*U = 321.5, n1 = 32, n2 = 32, P = <0.05*). Disturbance event activities are further broken down and analysed in question 3.

3.1.3 Bird disturbance rates

No plot was undisturbed, disruption (reaction scale 2-5) to birds was recorded at an overall mean site rate of (1.9±0.15 disturbances per hour, n = 96), scale 1 no actual response was not included in the analysis.

Plot A had a mean bird disturbance rate of (2.7±0.31 per hour, n = 32), Plot B had a lower disturbance rate of 1.8±0.21 (n = 32) with Plot C further lower (1.3±0.19 per hour, n = 32).

Plot A had significantly more number of bird disturbance events than Plot B (*U = 374, n1 = 32, n2 = 32, P <0.05*), further increasing in significance when comparing Plot A with C (*U = 269, n1 = 32, n2 = 32, P = <0.01*). Plot B also had a significantly more number of disturbance events than Plot C (*U = 384, n1 = 32, n2 = 32, P = <0.05*).

3.1.4 Tidal bird disturbance rates (all, high tide, falling tide, low tide, rising tide)

Table 3.1.4: Mean bird disturbance rates (per hour) across tides

Tide	N	High-tide	Falling-tide	Low-tide	Rising-tide
All plots	96	2.1±0.35	1.6±0.24	2.0±0.28	1.8±0.31
Plot A	32	3.4±0.79	2.0±0.42	2.6±0.60	2.6±0.63
Plot B	32	2.0±0.38	2.3±0.37	1.7±0.55	1.3±0.31
Plot C	32	1.7±0.59	0.7±0.25	1.8±0.16	1.7±0.59

High tide across all plots had the highest mean bird disturbance rate of (2.1±0.35 per hour, n = 32) with falling tide the lowest rate (1.6±0.24 per hour, n = 32). Plot A high tide has the highest disturbance rate (3.4±0.79 per hour, n = 32), with Plot C falling-tide (0.7±0.25, n = 32) the lowest.

There was no significant difference between bird disturbance across all tides (*H = 1.17, DF = 3, P = >0.05*), Plot A all tides (*H = 1.88, DF = 3, P = > 0.05*), Plot B all tides (*H = 4.23, DF = 3, P = > 0.05*), Plot C all tides (*H = 7.56, DF = 3, P = > 0.05*).

At high tide there was no difference between Plot A/B (*U = 20, n1 = 8, n2 = 8, P = >0.05*), there was a significant difference between Plot A/C at high tide (*U = 12, n1 = 8, n2 = 8, P < 0.05*). Plot B also had a significantly higher number of disturbance events than Plot C (*U = 15, n1 = 8, n1 = 8, P = <0.05*).

At low tide there was no significant difference between Plot A/B (*U = 20, n1 = 8, n2 = 8, P = >0.05*) also Plot A/C and Plot B/C at low tide (*U = 24, n1 = 8, n2 = 8, P = >0.05*).

Looking at bird disturbance rates at falling tide there was a significant difference between Plot A/C (*U = 10.5, n1 = 8, n2 = 8, P = <0.05*) also B/C (*U = 6.5, n1 = 8, n2 = 8, P = <0.01*) but A/B were not different (*U = 27, n1 = 8, n2 = 8, P = >0.05*).

Rising tide had no difference in bird disturbance rates between plots. A/B (*U = 16, n1 = 8, n2 = 8, P = >0.05*), A/C (*U = 20, n1 = 8, n2 = 8, P = >0.05*), B/C (*U = 30.5, n1 = 8, n2 = 8, P = >0.05*).

3.1.5 Seasonal bird disturbance rates (autumn/winter)

Table 3.1.5: Mean seasonal disturbance rates (per hour) autumn/winter

Season/Plot	N	All plots	Plot A	Plot B	Plot C
Autumn (1/10/18-28/11/18)	46	1.8±0.20	2.2±0.34	1.8±0.34	1.4±0.34
Winter (5/12/17-12/2/2018	50	2.3±0.22	3.2±0.47	1.8±0.25	1.1±0.18

Total mean bird disturbance rates were similar for autumn (1.8±0.20 per hour, n = 46) and winter (2.3±0.22 per hour winter, n = 50). Plot A had the highest autumn rates (2.2±0.34 per hour, n = 15) and winter rates (3.2±0.47 per hour, n = 15), whereas Plot C had the lowest autumn (1.4±0.34 per hour, n = 15) and winter rates (1.1±0.18 per hour, n = 15).

Plot A disturbance rates were slightly higher for winter (3.2±0.47 per hour) than (2.2±0.34 autumn). There was no significant difference between Plot A autumn/winter (*U = 78, n1 = 15, n2 = 15, P > 0.05*) or Plot B (autumn 1.8±0.34 per hour/winter 1.8±0.25 per hour) (*U = 123.5, n1 = 16, n1 = 16, P = >0.05*) and Plot C (autumn 1.4±0.34 per hour/winter 1.1±0.18 per hour) (*U = 16.5, n1 = 15, n2 = 15, P = >0.05*).

Looking at different autumn/winter plot comparisons, Plot A (autumn)/Plot B(winter) rates were not significantly different (*U = 94.5, n = 15, n2 = 15, P > 0.05*).

Plot A (autumn) had significantly higher seasonal rates than Plot C (winter) (*U = 67, n1 = 15, n2 = 15, P = <0.05*) but Plot B (autumn)/Plot C (winter) disturbance rates were not significantly different (*U = 92.5, n1 = 16, n2 = 16, P = >0.05*).

3.2 RQ2: What recreational activities (walkers, dogs, boats/canoes, trams) affect water bird abundance within/between the three habitat plots?

A: Do different types of mean recreational disturbance levels correlate negatively with mean avian species abundance on spatial habitat zones on the three plots?

3.2.1 Potential disturbance events

Potential disturbance rates have been compared by plot, tide and season in Q1, here they are further broken down into number of types of activities across plots (Table 3.2.1). Out of 208 potential disturbance events, trams (31%), walkers (27%) and dogs (14%) were the most common potential disturbance events across all plots (n = 96).

Out of 89 events in Plot A (n = 32) walkers (48%), dogs (16%) and other activities (15%) were most common. In Plot B (n = 32) trams (24%), dogs (21%) and walker (18%) events occurred. In Plot C trams were most common (68%), followed by raptors (17%).

Potential disturbance events are further broken down by activity/zone and response of birds in Table 3.3.1 Q3.

Table 3.2.1: Number of potential disturbance events per plot

Number of potential disturbance events	Plot A	Plot B	Plot C	Total
No of samples	32	32	32	96
No of tram events	12	16	36	64
No of walker events	43	12	1	56
No of dog events	14	14	2	30
No of other events	13	7	3	23
No of raptor events	2	9	9	20
No of boat/canoe events	5	8	2	15
Total	89	66	53	208

3.2.2 Species abundance (bird counts)

During the study a total of 5025 individuals of 23 water bird species were recorded. Overall on average, (52.34, n = 96) species were recorded per survey. In terms of UK population status (Eaton et al 2015); four species (17%) were red status, 13 species (57%) were amber status and six species (26%) were green status. Red listed species (black-tailed godwit, curlew and lapwing) were recorded across all plots. 13 species were recorded in Plot A, 17 in Plot B and 19 in Plot C.

