

# The *Sea Empress* oil spill (Wales, UK): Effects on Common Scoter *Melanitta nigra* in Carmarthen Bay and status ten years later

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## Abstract

Carmarthen Bay, UK, regularly supports internationally important numbers (>16,000) of non-breeding Common Scoters *Melanitta nigra*. The spill of 72,000 tonnes of crude oil from the *Sea Empress* in 1996 affected birds both through direct mortality and likely pollution of key food resources. Numbers were greatly reduced following the spill, whilst changes in the distribution of birds within Carmarthen Bay suggested that potentially sub-optimal foraging zones were used. However, ten years after the incident, numbers of Common Scoter were no different to those recorded immediately before the spill. Compared to some other spills, rapid revival is evident. Numbers increased to pre-spill levels within three winters and distributional changes suggested a concurrent return to previously contaminated feeding areas, implying that the ecosystem had regenerated sufficiently to support its top predator. The importance of prolonged, standardised monitoring of bird numbers and distribution as indicators of ecological recovery from environmental damage is emphasised.

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**Keywords:** Seaducks; Wales; Population recovery; Crude oil; Ecosystem health; Shipwreck

## 1. Introduction

In February 1996, the stricken oil tanker *Sea Empress* leaked approximately 72,000 tonnes of crude oil into the mouth of Milford Haven, south west Wales, UK. Prevailing winds forced approximately 15,000 tonnes of oil east along the southern Pembrokeshire coast and into parts of Carmarthen Bay (Law and Kelly, 2004; Fig. 1). The bay is a wintering ground of international importance for Common Scoters *Melanitta nigra* (Smith et al., 2007), which exploit the shallows (<10 m deep) of the bay which are rich in benthic invertebrate prey including bivalves and polychaetes (Woolmer, 2003). Recent estimates of Common

Scoter numbers suggest that between 10% and 20% of the UK non-breeding total winters in Carmarthen Bay (Cranswick et al., 2005; Banks et al., 2006), making it both the most important spatially discrete site for the species in the UK and of international importance as numbers exceed 1% of the biogeographic population (=16,000 birds), the threshold for designation as a Special Protection Area (SPA) under the EC Directive on the Conservation of Wild Birds (Council Directive 79/409/EEC).

Common Scoters feed typically on bivalves and other invertebrates such as polychaetes and amphipods (Fox, 2003; Woolmer et al., 2004). Mass strandings of bivalves were reported following the spill (Law and Kelly, 2004), suggesting that key feeding areas for Scoters were severely damaged. Birds were also directly affected by the oil, either being immobilised or poisoned. Estimates of 3600 casualties were made (Stewart et al., 1997); a further 1100

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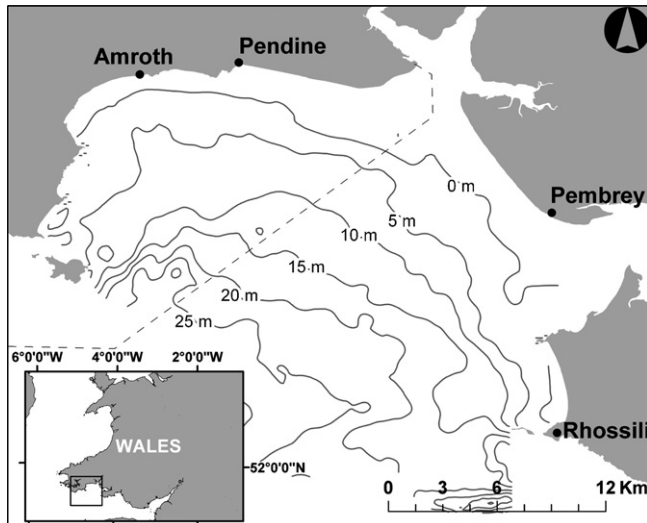


Fig. 1. Map of Carmarthen Bay, Wales, UK, showing approximate extent of heavily oiled area (north and west of dashed line), bathymetric depth contours and ground count stations.

rehabilitated birds were thought likely to die within a year (Hughes et al., 1997). As well as the clear immediate reduction in the size of local numbers, it was unclear to what extent, and over what time period, the ecosystem as a whole would recover to support even relatively small numbers of Scoters in future winters.

