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The Abundance and Distribution of Waterfowl Within Milford Haven After The *Sea Empress* Oil Spill Year 1 Report, September 1997

Authors

M.J.S. Armitage, N.H.K. Burton & M.M. Rehfisch

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EXECUTIVE SUMMARY

1. **On 15 February 1996 the *Sea Empress* oiltanker, laden with 130,000 tonnes of crude oil, ran aground at the entrance to Milford Haven. Some 72,000 tonnes of crude oil and between 480 and 760 tonnes of heavy fuel oil were released over the next six days. Much of the local coastline was affected by the oil.**

2. **To assess whether the oilspill was to impact the nationally important waterfowl populations found in the area of Milford Haven this study was put in place. Two polluted (Angle Bay and Pembroke River) and two relatively unpolluted 'control' sites (the Carew/Cresswell and Cleddau Rivers) were chosen to be monitored intensively over the three winters after the oilspill. The mudflats of Angle Bay were heavily affected by secondary contamination consisting of heavy sheens of oil derived from the initial strandings of crude and heavy fuel oil high up the shoreline. No physical or chemical clean-up was undertaken of the mudflats, although they sustained some minor damage from straying vehicles. The physical clean-up was concentrated on the upper shore above the mudflats. Saltmarsh and mudflats at Pembroke River were also affected by heavy fuel oil and sheens of crude oil. Contaminated areas of the upper shore were covered with sand to stabilise the oil. No treatment was carried out on the saltmarsh or mudflats. No significant amounts of surface oil reached the other two sites. No chemical dispersants, which are known to impact strongly on the rate of environmental recovery, were used within the estuary.**

The four sites have been monitored following standard Wetland Bird Survey (WeBS) methodology to assess the numbers of waterfowl present, and following standard British Trust for Ornithology all-day (across the tidal cycle) count methodology to assess the feeding areas most used.

3. **The oilspill immediately affected birds in the area, causing thousands of mortalities. A significant proportion of the casualties were seabirds (in particular guillemots) and scoter outside the estuary. Few birds within the estuary were incapacitated, although daily WeBS counts carried out following the spill revealed that over 1,000 birds had oiled plumage (Parr *et al.*, 1997). The majority of these were gulls, but some waders and Shelduck were also affected.**

The loss of food resources and disturbance from the clean-up operations at the time will have affected all birds in addition to those that were oiled. There is evidence that birds moved away from the oiled embayments as a result.

4. **The results of the WeBS and all-day counts are summarised and are compared to available historical data: WeBS data collected since the 1981/82 winter and across the tidal cycle count data collected during the 1987/88 winter (Pr_s-Jones, 1989).**

5. **Comparing the 1987/88 winter across the tidal cycle count data to that of 1996/97 showed that of the waterfowl commonly found feeding on the four experimental sites Wigeon, Dunlin and Oystercatcher had increased in numbers while Shelduck, Teal, Curlew and Redshank had decreased (Figure 7.1). There was thus no evidence of a systematic increase or decrease in the abundance of all species over the time period (binomial test: p=0.5, n=7, *NS*).**

Further comparisons between the change in numbers of waterfowl recorded during the all-day counts according to the oiling of a site demonstrated that Curlew, Shelduck and Teal had fared better on oiled than on unoiled sites, whereas the opposite was true for Wigeon, Dunlin, Redshank and Oystercatcher (Figure 7.1). There was no evidence of all species doing systematically better on oiled rather than unoiled sites over the time period (binomial test: p=0.773, n=7, *NS*).

6. As waterfowl populations can fluctuate markedly from year to year, WeBS data collected at the four study sites since the 1981/82 winter were included in the analyses to help with the interpretation of the results. Dunlin, Teal, Bar-tailed Godwit, Oystercatcher and Grey Plover numbers were higher during the 1996/97 winter than during the 1995/96 winter of the spill, whereas Wigeon, Curlew and Redshank numbers had decreased (Figure 7.2). There was no evidence of a systematic increase or decrease in the abundance of all species over the time period (binomial test: p=0.746, n=9, *NS*).

Further comparisons between the change in numbers of waterfowl recorded during the WeBS counts according to the oiling of a site showed that Grey Plover, Wigeon, Bar-tailed Godwit, Teal, Dunlin and Shelduck appeared to fare better on oiled rather than unoiled sites, whereas the opposite was true for Oystercatcher, Redshank and especially Curlew (Figure 7.2). There was no evidence of all species doing systematically better on oiled rather than unoiled sites over the time period (binomial test: p=0.746, n=7, *NS*).

7. In overall summary, as yet there is no firm evidence of any major impact of the oilspill on waterfowl one year after the spill. The changes in feeding distributions and numbers in the four sites could be due to natural fluctuations in population sizes. The monitoring planned over the 1997/98 to 1998/99 winters may confirm that Oystercatcher, Redshank and perhaps Curlew may have been negatively affected by the oiling while Teal and Shelduck may have been able to take advantage of some consequence of oiling to do relatively better on the oiled sites. Invertebrate and plant data may help interpretation of the observed changes when they become available for the relevant period. It is possible, for example, that Teal and Shelduck have been able to exploit small but potentially very numerous invertebrates such as *Capitella* spp. and Nematoda that are able to take advantage of disturbed ecosystems, whereas Oystercatcher and Curlew that tend to rely on larger food items such as *Mytilus*, *Cerastoderma*, *Arenicola* and *Hediste* may have found that their food-stocks have been severely diminished by the oil. Large numbers of Wigeon stayed longer than usual at Pembroke River, perhaps exploiting the abundant growth of *Zostera* at the site.

8. After three years of data collection it will be possible to further develop the analyses following that outlined in the original proposal. The final report may also i) compare summed monthly WeBS counts over the various years as these are more closely linked to site carrying capacity; ii) compare WeBS counts made after the spill to those made at similar times in subsequent years; iii) look at residual waterfowl numbers by removing population trends which may help disguise any changes in the numbers of waterfowl at the experimental sites; iv) consider comparing the temporal change in residuals for oiled to unoiled sites; v) carry out analyses to assess whether any community recovery occurs (Hill *et al*., 1993), and; vi) incorporate any suitable plant and invertebrate data into the analyses which may help explain any observed changes.

1. GENERAL INTRODUCTION

The Cleddau Estuary[1] is of international importance for waterfowl, holding more than 20,000 birds (when gulls are included) in most winters (Pr_s-Jones, 1989; Poole, 1996). At a species level, the estuary is of national importance for its numbers of Shelduck, Wigeon, Teal and Curlew (Table 1.1).

The Oilspill

On 15 February 1996 the *Sea Empress*, laden with 130,000 tonnes of crude oil, ran aground on rocks at Mill Bay at the entrance to Milford Haven. Approximately 72,000 tonnes of crude oil and between 480 and 760 tonnes of heavy fuel oil were released from the tanker over the following six days. Some of the oil was carried into Milford Haven, affecting a large length of its coastline.

Crude oil first entered Angle Bay on 16 February, heavy fuel oil entered on 22 February. The initial strandings were at high tide, high up on the rock platforms, shingle and gravel shores above the mudflats (Sommerville, in litt.; Jane Hodges, pers. comm.). The mudflats themselves were heavily affected by secondary contamination derived from the initial high tide strandings. Heavy sheens of mostly crude oil were dragged down the shore and deposited by the ebb tide. The oil on the mudflats was then frequently 'lifted' and worked back up the shore by the flood tide. Apart from some minor trenching at the junction between the upper shingle shore and the mudflats, no physical or chemical clean-up was carried out of the mudflats. The physical clean-up operations were concentrated on the upper shore above the mudflats. Bulk oil was flushed into trenches and then extracted by vacuum tankers. Over 310 tonnes of oil were removed in the first week. During the first phase of the clean-up the upper beaches were disturbed and part of the *Zostera angustifolia* bed in the south-east corner of the bay was damaged by vehicles (Jane Hodges, pers. comm.). More detailed cleaning was carried out between May and August 1996. The second phase of the clean-up was concerned with the removal of surface and sub-surface oil in the shore above the mudflats. No heavy vehicles were used. The operation was manual, using shovels, a small dumper truck and a mini-excavator, working on small sections at a time to minimise disturbance.

Sheens of crude oil entered Pembroke River on 18 February, but the major shoreline impact occurred on 22 February when heavy fuel oil was carried into the embayment (Sommerville, in litt.). Areas of the shoreline between Bentlass and Goldborough Pill were most affected. A much smaller amount of heavy fuel oil was also stranded on the north shore east of Pennar Park. Due to the time of stranding, the impact was mostly restricted to the upper foreshore above the main bird feeding areas. In places, oil was deposited on saltmarsh between mean high water mark and mid-tide levels. *Zostera* beds and mudflats below were affected by secondary contamination derived from oil stranded on the upper shore, but not to the same extent as at Angle Bay. The main high tide roost at Brownslate was extensively impacted by heavy fuel oil and there was a high probability of contamination of birds using this area. Polluted areas were covered with sand during mid-

[1] **The Cleddau Estuary as defined by the Wetland Bird Survey (WeBS). This includes Milford Haven Waterway, the Daugleddau, Eastern and Western Cleddau and associated intertidal embayments, tributary rivers and pills.**

April to 'soak up' mobile oil, helping to stabilise it and reduce the birds' contact with the oil. As at Angle Bay, there was manual removal of oiled beach material. The dumper truck used to transport material was driven across part of the mudflats between the shingle ridge and the slip at church lakes, but not the saltmarsh. Again, the mudflats and saltmarsh were not subjected to physical or chemical treatments.

No significant amounts of surface oil reached booms that were deployed at Jenkin's Point at the entrance to the Carew and Cresswell Rivers (Sommerville, in litt.). Some oil sheens did enter the rivers, and a small quantity of brown oil (emulsified crude oil) was stranded on the upper shore at Jenkin's Point (Jane Hodges, pers. comm.).

Sheens of oil and oily seaweed were stranded on the foreshore as high up the estuary as Black Tar on the Western Cleddau. Brown oil was seen on the water in the Eastern Cleddau upstream of Picton Point (Jane Hodges, pers. comm.). These are unlikely to have seriously affected the shoreline or mudflats (Sommerville, in litt.).

In summary, no treatments involving the use of chemical dispersants were used within the estuary. Such treatments are known to have a major impact on the rate of recovery of the environment (Smith, 1968).

The Study

The *Sea Empress* spill has provided the opportunity to assess the impact of oil deposits on the waterfowl of intertidal areas. Other studies aim to assess the impact of the oil on the waterfowls' invertebrate prey in the intertidal sediments. Close links between this study and work on the sediment infauna may reveal the underlying reasons for the birds' distribution. In heavily oiled areas, the prey organisms may have been heavily depleted. Birds that used affected mudflats may have remained and as a result suffered increased mortality rates or may have been forced into other areas to feed. In either case, the local populations would be expected to have decreased in the immediate aftermath of the incident.