In Plot A wigeon on average had the highest total mean abundance ($\overline{x}$ = 19.69, n = 32), following by lapwing ($\overline{x}$ = 11.22, n = 32) and oystercatcher ($\overline{x}$ = 4.47, n = 32). In Plot B lapwing had the highest total mean abundance ($\overline{x}$ = 16.28, n = 32), closely followed by wigeon ($\overline{x}$ = 15.29, n = 32) and redshank ($\overline{x}$ = 13.50, n = 32). In Plot C lapwing ($\overline{x}$ = 16.38, n = 32) had the highest total mean abundance followed by mallard ($\overline{x}$ = 5.78, n = 32) and redshank ($\overline{x}$ = 5.09, n = 32). Table 3.2.2 provides a summary of bird count data.

Table 3.2.2: Summary of bird count data. Table gives the mean (range) [number of counts in which species present], for all species and all locations. The total number of counts undertaken at each plot are given in the first row, + = data from IUCN, * = BoCC list from Eaton et al 2015

Common Name	Scientific Name	Plot A	Plot B	Plot C	IUCN+	UK BoCC*
No of counts		32	32	32	LC	
Bar-tailed godwit	*Limosa lapponica*	0.03 (0-1) [1]	0 (0-0) [0]	0 (0-0) [0]	LC	Amber
Black-tailed godwit	*Limosa limosa*	0.34 (0-7) [2]	8 (0-35) [13]	0.34 (0-3) [4]	LC	Red
Canada goose	*Branta canadensis*	0 (0-0) [0]	0.16 (0-5) [1]	3.07 (0-96) [2]	LC	Green
Common sandpiper	*Actitis hypoleucos*	0.41 (0-2) [9]	0 (0-0) [0]	0 (0-0) [0]	LC	Amber
Cormorant	*Phalacrocorax carbo*	0.81 (0-4) [15]	0.03 (0-1) [1]	0.72 (0-6) [10]	LC	Green
Curlew	*Numenius arquata*	0.44 (2)[9]	6.19 (0-45) [19]	2.34 (0-50) [13]	LC	Red
Dunlin	*Calidris alpina*	0 (0-0) [0]	0.13 (0-2) [2]	0.63 (0-20) [1]	LC	Amber
Greenshank	*Tringa nebularia*	0 (0-0) [0]	0.03 (0-1) [1]	0 (0-0) [0]	LC	Amber
Grey Heron	*Ardea cinerea*	0 (0-0) [0]	0 (0-0) [0]	0.09 (0-1) [3]	LC	Green
Lapwing	*Vanellus vanellus*	11.22 (0-61) [15]	16.28 (0-340) [6]	16.38 (0-200) [8]	LC	Red
Little egret	*Egretta garzetta*	0.31 (2) [8]	0.94 (0-5) [18]	0.28 (1) [9]	LC	Green
Little grebe	*Tachybaptus ruficollis*	0.09 (2) [2]	0.53 (5) [8]	0.59 (3) [13]	LC	Green
Mallard	*Anas platyrhynchos*	2.53 (10) [20]	6.34 (22) [22]	5.78 (28) [24]	LC	Amber
Moorhen	*Gallinula chloropus*	0 (0-0) [0]	0.03 (0-1) [1]	1.38 (0-5) [18]	LC	Green
Mute swan	*Cygnus olor*	0 (0-0) [0]	0 (0-0) [0]	0.03 (0-1) [1]	LC	Amber
Oystercatcher	*Haematopus ostralegus*	4.47 (0-15) [20]	1.34 (8) [10]	0.06 (2) [1]	LC	Amber
Redshank	*Tringa totanus*	2.09 (0-10) [23]	13.50 (0-47) [29]	5.09 (0-31) [21]	LC	Amber
Ringed plover	*Charadrius hiaticula*	0 (0-0) [0]	0.16 (0-4) [2]	0 (0-0) [0]	LC	Red
Shelduck	*Tadorna tadorna*	0.50 (0-4) [6]	0.78 (0-6) [9]	0.91 (0-7) [8]	LC	Amber
Snipe	*Gallinago gallinago*	0 (0-0) [0]	0 (0-0) [0]	0.88 (0-17) [2]	LC	Amber
Spotted redshank	*Tringa erythropus*	0 (0-0) [0]	0 (0-0) [0]	0.03 (0-1) [1]	LC	Amber
Teal	*Anas crecca*	0 (0-0) [0]	0.06 (2) [1]	2.44 (0-22) [10]	LC	Amber
Wigeon	*Anas penelope*	19.69 (0-130) [21]	15.29 (0-156) [14]	3.31 (0-51) [9]	LC	Amber

3.2.3 Mean species abundance per plot per count

There was a south to north gradient in terms of mean species abundance per plot/per count. Plot A had a mean abundance of (7.72±0.33, n = 32) Plot B (10.73±0.20, n = 32) and Plot C (11.53±4.13, n = 32) but there was no significant difference between the mean counts per sample of Plot A/B/C (*H = 3.49, DF = 2, P = >0.05*), also no difference between mean counts per sample in plots A/B (*U = 397.6, n1 = 32, n2 = 32, P = >0.05*) and plots A/C (*U = 505, n1 = 32, n2 = 32, P = >0.05*) but there was a slight difference between Plot B/C (*U = 386.5, n1 = 32, n2 = 32, P < 0.05*).

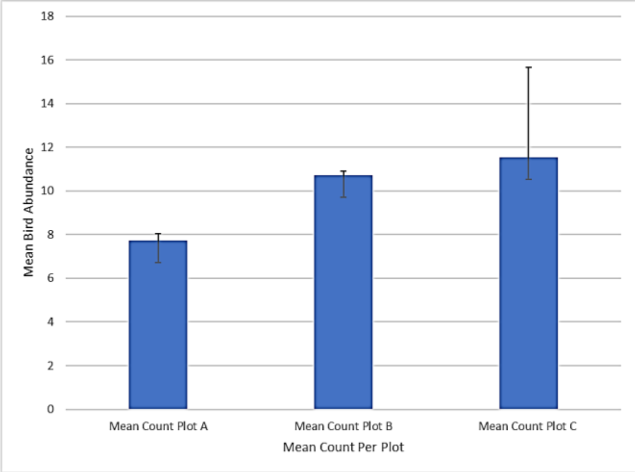

Figure 3.2.3: Mean bird abundance (±SE) observed per count for Plot A B C

3.2.4 Disturbance events and bird count correlations

For each plot mean reaction per disturbance event and mean bird count (previous hour) were tested for correlations. All correlation coefficients are given in Table 3.2.4.

Correlation coefficients range from -1 to 1, and the closer the value of 0 the weaker the correlation. Negative values indicate the higher the levels of disturbance the lower the number of birds, due to being moved away from the plot. Table 3.2.4 provides shaded cells with a significance of at least <0.05 (amber) and <0.01 (red). Blank spaces show plots with under eight samples.

