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A CASE STUDY OF THE IMPACTS OF PIPELINE CONSTRUCTION ON BIRD DISTRIBUTION IN THE DUDDON ESTUARY

PART II: POST CONSTRUCTION, WINTER 1993/94

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EXECUTIVE SUMMARY

As part of the Pennington to Sellafield pipeline it was necessary to lay a gas pipeline across the Duddon Estuary from Askam-in-Furness to Millom in 1992, using the directional drilling method.

The Duddon Estuary is a Site of Special Scientific Interest, supporting both nationally and internationally important waterfowl populations.

Data on bird numbers and distribution were collected by low tide and all day counts, both before and after construction of the pipeline. These data were analyzed to investigate whether the laying of the gas pipeline had an affect on waterfowl using the intertidal areas of the Duddon Estuary.

Comparison of the before and after data revealed that the number of birds present on the Duddon Estuary at low tide was lower in winter 1993/94 than in 1991/92. It was considered that the decrease in bird numbers was not due to the construction of the pipeline but was the result of natural fluctuation.

There was a difference in mudflat usage in 1993/94 compared to 1991/92 for many species on the area studied in detail, along the pipeline route. However, usage of a transect immediately above the pipeline did not differ from the other transects. Comparisons of bird density both before and after the pipeline construction and differences in the mean counts of bird throughout the tidal cycle on each count area also revealed no significant differences.

The results of this study suggest that the construction of the pipeline did not have any effect on waterfowl usage of the Duddon Estuary two years after its completion. The highly mobile nature of the sediments in the estuary is likely to have resulted in a rapid recovery of the substrate from any disturbance due to pipeline construction. This rapid recovery would be likely to obscure any immediate impacts of construction on bird populations, if there were any, by rendering them undetectable within 2 years.

1.INTRODUCTION

In 1992 a gas pipeline was laid across the Duddon Estuary between Askam and Millom as part of the Pennington to Sellafield link. The aim of this study was to assess the impact on waterfowl populations of laying the gas pipeline. This was investigated by detailed bird surveys along the pipeline route, together with counts of birds carried out at low tide on the whole Duddon Estuary.

A study carried out by the BTO and funded by British Gas in winter 1991/92 (Warbrick, *et al.* 1992) on the Duddon Estuary identified important ornithological areas likely to be affected by the laying of the pipeline. The study also looked in detail at the proposed pipeline route to determine whether the laying of the pipe would have an effect at a local level. This provided useful baseline data which could be compared with data collected post pipeline laying to enable the effects of the operation to be assessed.

The Duddon Estuary is situated near Barrow-in-Furness, in the south-west corner of the Lake District. In 1991 the whole Duddon Estuary was designated as a Site of Special Scientific Interest (SSSI) covering 5122 ha in area. The Duddon Estuary SSSI was formed from the amalgamation of five separate SSSI's (Duddon Sands, Haverigg Haws, Hodbarrow Lagoon, North Walney and Sandscale Haws). Part of the estuary is a National Nature Reserve and it is a candidate Special Protection Area (SPA) and a candidate Ramsar site. The estuary regularly holds over 20,000 wintering waterfowl and by virtue of this it is a wetland of international importance. Internationally important populations of wintering Pintail, Knot and Redshank and nationally important populations of wintering Shelduck, Red-breasted Merganser, Oystercatcher, Ringed Plover, Curlew, Sanderling and Dunlin occur on the Duddon Estuary (Pritchard *et al.* 1992).

2.METHODS

The methods used for this study are the same as those used for the 1991/92 study (Warbrick *et al.* 1992). Data presentation and basic data analysis are also the same as in the 1991/92 study. However as both pre and post pipeline data had been collected it has been possible to carry out detailed comparative analysis.

2.1Data collection

2.1.1Low tide counts

To obtain post pipeline distribution data for waterfowl using the intertidal areas of the whole Duddon Estuary, for comparison with data collected pre-pipeline, it was necessary to carry out counts around low water. In order to do this the estuary was divided into 40 sections or count areas. The count areas used in 1993/94 were the same as those used in 1991/92. In 1991/92 the count areas were established using local knowledge so that they could be easily distinguished between counts. In order to prevent double counting the estuary was counted from both sides, and was divided in two, using the central river channel as the division (Figure 2.1.1.1).

The habitat and substrate type of the separate count areas are described in the earlier report (Warbrick *et al.* 1992). It is unlikely that the count areas have changed since 1991/92.