This study aims to monitor the use made by waterfowl of intertidal areas in the Cleddau Estuary over three winter seasons in relation to oiling levels. Four sites are being studied: a heavily oiled site, Angle Bay, a moderately oiled site, Pembroke River and two effectively non-oiled sites, the Carew/Cresswell rivers and the Cleddau river where the Eastern and Western Cleddau meet. The non-oiled sites are similar to Pembroke River in topography and substrate composition. There is no site similar to Angle Bay that has not been oiled. Within the constraints of the study, Angle Bay and Pembroke River are considered oiled while the Carew/Cresswell and Cleddau Rivers are considered to act as relatively unoiled control sites.

At the oiled sites, waterfowl populations are expected to recover with time as did most shoreline faunas after the *Torrey Canyon* spill (Figure 1.1). It is expected that the recovery rates, measured by waterfowl usage (see methods), will be more rapid at Pembroke River than at Angle Bay due to the less comprehensive deposition of oil at the former site. Furthermore, it is expected that the recovery rates will also differ between species according to their feeding preferences and will be dependant upon the mortality and recolonisation rates of their food organisms. The use of the non-oiled sites is expected to reflect the natural population changes, although initially there may be an increase due to a

possible influx of birds from oiled areas. ***Other Oilspills***

It would be useful to compare the effects of the *Sea Empress* spill to those recorded during other oilspills. After the Mersey oilspill in August 1989, there were significant changes in the distribution and number of 10 out of 14 species studied, but none of these changes could be directly attributable to the effect of the oil (Clark *et al.*, 1990). However, the Mersey spill is barely comparable with the *Sea Empress* spill. Only 150 tonnes of oil were released and most of the impacted oil had been cleared or washed away by the time birds had arrived for the winter.

The *Exxon Valdez* oilspill in March 1989 off Prince William Sound, Alaska, was much larger (41,000,000 litres). There were strong initial impacts on the marine bird community, but it was found that both habitats and bird populations have considerable resiliency to severe but short-term perturbations (Wiens *et al.*, 1996). The strongest impacts were on wintering or resident species feeding on or close to the shore. After only one and a half years, however, there was no evidence of a continuing impact on these birds. Grebes, divers and cormorants showed no effect of oiling during the community monitoring following the spill.

PART 1: PRESENT DISTRIBUTION STUDIES

2. METHODS

2.1 Study Area

The study area consists of four sites: Angle Bay (Figure 2.1.1), Pembroke River (Figure 2.1.2), Carew/Cresswell (Figure 2.1.3) and Upper Cleddau (Figure 2.1.4). Each site was divided into several sectors to allow detailed analyses of results. Angle Bay was divided into 10 sectors, all affected by the spill. Sector 4 is an area of rocky shore and sector 10 is a small harbour. Each of the other three sites were divided into 12 sectors. At Pembroke River, sectors counted at the eastern end of the site (sectors 7, 8, 10, 11 and 12) extend as far upriver as Quoits Water Pill and were not affected by oil deposition. The count area at Carew/Cresswell extends to Newshipping Point on the Carew River and nearly to New Park on the Cresswell River. The area covered at the Upper Cleddau site includes the entrance to Landshipping Quay, the mouth of Millin Pill, the mouth of Sprinkle Pill and the intertidal areas at the confluence of the Eastern and Western Cleddau Rivers. Saltmarsh is found at the fringes of all sites, except Angle Bay, but was not surveyed. Where possible, the boundaries of the sectors follow those laid down by Hellawell & Phillips (1987) and Pr_s-Jones (1989). For the purposes of this study however, some count areas used by those studies have been divided into smaller units.

The species recorded include divers, grebes, cormorants, herons, wildfowl, waders and auks. In order to monitor all species comprehensively, an area of open water (sector 88) was also counted at each site.

2.2 Count Methodology

In order to gain a full picture of the use of the four intertidal areas by waterfowl and other birds, counts were carried out across the tidal cycle (an 'all-day' count - see Clark, 1990). This choice of methodology allows the most important feeding areas to be identified. Each site was counted once every hour from six hours before to five hours after low tide. Counts were made throughout the hours of daylight. Feeding and roosting birds were counted separately and factors such as disturbance to a sector or impaired visibility were noted. All birds present on the exposed sectors were counted. Wildfowl in the shallow water offshore, which were feeding on invertebrates or plants on or in the substrate were included in the counts for the respective sector. Those species such as divers, grebes, cormorants and diving ducks which use open water were counted as feeding or roosting over the appropriate sector or on the open water count area. Birds roosting in areas of saltmarsh were not counted, as accurate counts are very difficult in this habitat.

Counts during winter took place between November and March as the estuary is most important for birds during the winter period. The migration and early autumn periods have been excluded because numbers of birds can fluctuate widely from year to year, for reasons not associated with the estuary. Each site was counted twice a month with one count on a spring tide and one on a neap tide where possible. In this first year, only one count was carried out at each site in November.

Analysis follows Evans *et al*. (1990). All-day counts were used to calculate the following:

1. **the average exposure time per tidal cycle of each sector;**
2. **the average number of feeding bird hours per tidal cycle ('all-day usage' - the term 'usage' will be used throughout the report) for each species for each count sector;**
3. **the average number of birds of each species present on each of the four sites at each hour of the tidal cycle and the proportion feeding.**

For each species of wader and heron, all-day usage was calculated for each count sector as:

$$\sum_{A=+5}^{A=-6} (BxC)$$

where A is the hours from low tide (0 hours being low tide and +5/-6 high tide, B is the average number of birds feeding at time A on the exposed area, and C is the proportion of counts when the area was exposed at time A.

For wildfowl and other species that may feed on or under the water, all-day usage was calculated as:

$$\sum_{A=+5}^{A=-6} B$$

where the area is considered available from *A* = +5 to *A* = -6.

2.3 Presentation of Results

All species observed at the three sites during the period of study are discussed, but most emphasis is given to Shelduck, Wigeon, Teal, Oystercatcher, Grey Plover, Dunlin, Bar-tailed Godwit, Curlew and Redshank. Detailed accounts of their numbers and distribution at each site are given. These are supported by dot maps displaying the number of bird-feeding-hours per tidal cycle and graphs showing the average number of birds and the proportion feeding at each hour through the tidal cycle.

For other species, the main feeding areas are described and the peak numbers present during the winter are given. Those species recorded in the estuary on less than ten occasions during the winter are detailed in a table.

The order of the species accounts follows Voous (1973).

3. RESULTS AND SPECIES ACCOUNTS

One complete count was carried out at each site in November and two every month between December and March. A total of 44 species were recorded during the counts in the first year.

3.1 Main Species

3.1.1 Shelduck *Tadorna tadorna*

About 10,600 pairs of Shelduck breed in Britain mostly at coastal locations, but increasingly, at inland sites (Gibbons *et al.*, 1993). Following breeding, most adult Shelduck both from the UK and continental Europe move to moulting grounds in the German Wadden Sea and return to their wintering areas from September onwards. The British wintering population was at its lowest for five years in 1994/95, but was not unusually low in the context of normal yearly fluctuations in numbers (Waters *et al.*, 1996). Shelduck bred very successfully on the Cleddau Estuary in 1996, with 25 broods and a total of 217 ducklings reported. There was no evidence that they had been impacted by the oilspill (Hodges, 1997). During the winter, the Cleddau Estuary hosts nationally important Shelduck numbers (Table 1.1).

At Angle Bay, feeding Shelduck were concentrated mostly on mudflats 2 and 3 on the west side of the bay. Smaller numbers occurred on all the sectors at the east end of the bay (Figure 3.1.1.1). Between 50 and 80 birds were present on average (Figure 3.1.1.3) with a peak of 183 in January. Most Shelduck fed for the four hours either side of low tide. Birds roosted on the water or on the upper shore of sectors 2, 3 and 4 at high tide.

Shelduck at Pembroke River showed a similar pattern of feeding and roosting through the tidal cycle to those at Angle Bay. A peak of 412 was recorded in January although on average, between 130 and 170 birds were present (Figure 3.1.1.3). At high tide most roosted on the south shore between sectors 6 and 9, or during spring high tides, on the water or in fields south of sectors 3, 4, 5 and 6. Shelduck were found feeding on all sectors. The most important areas were the extensive mudflats between sectors 3 and 9 and sectors 7 and 11 to the east (Figure 3.1.1.1).

At Carew/Cresswell, Shelduck used all the sectors for feeding, although few were noted on sectors 3, 6 and 10 (Figure 3.1.1.2). Between 35 and 55 were present on average (Figure 3.1.1.3) with a peak of 153 in January. Numbers fluctuated erratically through the cycle, probably due to birds moving in and out of areas of saltmarsh. Most Shelduck fed for the four hours either side of low tide, although at low tide, some birds roosted on the mudflats. A small proportion of Shelduck also continued to feed during high water.

Shelduck at the Upper Cleddau numbered between 45 and 60 on average (Figure 3.1.1.3). A peak of 97 was recorded in January. Feeding was concentrated on the count sectors at the entrance to Millin Pill and Sprinkle Pill and sector 12 opposite Millin Pill (Figure 3.1.1.2). Smaller numbers were noted feeding on sectors 4 and 5. A different pattern of feeding was seen at this site. A peak in numbers feeding occurred on the ebb tide, but only 60%, on average, fed during the flood tide.

3.1.2 Wigeon *Anas penelope*

Wigeon breed amongst upland lakes and peat bogs. There is a small population in Britain of about 300-500 pairs (Gibbons *et al.*, 1993). In winter, many thousands of birds (a peak WeBS count of 390,000 in 1994/95) from Siberia, Scandinavia and Iceland arrive on British estuaries. Nationally important numbers of Wigeon use the Cleddau Estuary (Table 1.1).

Wigeon were seen feeding on all count sectors at Angle Bay. The highest numbers were on sectors 2, 3 and 6 (Figure 3.1.2.1). Average numbers varied between about 60 and 100 with a peak during the two hours after low water (Figure 3.1.2.3). Wigeon fed on the count sectors and adjacent fields throughout the tidal cycle.

Pembroke River normally holds a significant proportion of Wigeon on the estuary. Between 300 and 500 Wigeon were present on average across the winter, although there was a peak of 1400 in November. The birds generally arrive there earlier in the year than at the other sites and leave earlier. In 1996/97, larger numbers stayed longer than usual (Poole, pers. comm.). Feeding birds were concentrated on the extensive mudflats on the south side, particularly sectors 5 and 6 (Figure 3.1.2.1). Two peaks in feeding activity occurred, three to four hours before and three hours after low water (Figure 3.1.2.3). Between these periods, around low water, most birds roosted on the mudflats. At high tide Wigeon roosted on the water or on fields south of the estuary.