Table 3.2.4: Correlation matrix between disturbance level and bird count

Species group	Activity	All Plots	Plot A	Plot B	Plot C
n (total count sample)		96	32	32	32
All birds	All habitat zones	-0.382	-0.368	-0.482	-0.405
All birds	All water habitat	-0.299			
All birds	All intertidal habitat	-0.671	-0.587	-0.743	
All birds	All dogs/intertidal	-0.618	-0.467	-0.710	
All birds	All walkers/intertidal	-0.691	-0.687	-0.745	
All birds	All trams/west sea wall	-0.148	-0.189	-0.447	-0.100
Black-tailed godwit	All habitat zones	-0.126			
Curlew	All habitat zones	-0.235		-0.231	
Lapwing	All habitat zones	-0.726			

n = maximum total number of counts, red = highly significant correlation <0.01, amber = significant correlation <0.05, blanks = less than 8 samples.

Across all plots correlations were significantly negative. On Plot B there was a highly significant correlation (r_s = *-0.482, n = 32, P = <0.01*) with high levels of disturbance (all habitat zones) and lower bird counts (all birds). There were no significant correlations with disturbance of birds on water habitats, this could possibly linked to a small sample size (n = 11).

Plot A (r_s = *-0.587, n = 24, P = <0.01*) and Plot B (r_s = *-0.743, n = 17, P = <0.01*) disturbance levels on all intertidal habitats negatively correlated with bird counts to a high level; Plot C did not have enough samples due to non-access to the general public. There were significant correlations on Plot A and B for all walkers on intertidal habitat, Plot A highly significant (r_s = *-0.687, n = 19, P = <0.01*) probably due to being close to Seaton harbour. Dog disturbance on intertidal habitats had a highly significant correlation with bird counts across all plots combined (*r_s = -0.618, n = 24, P = <0.01*), also a significant correlation in Plot B (*r_s = -0.710, n = 12, P = <0.05*). Interestingly, there were no negative correlations with tram activity across all plots.

3.2.5 B Do different types of mean recreational disturbance levels correlate negatively with conservation target species (black-tailed godwit, curlew, lapwing) abundance on the three plots?
Focusing on red listed target species correlations, samples had to be combined across all plots due to lower sample numbers; there were highly significant negative correlations with sensitive species such as lapwing (*r_s = -0.726, n = 18, p = <0.01*) and curlew (*r_s = -0.235, n = 8, P = <0.05*) reacting to human presence (Table 3.2.4).

3.3 RQ3: What different disturbance events increase the probability of major bird flight responses on the three plots?

3.3.1 Levels of disturbance: behavioural response

208 potential disturbance events generated a total of 298 species specific observations. Of these 36 (12%) resulted in no visible change in behaviour. 182 (61%) of these observations resulted in a disturbance of a given species, with 80 (27%) involving birds undertaking a major flight (displacement of over 50 metres). Dogs with leads off (29%, n = 23), canoes (21%, n = 17) and walkers (18%, n = 14) caused most of the major flight events.

Table 3.3.1 summarizes all potential disturbance observations according to zone and activity. Over a third of observations took place on the intertidal (38%, n = 113), followed by (27%, n = 81) on the tram bank and (15%, n = 44) by air.

Intertidal events (48%, n = 38) resulted in most major flights, followed by water events (25%, n = 20) and air events (16%, n = 13). Notably (71%, n = 20) of all water events resulted in a major flight compared to (34%, n = 38) on the intertidal.

Table 3.3.1: Number of potential disturbance observations and response of birds by activity and zone

Activity by zone	No response	Alert	Walk/swim	Short flight	Major flight	Totals
Intertidal						
Dog walker, dog off lead	0	8	3	0	23	34
Dog walker, dog on lead	2	2	4	1	1	10
Walker	4	32	14	5	14	69
Intertidal total	6	42	21	6	38	113
Water						
Boat	0	3	0	0	3	6
Canoe	0	4	1	0	17	22
Water total	0	7	1	0	20	28
Air						
Raptor	0	25	4	2	13	44
Air total	0	25	4	2	13	44
West tram bank						
Tram	27	21	16	8	9	81
Tram total	27	21	16	8	9	81
Other						
Cars, lorries, buses	3	21	6	2	0	32
Other total	3	21	6	2	0	32
Totals	36	116	48	18	80	298

3.3.2 Variation between sites

There was some variation between plots in the number of potential disturbance observations recorded and the proportion that resulted in a major flight (Table 3.3.2). Plot B recorded the highest major flight proportion (32%, n = 32), followed by slightly lower Plot A (25%, n = 29) and Plot C (23%, n = 19). There was no significant variation in scale of reaction responses per plot. Plot A/B/C (*H = 4, DF = 4, P = > 0.05*).

Table 3.3.2: Number of different types of response to disturbance activities by location

Location	Number of surveys	No response	Alert	Walk/swim	Short flight	Major Flight	Total
Plot A	32	4	54	20	11	29	118
Plot B	32	16	32	14	5	32	99
Plot C	32	16	30	14	2	19	81
Total	96	36	116	48	18	80	298

3.3.3 What activities increase the probability of a major flight response?

Binary logistic regression was used to determine the probability of what disturbance activities caused a major flight across all birds. The model contained four activities (dogs without leads, dogs with leads, boats/canoes and walkers), plus raptors Plot C. Plot A, B and C were tested separately.

Plot A

The model was statistically significant χ^2 (4, n = 118) = 30.48, P = <0.001 and explained between 23% (Cox and Snell R squared) and 34% (Nagelkerke R Squared) of the variance in major flights and correctly classified 80.5% of cases.

As shown in Table 3.3.3a, three of the variables made a statistically significant contribution to the model. The strongest predictor of major flight was canoes/boats reporting an odds ratio of 55% then dogs off lead (49.5%) and walkers (8.4%). Dogs off lead were nearly six time more likely than walkers to flush birds, canoes/boats slightly more. Dogs on lead may have had too few samples for the model.

Table 3.3.3a: SPSS output of binary logistic regression Plot A, activities determined by major flight

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	DOGSOFFLEAD	3.902	1.113	12.292	1	.000	49.500	5.588	438.472
	DOGSONLEAD	-17.706	28420.722	.000	1	1.000	.000	.000	.
	WALKERS	2.133	1.070	3.976	1	.046	8.442	1.037	68.715
	CANOESBOATS	4.007	1.250	10.270	1	.001	55.000	4.742	637.898
	Constant	-3.497	1.015	11.866	1	.001	.030		

a. Variable(s) entered on step 1: DOGSOFFLEAD, DOGSONLEAD, WALKERS, CANOESBOATS.

Plot B

The model was statistically significant χ^2 (4, n = 99) = 30.14, P = <0.001 and explained between 26% (Cox and Snell R squared) and 37% (Nagelkerke R Squared) of the variance in major flights and correctly classified 80.8% of cases.

As shown in Table 3.3.3b, two of the variables made a statistically significant contribution to the model. The strongest predictor of major flight was dogs of leads reporting an odds ratio of 12.30%

then then canoes/boats (11.28%). Dogs off lead were 35 times more likely to flush birds than walkers, with canoes/boats slightly less.

Table 3.3.3b: SPSS output of binary logistic regression Plot B, activities determined by major flight

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	DOGSOFFLEAD	2.510	.754	11.072	1	.001	12.300	2.805	53.938
	DOGSONLEAD	-.535	1.126	.226	1	.635	.586	.064	5.320
	WALKERS	-1.074	1.099	.955	1	.328	.342	.040	2.945
	CANOESBOATS	2.423	.682	12.613	1	.000	11.275	2.961	42.928
	Constant	-1.411	.353	16.005	1	.000	.244		

a. Variable(s) entered on step 1: DOGSOFFLEAD, DOGSONLEAD, WALKERS, CANOESBOATS.