Six counts were carried out during the winter 1993/94, between November and February. The counts were carried out over the low tide period which is two hours before and two hours after low water. On each of the counts, the number of birds roosting and feeding for each species was recorded on each section.

2.1.2All day counts

The methods used to collect the all day count data, post construction, were the same as those used to collect the pre-construction data (Warbrick *et al.* 1992). The study site was situated in the central section of the Duddon Estuary between Millom and Askam-in-Furness (Figure 2.1.2.1). As in 1991/92 the study site was divided into ten transects (Figure 2.1.2.2). The eight inner transects (2 to 9) which were centred over and ran parallel to the recently constructed pipeline were 100m wide. The two outer transects (1 and 10) were >200m wide. In 1991/92 the transects were marked out with a large number of wooden stakes. However, problems caused by stakes being washed away and removed by people made it necessary to devise a slightly different method of dividing the study site into transects. Before counting started, one wooden stake was positioned on the transect line, on the Askam shore. A second post was positioned on the same transect line 500m out from the shore. Posts were positioned like this on all the dividing lines of the transects. Once in place sight lines were established along the two posts with certain objects (*e.g.* churches, characteristic buildings and trees) being used as points of reference. These reference points, together with compass bearings, were drawn onto a sketch map. The sight lines and reference points were then used when

the wooden stakes disappeared. During times of poor visibility, when it was not possible to clearly see the Millom side of the estuary, the compass bearings were used.

The transects were further divided into three sections across the estuary using the main the Askam channel and another minor channel as the divisions. The substrate within the transects in 1993/94 were similar to those described in the 1991/92 report.

Birds using each count area were counted once in every hour throughout the tidal cycle. This often resulted in counts covering more than one day as during winter day length is usually less than 12 hours. Feeding and roosting birds were recorded separately. Data from a total of six tidal cycles were collected with one tidal cycle being collected in November 1993, two tidal cycles in December 1993 and January 1994, and one tidal cycle in February 1994. Unlike the first study, no days of fieldwork were lost to severe weather. However, dense fog and mist resulted in some of the Millom side count areas (1.2 to 10.2) not being counted at various times throughout the winter and at different times of the tidal cycles. It was considered, however, that the missing data resulting from this was unlikely to affect the data set as it is known that very few birds use the Millom section of the study site.

2.2Data analysis

2.2.1Basic analysis

Low tide counts

Using a BTO developed FORTRAN program it was possible to calculate the average number of feeding and roosting birds on each count area for each species recorded within the estuary. The average number of feeding birds was then plotted to produce a feeding distribution map for each species which had an average of more than five birds.

All day counts

For each species which frequently used the study site a measure of bird "density" was calculated. This was done by calculating all day usage (average number of bird hours per tidal cycle) using a method developed by the BTO (Clark 1989).

All day usage was calculated using:

$$\text{Usage} = \sum_{A=+5}^{A=\_6} (BxC)1$$

A = hours from low tide
B = average number of birds feeding at time A when area was exposed
C = proportion of counts when area was exposed at time A

A measure of density was derived from this, where bird density =

Usage/area of count area. This is equivalent to the average number of bird hours/tidal cycle/hectare.

The results from this analysis can be represented graphically by plotting bird density on maps of the study site. By using plotting density profiles across the transect areas (Figure 2.2.1.1) it was possible to show in greater detail the distribution of birds across the study site, both before and after the construction of the pipeline.

The mean number of birds present and the percentage feeding was also calculated for different stages of the tidal cycle. The standard errors of these means are inevitably large due to the comparatively small samples from which they are calculated.

2.2.2Analysis comparing pre and post-pipeline data

Low tide data

The data collected by the low tide counts in 1993/94, when expressed diagrammatically, can be compared to the 1991/92 data and can be used to assess the overall changes in bird numbers and distribution throughout the whole Duddon Estuary. This provides useful information which can be used when drawing conclusions from the detailed analysis of bird numbers on the pipeline transect site.

All day data

The distribution maps resulting from the all day counts for 1993/94 when compared to the maps of the 1991/92 data give an overall impression of any differences in bird distribution between the two years. A graphical plot of bird density across the all day site for both years show if there are any trends in mudflat usage resulting from the construction of the pipeline.

Between year comparisons

The differences in the mean number of birds counted on each mudflat throughout the tidal cycle gives an assessment of the effect of laying the pipeline across the Duddon mudflats on bird numbers and distribution. This difference has been plotted for the species that were present in substantial numbers.