At Carew/Cresswell, the highest number of Wigeon occurred during the flood tide when there was an average of 130 birds present (Figure 3.1.2.3). At high tide, birds used the saltmarsh and upper reaches of the river and only gradually moved out onto the count sectors within the study area as the tide ebbed. There were two peaks of feeding activity, during the same periods as at Pembroke River. However, a higher proportion were feeding during those periods (up to 80%) and more birds also fed at high tide, usually at the edge of the saltmarsh. Wigeon fed on all the count sectors although there were few on sector 11 (Figure 3.1.2.2). Numbers peaked at nearly 300 in November.

At the Upper Cleddau, Wigeon numbers averaged between 30 and 80. The trends in numbers and feeding activity were similar to those at Carew/Cresswell (Figure 3.1.2.3), although an average 50% of birds present were still feeding five hours after low water. Birds fed on all count sectors, but in low numbers on sectors 7, 8 and 12 (Figure 3.1.2.2), possibly due to disturbance from walkers, including the observer.

3.1.3 Teal *Anas crecca*

The British breeding population of Teal is thinly distributed in areas throughout England, Scotland and Wales and there has been a marked contraction in its range over the last 20 years (Gibbons *et al.*, 1993). The wintering population in contrast, has shown a general increase with numbers of 130,000 in 1994/95 being the highest for several years (Waters *et al.*, 1996). The Cleddau estuary regularly holds nationally important numbers; nearly 3,000 were present in 1995/96 (Table 1.1).

A flock of up to 230 Teal was occasionally present at Angle Bay, sometimes feeding on the flood tide with Wigeon on sectors 2 and 3 (Figures 3.1.3.1 and 3.1.3.3).
Teal were only rarely recorded on the count areas at Pembroke River. A maximum of 55 were seen in January feeding on the flood tide at the entrance to Goldborough Pill. Small

groups of up to sixteen birds were also seen at the eastern end of the study site (Figure 3.1.3.1).

There were up to about 40 Teal on average at Carew/Cresswell (Figure 3.1.3.3), although a peak of 161 occurred in December. The main concentrations of feeding birds were on sectors 1, 2 and 3, although they also fed on sectors 4, 5, 7, 9 and 12 (Figure 3.1.3.2). Figure 3.1.3.3 shows that numbers fluctuated considerably over the tidal cycle, probably as a result of birds moving into unsurveyed saltmarsh. At low water, Teal often fed or roosted unsighted along tidal creeks and banks. The proportion of birds feeding was highest three to four hours after low water. There was also a smaller peak in the proportion feeding three to four hours before low water.

The largest number of Teal were present at the Upper Cleddau, with a peak of 470 in November. An average of about 200 birds were present four hours after low water (Figure 3.1.3.3). At low water, however, only 20 birds were recorded on average, as birds had yet to appear from the larger channels, especially at Sprinkle and Millin Pill (Figure 3.1.3.2). As at Carew/Cresswell, birds were often hidden along the banks of creeks and channels. Feeding activity peaked two to three hours before and again two to three hours after low water.

3.1.4 Oystercatcher *Haematopus ostralegus*

A population of 33,000-43,000 pairs of Oystercatcher breed in Britain, occupying both inland and coastal sites (Piersma, 1986; Gibbons *et al.*, 1993). In autumn and winter, the number of birds increases with an influx of migrants from northern Europe. A peak of 237,000 was recorded on the estuaries and coasts of Britain in 1994/95 (Waters *et al.*, 1996). The Cleddau estuary usually holds between 300-500 Oystercatchers in winter and is not nationally important for the species (Table 1.1).

An average of between 45 and 60 Oystercatchers frequented Angle Bay (Figure 3.1.4.3), with a peak of 107 in December. Most fed on sectors 2, 3, 8 and 9, while few used sector 10 (Figure 3.1.4.1). Birds fed through the entire exposure period, and roosted or fed in nearby fields at high tide. As with Curlew, they also fed on the rock platforms on the upper-mid shore.

Pembroke River hosted similar numbers of Oystercatchers to Angle Bay on average (Figure 3.1.4.3). However, few were present in this embayment at low tide, suggesting that they may move out onto areas in the main waterway at that time. Oystercatchers fed on all areas as they were exposed, with the exception of sectors 2 and 3. Most fed on sectors 5, 6 and 9 (Figure 3.1.4.1).

There were between 10 and 17 Oystercatcher on average at Carew/Cresswell. Birds fed throughout the exposure period (Figure 3.1.4.3). Feeding was concentrated on sectors 6, 7 and 11, with fewer birds on sectors 3, 5, 8, 9 and 12 (Figure 3.1.4.2). They only occasionally fed on sectors 1, 2 and 4.

Numbers of Oystercatcher at the Upper Cleddau averaged between 20 and 25 across the winter (Figure 3.1.4.3). All the count sectors were used when exposed, but feeding was concentrated on sectors 2, 3, 4, 5, 9 and 12 (Figure 3.1.4.2).

3.1.5 Grey Plover *Pluvialis squatarola*

The British wintering population of Grey Plover originates mainly from breeding areas between the White Sea and the Taimyr Peninsula in Russia (Prater, 1981). Recent winters have seen numbers increasing rapidly and in 1994/95 there was a peak WeBS count of 49,000 (Waters *et al.*, 1996). Numbers on the Cleddau estuary do not exceed the level of national importance (Table 1.1).

Numbers of Grey Plover averaged between seven and 21 at Angle Bay (Figure 3.1.5.3), although there was a peak of 86 in February. Most birds fed between four hours before low water until two hours after low water and were concentrated on sectors 1, 2, 5 and 6 (Figure 3.1.5.1).

At Pembroke River, feeding Grey Plover were concentrated on sectors 5, 6 and 9 on the south side of the estuary (Figure 3.1.5.1). The highest numbers occurred around low water when there was an average of 21 present across the winter (Figure 3.1.5.3). In January there was a peak of 94 birds in the embayment.

Grey Plover were less common at Carew/Cresswell and Upper Cleddau than at the lower embayments, averaging only six to 10 birds across the winter (Figures 3.1.5.3 and 3.1.5.3). Peak numbers were 35 at Carew/Cresswell and 30 at Upper Cleddau in January. At Carew/Cresswell, most feeding occurred on sectors 5, 6, 7 and 8 (Figure 3.1.5.2). At Upper Cleddau, birds fed on sectors 1 and 2 at the entrance to Sprinkle Pill and on sector 12 (Figure 3.1.5.2).

3.1.6 Dunlin *Calidris alpina*

Almost 10,000 pairs of Dunlin breed in Britain (Reed, 1985; Stone *et al.*, 1997), mainly in the flows of northern Scotland and on peaty bogs in the English and Scottish uplands (Stroud *et al.*, 1987). The wintering population is boosted by the arrival of large numbers of migrant birds from northern Scandinavia and the former USSR (Lack, 1986). There was a WeBS count of over 530,000 birds around the estuaries and shores of Britain in 1994/95 (Waters *et al.*, 1996). The Cleddau estuary usually holds between 3,000 and 5,000 Dunlin in winter and is not nationally important for the species (Table 1.1).

Dunlin fed on all areas at Angle Bay, except the rocky surface of sector 4 (Figure 3.1.6.1). An average 175 to 200 birds were present from two hours before to two hours after low water, the majority of which was feeding (Figure 3.1.6.3). There was a peak of 465 birds in February.

At Pembroke River, numbers of Dunlin averaged between 400 and 600 birds (Figure 3.1.6.3), with a peak of over 1,450 in February. The majority of birds fed for the entire tidal cycle. Roosting only occurred for a short period around high water. Birds fed on all the sectors, but the highest concentrations were found on the extensive mudflats of sectors 5, 6 and 9 (Figure 3.1.6.1).

The average number of Dunlin at Carew/Cresswell was similar to that at Pembroke River (Figure 3.1.6.3). A peak of 1,750 birds was recorded in January. Feeding was concentrated on sectors 5, 6, 7 and 8 (Figure 3.1.6.2).

The average number of Dunlin at the Upper Cleddau varied greatly across the tidal cycle. There was a peak (average) of 275 one hour before low water but numbers dropped to 75

an hour later (Figure 3.1.6.3). At low water, Dunlin may have moved away from the study site to feeding areas outside. Within the study site, birds fed mainly on sectors 5 and 12 (Figure 3.1.6.2). Smaller numbers were present on all the other count sectors, with the exception of sectors 3 and 11.

3.1.7 Bar-tailed Godwit *Limosa lapponica*

WeBS counts revealed a peak of 44,000 Bar-tailed Godwits in 1994/95. Nationally, numbers have declined since the 1980s (Waters *et al.*, 1996). The species occurs irregularly on the Cleddau Estuary in winter, usually in small numbers, and occasionally not at all.

Angle Bay held about 16 Bar-tailed Godwit on average across the winter (Figure 3.1.7.2). The birds usually fed at the water's edge on sector 2 and all count sectors at the east end of the bay (Figure 3.1.7.1). There was a peak of 32 birds in January.

There was a peak of 20 Bar-tailed Godwits feeding at Pembroke River, but across the winter, numbers averaged no more than five (Figure 3.1.7.2). Birds favoured sector 7, but also fed on sectors 6, 9 and 11 (Figure 3.1.7.1).

One Bar-tailed Godwit was recorded at the Upper Cleddau during November and December, often associated with a small party of Black-tailed Godwits.

None were recorded at Carew/Cresswell.

3.1.8 Curlew *Numenius arquata*

The Curlew characteristically breeds on damp upland moorlands, but this century has colonised many lowland regions, including agricultural habitats (Gibbons *et al.*, 1993). The breeding population of Britain has been estimated at 33,000-38,000 pairs (Reed, 1985; Stone *et al.*, 1997). Some of this population winters in France, but many other Curlew from continental Europe, notably Scandinavia, migrate to Britain to winter (Prater, 1981). A peak of 88,000 wintered on the estuaries and shores of Britain in 1994/95 (Waters *et al.*, 1996), an increase on the previous year (Cranswick *et al.*, 1995). The Cleddau estuary normally holds nationally important numbers of Curlew during the winter (Table 1.1).

Numbers of Curlew at Angle Bay peaked at 155 in November. The average number of birds present built up to a peak (just over 60 at low water) as the tide ebbed and then fell on the flood tide, as did the proportion of birds feeding (Figure 3.1.8.3). Curlew feed extensively in fields above the foreshore (Jane Hodges, pers. comm.) so this suggests that birds may have moved onto the count sectors from nearby fields to feed as larger areas were exposed by the receding tide. Curlew fed on all areas of the bay, but most used sectors 2 and 3 (Figure 3.1.8.1).