Plot C

The model was statistically significant χ2 (4, n = 81) = 26.68, P = <0.001 and explained between 28% (Cox and Snell R squared) and 42% (Nagelkerke R Squared) of the variance in major flights and correctly classified 86.4% of cases.

As shown in Table 3.3.3c, only one of the variables made a statistically significant contribution to the model. The strongest predictor of a major flight was canoes/boats with an odds ratio of 43%. Canoes/boats were predicted to be around 18 times more likely to flush birds than raptors, there was not enough samples in the model to predict dogs off lead and walkers.

Table 3.3.3c: SPSS output of binary logistic regression Plot C, activities determined by major flight

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	DOGSOFFLEAD	23.355	28420.721	.000	1	.999	1.389E+10	.000	.
	WALKERS	23.355	28420.721	.000	1	.999	1.389E+10	.000	.
	CANOESBOATS	3.761	1.193	9.940	1	.002	43.000	4.149	445.609
	RA	.871	.692	1.584	1	.208	2.389	.615	9.272
	Constant	-2.152	.472	20.739	1	.000	.116		

a. Variable(s) entered on step 1: DOGSOFFLEAD, WALKERS, CANOESBOATS, RA.

4 DISCUSSION

4.1 Disturbance rates of waterbirds

The south of the Axe Estuary received higher rates of bird disturbance than the north, demonstrated by a significant difference in number of total events between Plot A (Seaton harbour), with access on both sides of the estuary and Colyford Common (Plot C), with restricted access. This was further confirmed with actual disturbance events, where there were were significant differences between Plot A and Plot B (mid-Axmouth), increasing in significance between Plot A/C.

Tidal bird disturbance rates at high and falling tide were also more significant in south than the north, where waterbirds had limited areas of intertidal habitat to feed and roost on. There was no difference in disturbance rates between low and rising tide, maybe due to birds having larger areas to feed on. Also, there were no seasonal differences in bird disturbance due number of activities rising over the Christmas holiday levelling out events.

This study is comparable to other waterbird disturbance studies; the Axe Estuary disturbance rate (1.9 per hour) was much lower than the Exe study (18.04 per hour), Solent study (12.87 per hour) and nearer the north Kent study (4.18 per hour) (Liley et al 2011). Disturbance rates were similar to the Stour-Orwell SPA bird disturbance study (Ravenscroft et al 2007), where the Stour Estuary had a lower disturbance rate of 1.9 per hour than the busier Orwell (6.5 per hour).

The highest disturbance rate occurred at Plot A high tide (3.5 per hour), probably due to ease of access for boats, canoes and walkers. Bird disturbance will surely increase in frequency when Seaton Quay is built on the western sea wall.

4.2 Recreational effects on waterbird distribution

A range of recreational activities occur on the Axe Estuary including regular trams, dog walkers and canoeing. Interestingly, there was a higher mean abundance of birds further north on Plot B/C including more sensitive species such as lapwing and curlew.

Across all plot habitats there is evidence that higher disturbance levels reduce waterbird abundance and change distribution; highly significant in Plot B. On the intertidal habitats of Plot A and B higher disturbance reduced bird numbers, probably linked to easy seawall access. Dog disturbance on the intertidal further reduced waterbird numbers across all plots, particularly Plot B, also walkers reduced bird numbers significantly on Plot A. Dog walking accounted for a large proportion of bird disturbance on the Exe (Liley 2011) and was found to reduce bird abundance by 41% in a study by (Banks et al 2007).

Recreational events on the water (all plots) did not reduce bird numbers significantly (more significant on the larger Exe), maybe due to a lower number of samples. This was also the case with trams on the western sea wall, species such as wigeon *Anas Penelope* and curlew may have habituated to the slow-moving tram. Ravenscroft et al 2007 also encountered habituation on the Stour-Orwell where birds did not respond significantly to vehicles.

Across all plots disturbance did reduce the number of lapwing and curlew numbers significantly, demonstrating their sensitive nature; there were higher mean numbers of lapwing, curlew and redshank on less disturbed Plots B/C.

As predicted, Plot A had higher disturbance rates and mean disturbance levels with lower mean abundance of birds and species; with more development this area of intertidal saltmarsh could be further underutilised.

4.3 What increased the probability of a major flight event?

Dogs off lead in Plot A and B resulted in an increased likelihood of waterbirds flying off, the Exe Estuary study also reported dogs off lead increasing the probability of major flights (Liley 2011). Across all plots canoes on the water had a similar negative effect as they easily penetrated more shallow waters (Kirby 2004), particularly flushing high tide roosts. White 1993 also demonstrated waterbirds were often forced to fly between lakes at Lee Valley Park in response to sailing. Interestingly, flocks of lapwing and wigeon were regularly flushed north to Colyford Common grassland from Plot A and B after dog and canoe disturbance events. The wider floodplain does provide essential areas of lagoon and wet grassland feeding and roosting habitat if there are higher levels of disturbance on the estuary.

4.4 Limitations and recommendations

This study should be compared before and after construction to ascertain in there are increased levels of disturbance, particularly on Plot A.

Throughout the construction period care should be taken not to pollute or damage the estuarine habitats and screening measures should be used to shield birds from noise disturbance.

In future studies it would be useful to control for prey density to ascertain if there is any difference across the plots (Gill et al 2001), also disturbance distance (Liley et al 2011).

5 CONCLUSION

Disturbance rates of waterbirds decreased significantly from Seaton harbour (Plot A) in the south to Colyford in the north (Plot C). At high/falling tide there were significant declines in disturbance rates between Plot A/Plot C, linked to ease of access for canoes and dog walkers on the southern mudflats.

Number of disturbance events also decreased from Plot A to C with significant increases in counts of waterbirds between Plot B/C. Events significantly changed the distribution of birds, as disturbance levels increased there were several negative correlations with reduced number of birds across all plots, walkers on the intertidal and loose dogs reduced numbers of waterbirds on Plot A and B. Sensitive species such as lapwing and curlew were more abundant on Plot B and C, probably due to higher disturbance on Plot A.

Canoes and loose dogs increased the probability of major flights in waterbirds on Plot A and B in line with the Exe Estuary Study (Liley 2011).

The construction of Seaton Quay will probably increase the levels of disturbance on Plot A and push more birds north possibly leading to 250m^2 of intertidal habitat being further underutilised.

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APPENDICES

Appendix 1: Field Plot Maps

Axe Estuary Bird Disturbance Study Plot A Field Map

Key: Plot A Count Zones: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shore line, E = central water

Axe Estuary Bird Disturbance Study Plot B Field Map

Key: Count Zone: Plot B: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shore line, E = central water

Axe Estuary Bird Disturbance Study Plot C Field Map

Key: Count Zone: Plot C: A = east mudflat, B = west mudflat, C = east saltmarsh, D = west saltmarsh, E = east reedbed, F = west reedbed, G = central water

Appendix 2: Email from East Devon District Council confirming permission to undertake survey work on Council owned reserves.