In order to assess in greater detail whether the numbers and distribution of birds present in winter 1993/94 was different from winter 1991/92, a two-way analysis of variance (ANOVA) (Sokal & Rohlf 1969) was calculated. In order to perform the test it was first necessary to calculate a test statistic, as follows:

$$d = \frac{x - y}{x + y} 2$$

where$d$ = test statistic
x =mean number of feeding birds at each hour of the tidal cycle on each mudflat in 1993/94

y = mean number of feeding birds at each hour of the tidal cycle on each mudflat in 1991/92

To improve the sample sizes for the statistical tests, the data from the Askam mudflats and the middle mudflats of a transect (*e.g.* 1 & 1.1, 2 & 2.1) have been combined. The combined mudflats have been assigned the following codes:

Mudflats 1 & 1.1 = Mudflat code A
Mudflats 2 & 2.1 = Mudflat code B
Mudflats 3 & 3.1 = Mudflat code C
Mudflats 4 & 4.1 = Mudflat code D
Mudflats 5 & 5.1 = Mudflat code E
Mudflats 6 & 6.1 = Mudflat code F
Mudflats 7 & 7.1 = Mudflat code G
Mudflats 8 & 8.1 = Mudflat code H
Mudflats 9 & 9.1 = Mudflat code I
Mudflats 10 & 10.1 = Mudflat code J

The Millom mudflats (1.2 to 10.2) have not been included in the detailed analysis as missing data caused by poor weather conditions may have biased the results of the statistical tests.

The output from the ANOVA was used in two ways: 1, to test whether there was a difference between the 1991/92 and 1993/94 counts of bird numbers; 2, to identify differences between the means using t-tests. This tests whether the transect carrying the pipeline was different from the other transects. It was also possible to calculate 95% confidence limits of the difference (Sokal & Rohlf 1969).

The detailed analysis was only carried out on a suite of key species. These being species which occur in high numbers and are more likely to indicate any detrimental effects caused by the construction of the pipeline. The key species for this study are: Shelduck, Oystercatcher, Dunlin, Curlew and Redshank.

3.RESULTS

3.1Species Accounts

Each species of bird recorded regularly during the low tide counts is discussed below in terms of the numbers present and its distribution. The numbers and distribution of birds observed during the low tide counts in winter 1993/94 are compared with birds observed in winter 1991/92. If a species was present in sufficiently high numbers to qualify for international or national importance it is stated below. The low tide data are summarized in Table 3.1.1. The current qualifying levels for national and international importance for waders and wildfowl are given in Table 3.1.2.

For species which were regularly seen in high numbers on the pipeline transects the numbers present throughout the tidal cycle and the distribution of these birds are presented graphically. The differences in the average number of birds present on each count area in both winter 1991/92 and 1993/94 are also plotted for species present in high numbers. Density profiles for both years have been plotted to show whether the construction of the pipeline has altered the distribution of birds across the transect study site. For the "Key Species", which were analyzed in greater detail, the results of the analysis are presented. For between year comparisons it is essential that the graphs and tables presented in this report are compared with the graphs presented in Warbrick *et al.* (1992).

Pink-footed Goose

Although present in lower numbers, the Pink-footed Geese recorded using the Duddon Estuary at low tide in winter 1993/94 followed similar trends to those in 1991/92 (Table 3.1.1). The number of birds present increased through the winter to a peak in late February. As in 1991/92 the Pink-footed Geese were confined to the raised saltmarsh areas at the head of the estuary. No Pink-footed Geese were recorded in the vicinity of the pipeline (Figure 3.1.1).

Greylag Goose

Lower numbers of Greylags were recorded using the Duddon Estuary at low tide during winter 1993/94 compared to winter 1991/92 (Table 3.1.1). However, flocks of feeding birds were regularly observed outside the estuary feeding on agricultural fields. The birds observed within the estuary fed on the saltmarsh areas (Figure 3.1.2). It is likely that the majority of these birds were from the feral population. Greylags were not recorded in the pipeline area.