At Pembroke River, all the count sectors were used by feeding Curlew, with the highest concentrations on sectors 5, 6 and 9 (Figure 3.1.8.1). Between the ebb and flood tides, numbers averaged around 80 birds at times during the tidal cycle when the mud was exposed (Figure 3.1.8.3). However, even at low water, over 20% of were roosting. The number of Curlew peaked at 152 in November.

At Carew/Cresswell, Curlew used all count sectors for feeding (Figure 3.1.8.2). Numbers

peaked at 76 in February. On average, between 40 and 45 were present, up to 90% of which were feeding (Figure 3.1.8.3).

Curlew at the Upper Cleddau fed on all the count sectors, but were concentrated on sectors 2 and 10 (Figure 3.1.8.2). Numbers rose sharply on the ebb tide as birds arrived from outside the area and from surrounding saltmarsh (Figure 3.1.8.3). The highest number occurred at low water when there was an average of 80 birds present, then numbers fell on the flood tide. On average, at least 30% of the Curlew present were roosting. Numbers peaked at 134 in February.

3.1.9 Redshank *Tringa totanus*

An estimated 30,000-34,000 pairs of Redshank breed in Britain, mainly on wet grasslands and on coastal saltmarshes (Reed, 1985; Gibbons *et al.*, 1993; Stone *et al.*, 1997). The British wintering population is formed of birds from both Britain and Ireland, and Iceland (Prater, 1981). A minimum population of 83,000 wintered on Britain's estuaries and shores in 1994/95 (Waters *et al.*, 1996). Numbers of Redshank on the Cleddau estuary have declined and have not been at a level of national importance since the 1980s (Table 1.1).

Angle Bay held an average of 15 Redshank (Figure 3.1.9.3), with a peak of 28 birds in February. The majority of birds fed for the entire exposure period. Feeding activity was concentrated on the western count sectors, particularly sector 10 (Figure 3.1.9.1).

At Pembroke River Redshank numbers averaged between 25 and 40 through the winter (Figure 3.1.9.3). Most feeding birds were found on sector 5 and count sectors at the eastern end of the embayment (Figure 3.1.9.1).

At Carew/Cresswell, Redshank numbers averaged between 20 and 33 (Figure 3.1.9.3), with a peak of 70 birds in November. Birds used all count sectors, although few were recorded on sectors 6 and 10 (Figure 3.1.9.2).

The few Redshank that were recorded at the Upper Cleddau study site favoured the count sectors at Landshipping and the entrance to Sprinkle Pill (Figure 3.1.9.2). Many more Redshank are present in Sprinkle Pill, Millin Pill and upriver on the Eastern and Western Cleddau (Pr_s-Jones, 1989; Poole, 1996). Around low water, birds often fed unsighted along the banks of channels (Figure 3.1.9.3).

3.2 Other Species

3.2.1 Great-crested Grebe *Podiceps cristatus*

Great-crested Grebes were most numerous at Angle Bay. A peak of eight feeding birds was recorded in February, but more roosted on the water in the bay (a maximum of 24 on 27 January). It is possible that birds feeding out to sea or in the main Milford Haven Waterway roost in the shelter provided by the bay.

One to four Great-crested Grebes were often feeding or roosting at Pembroke River, particularly at the western end. A peak of six birds was recorded in February.

A single Great-crested Grebe was occasionally present at Carew/Cresswell between January and March.

One to five birds were often recorded feeding at the Upper Cleddau, with a peak of seven in February.

3.2.2 Little Grebe *Tachybaptus ruficollis*

Little Grebes were regularly recorded throughout the winter at Pembroke River, Carew/Cresswell and the Upper Cleddau, but they were absent from Angle Bay. Peak counts of 11 were noted at the two former sites and a peak of nine at the Upper Cleddau.

3.2.3 Cormorant *Phalacrocorax carbo*

One to two Cormorants were recorded on several dates throughout the winter at Angle Bay.

At Pembroke River, one or two often fed or roosted at the western end near the mouth of the river, with a peak of five there on 25 November.

One or two were also present on occasions throughout the winter at Carew/Cresswell.

Cormorants were most often recorded at the Upper Cleddau. Birds fed on the open water throughout the study site and roosted mainly on exposed sectors 3 and 5. A maximum of seven was noted in March roosting on sector 3.

3.2.4 Little Egret *Egretta garzetta*

One Little Egret was at Angle Bay on 13 December and one or two were recorded occasionally at the other three sites throughout the winter. A peak of five was noted at Carew/Cresswell on 21 March.

3.2.5 Grey Heron *Ardea cinerea*

Grey Heron were present on several dates throughout the winter at Angle Bay and Pembroke River, with a peak of five in December at both sites. A single Heron was recorded on several dates at Carew/Cresswell. One or two were occasionally present at the Upper Cleddau.

3.2.6 Mallard *Anas platyrhynchos*

Mallards were most numerous at Angle Bay during December, with a peak of 57, although between 10-20 were more typically recorded. Feeding activity was concentrated on sector 2, with smaller numbers on sectors 1, 3, 6, 9 and 10.

Up to 16 Mallards were recorded at Pembroke River. Most feeding activity occurred in shallow water covering sectors 1 and 2.
At Carew/Cresswell, Mallards were typically seen feeding at the water's edge of sectors 2 and 10. A peak of 45 was noted on 15 December.

Around 20 birds often fed at the Upper Cleddau, favouring sectors 1 and 6. A peak of 93 was recorded on 23 November.

3.2.7 Goldeneye *Bucephala clangula*

Two Goldeneye were seen feeding in Angle Bay on 13 January.

At Pembroke River, usually up to seven Goldeneye were present feeding in all areas of the site, although there was a peak of 16 in January.

Up to five birds were usually recorded at Carew/Cresswell, with a peak of 10 in January. Birds fed in all areas of the site.

At the Upper Cleddau, up to eight Goldeneye were present in January. One to three birds were generally recorded during the other winter months. All areas of the site were used for feeding.

3.2.8 Red-breasted Merganser *Mergus serrator*

One or two Red-breasted Mergansers were recorded on three occasions at Angle Bay.

At Pembroke River, one to three birds were present during January. Singles were recorded during the other winter months.

A peak of five was noted on 25 November at Carew/Cresswell, then one or two until the end of January

Red-breasted Mergansers were present throughout the winter at the Upper Cleddau, with up to five birds feeding in all areas of the site.

3.2.9 Ringed Plover *Charadrius hiaticula*

Twenty-five Ringed Plover were on sector 6 of Angle Bay on 16 February, most of which were roosting. Ringed Plover were, however, only occasional visitors to the bay and only up to four were usually noted.

At Pembroke River, up to 14 were present on sectors 7 and 8 during December.

No Ringed Plover were recorded at Carew/Cresswell.

Up to 15 were occasionally recorded between December and February at the Upper Cleddau, feeding mostly on sectors 7 and 8.

3.2.10 Golden Plover *Pluvialis apricaria*

Large flocks of mainly roosting Golden Plover were present at Angle Bay and Carew/Cresswell. Up to 410 were recorded at Angle Bay between November and mid-January.

At Carew/Cresswell, 300 were recorded in December, but more often, only around 25 were

present.

At the Upper Cleddau, 18 Golden Plover were present on 16 December and one was recorded on 21 January.

No Golden Plover were seen at Pembroke River

3.2.11 Lapwing *Vanellus vanellus*

At Angle Bay, 540 Lapwing roosted on sectors 3 and 4 on 1 December. Smaller groups of up to 20 were recorded on three other occasions.

Large flocks of Lapwing, the majority of which were roosting, were also present at Carew/Cresswell from November to February. Birds used sectors associated with the River Cresswell (sectors 1-6). A peak of 775 was recorded on 15 December.

Similarly, large flocks of mainly roosting birds used most sectors at the Upper Cleddau from November to January. A peak of 1,013 was recorded on 26 November.

No Lapwing were seen at Pembroke River.

3.2.12 Knot *Calidris canutus*

At Angle Bay, small feeding flocks of up to 43 Knot were present, mainly on sectors 5 and 6, from December to February.

Knot were recorded on several dates at Pembroke River between November and January. Up to 56 feeding birds mostly used sectors 6 and 9.

At the Upper Cleddau, up to three Knot were seen feeding on 24 January and 20 February.

No Knot were recorded at Carew/Cresswell.

3.2.13 Black-tailed Godwit *Limosa limosa*

Black-tailed Godwits were most numerous at the Upper Cleddau, with up to 13 present from November to January, mainly at the mouth of Sprinkle Pill.

At Pembroke River, nine roosting birds were recorded on 21 March.

No Black-tailed Godwits were seen at Angle Bay or Carew/Cresswell.

3.2.14 Greenshank *Tringa nebularia*

One to three Greenshank fed on sectors on the west side of Angle Bay infrequently throughout the winter. At the other three sites, one or two Greenshank were recorded on several occasions using various sectors for feeding.

3.2.15 Turnstone *Arenaria interpres*

Turnstone were recorded only at the lower embayments. At Angle Bay, groups of up to 16

feeding birds were recorded mostly on the west side of the bay on several dates from November to February. At Pembroke River, up to 12 birds fed mostly on sectors 7 and 8 from November to February.

3.3 Occasional Species

Twenty other species were recorded during counts, but in numbers too small to be included in the separate species accounts. These are shown in Table 3.3.1.

4. DISCUSSION

At this stage of the project, conclusions can only be tentatively made about the bird populations in the study area. After the second and third years of the project, it will be possible to compare the changes in all-day usage at Angle Bay and Pembroke River with changes caused by natural population fluctuations at Carew/Cresswell and the Upper Cleddau. The latter sites, however, may not be perfect controls as it is possible that there may have been an influx of birds to them following the oilspill. Poole (1996) reported that numbers of birds on the estuary returned to normal levels soon after the oilspill, but with a majority of birds found in the upper estuary embayments.

It would be useful, therefore, to compare waterfowl population changes at the sites in the Milford Haven complex with those at sites away from the incident. Cardiff Bay, some 100 miles away is being studied using similar techniques (Burton *et al.*, 1997). Unfortunately, with the completion of the Cardiff Bay Barrage in mid-1998, the mudflats there will be flooded. Nevertheless, trends in waterfowl populations both in Milford Haven and other areas will be available through WeBS data, making the inferred conclusions more robust. Comparisons between bird populations on the Cleddau Estuary this year and those of previous years are discussed in Part 2.

PART 2: PREVIOUS DISTRIBUTION STUDIES

5. PREVIOUS STUDIES

Baseline data from counts at various states of tide are available from three previous studies (Haycock, 1986; Hellawell & Phillips, 1987; Pr_s-Jones, 1989). Wetland Bird Survey (WeBS) counts provide an additional picture of the numbers of waterfowl present before, during and after the oilspill.