From: James Chubb [JChubb@eastdevon.gov.uk]
Sent: 15 August 2017 09:41
To: Matthew White; Charles Plowden
Subject: RE: University of Oxford Axe Estuary bird disturbance study - UNCLASSIFIED:

Hi Matthew,

My apologies, I thought that I had already given you a green light email?

In which case, please take this to be a confirmation that the EDDC Countryside Service are supportive of your project proposal and will be happy to provide support in terms of access and facilities on the Seaton Wetlands side of the estuary.

Best wishes
James

James Chubb
Countryside Team Leader (Sites)
East Devon District Council
07964 132 282

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Appendix 3: Bird Survey and Weather Timetable

DATE	TIME	PLOT	TIDE	CLOUD	RAIN	TEMP	WIND DIRECTION	WIND STRENGTH
01/10/2017	10:41	A	LT	8	LIGHT	15	SSW	3
01/10/2017	12:41	B	RT	8	LIGHT	16	SW	4
01/10/2017	16:03	C	HT	8	NONE	18	WSW	4
02/10/2017	09:33	A	FT	1	NONE	15	W	3
02/10/2017	11:33	B	LT	4	NONE	16	W	4
02/10/2017	13:33	C	RT	7	NONE	16	W	4
09/10/2017	09:27	A	HT	7	NONE	15	WNW	2
09/10/2017	12:27	B	FT	8	NONE	16	WNW	3
09/10/2017	15:07	C	LT	7	NONE	16	NW	3
10/10/2017	09:07	A	RT	8	NONE	14	WSW	3
10/10/2017	11:07	B	HT	8	NONE	15	SW	4
10/10/2017	13:07	C	FT	8	LIGHT	15	SW	4
17/10/2017	11:48	A	LT	8	NONE	13	WSW	3
17/10/2017	13:48	B	RT	8	MOD	13	SW	2
17/10/2017	18:08	C	HT	8	LIGHT	13	ENE	2
18/10/2017	10:34	A	FT	8	LIGHT	12	NE	3
18/10/2017	12:34	B	LT	8	LIGHT	12	NNE	2
18/10/2017	14:34	C	RT	8	NONE	13	NNE	2
26/10/2017	11:32	A	HT	8	NONE	14	SW	2
26/10/2017	13:32	B	FT	5	NONE	15	SW	2
26/10/2017	16:13	C	LT	8	NONE	15	S	2
27/10/2017	10:29	A	RT	2	NONE	8	WNW	2
27/10/2017	12:29	B	HT	8	NONE	13	WNW	3
27/10/2017	14:29	C	FT	8	NONE	15	WNW	3
04/11/2017	11:42	A	LT	4	NONE	11	NW	4
04/11/2017	13:42	B	RT	4	NONE	11	NW	4
05/11/2017	10:53	A	FT	3	NONE	10	NW	4
05/11/2017	13:24	B	LT	5	LIGHT	10	NW	4
05/11/2017	15:24	C	RT	4	NONE	10	NW	4
08/11/2017	09:54	C	HT	1	NONE	8	N	3
10/11/2017	11:32	A	HT	3	NONE	12	NW	3
10/11/2017	13:32	B	FT	4	NONE	12	NW	4
10/11/2017	16:22	C	LT	6	NONE	10	NW	3
13/11/2017	13:09	A	RT	5	NONE	9	N	3
13/11/2017	15:09	B	HT	6	NONE	8	N	3
13/11/2017	17:09	C	FT	6	NONE	6	NW	2
20/11/2017	12:48	A	LT	8	NONE	13	WSW	4
20/11/2017	15:48	B	RT	8	NONE	12	WSW	3
21/11/2017	14:32	B	LT	8	LIGHT	14	SW	4
21/11/2017	16:23	C	RT	8	NONE	14	SW	4
23/11/2017	09:45	C	HT	1	NONE	9	WSW	4
23/11/2017	11:45	A	FT	1	NONE	11	WSW	4

27/11/2017	14:03	B	FT	8	NONE	9	W	3
27/11/2017	15:03	C	FT	8	LIGHT	9	WSW	3
28/11/2017	11:28	A	RT	1	NONE	7	NNW	4
28/11/2017	13:28	B	HT	2	NONE	7	NW	3
05/12/2017	12:57	C	LT	8	NONE	10	WNW	2
06/12/2017	09:00	A	HT	8	NONE	10	SW	3
09/12/2017	13:08	A	FT	8	NONE	5	WSW	2
09/12/2017	16:08	B	LT	8	NONE	4	SW	2
11/12/2017	11:14	C	RT	8	NONE	2	N	5
11/12/2017	12:14	C	HT	5	NONE	3	N	5
13/12/2017	08:01	A	LT	8	LIGHT	10	WSW	4
13/12/2017	10:01	B	RT	8	LIGHT	10	WSW	4
17/12/2017	15:00	A	RT	8	NONE	10	WSW	3
18/12/2017	09:40	B	FT	1	NONE	6	N	2
18/12/2017	11:50	C	LT	1	NONE	7	NNE	2
21/12/2017	08:00	A	HT	8	NONE	10	WSW	2
21/12/2017	10:00	C	FT	8	NONE	11	WSW	2
22/12/2017	08:30	B	HT	8	NONE	10	WSW	2
24/12/2017	15:14	A	LT	8	NONE	10	SW	3
25/12/2017	09:01	C	HT	8	NONE	11	SSW	5
25/12/2017	11:01	A	FT	8	NONE	11	SSW	5
26/12/2017	08:03	C	RT	6	NONE	5	WSW	3
27/12/2017	08:00	B	RT	8	NONE	5	NNW	5
29/12/2017	08:58	B	LT	8	NONE	8	W	4
31/12/2017	10:10	C	LT	8	NONE	8	SW	3
31/12/2017	13:10	A	RT	8	MOD	10	SW	4
01/01/2018	09:00	B	FT	8	MOD	6	WNW	3
04/01/2018	08:54	B	HT	8	NONE	12	WSW	4
04/01/2018	11:15	C	FT	7	NONE	12	WSW	5
05/01/2018	09:36	A	HT	2	NONE	6	WSW	3
06/01/2018	15:00	A	LT	7	NONE	5	NNE	3
06/01/2018	17:00	B	RT	7	NONE	5	NNE	3
07/01/2018	12:48	A	FT	3	NONE	5	NE	4
07/01/2018	15:48	B	LT	3	NONE	3	NE	3
09/01/2018	10:38	C	RT	8	NONE	8	SSE	8
09/01/2018	12:38	C	HT	8	NONE	9	SSE	3
12/01/2018	15:46	B	HT	8	NONE	8	SSE	3
12/01/2018	17:46	C	FT	8	NONE	8	SSE	3
13/01/2018	15:01	A	RT	8	NONE	7	SSE	4
13/01/2018	17:01	A	HT	8	NONE	7	SSE	3
15/01/2018	09:51	C	LT	8	MOD	11	W	4
16/01/2018	09:31	B	FT	3	NONE	6	W	4
27/01/2018	16:06	A	FT	8	NONE	11	WSW	3
28/01/2018	09:45	A	LT	8	NONE	11	WSW	3
28/01/2018	11:45	B	RT	7	NONE	11	SW	3