Shelduck

The Duddon Estuary is a nationally important site for wintering Shelduck (Table 3.1.2). Shelduck numbers and distribution were roughly similar in winters 1991/92 and 1993/94 at low tide on the Duddon Estuary (Table 3.1.1 and Figure 3.1.3). Shelduck

were noticeably absent from the larger sandy mudflats at the mouth of the estuary. As in 1991/92 the highest concentrations of Shelduck were on the mudflats adjacent to saltmarsh (Figure 3.1.3)

Similar numbers of birds were observed on the transect area, although bird numbers were slightly higher in winter 1993/94 compared to 1991/92. The presence of birds throughout the tidal cycle was roughly similar in both years with the lowest number of birds present one to three hours before low tide (Figure 3.1.4). The peak count of birds was one to three hours after low tide. Birds showed a more widespread distribution in 1993/94 (Figure 3.1.5) with most transects having on average one or two more birds than in 1991/92. There was a significant difference in the usage of the transect count areas by Shelduck in winter 1991/92 compared to winter 1993/94 (ANOVA two-way, $F_{9,47}$=3.57 P=0.0019). However, usage of the pipeline transect by Shelduck was not significantly different compared to the other transects (t=0.6765, df=62, P=0.5, ns) in 1993/94.

Wigeon

Lower numbers of Wigeon used the Duddon Estuary in winter 1993/94 compared to 1991/92 (Table 3.1.1). As a consequence feeding birds seen were less widely distributed, occurring on only three of the count areas (Figure 3.1.6). High numbers of roosting birds were counted throughout the winter on the Duddon Estuary.

Only single birds were seen on the transect area.

Mallard

The number of Mallard present at low tide on the Duddon Estuary in winter 1993/94 was slightly lower than in winter 1991/92 (Table 3.1.1). Feeding Mallard were observed using similar mudflats in both years, however the birds were more widely distributed in 1991/92 (Figure 3.1.7).

Small numbers of Mallard were regularly seen feeding and roosting on the transect area.

Pintail

The Duddon Estuary is a nationally important site for Pintail in winter (Pritchard *et al.* 1992). The number of birds seen at low tide on the Duddon Estuary in winter 1993/94 was slightly lower than in winter 1991/92 (Table 3.1.1). Feeding and roosting birds occurred in similar areas in both years with the majority of the birds being seen on the main river channel (Figure 3.1.8).

Only single birds were seen feeding in the transect area.

Eider

The number of Eider seen within the Duddon Estuary at low tide in winter 1993/94 was very much lower than winter 1991/92 (Table 3.1.1).

Only one or two birds were seen in the transect area.

Goldeneye

Fewer birds were seen on the Duddon Estuary at low tide in winter 1993/94 compared to winter 1991/92 (Tables 3.1.1). The birds present had a similar distribution in both years (Figure 3.1.9).

Only single Goldeneye were seen in the transect area.

Red-breasted Merganser

The number of birds seen at low tide on the Duddon Estuary in winter 1993/94 was slightly lower than in winter 1991/92 with the birds present being less widespread (Table 3.1.1 and Figure 3.1.10). Feeding birds were found solely in the main river channel.

No birds were seen in the transect area.

Oystercatcher

The Duddon Estuary is a nationally important site for Oystercatcher in autumn and winter (Table 3.1.2). The number of birds observed at low tide on the Duddon Estuary in winter 1993/94 was slightly lower than in winter 1991/92 (Table 3.1.1). As in 1991/92 Oystercatcher were distributed widely, occurring on almost all the intertidal areas of the estuary. Birds were not as concentrated in certain areas as they were in 1991/92 (Figure 3.1.11).

Oystercatcher numbers were on average slightly higher on the transect count area in 1993/94 compared to 1991/92 with the peak mean count being around 600 compared to 400 (Figure 3.1.12). In 1993/94 bird numbers increased sharply one hour after high tide and then continued to increase slowly throughout the tidal cycle, until two hours before the next high tide when numbers fell rapidly. This differs from 1991/92 when there were two distinct troughs in bird numbers three hours either side of low tide (Figure 3.1.12). The distribution of feeding birds across the transect site was very similar in both winters (Figure 3.1.13). The combined count areas of one and 1.1 had the largest increase in bird numbers in 1993/94, the other mudflats had an increase of around 10 birds (Figure 3.1.14). The density profiles across the transects (Figure 3.1.15) show no real affect caused by the pipeline. There was a significant difference in the usage of the count areas in 1993/94 compared to 1991/92 (ANOVA two-way, $F_{9,63}=4.31$, P=0.0002). However, usage of the pipeline transect by Oystercatcher was not significantly different compared to the other transects (t=1.0700, df=78, P=0.2879, ns).

Ringed Plover

The Duddon Estuary is nationally important for Ringed Plover in

autumn and winter (Table 3.1.2). There was a slight increase in the number of Ringed Plover observed using the Duddon Estuary at low tide in winter 1993/94 compared to 1991/92 (Table 3.1.1). The distribution of feeding birds was similar in both years (Figure 3.1.16).