Haycock (1986) recorded the movement of selected species at several places on the Cleddau Estuary, including the sites covered in the present study. This was carried out on a single day in February 1986. Birds at each site were counted at high water, then their movements were logged during each subsequent 20 minute period until low water.

Hellawell & Phillips (1987) studied the feeding and roosting areas of selected species at all the sites included in the present study. The fieldwork, involving timed observations of birds, was carried out between February and March 1987. As numbers of Wigeon, Teal, Curlew and Redshank had decreased through migration, the report concentrates on the distribution of Shelduck.

Pr_s-Jones (1989) analysed waterfowl counts carried out at Angle Bay, Pembroke River, Carew/Cresswell and the Eastern and Western Cleddau at various states of tide between November 1987 and February 1988. Each site was split into count sectors and the results were given as peak counts of each species on each sector. Information from monthly Birds of Estuaries Enquiry (BoEE) counts (now WeBS) was also examined to show long-term trends in waterfowl numbers.

WeBS counts are carried out by a network of volunteers, on a preselected day each month, mainly at high tide when many waterfowl congregate at roosting sites. WeBS counts thus vary from the counts made during this study, which records waterfowl at all stages of the tidal cycle. Our counts will be of roosting birds as well as feeding birds and even within a sector these need not be the same, as birds may feed and roost in different parts of an estuary.

6. COMPARISON WITH PREVIOUS STUDIES

Some count sectors used in the present study have been combined to provide a comparison with those of Pr_s-Jones (1989). These are detailed in Table 6.1 and shown in Figures 6.1 and 6.2. Dotmaps display the peak number of each species on each sector in each of the two studies. At Pembroke River, sectors C and D do not coincide well enough with sectors used in the present study (sectors 11 and 12) for a comparison to be made. The same problem occurs with sectors A and E at Carew/Cresswell (sectors 4 and 9 in the present study).

The average mid-winter (November to February) WeBS counts from 1981/82 to 1996/97 at Angle Bay, Pembroke River, Carew/Cresswell and the Eastern and Western Cleddau are also shown. The March counts were not included in calculating the average because they were not always available in the datasets. In some years, not enough counts were carried out to determine an average, or counts were of low quality. These years have been excluded from the data set. In years when only one count was unavailable, a missing value was calculated and included in the average. The counts for the Eastern and Western Cleddau have been calculated by summing the counts at the Western Cleddau between Little Milford and Sprinkle Pill and the whole of the Eastern Cleddau.

6.1 Shelduck

At Angle Bay, Haycock (1986) recorded 120 Shelduck in February 1986 and Hellawell and Phillips (1987) a peak of 80 in winter 1986/87, the majority using the eastern side of the bay for feeding. Up to 75 birds fed in the bay, mostly on the south-east side in winter 1987/88 (Pr_s-Jones, 1989). In winter 1996/97, more birds used sector B than in these previous studies, but there were fewer on sector D (Figure 6.3). The average mid-winter WeBS count in 1996/97 was 70, lower than in winter 1995/96 which was the highest number recorded in the last 15 years (Figure 6.7).

At Pembroke River, sectors A and E were more important to Shelduck in winter 1996/97 than they were in winter 1987/88, but sector B was less important (Figure 6.4). The average mid-winter WeBS count this year of 171 birds was the lowest for the embayment in the last 15 years but is part of a continuing trend of decreasing numbers since 1990/91 (Figure 6.7).

At Carew/Cresswell, the highest concentrations of Shelduck were recorded by Pr_s-Jones (1989) at the confluence of the two rivers. Fewer birds were recorded on the upper reaches. Similarly, Hellawell and Phillips (1987) reported the area near Black Mixen (at the confluence) being most important for Shelduck. This year, all sectors were used by feeding Shelduck but fewer were noted on the sectors B and C at the confluence of the rivers than by Pr_s-Jones (1989) (Figure 6.5). An average of 112 Shelduck was recorded by WeBS counts, a figure lower than that recorded in most years (Figure 6.7), but similar to that of winter 1995/96.

At the Upper Cleddau, the distribution of Shelduck in winter 1996/97 was similar to that recorded by Pr_s-Jones (1989) and Hellawell and Phillips (1987), with the areas at the mouth of Sprinkle and Millin Pills being the most important. This winter, fewer birds were recorded on sectors D and E than in 1987/88, but more were seen using sectors C and F (Figure 6.6). The number of Shelduck present in winter 1996/97 was, however, lower than in those previous studies. The average WeBS count of 125 birds for the Cleddau Rivers in

winter 1996/97 was typical (Figure 6.7).

6.2 Wigeon

At Angle Bay, the distribution of Wigeon in 1996/97 differed to that recorded by Pr_s-Jones (1989) in winter 1987/88. More use was made of sectors A, B and C, but fewer were recorded on sector D (Figure 6.8). An average count of only 79 Wigeon was recorded by WeBS in 1996/97, which is lower than in most years and well below the number recorded in 1995/96 (Figure 6.12).

At Pembroke River, the numbers and distribution of Wigeon in 1996/97 were similar to those recorded by Pr_s-Jones (1989) in winter 1987/88 (Figure 6.9). The most important feeding area was again sector F, around Goldborough Pill. Fewer Wigeon were present on sector G this year than in winter 1987/88, when it was mainly used by roosting birds. WeBS recorded an average mid-winter count of 1,423 Wigeon in 1996/97, the highest figure in the last 15 years (Figure 6.12).

At Carew/Cresswell, the distribution and numbers of Wigeon in 1996/97 were similar to those in winter 1987/88 (Figure 6.10). On just one sector (B), fewer Wigeon were recorded in 1996/97. The average number of Wigeon recorded by WeBS counts in 1996/97 was 274, a fairly high count, although slightly lower than that recorded during the 1995/96 winter (Figure 6.12).

At the Upper Cleddau, Pr_s-Jones (1989) reported that the most important areas for Wigeon were at Sprinkle Pill (sector D) and the lower Eastern Cleddau (sector F). In winter 1996/97, Wigeon were well distributed across all sectors (Figure 6.11). Higher peak counts occurred on four sectors this year and a lower count only on sector F. The average WeBS count of 181 in winter 1996/97 was fairly typical, but slightly lower than that of the winter of the spill (Figure 6.12).

6.3 Teal

At Angle Bay, Teal were not recorded in any of the previous studies. They have occasionally been recorded there during WeBS counts (Figure 6.17). In winter 1996/97 a peak count of 230 was recorded by this study, mainly on sector B (Figure 6.13). The average WeBS count of 88 birds this year was by far the highest recorded in the last 15 years (Figure 6.17).

At Pembroke River, Pr_s-Jones (1989) reported that Teal were restricted to the Goldborough Pill area (sector F) and sector G in winter 1987/88 (Figure 6.14). In winter 1996/97, 55 birds were recorded once on sector F, but smaller numbers were also recorded on the adjacent sector E (Figure 6.14). The average count recorded by WeBS this year was 54, the highest figure recorded in the last seven years, but much lower than counts in the 1980s (Figure 6.17). There may be some discrepancy between the counts made during this study, Pr_s-Jones (1989) and WeBS. Teal are difficult to count until the tide flushes them out of the channels. Counts by Pr_s-Jones (1989) were carried out from the south shore close to Goldborough Pill and WeBS counts are carried out from within Goldborough Pill. In this study, counts of birds using the sector which includes Goldborough Pill were carried out from the north shore near Pennar, from where Teal are very difficult to see.

At Carew/Cresswell, Teal were widely distributed in winter 1987/88, though there were notable concentrations along the middle Cresswell, with flocks of over 100 birds. In winter 1996/97, peak counts of Teal were lower than in 1987/88 on all three sectors (Figure 6.15). WeBS recorded an average count of 226 Teal in winter 1996/97, an increase on winter 1995/96, but much lower than counts in the 1980s (Figure 6.17).

On the Eastern Cleddau, Haycock (1986) recorded 100-200 Teal, with a further 150 Teal at Sprinkle Pill. Hellawell and Phillips (1987) found Teal throughout the Cleddau Rivers, with the highest concentrations at the entrance to Millin and Sprinkle Pills. Pr_s-Jones recorded a minimum of 400 Teal in the Sprinkle Pill area in winter 1987/88. In winter 1996/97, Teal were concentrated in the same areas, but peak counts were higher on sectors A (Millin Pill) and E (Landshipping) and lower on sectors B and F (Figure 6.16). The average mid-winter WeBS count in 1996/97 was slightly lower than in winter 1995/96 (Figure 6.17).

6.4 Oystercatcher

At Angle Bay, Haycock (1986) recorded 80-95 Oystercatcher in February 1986. A maximum of 80 Oystercatcher were recorded in winter 1987/88. Birds were spread widely over the sectors and the fields surrounding the bay (Pr_s-Jones, 1989). More birds were found on sector A in 1996/97 than in 1987/88 (Figure 6.18). The average WeBS count this winter of 75 birds was lower than in winter 1995/96 but not atypical of the whole dataset (Figure 6.20).

At Pembroke River, up to 75 Oystercatcher were recorded at roost in winter 1987/88, often on sector G. Birds fed in small groups throughout the embayment (Pr_s-Jones, 1989). In 1996/97, peak counts were higher on sectors E and F but lower on sectors B and G than in 1987/88 (Figure 6.19). The average count recorded by WeBS in winter 1996/97 was of 109 birds, a much higher figure than 1995/96 but not atypical of the whole dataset (Figure 6.20).

At Carew/Cresswell, Haycock (1986) recorded only two to five Oystercatcher in February 1986 and Pr_s-Jones (1989), a maximum of 17 along the lower reaches. The average mid-winter WeBS count of 30 birds in winter 1996/97 represents the third highest figure for the embayment in 15 years (Figure 6.20). The highest peak count recorded at Carew/Cresswell was in February of winter 1995/96.

On the Eastern Cleddau, Haycock (1986) recorded a maximum of 25 Oystercatcher at roost in February 1986. Pr_s-Jones (1989) reported Oystercatcher scattered in small numbers along the lower reaches of the Eastern and Western Cleddau, with a maximum 30 birds at roost. In contrast to this, WeBS recorded a mid-winter average of 30 birds on the Eastern and Western Cleddau in 1996/97, the highest count since 1990/91 (Figure 6.20).