30/01/2018	10:45	B	LT	1	NONE	3	SE	2
30/01/2018	12:45	C	RT	1	NONE	6	S	2
02/02/2018	07:46	C	HT	1	NONE	3	NW	3
04/02/2018	16:38	A	RT	4	NONE	4	NNE	3
05/02/2018	10:39	B	HT	3	NONE	2	NNE	3
05/02/2018	12:39	C	FT	3	NONE	4	NE	3
08/02/2018	12:45	A	HT	8	NONE	8	SSW	4
08/02/2018	14:45	B	FT	8	NONE	8	SSW	4
12/02/2018	11:04	C	LT	1	NONE	5	W	3

Appendix 4: Bird Disturbance Recording Sheet

AXE ESTUARY: BIRD DISTURBANCE STUDY 2017-18

Disturbance Recording Sheet

Plot (A,B,C)_____ Observer ______________________ Date___________Time (24h)__________________Tide (HT,FT,LT,RT) ________________

Weather: Cloud cover (0-8)______ Precipitation (LIGHT, MODERATE, HEAVY) _________________ Temp (C) from _____ to ________________

Wind (direction) _______ Strength (Beaufort 0-12) _______ Visibility (0-100m, 100-300m, 300m+)____

Event No.	Bird Species	Bird Count	Disturbance Type	Disturbance time	Reaction (Scale 1-5)	Habitat before event	Behaviour before event	Other comments

Disturbance type: WA = walker, WD = walker with dog, WL = walker with dog off lead, TR = tram, RA = raptor, CA = canoe, BO = boat, OT = other

Bird reaction: 1 = no response, 2 = alert heads up no change in position, 3 = alert, birds walked/swam a short distance, 4 = birds flew short distance, 5 = birds took flight and flew more than >50m

Habitat used before disturbance event: MF = mudflat, SM = saltmarsh, WA = water, SL = shoreline, WG = wet grassland, RB = reedbed

Behaviour before disturbance event: F = foraging, R = roosting, L = loafing/preening

Appendix 5: Water Bird Count Recording Sheet

AXE ESTUARY: BIRD DISTURBANCE STUDY 2017-18

Water Bird Count Sheet

Plot____ Observer ________________ Date ______________ Time_____________ Tide______________

Plot	Time	Bird species	Bird Count	Count Zone/Habitat	Bird Activity	Other comments

Count Zone: Plot A: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shore line, E = central water

Count Zone: Plot B: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shore line, E = central water

Count Zone: Plot C: A = east mudflat, B = west mudflat, C = east saltmarsh, D = west saltmarsh, E = east reedbed, F = west reedbed, G = central water

Bird Activity: F = foraging, R = roosting, L = loafing/preening

Appendix 6: Protocol and Variables Recorded

Protocol

This protocol relates to the two survey forms for recording bird disturbance events and bird counts taking place on the Axe Estuary. Please record details as explained below. Please note in all cases is it better to record more information than less in the other comments section of the form.

Bird Disturbance Recording Sheet

1 PLOT: Please record Plot A, Plot B or Plot C, plot field maps can be used for location.

2 OBSERVER: Please record your name.

3 DATE: Please record date.

4 TIME: Please record time of start and finish of survey (1 hour total, 24-hour clock).

5 TIDE: Please record tide (high tide, falling tide, low tide, rising tide). Surveys should take place 1 hour either side of high tide/low tide. For rising and falling surveys should be two hours before/after high/low tide.

6 WEATHER CLOUD COVER: Please record cloud cover on a scale of 0-8 (ocktas).

7 PRECIPITATION: Please record precipitation on a scale of light/moderate/heavy. Check weather forecast before survey, if heavy rain is predicted change survey time and date.

8 TEMP (FROM-TO): Please record range (low/high) of temperature (0^c) throughout survey.

9 WIND (DIRECTION): Please record general wind direction

10 WIND (STRENGTH): Please record wind strength on Beuford wind scale (0-12). If any survey has scale 7 (near gale) or above abandon survey due the possibility of skewing survey data.

11 EVENT: Please record individual event number.

12 BIRD SPECIES: Please record bird species possibly disturbed, using good quality field guide.

13 BIRD COUNT: Please record bird count number possibly disturbed.

14: DISTURBANCE TYPE: Please record type of disturbance. WA = walker, WD = Walker with dog, WL = walker with dog off lead, TR = tram, RA = raptor, CA = canoe, BO = boat, OT = other.

15 REACTION (SCALE 1-5): Please record bird disturbance reaction: 1 = no response, 2 = alert heads up no change in position, 3 = alert, birds walked/swam a short distance, 4 = birds flew a short distance, 5 = birds took flight more than >50m.

16 DISTURBANCE ZONE: Please record disturbance zone code on each plot for each event. Plot A: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shoreline, E = central water, Plot B: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shoreline, E = central water, Plot C: A = east mudflat, B = west mudflat, C = east saltmarsh, D = west saltmarsh, E = east reedbed, F = west reedbed, G = central water.

17 HABITAT BEFORE EVENT: Please record habitat before event code: MF = mudflat, SM = saltmarsh, WA = water, SL = shoreline, WG = wet grassland, RB = reedbed.

Water Bird Count Sheet

1 PLOT: Please record Plot A, Plot B or Plot C, plot field maps can be used for location.

2 OBSERVOR: Please record your name.

3 DATE: Please record date.

4 TIME: Please record time of start and finish of survey (24-hour clock). The count survey should be completed immediately after the hour of disturbance event surveys.

5 TIDE: Please record survey tide (high tide, falling tide, low tide, rising tide). Surveys should take place 1 hour either side of high tide/low tide. Rising and falling tide surveys should be at least two hours before/after high/low tide.

6 COUNT DATA, PLOT: Please record plot number birds are present in.

7 TIME: Please record time of individual observation.

8 BIRD SPECIES: Please record bird species name of individual observation using good quality field guide.

9 BIRD COUNT: Please record bird count of each individual species or flock of individual species present.

10 COUNT ZONE/HABITAT: Please record count zone on each plot for each event. Plot A: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shoreline, E = central water, Plot B: A = east mudflat, B = west mudflat, C = west saltmarsh, D = east shoreline, E = central water, Plot C: A = east mudflat, B = west mudflat, C = east saltmarsh, D = west saltmarsh, E = east reedbed, F = west reedbed, G = central water.

11 BIRD ACVITITY: Codes, F = foraging, R = roosting, L = loafing/preening.

12 OTHER COMMENTS: Please add any extra information e.g. territorial behaviour.

After each survey is completed check the forms, file them and input them as soon as possible into a pre-prepared Excel spreadsheet for later analysis.

SAFETY: Recorders should read and sign a site-specific risk assessment, obtain prior access and use a buddy system for lone working.

EQUIPMENT: Binoculars (10x42), weather proof folder, multiple copies of forms, pens and pencils, first aid kit, full weather proof clothes and boots, bird field guide.

Variables recorded

The following variables were recorded for each survey:

1 Date/time/tide/season/weather.

2 Water bird counts – end of one-hour survey to account for prior disturbance.

3 Broad priority habitat types/zones in plot – intertidal mudflats, coastal saltmarsh, river/water, coastal and floodplain grazing marsh, reed beds, that birds/disturbance was recorded on.

4 Number of potential disturbance events (within 50m of plot) per sample – all intertidal, water based or air activity were recorded whether they caused disturbance or not.