More birds were observed on the transect area in winter 1993/94 compared to winter 1991/92 (Figure 3.1.17). This was due mainly to the presence of a large flock of birds (350+) which fed predominantly on transect 1 and also on transect 2 throughout most of the winter. All the birds observed were feeding except at two-three hours before high tide when a small number of birds roosted (Figure 3.1.17). In 1991/92 the number of birds present through the tidal cycle remained fairly constant with only small fluctuations. However, in 1993/94 there was a distinct dip in the number of birds present from two hours before low tide until one hour after low tide (Figure 3.1.17). This possibly accounts for the absence of large numbers of Ringed Plover on the low tide counts. The distribution of birds across the transects was very similar in both years with birds being confined to the Askam shore of the estuary (Figure 3.1.18). The was no major difference in the distribution of Ringed Plover across the transects except for the combined transects of 1 and 1.1 which had an average increase of about 40 individuals. The pipeline transect and an adjacent transect had a slight increase of about two individuals (Figure 3.1.19). The density profile (Figure 3.1.20) of Ringed Plover across the site shows clearly the presence of an increased number of birds on count area 1 and over the pipeline area.

Grey Plover

The Duddon Estuary is a nationally important estuary for Grey Plover in autumn and winter (Table 3.1.2). The number of Grey Plover seen on the low tide counts and their distribution was similar in both winters (Table 3.1.1 & Figure 3.1.21). Very few individuals (<10) were regularly seen in the transect area.

Lapwing

Lower numbers of Lapwing were recorded using the Duddon Estuary at low tide in winter 1993/94 compared to 1991/92 at low tide (Table 3.1.1). However, large flocks of Lapwing were regularly seen on fields around the estuary. Birds were less widely distributed in 1993/94 being found on only a few of the mudflats (Figure 3.1.22).

In contrast to the low tide counts Lapwing numbers increased on the transect area in 1993/94 compared to 1991/92 (Figure 3.1.23). Figure 3.1.23 shows however, that there is a distinct decrease in the number of Lapwing present on the estuary around low tide. This is when birds move on to fields to feed. The majority of Lapwing which used the estuary in both years were roosting, with very rarely more than 50% of the birds feeding and usually much less. The increased number of birds present in 1993/94 resulted in birds being much more widely distributed (Figure 3.1.24). The majority of the birds were seen on the Askam side of the estuary.

Knot

The Duddon Estuary is nationally important for Knot in winter (Table 3.1.2). Many more Knot were recorded using the Duddon Estuary at low tide in winter 1993/94 compared to 1991/92 (Table 3.1.1). The majority of the birds were seen on the mudflats around North Walney, the rest being seen on mudflats to the south of Askam (Figure 3.1.25). Very few individuals were seen on the transect area with an occasional flock of round 40 birds using the area infrequently.

Sanderling

The Duddon Estuary is a nationally important site for Sanderling in winter, spring and autumn (Table 3.1.2). Fewer Sanderling were seen on the Duddon Estuary at low tide in winter 1993/94 compared to winter 1991/92 (Table 3.1.1). The distribution of birds present was similar in both years (Figure 3.1.26).

Small numbers of individuals (<20) were regularly seen feeding with Dunlin on the Askam side of the transect area (Figure 3.1.27). Peak numbers of birds were usually seen one to two hours either side of high tide. All the birds seen were feeding (Figure 3.1.28).

Dunlin

The Duddon Estuary is a nationally important site for Dunlin in winter and autumn (Table 3.1.2). In winter 1993/94 the average number of Dunlin on the Duddon Estuary at low tide was lower than in 1991/92 (Table 3.1.1). In real terms, there were more Dunlin on the Duddon Estuary in 1993/94 but a low count in early January greatly reduced the overall average. In both winters Dunlin were distributed widely throughout the estuary occurring on the majority of the mudflats. In 1991/92 most birds were concentrated to the north of Askam, however in 1993/94 Dunlin were more concentrated around the north of Walney Island and on the mudflats around Askam (Figure 3.1.29).