6.5 Grey Plover

At all four sites, Grey Plover numbers in 1996/97 were much higher than those recorded by Pr_s-Jones (1989). The average WeBS count at Angle Bay in winter 1996/97 was of 10 birds (Figure 6.21), a substantial increase on the previous year but not atypical of the whole dataset. At Pembroke River, an average of 61 Grey Plover was recorded by WeBS in

1996/97, the second highest figure in the last 15 years (Figure 6.21) and similar to that in 1995/96. The average WeBS count at Carew/Cresswell of 25 birds in 1996/97 was the highest in the last 15 years (Figure 6.21). At the Upper Cleddau, the average mid-winter WeBS count this year of 24 birds was also much higher than previously recorded (Figure 6.21).

6.6 Dunlin

At Angle Bay, Haycock (1986) recorded 235-250 Dunlin in February 1986. Up to 250 birds were noted feeding mainly on the south-east sector (sector C) by Pr_s-Jones (1989) in 1987/88 (Figure 6.22). Birds on sector D were mostly roosting. In winter 1996/97, feeding Dunlin were not restricted to the eastern side of the bay, but used all sectors for feeding (Figure 6.22). The peak numbers recorded on sectors A, B and C were higher this year than in 1987/88, but lower on sector D. The average number recorded by WeBS in winter 1996/97 was 155. This figure is similar to that of winter 1995/96 (Figure 6.26).

At Pembroke River, only up to 215 Dunlin were recorded by Haycock (1986). Pr_s-Jones noted far more birds in 1987/88, with over 1,000 present at times, particularly on sectors E and F. Up to 500 were also noted on sector G (Figure 6.23). In winter 1996/97, the most important areas for feeding were again sectors E and F, but fewer were recorded on sectors B and G (Figure 6.23). WeBS recorded large numbers of Dunlin at Pembroke River in 1996/97, with an average of 2,720 birds, by far the highest figure in the last 15 years (Figure 6.26).

At Carew/Cresswell, Pr_s-Jones (1989) noted flocks of only up to 70 Dunlin in winter 1987/88. Figure 6.24 shows that much higher numbers were present on all sectors in winter 1996/97. The average WeBS count of 1,180 in winter 1996/97 is the highest for the embayment in the last 15 years (Figure 6.26).

On the Eastern and Western Cleddau Rivers, Haycock (1986) recorded up to 200 Dunlin in February 1986. Hellawell and Phillips (1987) noted 600, the majority of which were feeding at the entrance to Millin and Sprinkle Pills, Fowborough Point and the lower Eastern Cleddau. Pr_s-Jones (1989) recorded Dunlin on sectors between Millin Pill and Sprinkle Pill with up to 700 at Sprinkle Pill. In winter 1996/97, large flocks fed in similar areas to those noted by Pr_s-Jones (1989), but birds also used sector A at the mouth of Millin Pill in 1996/97 (Figure 6.25). None, however, were recorded on sector C. The average mid-winter WeBS count of 234 in 1996/97 was the second lowest since the 1983/84 winter (Figure 6.26).

6.7 Bar-tailed Godwit

At Angle Bay, Pr_s-Jones (1989) recorded only two Bar-tailed Godwits in winter 1987/88, and none at Pembroke River. In contrast, in winter 1996/97, all-day counts at Angle Bay revealed a peak of 32 birds in January and at Pembroke River, up to 20 birds were recorded. The average WeBS count at Angle Bay was 22 birds, an increase on 1995/96 (Figure 6.27). At Pembroke River, an average of 11 birds was recorded by WeBS counts in 1996/97 (Figure 6.27), also an increase on the previous year. These were the second and third highest counts of the species made since the 1982/83 winter respectively.

At Carew/Cresswell, 11 Bar-tailed Godwits were noted at the confluence of the two rivers

in winter 1987/88 (Pr_s-Jones, 1989). None were recorded in the present study. Only two birds were registered by WeBS counts in winter 1996/97, the same as in 1995/96.
At the Eastern and Western Cleddau, Bar-tailed Godwits are not recorded in most winters (Figure 6.27). In winter 1996/97, one was recorded during both WeBS counts and the present study.

At all four sites, WeBS counts show that Bar-tailed Godwit numbers vary considerably from year to year (Figure 6.27).

6.8 Curlew

The eastern side of Angle Bay was favoured by feeding Curlew in winter 1987 (Hellawell & Phillips, 1987). Pr_s-Jones (1989) noted substantial roosting flocks on the south and south-east shores, with birds dispersing to feed on all sectors and in surrounding fields. In winter 1996/97, less use was made of the eastern side of the bay (Figure 6.28). The average mid-winter WeBS count of 42 Curlew in 1996/97 was by far the lowest in the last 15 years (Figure 6.32).

At Pembroke River, Pr_s-Jones (1989) noted Curlew feeding widely in winter 1987/88. A peak of over 250 were recorded roosting on sector G. In winter 1996/97, few birds were found there, although many birds roosted in the adjacent saltmarsh where they were not counted. Sectors A and E were more important to feeding birds this winter (Figure 6.29). The average WeBS count of 195 birds was the highest since 1989/90 and part of a continuing trend for increasing numbers since 1991/92 (Figure 6.32).

At Carew/Cresswell, Hellawell and Phillips (1987) noted a wide dispersion of feeding Curlew. A peak of 273 was recorded at roosts in February 1987. Pr_s-Jones (1989) recorded over 100 Curlew (the majority roosting) on some sectors and much movement of birds between the estuary and surrounding fields. In 1996/97, numbers of Curlew recorded were lower, particularly on the lower reaches of the River Carew (Figure 6.30). It should be noted, however, that birds in the saltmarsh were not counted. The average WeBS count of 116 birds in winter 1996/97 was low in comparison with most years and part of a continuing trend for decreasing numbers started during the 1992/93 winter (Figure 6.32).

At the Upper Cleddau, Hellawell and Phillips (1987) and Pr_s-Jones (1989) also noted that feeding Curlew were widely dispersed. Pr_s-Jones (1989) only found concentrations of over 100 birds at high tide roosts (Figure 6.31). In winter 1996/97 peak counts were lower on sectors B and C, around the north of Fowborough Point than in 1987/88. The average mid-winter WeBS count of 238 for the Eastern and Western Cleddau Rivers was slightly higher than in 1995/96 but not atypical (Figure 6.32).

6.9 Redshank

At Angle Bay, Pr_s-Jones (1989) recorded small numbers of Redshank distributed throughout. In winter 1996/97, birds were concentrated on sector A, with smaller numbers on sectors B and C (Figure 6.33). None were recorded on sector D. WeBS recorded an average of 14 birds at Angle Bay during winter 1996/97, a figure similar to those of the previous six years, but much lower than in the 1980s (Figure 6.37).

At Pembroke River, Haycock (1986) noted 40 Redshank roosting near the Power Station (sector G) in February 1986, which then dispersed locally to feed. Pr_s-Jones (1989) recorded feeding birds well spread on the mudflats at Pembroke River, although with the bulk of the population south of the main channel (Figure 6.34). In the present study, fewer birds were recorded in this area and more were present on sector B north of the channel. In both studies, however, numbers were likely to have been underestimated, as birds may have been hidden in creeks, particularly at Goldborough Pill (sector F). The average mid-winter WeBS count for 1996/97 was of 72 birds, lower than in 1995/96 (Figure 6.37).

At Carew/cresswell, Pr_s-Jones (1989) noted up to 25 Redshank evenly distributed across the count sectors. In winter 1996/97, peak counts on each sector were lower than in 1987/88 (Figure 6.35), although again, numbers are likely to have been underestimated. The average WeBS count of 90 birds in 1996/97 was the second lowest in 15 years and part of a continuing trend for decreasing numbers since the 1993/94 winter (Figure 6.37).

At the Cleddau Rivers, the largest concentrations of Redshank are upriver of the count areas of the present study (Hellawell & Phillips, 1987; Pr_s-Jones, 1989). Pr_s-Jones (1989) recorded birds on all sectors at the Upper Cleddau with peak counts of over 50 birds on sectors B and D (Figure 6.36). Numbers of Redshank recorded in 1996/97 were much lower on all sectors, with a peak count of only 33 birds for the whole site. Again, the number of birds is likely to have been underestimated, as birds fed along creeks out of sight. The average mid-winter WeBS count in 1996/97 was higher than in 1995/96, going against the declining trend of the last ten years (Figure 6.37).

7. DISCUSSION: THE IMPACT OF THE SPILL ON BIRDS

The oilspill immediately affected birds in the area, causing thousands of mortalities. A significant proportion of the casualties were seabirds (particularly guillemots) and scoter outside of the estuary. Few birds within the estuary were incapacitated, although daily WeBS counts carried out following the spill revealed that over 1,000 birds had oiled plumage (Parr *et al.*, 1997). The majority of these were gulls, but some waders and Shelduck were also affected.

The loss of food resources and disturbance from the clean-up operations at the time will have affected all birds in addition to those that were oiled. There was pronounced movement of birds away from the oiled embayments as a result, especially during the first two weeks following the spill (Jane Hodges, pers. comm.). The number of Oystercatchers counted at Carew/Cresswell on 18 February 1996 shortly after the oilspill began, was the highest in the last 15 years and suggests that birds may have moved there from oiled areas. Poole (1996) reports that daily WeBS count totals were erratic for a short period following the spill, but returned to 'normal' levels within a week. However, this may have been due, in part, to the normal 'noise' of frequent counts compared with monthly counts.

Figures 7.1 and 7.2 display the changes recorded in Tables 7.1 and 7.2, changes in waterfowl numbers between the pre-oilspill years and post-oilspill year. Species with positions on the right half of the graphs have increased at the four sites overall in the year after the spill. Species with positions on the lower half of the graphs have fared better on the 'clean' sites relative to the oiled sites since the spill.

Comparing the 1987/88 winter across the tidal cycle count data to that of 1996/97 showed that of the waterfowl commonly found feeding on the four experimental sites, Wigeon, Dunlin and Oystercatcher had increased in numbers, while Shelduck, Teal, Curlew and Redshank had decreased (Figure 7.1). There was thus no evidence from the all-day counts of a systematic increase or decrease in the abundance of all species over the time period (binomial test: p=0.5, n=7, *NS*: Siegal & Castellan, 1988).

Further comparisons between the change in numbers of waterfowl recorded by all-day counts according to the oiling of a site demonstrated that Curlew, Shelduck and Teal had fared better on oiled than on unoiled sites, whereas the opposite was true for Wigeon, Dunlin, Redshank and Oystercatcher (Figure 7.1). There was no evidence of all species doing better on oiled rather than unoiled sites over the time period (binomial test: p=0.773, n=7, *NS*).

As waterfowl populations can fluctuate markedly from year to year, WeBS data collected at the four experimental sites since the 1981/82 winter were included in the analyses to help with the interpretation of the results. Grey Plover, Oystercatcher, Bar-tailed Godwit, Teal and Dunlin numbers were higher during the 1996/97 winter than during the 1995/96 winter of the spill, whereas Wigeon, Curlew and Redshank numbers had decreased (Figure 7.2). Shelduck numbers were similar in both winters. There was no evidence of a systematic increase or decrease in the abundance of all species over the time period (binomial test: p=0.746, n=9, *NS*).