The Countryside Council for Wales (CCW) has supported dedicated ground-based counts of Common Scoter in Carmarthen Bay from 1994/95 (Stewart, 1995) to the time of writing. Owing to the large size of the bay, it is not possible to count all the birds present from the shore. To combat this problem, periodic aerial surveys have been conducted in an attempt to account for birds out of sight from shore and thus understand 'true' numbers present. However, aerial surveys themselves have drawbacks and have developed over time so that it is difficult to construct a reliable quantitative local trend from these counts. Because aerial surveys have successfully indicated that key foraging areas of Carmarthen Bay are visible from the land, in the present study we analysed land-based counts to generate indexed abundance estimates.

This paper aims to display firstly, the effect the oil spill had on Common Scoter numbers immediately after the spill; secondly, how long the effects of the spill appeared to last; and thirdly, to what extent Common Scoter numbers within Carmarthen Bay have recovered since the oil spill. Finally, data on the distribution patterns of scoters in the bay were examined to determine if the effects of the oil spill may have led to local redistribution within the bay.

## 2. Materials and methods

### 2.1. Data collection

Counts of Common Scoters in Carmarthen Bay were made between the winters of 1994/95 and 2005/06 from

four count stations on the shore, chosen for favourable viewing elevation and distributed around the bay to ensure maximal coverage of coastal areas known to contain principal feeding areas and, initially, contaminated shore areas (e.g., Law and Kelly, 2004). These were situated at Amroth, Pendine, Pembrey and Rhossili (Fig. 1). Early surveys divided the bay into eight separate recording zones, all of which were visible from the count stations in later surveys. A comparable area was therefore surveyed in each of 12 consecutive winters.

At each site, full sea scans were carried out using a tripod-mounted telescope (20–60 × zoom magnification, 80 mm objective). Because of the typically elevated viewing positions at the count stations, visibility in ideal weather and sea state conditions extended up to ca. 6 km. Birds were counted using a tally counter, and counts typically lasted for 2 h at each count station; birds tended to remain within the same general region of the bay during a 2 h count, with any larger movements recorded by the counter. Owing to the increased attention generated by the *Sea Empress* spill, more counts were undertaken in the winters of 1996/97 to 1999/2000 than in previous winters.

The aerial survey method used between 1997/98 and 2003/04 was based on a grid of discrete rectangular cells of size 2 × 1 km. Although there were differences in the precise orientation of the grid between the first three and last three winters for which survey data were available, a comparable area was covered in all winters, with the exception of 2001/02 when no aerial surveys were undertaken. The aircraft used was a Partenavia PN68, flown at an altitude of approximately 160 m and a ground speed of approximately 50 ms<sup>-1</sup>. Flights were conducted along transects alternating east to west then west to east, starting in the north of the Bay and continuing southwards, with each new transect 1 km further south. Between 1998 and 2000, the south east corner of the bay was surveyed on transects running north–south, beginning on the east coast and continuing west; this area was surveyed latterly on east–west transects. A pair of trained observers situated on either side of the aeroplane recorded all birds to an estimated distance of 500 m from the transect line. A navigator equipped with GPS assisted the pilot and notified observers when entering a new recording cell.

### 2.2. Data analysis

Generalised Linear Models (GLMs: McCullagh and Nelder, 1989) were used to investigate temporal changes in the count data. Only data collected during the winter period (November–February) were considered, as data from outside this period were only collected consistently during the winters immediately following the oil spill and thus year-round data were not available for every year. Furthermore, peak numbers of scoters in Carmarthen Bay consistently appear in these months. To reduce pseudoreplication problems potentially resulting from repeat counting in the same month, counts within a month were

summed prior to analysis. Models then related the summed numbers of birds counted each month to month and year class variables, with the number of counts treated as an offset. An index of population change was derived from the exponential of estimated model parameter values for the year factor, indicating the variation of counts each winter in relation to 2005/06. The model assumed a Poisson distribution for the number of birds and specified a log link function; the problem of overdispersion caused by a combination of several low counts and several very high counts, typical of flocking species, was addressed by applying a scale factor estimated from the square root of the Pearson's  $\chi^2$  statistic divided by its degrees of freedom.