More individuals were present on the transect area in 1993/94 than in 1991/92 (Figure 3.1.30). In 1993/94 flocks of around 1500 to 2500 were usually present throughout the tidal cycle, although on occasions up to 6000 individuals were observed. In both years the peak number of birds was usually two to three hours before and after high tide. Almost all the birds seen were feeding. In both winters the majority of the birds utilised the mudflats along the Askam shore with birds being particularly concentrated on the two mudflats just to the north of Askam Pier (Figure 3.1.31). These more sheltered mudflats were likely to have supported higher numbers of invertebrate prey for feeding birds. Except for a large increase in bird numbers on the combined mudflats of 1 and 1.1, the other mudflats had only minor changes in the amount of usage they received (Figure 3.1.32). The profile densities (Figure 3.1.33) of Dunlin clearly show the increased usage of count area 1. There also appears to be a slight increase in usage of the pipeline transect (count area 5). There was a significant

difference in the usage of the transect mudflats in 1993/94 compared to 1991/92 (ANOVA two-way, $F_{9,56}$=2.36 P=0.0243). Usage of the pipeline transect by Dunlin was not significantly different compared to the other transects (t=1.8576, df=72, P=0.2879, ns).

Bar-tailed Godwit

Similar numbers of Bar-tailed Godwits were observed in both winters 1991/92 and winter 1993/94 at low tide on the Duddon Estuary (Table 3.1.1). The birds present in 1993/94 were less distributed than in 1991/92 but occurred on similar mudflats (Figure 3.1.34).

Curlew

The Duddon Estuary is a nationally important site for Curlew in winter, spring and autumn (Table 3.1.2). Curlew numbers were lower at low tide on the Duddon Estuary in winter 1993/94 compared to winter 1991/92 (Figure 3.1.1). Curlew were widespread throughout the estuary in 1993/94 but occurred on fewer count areas than in 1991/92. Curlew were particularly concentrated around north Walney and in the middle sections of the estuary (Figure 3.1.35).

Around 250 to 350 Curlew were observed throughout the tidal cycle which was an increase on 1991/92 (Figure 3.1.36). Birds numbers tended to be at their lowest two to three hours before and after high tide. This differs slightly from the trend observed in 1991/92 (Figure 3.1.36). Curlew distribution across the transects was similar in both years (Figure 3.1.37) with only very minor variations in bird numbers present (Figure 3.1.38). The profiles of bird density (Figure 3.1.39) show also how bird numbers fluctuate between the two winters but do not show any major trends. However, count areas 2.1 to 10.1 were all consistently higher in winter 1993/94 compared to winter 1991/92. There was no difference in the usage of the transects by Curlew in winter 1993/94 compared to winter 1991/92 (ANOVA two-way $F_{63,9}$=0.97, P=0.4748, ns). In addition there was no difference in the usage of the pipeline transect compared to the other transects (t=0.6853, df=78, P=0.4952, ns).

Redshank

The Duddon Estuary is a nationally important site for Redshank in winter and autumn (Table 3.1.2). Higher numbers of Redshank were observed using the Duddon Estuary at low tide in winter 1993/94 compared to 1991/92 (Table 3.1.1). Redshank were similarly distributed in both years with the majority of the birds concentrated around North Walney and to the north of Askam Pier (Figure 3.1.40).

Around a hundred more Redshank used the transect area in winter 1993/94 than in winter 1991/92 (Figure 3.1.41). In 1993/94 Redshank numbers increased steadily for the first three hours after high tide, dipped around low tide, and increased again until three hours before low tide. Bird numbers decreased rapidly with the incoming tide (Figure 3.1.41). Usually more than 80% of the birds present were feeding. Birds were more evenly distributed in 1993/94 with birds using more of the middle count areas (Figure 3.1.42). All of the count areas,

except Mudflat code B, had an increase in usage by Redshank (Figure 3.1.43). Count areas 1 and 1.1 had the greatest increase in birds caused by the presence of a large feeding flock (250+ individuals) which was present throughout most of the counts. Profiles of feeding densities of Redshank across the count areas show no major changes in usage between years (Figure 3.1.44). There was a significant difference in usage of the mudflats by Redshank in winter 1993/94 compared to 1991/92 (ANOVA two-way $F_{9,63}=10.12$, $P<0.0001$). However, usage of the pipeline transect by Redshank was not significantly different compared to the other transects ($t=1.7334$, df=78, P=0.087, ns).

Turnstone

Very small numbers of Turnstone use the Duddon Estuary in winter. In winter 1993/94 fewer Turnstone were observed at low tide than in 1991/92 (Figure 3.1.1). Turnstone were absent from the main part of the estuary in 1993/94, being found only around North Walney (Figure 3.1.45). On the transect area only four or five birds were seen usually for only one or two hours at low tide. These birds were only seen on the stony area of count areas 5 and 6 at Askam.