5 Bird response rank (scale 1-5, from Liley et al 2011) – 1 = no response, 2 = alert, heads up no change in position, 3 = alert, birds walked/swam short distance, 4 = birds flew short distance, <50m, 5 = birds took flight and flew more than >50m.

6 Bird response disturbance time (seconds) – recorded for good practice.

7 Number of each species disturbed per disturbance event.

Appendix 7: Output for statistically significant tests

Question 1: QED output: Mann Whitney U Test: Total Number of Events Plot A versus Plot C

Sample 1	a
Sample 2	c
U	321.5
z	2.55787
Prob.	0.00524168
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different a is larger than c (U = 321.5, n1 = 32, n2 = 32, P = <0.05)

Mann Whitney U Test: Total Number of Disturbance Events Plot A versus Plot B

Sample 1	TOTAL NO OF DISTURBANCE EVENTS A
Sample 2	TOTAL NO OF DISTURBANCE EVENTS B
U	374
z	1.85295
Prob.	0.0319658
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS A is larger than TOTAL NO OF DISTURBANCE EVENTS B (U = 374, n1 = 32, n2 = 32, P = <0.05)

Mann Whitney U Test: Total Number of Disturbances Events Plot A versus C

Sample 1	TOTAL NO OF DISTURBANCE EVENTS A
Sample 2	TOTAL NO OF DISTURBANCE EVENTS C
U	269
z	3.2628
Prob.	0.000534787
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS A is larger than TOTAL NO OF DISTURBANCE EVENTS C (U = 269, n1 = 32, n2 = 32, P = <0.05)

Mann Whitney U Test: Total Number of Disturbance Events Plot B versus C

Sample 1	TOTAL NO OF DISTURBANCE EVENTS B
Sample 2	TOTAL NO OF DISTURBANCE EVENTS C
U	384
z	1.71868
Prob.	0.042856
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS B is larger than TOTAL NO OF DISTURBANCE EVENTS C (U = 384, n1 = 32, n2 = 32, P = <0.05)

Mann Whitney U Test: High Tide Number of Disturbance Events Plot A versus C

Sample 1	TOTAL NO OF DISTURBANCE EVENTS A HT
Sample 2	TOTAL NO OF DISTURBANCE EVENTS C HT
U	12
z	NAN
Prob.	0.0189588
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS A HT is larger than TOTAL NO OF DISTURBANCE EVENTS C HT (U = 12, n1 = 8, n2 = 8, P = <0.05)

Mann Whitney U Test: High Tide Number of Disturbance Events Plot B versus C

Sample 1	TOTAL NO OF DISTURBANCE EVENTS B HT
Sample 2	TOTAL NO OF DISTURBANCE EVENTS C HT
U	15
z	NAN
Prob.	0.0414918
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS B HT is larger than TOTAL NO OF DISTURBANCE EVENTS C HT (U = 15, n1 = 8, n2 = 8, P = <0.05)

Mann Whitney U Test: Falling Tide Number of Disturbance Events Plot A versus C

Sample 1	TOTAL NO OF DISTURBANCE EVENTS A FT
Sample 2	TOTAL NO OF DISTURBANCE EVENTS C FT
U	10.5
z	NAN
Prob.	0.0140637
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS A FT is larger than TOTAL NO OF DISTURBANCE EVENTS C FT (U = 10.5, n1 = 8, n2 = 8, P = <0.05)

Mann Whitney U Test: Falling Tide Number of Disturbance Events Plot B versus C

Sample 1	TOTAL NO OF DISTURBANCE B EVENTS FT
Sample 2	TOTAL NO OF DISTURBANCE EVENTS C FT
U	6.5
z	NAN
Prob.	0.0034965
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE B EVENTS FT is larger than TOTAL NO OF DISTURBANCE EVENTS C FT (U = 6.5, n1 = 8, n2 = 8, P = <0.05)

Mann Whitney U Test: Season Plot A Autumn versus Plot C Winter

Sample 1	TOTAL NO OF DISTURBANCE EVENTS A autumn (15)
Sample 2	TOTAL NUMBER OF DISTURBANCE EVENTS c winter 17-2=15
U	67
z	NAN
Prob.	0.0306396
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different TOTAL NO OF DISTURBANCE EVENTS A autumn (15) is larger than TOTAL NUMBER OF DISTURBANCE EVENTS c winter 17-2=15 (U = 67, n1 = 15, n2 = 15, P = <0.05)

Question 2: QED statistically significant output for evidence

Mann Whitney U Test: Mean Species Abundance Per Plot Per Count Plot B versus Plot C

Sample 1	Mean Count Plot B
Sample 2	Mean Count Plot C
U	386.5
z	1.68511
Prob.	0.0460053
Number of tails	Two
This means	The null hypothesis is rejected. The two medians are significantly different Mean Count Plot B is larger than Mean Count Plot C (U = 386.5, n1 = 32, n2 = 32, P = <0.05)

Spearman Rank Correlation: All Bird Disturbance Mean Scale versus All Counts Mean

Samples	MEAN EVENT REACTION vs. MEAN COUNT
r uncorrected	-0.368095
r corrected	-0.381621
N	96
Prob.	0.000124863
This means	There is a significant correlation between the two variables (r = -0.381621, DF = 96, P = <0.05)

Spearman Rank Correlation: Plot A Bird Disturbance Mean Scale versus Plot A Counts Mean

Samples	MEAN REACTION vs. MEAN COUNT
r uncorrected	-0.351265
r corrected	-0.368216
N	32
Prob.	0.03812
This means	There is a significant correlation between the two variables (r = -0.368216, DF = 32, P = <0.05)

Spearman Rank Correlation: Plot B Bird Disturbance Mean Scale versus Plot B Counts Mean

Samples	MEAN REACTION B vs. MEAN COUNT B
r uncorrected	-0.458578
r corrected	-0.481993
N	32
Prob.	0.0052154
This means	There is a significant correlation between the two variables (r = -0.481993, DF = 32, P = <0.05)

Spearman Rank Correlation: Plot C Bird Disturbance Mean Scale versus Plot C Counts Mean

Samples	DISTURBANCE EVENTS REACTION SCALE C vs. MEAN COUNT C
r uncorrected	-0.386913
r corrected	-0.404709
N	32
Prob.	0.0215854
This means	There is a significant correlation between the two variables (r = -0.404709, DF = 32, P = <0.05)

Spearman Rank Correlation: All Bird Disturbance Intertidal Mean Scale versus All Counts Mean

Samples	MEAN REACTION INTERTIDAL vs. MEAN COUNT
r uncorrected	-0.635948
r corrected	-0.671042
N	43
Prob.	8.45634E-007
This means	There is a significant correlation between the two variables (r = -0.671042, DF = 43, P = <0.05)

Spearman Rank Correlation: Plot A Bird Disturbance Intertidal Mean Scale versus Plot A Counts Mean

Samples	MEAN REACTION INTERTIDAL vs. MEAN COUNT
r uncorrected	-0.548478
r corrected	-0.586572
N	24
Prob.	0.00258945
This means	There is a significant correlation between the two variables (r = -0.586572, DF = 24, P = <0.05)

Spearman Rank Correlation: Plot B Bird Disturbance Intertidal Mean Scale versus Plot B Counts Mean