Further comparisons between the change in numbers of waterfowl recorded during the

WeBS counts according to the oiling of a site showed that Shelduck, Dunlin, Teal, Bar-tailed Godwit, Wigeon and Grey Plover appeared to fare better on oiled rather than unoiled sites, whereas the opposite was true for Oystercatcher, Redshank and especially Curlew (Figure 7.2). There was no evidence of all species doing systematically better on oiled rather than unoiled sites over the time period (binomial test: p=0.746, n=7, *NS*).

One year after the spill, some of the main species present on the estuary appear to be largely unaffected by the oilspill. Indeed, at the oiled sites, comparison of the mid-winter average WeBS counts this year with those of the previous year and of the all-day counts this year with those of 1987/88 show that numbers of Shelduck, Teal and Bar-tailed Godwit were relatively high compared to unoiled sites (Figures 7.1 and 7.2 and Tables 7.1 and 7.2).

Bar-tailed Godwit numbers fluctuate erratically from year to year and they usually favour the lower embayments, so few conclusions can be drawn about their change in numbers.

The high number of Teal using the oiled sites (particularly Angle Bay), however, may be explained by the availability of their food organisms. Teal feed mainly on seeds and invertebrates (Cramp & Simmonds, 1977). Gaston (1994) found that they feed on minute invertebrates such as meiofaunal nematodes. After the spill it has been suggested that many *Capitella* species (small polychaetes) were present in abundance. This species complex is known to take advantage of disturbed and polluted conditions. Teal also feed on eelgrass *Zostera* spp. (Cramp & Simmonds, 1977), which was also growing in abundance at Angle Bay following the oilspill (Jane Hodges, pers. comm.). However, the main feeding distribution of Teal on the south-west side of the bay does not correspond with the location of the *Zostera* beds. It is possible they were utilising some other abundant resource, *eg. Enteromorpha* or *Ulva*.

The ranking of Shelduck has not changed considerably since 1987/88 or since the year of the spill. Figures 7.1 and 7.2 show that both WeBS and all-day count data indicate that Shelduck showed a positive response to oiling (they have fared better on the oiled sites compared to the unoiled sites). This is another species which may have benefited from the increased productivity of small invertebrates such as *Capitella*.

Both the all-day counts and the WeBS counts show that Redshank and Oystercatcher have responded negatively to oiling (they have fared better on the unoiled rather than the oiled sites).

Redshank have been declining on the Cleddau Estuary since the 1980s and both Figures 7.1 and 7.2 indicate a continued decline. They appear to have fared better on the unoiled than on the oiled sites, although this may not be a consequence of oiling. Redshank favour the upper embayments of the estuary, so their declining trend may be more apparent at the lower embayments.

Oystercatcher is a long-billed species which probes in the mud to find prey. It has been confirmed by analysis that hydrocarbons are still present in the sediments (Rostron, pers. comm.) and a visual inspection of parts of the mudflat in the south-east part of Angle Bay in July 1997 indicated that oil has remained beneath the surface of the mudflats (Jane Hodges, pers. comm.). This could have affected the longer-billed species as they foraged for food, either directly through ingestion, or indirectly through a lack of food. The average WeBS count of Curlew, also a long-billed species, was extremely low at Angle Bay

in winter 1996/97. The low number of Curlew may also have been due, in part, to increased levels of disturbance, as they are a particularly 'nervous species' (Davidson & Rothwell, 1993).

Comparison of the rank of the average WeBS count of Dunlin in the year after the spill to the rank of the year of the spill (Figure 7.2) shows that they responded positively to oiling. Comparing the all-day counts of 1987/88 to those of 1996/97, however, shows the response to oiling was negative (Figure 7.1). Conclusions regarding this species cannot therefore be made. The case is the same for Wigeon, although it should be noted that at Pembroke River, larger numbers of Wigeon were present for longer than usual, possibly exploiting the abundant growth of *Zostera* at the site.

Grey Plover numbers on the estuary were very high in winter 1996/97 compared to the previous year, but there was only a slight increase at the oiled sites relative to the unoiled sites. This may be a result of their favouring the lower embayments of the estuary.

When the information on the sediment infauna becomes available, it may be possible to link the distribution and abundance of bird species at Angle Bay and Pembroke River to their food organisms. Early indications are that there have been some changes in the populations of invertebrates at Angle Bay (Rostron, pers. comm.).

8. FINAL YEAR ANALYSES

One year after the oilspill it is difficult to tease out changes in waterfowl numbers that are due to the effects of the spill from those that result from natural population fluctuations. Two years hence, after three years of across the tidal cycle count data collection and with three years of WeBS data collected after the spill, there will be greater value in comparing the pre-oilspill counts to those made after the oilspill. It would be expected that by then the community of waterfowl would tend to have reverted to its pre-spill constituents (Wiens *et al.*, 1996), that the species that increased in the winter after the spill might decrease slightly and *vice versa* for the species that decreased during the 1996/97 winter.

After three years of data collection it will be possible to further develop these analyses following that outlined in the original proposal. The final report may also:

i **compare summed monthly WeBS counts over the various years as these are closely linked to site carrying capacity;**

ii **compare the WeBS counts made just after the spill to those made at similar times of the subsequent years;**

iii **look at residual waterfowl numbers by removing national or regional population trends which may help disguise any decreases in waterfowl numbers at the sites;**

iv **consider comparing the temporal change in residuals for oiled and unoiled sites, wherever possible accounting for serial autocorrelation within the counts (*eg* Gardarsson & Einarsson, 1997).**

v **carry out analyses to assess whether any community recovery occurs (Hill *et al*., 1993), and;**

vi **incorporate suitable vegetation and invertebrate data as these may help explain observed changes.**

The analyses used will be selected after visual inspection of the data.

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References

Burton, N.H.K., Toomer, D.K., Balmer, D.E., Rehfisch, M.M. & Clark, N.A. (1997) ***The Effect of the Cardiff Bay Barrage on Waterfowl Populations 7. Distribution and Movement Studies. August 1995 - May 1996.*** **BTO Research Report to Cardiff Bay Development Corporation. British Trust for Ornithology, Thetford.**

Clark, N.A. (1990) ***Distribution Studies of Waders and Shelduck in the Severn Estuary.*** **Report to U.K. Department of Energy's Renewable Energy Research and Development Programme (ETSU TID 4076).**

Clark, N.A., Donald, P.F., Mawdesley, T.M. and Waters, R.J., (1990) ***The Impact of the Mersey Oil Spill of August 1989 on the Populations and Distributions of Waterfowl.*** **BTO Research Report No. 62 to Mersey Oil Spill Project Advisory Group. British Trust for Ornithology, Tring.**

Cramp, S. & Simmonds, K.E.L. (eds) (1977) ***The birds of the Western Paleartic*****. 1, 722pp. Oxford University Press, Oxford.**

Cranswick, P.A., Waters, R.J., Evans, J. & Pollitt, M.S. (1995) The Wetland Bird Survey 1993-94: Wildfowl and Wader Counts. BTO/WWT/RSPB/JNCC, Slimbridge.

Davidson, N.C. & Rothwell, P.I. (1993) ***Disturbance to waterfowl on estuaries. Wader Study Group Bulletin*****, 68 Special Issue, RSPB, Sandy.**

Evans, J., Clark, N.A. & Donald, P.F. (1990) ***The Effect of the Cardiff Bay Barrage on Waterfowl Populations: 1. Distribution and Movement Studies, November 1989 - May 1990.*** **BTO Research Report No. 69 to Cardiff Bay Development Corporation. British Trust for Ornithology, Tring.**

Gardarsson, A. & Einarsson, A. (1997) Numbers and production of Eurasian wigeon in relation to conditions in a breeding area, Lake Myvatn, Iceland. ***Journal of Animal Ecology*****, 66, 439-451.**

Gaston, G.R. (1994) Green-winged Teal ingest epibenthic meiofauna. ***Estuaries*****, 15, 227-229.**

Gibbons, D.W., Reid, J.B., & Chapman R.A. (1993) ***The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991.*** **T. & A.D. Poyser, London.**

Haycock, R.J. (1986) ***A Report on the Results of a Milford Haven/Cleddau Estuary All Day Count of Selected Wader and Waterfowl species - 2nd February 1986.*** **Cyclostyled report, NCC.**

Hellawell, T.C. & Phillips, B.N. (1987) ***Feeding and Roosting Patterns of Waders & Wildfowl in Milford Haven in February and March 1987.*** **A report to the Nature Conservancy Council, Dyfed Powys Region.**

Hill, D., Rushton, S.P., Clark, N., Green, P. & Pr_s-Jones, R.P. (1993) Shorebird communities on British estuaries: factors affecting community composition. *Journal of Applied Ecology*, 30, 220-234.

Hodges, J.E. (1997) *Daugleddau Estuary and Milford Haven Waterway: Annual Summer Shelduck Survey 1996.* Unpublished report to the Milford Haven Waterway Environmental Monitoring Steering Group.

Lack, P. (1986) *The Atlas of Wintering Birds in Britain and Ireland.* T. & A.D. Poyser, Calton.

Parr, S.J., Haycock, R.J. & Smith, M.E. (1997) International Oil Spill Conference. Improving Environmental Protection. Progress, challenges, responsibilities. American Petroleum Institute publication, no. 4651, Washington DC, US.

Piersma, T. (1986) Breeding waders in Europe: a review of population size estimates and bibliography of information sources. *Wader Study Group Bulletin*, 48, Supplement.

Poole, A. (1996) *Milford Haven and Cleddau Estuary Wetland Bird Survey 1995-1996.* Report prepared for the Milford Haven Waterway Environmental Monitoring Steering Group on behalf of the Dyfed Wildlife Trust and the Pembrokeshire Ornithological Research Committee.

Prater, A.J. (1981) *Estuary birds of Britain and Ireland.* T & A D Poyser, Calton. 440pp.

Pr_s-Jones, R.P. (1989) *The Abundance and Distribution of Wildfowl and Waders on the Cleddau (Milford Haven).* NCC Chief Scientist Directorate commissioned research report no. 964.

Reed, T. (1985) Estimates of British breeding wader populations. *Wader Study Group Bulletin*, 45, 11-12.

Siegal, S. & Castellan, N.J. (1988) *Nonparametric statistics for the Behavioural Sciences.* McGraw-Hill Book Company, New York. 2nd edition.

Smith, J.E. (1968) *'Torrey Canyon' pollution and marine life.* A report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. Cambridge University Press, Cambridge.