4.DISCUSSION AND CONCLUSIONS

A large number of waterfowl, of a variety of species, were observed on the Duddon Estuary during winter 1993/94. The key species chosen for the detailed analyses were all present in sufficient numbers to allow all the necessary analyses to be carried out.

In winter 1993/94 the number of individuals seen, of many species, at low tide on the entire Duddon Estuary was on average lower than in 1991/92. It is very difficult to account precisely for the variation in bird numbers between years as this could be due to a variety of reasons. Firstly, as only one year of bird data was collected before the construction of the pipeline it is not known whether winter 1991/92 was a particularly good year, with higher than usual numbers of waterfowl using the Duddon Estuary. Alternatively winter 1993/94 may have been a poor year for waterfowl, due to natural conditions. For example, decreased numbers in winter 1993/94 may have been due to reduced breeding success in spring/summer 1993. Alternatively reduced food availability, brought about by poor recruitment success of invertebrates, may have resulted in a reduction to the Duddon Estuary's carrying capacity for waterfowl. As the reduction in numbers occurred across the whole Duddon Estuary and was not concentrated solely near the pipeline, it is likely that the decrease in bird numbers was not due to the construction of the pipeline but to natural conditions.

On the transect area, where counts were carried out in much more detail, the number of birds seen during winter 1993/94 was higher than in winter 1991/92 for many species. All the key species (Shelduck, Oystercatcher, Dunlin, Curlew and Redshank) had an increased number of individuals on the transect area as did Ringed Plover and Lapwing. For the majority of the species which were present in higher numbers the increase was due to large concentrations of feeding birds on the count areas immediately to the north of Askam Pier. This area is very sheltered and consequently provides good conditions for invertebrates on which the waterfowl feed.

For all the key species, except Curlew, there was a significant difference in the usage of the transect count areas in winter 1993/94 compared to 1991/92. However, as none of the species showed any difference in usage of the count area above the pipeline compared to the other count areas it was considered unlikely that variation in count area usage between winters was due to the construction of the pipeline. In addition the density profiles graphs (*e.g.* Figure 3.1.15) show no major positive or negative trends across the pipeline transects which are likely to have arisen from the construction of the pipeline. It is therefore likely that the differences in usage of the count areas, between years, is probably due to natural variation in the distribution of waterfowl across the site. A plot of between year differences in mean counts on each mudflat through the tidal cycle for the key species (Figure 4.1) shows that there was very little variation in usage in 1993/94 compared to 1991/92. An exception to this is mudflat A where large

increases in Dunlin numbers dramatically affected the overall mean. This is further evidence that the construction of the pipeline is unlikely to have affected mudflat usage by waterfowl.

The results of this study suggest that the construction of a gas pipeline across the mudflats of the Duddon Estuary has had no apparent effect on the usage of the estuary by waterfowl, two years after completion of the pipeline. There may have been an effect immediately after construction but, due to the nature of the estuary, these are likely to have been very short lived. The Duddon Estuary sediments are very mobile with the majority of the estuary near the pipeline being made up of sand "mega" ripples. This would result in any exogenous changes to the estuary substrate being rapidly modified as the ripples are continually on the move. This is in contrast to the nearby Walney Channel which is relatively sheltered and more muddy in nature where changes to the substrate are likely to take a much longer time to stabilise.

The data collected for this study were sufficient to show whether any changes to mudflat usage by waterfowl resulted from the construction of the gas pipeline across the Duddon Estuary. However, it is recommended for future studies of a similar nature that several years of pre-construction data, as well as post-construction data, should be collected. This will also allow for natural fluctuations in waterfowl populations to be taken into account and therefore increase the statistical power of any analysis.