Samples	MEAN REACTION INTERTIDAL vs. MEAN COUNT
r uncorrected	-0.716912
r corrected	-0.742607
N	17
Prob.	<0.01
This means	There is a significant correlation between the two variables (r = -0.742607, DF = 17, P = <0.05)

Spearman Rank Correlation: All Bird Disturbance Dogs Mean Scale versus All Counts Mean

Samples	MEAN REACTION DOGS vs. MEAN COUNT
r uncorrected	-0.508913
r corrected	-0.617604
N	24
Prob.	0.00130182
This means	There is a significant correlation between the two variables (r = -0.617604, DF = 24, P = <0.05)

Spearman Rank Correlation: Plot B Bird Disturbance Dogs Mean Scale versus Plot B Counts Mean

Samples	MEAN REACTION DOGS vs. MEAN COUNT
r uncorrected	-0.631119
r corrected	-0.709477
N	12
Prob.	<0.05
This means	There is a significant correlation between the two variables (r = -0.709477, DF = 12, P = <0.05)

Spearman Rank Correlation: All Bird Disturbance Walkers Mean Scale versus All Counts Mean

Samples	MEAN REACTION WALKERS vs. MEAN COUNT WALKERS
r uncorrected	-0.637315
r corrected	-0.691166
N	29
Prob.	3.30613E-005
This means	There is a significant correlation between the two variables (r = -0.691166, DF = 29, P = <0.05)

Spearman Rank Correlation: Plot A Bird Disturbance Walkers Mean Scale versus Plot A Counts Mean

Samples	MEAN REACTION WALKERS vs. MEAN COUNT
r uncorrected	-0.622368
r corrected	-0.687247
N	19
Prob.	<0.01
This means	There is a significant correlation between the two variables (r = -0.687247, DF = 19, P = <0.05)

Spearman Rank Correlation: Plot B Bird Disturbance Walkers Mean Scale versus Plot B Counts Mean

Samples	MEAN REACTION WALKERS vs. MEAN COUNT
r uncorrected	-0.679167
r corrected	-0.744931
N	9
Prob.	<0.05
This means	There is a significant correlation between the two variables (r = -0.744931, DF = 9, P = <0.05)

Spearman Rank Correlation: All Curlew Bird Disturbance Mean Scale versus All Counts Mean

Samples	MEAN REACTION CURLEW vs. MEAN COUNT CURLEW
r uncorrected	-0.183835
r corrected	-0.234916
N	20
Prob.	-1
This means	There is a significant correlation between the two variables (r = -0.234916, DF = 20, P = <0.05)

Spearman Rank Correlation: All Lapwing Bird Disturbance Mean Scale versus All Counts Mean

Samples	MEAN REACTION LAPWING vs. MEAN COUNT LAPWING
r uncorrected	-0.631063
r corrected	-0.725577
N	18
Prob.	<0.01
This means	There is a significant correlation between the two variables (r = -0.725577, DF = 18, P = <0.05)

Question 3: SPSS output for evidence

Plot A Binary Logistic Regression Probability of a Major Flight

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	30.479	4	.000
	Block	30.479	4	.000
	Model	30.479	4	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	101.122[a]	.228	.339

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	3	1.000

Contingency Table for Hosmer and Lemeshow Test

		MAJORFLIGHT = NO		MAJORFLIGHT = YES		
		Observed	Expected	Observed	Expected	Total
Step 1	1	2	2.000	0	.000	2
	2	33	33.000	1	1.000	34
	3	43	43.000	11	11.000	54
	4	8	8.000	12	12.000	20
	5	3	3.000	5	5.000	8

Classification Table[a]

			Predicted		
			MAJORFLIGHT		Percentage Correct
Observed			NO	YES	
Step 1	MAJORFLIGHT	NO	78	11	87.6
		YES	12	17	58.6
	Overall Percentage				80.5

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	DOGSOFFLEAD	3.902	1.113	12.292	1	.000	49.500	5.588	438.472
	DOGSONLEAD	-17.706	28420.722	.000	1	1.000	.000	.000	.
	WALKERS	2.133	1.070	3.976	1	.046	8.442	1.037	68.715
	CANOESBOATS	4.007	1.250	10.270	1	.001	55.000	4.742	637.898
	Constant	-3.497	1.015	11.866	1	.001	.030		

a. Variable(s) entered on step 1: DOGSOFFLEAD, DOGSONLEAD, WALKERS, CANOESBOATS.

Plot B Binary Logistic Regression Probability of a Major Flight

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	30.143	4	.000
	Block	30.143	4	.000
	Model	30.143	4	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	94.454[a]	.262	.367

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	3	1.000

Contingency Table for Hosmer and Lemeshow Test

		MAJORFLIGHT = NO		MAJORFLIGHT = YES		
		Observed	Expected	Observed	Expected	Total
Step 1	1	12	12.000	1	1.000	13
	2	7	7.000	1	1.000	8
	3	41	41.000	10	10.000	51
	4	4	4.000	11	11.000	15
	5	3	3.000	9	9.000	12

Classification Table[a]

Observed			Predicted: MAJORFLIGHT NO	Predicted: MAJORFLIGHT YES	Percentage Correct
Step 1	MAJORFLIGHT	NO	60	7	89.6
		YES	12	20	62.5
	Overall Percentage				80.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	95% C.I.for EXP(B) Upper
Step 1[a]	DOGSOFFLEAD	2.510	.754	11.072	1	.001	12.300	2.805	53.938
	DOGSONLEAD	-.535	1.126	.226	1	.635	.586	.064	5.320
	WALKERS	-1.074	1.099	.955	1	.328	.342	.040	2.945
	CANOESBOATS	2.423	.682	12.613	1	.000	11.275	2.961	42.928
	Constant	-1.411	.353	16.005	1	.000	.244		

a. Variable(s) entered on step 1: DOGSOFFLEAD, DOGSONLEAD, WALKERS, CANOESBOATS.

Plot C Binary Logistic Regression Probability of a Major Flight

Block 1: Method = Enter

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	26.678	4	.000
	Block	26.678	4	.000
	Model	26.678	4	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	61.569[a]	.281	.423

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	.000	1	1.000

Contingency Table for Hosmer and Lemeshow Test

		MAJORFLIGHT = NO		MAJORFLIGHT = YES		
		Observed	Expected	Observed	Expected	Total
Step 1	1	43	43.000	5	5.000	48
	2	18	18.000	5	5.000	23
	3	1	1.000	9	9.000	10

Classification Table[a]

			Predicted		
			MAJORFLIGHT		Percentage Correct
Observed			NO	YES	
Step 1	MAJORFLIGHT	NO	61	1	98.4
		YES	10	9	47.4
	Overall Percentage				86.4

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1[a]	DOGSOFFLEAD	23.355	28420.721	.000	1	.999	1.389E+10	.000	.
	WALKERS	23.355	28420.721	.000	1	.999	1.389E+10	.000	.
	CANOESBOATS	3.761	1.193	9.940	1	.002	43.000	4.149	445.609
	RA	.871	.692	1.584	1	.208	2.389	.615	9.272
	Constant	-2.152	.472	20.739	1	.000	.116		

a. Variable(s) entered on step 1: DOGSOFFLEAD, WALKERS, CANOESBOATS, RA.