Stone, B.H., Sears, J., Cranswick, P.A., Gregory, R.D., Gibbons, D.W., Rehfisch, M.M., Aebischer, N.H. & Reid, J.B. (1997) Population estimates of birds in Britain and in the United Kingdom. *British Birds*, 90, 1-22.

Stroud, D.A., Reed, T.M., Pienkowski, M.W. & Lindsay, R.A. (1987) *Birds, Bogs and Forestry. The Peatlands of Caithness and Sutherland.* NCC, Peterborough.

Voous, K.H. (1973) A List of Recent Holarctic Species. Non-passerines. *Ibis*, 115, 612-638.

Waters, R.J., Cranswick, P.A., Evans, J. & Pollitt, M.S. (1996) *The Wetland Bird Survey*

1994-95: Wildfowl and Wader Counts. **BTO/WWT/RSPB/JNCC, Slimbridge.**

Wiens, J.A., Crist, T.O., Day, R.H., Murphy, S.M. & Hayward, G.D. (1996) Effects of the *Exxon Valdez* oil spill on marine bird communities in Prince William Sound, Alaska. *Ecological Applications*, 6, 828-841.

	Mean peak winter count on the Cleddau Estuary	Percentage of British wintering population
Shelduck *Tadorna tadorna*	**919**	**1.23%**
Wigeon *Anas penelope*	**2885**	**1.03%**
Teal *Anas crecca*	**1959**	**1.40%**
Oystercatcher *Haematopus ostralegus*	**345**	**0.10%**
Grey Plover *Pluvialis squatarola*	**81**	**0.19%**
Dunlin *Calidris alpina*	**3449**	**0.65%**
Bar-tailed Godwit *Limosa lapponica*	**17**	**0.03%**
Curlew *Numenius arquata*	**1322**	**1.10%**
Redshank *Tringa totanus*	**685**	**0.62%**

Table 1.1 **The importance of the Cleddau Estuary for selected waterfowl at a national level. A wetland site is considered nationally important for a species if it regularly holds at least 1% of the estimated British population for that species. The figures used in the calculations are the means of the winter (November -March) peak counts between 1991/92 and 1995/96.**

Species	Location	Occurrence
Red-throated Diver *Gavia stellata*	Upper Cleddau	1 15 March feeding at entrance to Sprinkle Pill
Great Northern Diver *Gavia immer*	Angle Bay Pembroke River	Singles on 26 and 28 November Up to 3 between November and February at Pennar
Red-necked Grebe *Podiceps grisegena*	Angle Bay Pembroke River	1-2 on three dates between November and March Singles on 12 and 14 December
Slavonian Grebe *Podiceps auritus*	Angle Bay Pembroke River	1-2 several dates between December and March Two on 18 and 19 February
Shag *Phalacrocorax aristotelis*	Angle Bay Pembroke River	1 on 25 February 1-2 occasionally present at Pennar
Mute Swan *Cygnus olor*	Pembroke River Carew/Cresswell Upper Cleddau	3 in March at eastern end 1 on 19 December 9 at Landshipping on 26 November
Pink-footed Goose *Anser brachyrhynchus*	Upper Cleddau	2 birds with Canada Geese 11 and 16 December
Canada Goose *Branta canadensis*	Upper Cleddau	Flock of 195-264 at Fowborough Point on four days between November and February
Brent Goose *Branta bernicla*	Angle Bay Carew/Cresswell Upper Cleddau	9 on 28 January, 1 on 16 and 20 March 1 on 19 December 1 at Hook on 26 November
Gadwall *Anas strepera*	Carew/Cresswell	2 on 15 December, 4 on 18 January
Pintail *Anas acuta*	Angle Bay Carew/Cresswell Upper Cleddau	Up to 10 in January Up to 4 in January 5 at Sprinkle Pill on 15 March
Shoveler *Anas clypeata*	Pembroke River Upper Cleddau	5 on 22 January, 3 on 13 March 3 on 23 and 26 November and 20 February
Pochard *Aythya ferina*	Carew/Cresswell Upper Cleddau	1 male on 27 January Male and female on 21 December
Scaup *Aythya marila*	Angle Bay Pembroke River	1 male on 22 January 1-2 females in January and February
Eider *Somateria mollissima*	Pembroke River	1 female in December and January
Goosander *Mergus merganser*	Pembroke River	8 on 19 January
Sanderling *Calidris alba*	Angle Bay	2 on 13 and 28 January
Snipe *Gallinago gallinago*	Angle Bay Carew/Cresswell	5 in harbour on 17 December 1 on 15 December, 3 on 14 February
Spotted Redshank *Tringa erythropus*	Upper Cleddau	2 on 23 November, 3 on 21 January
Guillemot *Uria aalge*	Carew/Cresswell	1 on 12 March near Black Mixen

Table 3.3.1 Species recorded only occasionally on the study sites.

Site	Sectors in the present study	Corresponding sectors in Pr_s-Jones (1989)	Renamed sectors from Pr_s-Jones (1989)
Angle Bay	**1 10**	**1**	**A**
	2 3	**2**	**B**
	4 5 6 7 8	**3**	**C**
	9	**4**	**D**
Pembroke River	**1**	**1**	**A**
	7	**2**	**B**
	12	**3 (part of west end)**	**C (part of west end)**
	11	**4 (part of west end)**	**D (part of west end)**
	9 10	**5**	**E**
	4 5 6	**6**	**F**
	2 3	**7**	**G**
Carew/Cresswell	**4**	**2 (south sector only)**	**A (south sector only)**
	3 5	**3**	**B**
	1 2 6 10	**4**	**C**
	7 8 11 12	**5**	**D**
	9	**6 (east sector only)**	**E (east sector only)**
Upper Cleddau	**10 11 12**	**Western Cleddau 8**	**A**
	7 8 9	**Western Cleddau 9**	**B**
	3	**Western Cleddau 10**	**C**
	1 2	**Western Cleddau 11**	**D**
	4	**Eastern Cleddau 7**	**E**
	5 6	**Eastern Cleddau 6**	**F**

Table 6.1 Comparison of count sectors used in the present study and those of Pr_s-Jones (1989).

Species	Site	Number of sectors	Sectors ↑	Sectors ↓	Change	Overall change	Polluted: clean
Shelduck	Angle Bay	4	1	1	0		
	Pembroke River	5	2	1	+1	-1	+3
	Carew/Cresswell	3	0	2	-2		
	Upper Cleddau	6	2	2	0		
Wigeon	Angle Bay	4	3	1	+2		
	Pembroke River	5	0	1	-1	+3	-1
	Carew/Cresswell	3	0	1	-1		
	Upper Cleddau	6	4	1	+3		
Teal	Angle Bay	4	2	0	+2		
	Pembroke River	5	1	2	-1	-2	+4
	Carew/Cresswell	6	0	3	-3		
	Upper Cleddau	3	2	2	0		
Oystercatcher	Angle Bay	4	1	0	+1		
	Pembroke River	5	3	2	+1		
	Carew/Cresswell	3	3	0	+3	+11	-7
	Upper Cleddau	6	6	0	+6		
Dunlin	Angle Bay	4	3	1	+2		
	Pembroke River	5	1	2	-1	+4	-2
	Carew/Cresswell	3	3	0	+3		
	Upper Cleddau	6	1	1	0		
Curlew	Angle Bay	4	1	2	-1		
	Pembroke River	5	2	3	-1	-6	+2
	Carew/Cresswell	3	0	2	-2		
	Upper Cleddau	6	0	2	-2		
Redshank	Angle Bay	4	1	2	-1		
	Pembroke River	5	0	3	-3	-13	+5
	Carew/Cresswell	3	0	3	-3		
	Upper Cleddau	6	0	6	-6		

Table 7.1 **Summary of the changes that have occurred in the peak numbers on sectors at each site between the winter of 1987/88 (pre-oilspill) and the winter of 1996/97 (post-oilspill). The change in the numbers for each of the four sites are given as is the overall change for all sites. Polluted : clean gives an indication of the direction of change, where negative values represent a relative decrease in the numbers of waterfowl at the oiled sites (Angle Bay and Pembroke River) compared to the 'clean' sites (Carew/Cresswell and Upper Cleddau), *ie* the waterfowl avoid the oiled sites.**

Species	Site	Total years of data	Rank of year of oil spill	Rank of year after spill	Change	Overall change	Polluted: clean
Shelduck	Angle Bay	14	1	5	-4	0	-10
	Pembroke River	14	13	14	-1		
	Carew/Cresswell	15	8	10	-2		
	E & W Cleddau	13	10	3=	+7		
Wigeon	Angle Bay	14	3	11	-8	-5	+3
	Pembroke River	14	8	1	+7		
	Carew/Cresswell	15	2	3	-1		
	E & W Cleddau	13	4	7	-3		
Teal	Angle Bay	14	5=	1	+4	+3	+7
	Pembroke River	14	9	8	+1		
	Carew/Cresswell	15	12	11	+1		
	E & W Cleddau	13	8	11	-3		
Oystercatcher	Angle Bay	15	8	13	-5	+8	-4
	Pembroke River	15	10	3	+7		
	Carew/Cresswell	15	2	3	-1		
	E & W Cleddau	14	13	6	+7		
Grey Plover	Angle Bay	15	12	7	+5	+11	+1
	Pembroke River	15	3	2	+1		
	Carew/Cresswell	15	5	1	+4		
	E & W Cleddau	14	2	1	+1		
Dunlin	Angle Bay	15	11	9	+2	+3	+9
	Pembroke River	15	5	1	+4		
	Carew/Cresswell	15	4	1	+3		
	E & W Cleddau	14	7	13	-6		
Bar-tailed Godwit	Angle Bay	15	6=	2	+4	+7	+5
	Pembroke River	15	5=	3	+2		
	Carew/Cresswell	15	6=	6=	0		
	E & W Cleddau	14	4=	3	+1		
Curlew	Angle Bay	15	7	15	-8	-5	-9
	Pembroke River	15	6	5	+1		
	Carew/Cresswell	15	11	12	-1		
	E & W Cleddau	14	7	4	+3		
Redshank	Angle Bay	15	9	13	-4	-6	-6
	Pembroke River	15	11	13	-2		
	Carew/Cresswell	15	12	14	-2		
	E & W Cleddau	14	14	12	+2		

Table 7.2 **Summary of the changes that have occurred in the ranks of the WeBS waterfowl counts made between the year of the Sea Empress oil spill (1995/96) and the year after the spill. The change in the ranks for each of the four sites are given as is the overall change for all sites. Polluted : clean gives an indication of the direction of change, where negative values represent a relative decrease in the rank of the counts at the oiled sites (Angle Bay and Pembroke River) compared to the 'clean' sites (Carew/Cresswell and Upper Cleddau), *ie* the waterfowl avoid the oiled sites.**