5. REFERENCES

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	COUNT 1			COUNT 2			COUNT 3		
	1st - 15th December			15th - 31st December			1st - 15th January		
SPECIES	F	R	T	F	R	T	F	R	T
Pink-footed Goose	60	0	60	41	0	41	0	0	0
Greylag Goose	0	0	0	0	0	0	0	0	0
Shelduck	490	37	527	938	7	945	254	42	296
Wigeon	8	145	153	10	484	494	5	71	76
Teal	0	0	0	0	30	30	0	0	0
Mallard	110	83	193	283	186	469	87	91	178
Pintail	5	1187	1192	72	450	522	1150	100	1250
Eider	1	1	2	0	0	0	4	0	4
Goldeneye	30	0	30	50	0	50	50	0	50
Red-breasted Merganser	4	0	4	0	0	0	6	0	6
Oystercatcher	2464	0	2464	2535	0	2535	2240	0	2240
Ringed Plover	56	0	56	70	0	70	70	0	70
Grey Plover	108	0	108	134	0	134	209	21	230
Lapwing	22	270	292	42	380	422	0	544	544
Knot	2236	0	2236	518	45	563	424	0	424
Sanderling	13	0	13	23	0	23	4	0	4
Dunlin	3299	0	3299	6032	0	6032	9316	0	9316
Snipe	0	0	0	4	0	4	30	0	30
Bar-tailed Godwit	115	0	115	0	0	0	3	0	3
Curlew	505	199	704	774	307	1081	417	212	629
Redshank	1041	4	1045	994	1	995	620	0	620
Turnstone	16	0	16	21	0	21	16	0	16
Heron	0	0	0	0	0	0	0	0	0
Cormorant	0	0	0	0	0	0	0	0	0
Peregrine	0	0	0	0	0	0	0	0	0

Table 3.1.1 Summary of the low tide counts carried out over winter 1993/94.

	COUNT 4			COUNT 5			COUNT 6		
	16th - 31st January			1st - 15th February			16th - 28th February		
SPECIES	F	R	T	F	R	T	F	R	T
Pink-footed Goose	101	0	101	208	0	208	0	541	541
Greylag Goose	0	0	0	34	0	34	0	1	1
Shelduck	527	154	681	451	315	766	981	250	1231
Wigeon	0	80	80	10	128	138	4	270	274
Teal	0	0	0	10	0	10	4	5	9
Mallard	0	62	62	3	147	150	27	140	167
Pintail	0	700	700	6	370	376	64	500	564
Eider	0	0	0	0	0	0	0	0	0
Goldeneye	22	0	22	42	0	42	8	0	8
Red-breasted Merganser	0	0	0	54	0	54	5	0	5
Oystercatcher	631	0	631	2307	283	2590	2175	372	2547
Ringed Plover	0	0	0	117	0	117	140	0	140
Grey Plover	55	0	55	228	0	228	156	0	156
Lapwing	0	34	34	50	541	591	148	234	382
Knot	1500	0	1500	654	0	654	1228	0	1228
Sanderling	0	0	0	71	0	71	12	0	12
Dunlin	5	0	5	7446	0	7446	13479	0	13479
Snipe	0	0	0	0	0	0	0	0	0
Bar-tailed Godwit	5	0	5	28	0	28	0	0	0
Curlew	315	244	559	699	217	916	971	134	1105
Redshank	380	0	380	1069	160	1229	1461	1	1462
Turnstone	8	0	8	0	0	0	11	0	11
Heron	0	0	0	0	0	0	0	0	0
Cormorant	0	0	0	0	0	0	0	1	1
Peregrine	0	0	0	0	0	0	0	0	0

Table 3.1.1Summary of the low tide counts carried out over winter 1993/94.

SPECIES	WINTER			SPRING			AUTUMN		
		% of population			% of population			% of population	
	Mean	% British	% East Atlantic Flyway	Mean	% British	% East Atlantic Flyway	Mean	% British	% East Atlantic Flyway
Shelduck	895	1.19	0.36	---	---	---	---	---	---
Oystercatcher	7045	2.52	0.78	2292	0.82	0.25	7317	2.61	0.81
Lapwing	1789	0.18	0.09	228	0.02	0.01	1270	0.13	0.06
Ringed Plover	247	1.07	0.49	260	0.87	0.52	443	1.48	0.89
Grey Plover	249	1.19	0.17	66	0.31	0.04	223	1.06	0.15
Turnstone	309	0.69	0.44	224	0.50	0.32	556	1.24	0.79
Curlew	2178	2.39	0.62	1057	1.16	0.30	2891	3.18	0.83
Bar-tailed Godwit	236	0.39	0.24	39	0.06	0.04	90	0.15	0.09
Redshank	1419	1.89	0.95	801	0.67	0.53	1871	1.56	1.25
Knot	3842	1.75	1.10	813	0.37	0.23	494	0.22	0.19
Dunlin	9097	2.12	0.65	905	0.45	0.06	2649	1.32	0.19
Sanderling	450	3.21	0.45	822	2.74	0.82	530	1.77	0.53
Purple Sandpiper	43	0.27	0.09	31	0.19	0.06	0	0.00	0.00

Table 3.1.2The national and international importance of the Duddon Estuary for Shelduck and waders 1988-1992 (data from WeBS and Waters & Cranswick (1993)).