To determine how long local Common Scoter numbers remained depressed following the spill and when or if they recovered to pre-spill levels, a further model categorised counts into three time periods, representing pre-spill, immediate post-spill and 'new equilibrium' periods. The length of the second period was varied to provide the best model fit and so determine how long numbers were depressed. Likelihood ratio tests (LRTs) were used to investigate differences in numbers between categorical time periods.

For analysis of distribution and changes therein, aerial survey data were considered from comparable aerial surveys between 1997/98 and 2003/04; aerial survey methods differed prior to and subsequent to these dates. The initial surveys in winter 1997/98 spanned the months January 1998 to March 1998, and only data collected between January and March in each subsequent winter were included for analysis to avoid temporal confounds (future references to each winter use the latter year only as all data came from this period). Each grid cell score was transformed to a point representing the centre of the relevant grid cell, thus overcoming problems of slight incongruity between grids in different winters.

Generalised Linear Mixed Models (GLMMs: Littell et al., 1996) were used to model Common Scoter distribution. Because the aim of the analysis was to examine changes in relative density across the bay between years, binomial models were used to model the proportion of the average count at each locus in relation to the average count for the entire bay within the relevant winter. Year, month and sea depth were treated as categorical predictor variables. Tide could not be included in the model due to a lack of time-stamped data from earlier surveys; however, some 'paired flights' conducted in Carmarthen Bay as part of the experimental monitoring program in March 2000 at high and low tide suggested few differences in gross scoter distribution (Lucy Smith, unpublished PhD thesis). To attempt to account for spatial autocorrelation likely to be inherent in the data, sill and range parameters were estimated from a robust exponential semivariogram (using PROC VARIOGRAM in SAS; SAS Institute Inc. 2002–2003) and included as covariance parameters in the final models. Final models specified a binomial distribution and a log link function, included a multiplicative overdispersion parameter and nested all spatial random effects

within a year\*month covariance matrix. The residual degrees of freedom were used for *F*-tests, standard with overdispersed GLMs.

Additionally, the weighted mean centroid, a spatial measure of central tendency, was determined for each average winter distribution. Average distributions were obtained by taking the mean for each grid cell point across all aerial surveys undertaken between January and March in the relevant winter (on average 3.5 surveys per winter). The centre of the distribution was then weighted by average count using ArcMap GIS (ESRI, CA, USA). This enabled a visual interpretation of spatio-temporal changes in Common Scoter distribution within the Bay.

### 3. Results

Pre-spill numbers of Common Scoter in Carmarthen Bay peaked at 17,650 and 8446 in 1994/95 and 1995/96, respectively (Table 1). It should be noted that the two counts made in 1995/96 are lower than the actual number of Common Scoters known to have used the bay in that winter (at least 15,000: Stewart et al., 1997). It is possible that counts in January and February 1996 were made in sub-optimal count conditions but this cannot be confirmed. Following the oil spill in February 1996, numbers were extremely low during the winters of 1996/97 and 1997/98 with peaks of just 4768 and 2895, respectively, (Table 1). It is important to note that whilst some birds may have moved further offshore (beyond visible range) but still within Carmarthen Bay, in response to oil pollution, there are reasons to believe that overall numbers were still reduced (Cranswick et al., 1998; see discussion). The numbers observed in the winter of 1998/99 peaked at a level comparable with pre-spill levels, and in the majority of subsequent winters, Common Scoter numbers have peaked in excess of 15,000 birds, with a maximum of 24,460 in February 2005. Mean monthly ground counts of Common Scoter within Carmarthen Bay from all count months between the winters of 1994/95 and 2005/06 were plotted, with index values derived from models displaying

Table 1  
Mean and peak winter ground counts of Common Scoters in Carmarthen Bay, 1994/95–2005/06

| Winter  | Count months                       | Winter mean | Winter peak | Peak month |
|---------|------------------------------------|-------------|-------------|------------|
| 1994/95 | Dec, Jan, Feb                      | 13,244      | 17,650      | Dec        |
| 1995/96 | Jan, Feb                           | 5567        | 8446        | Feb        |
| 1996/97 | Nov (2), Dec, Jan (2), Feb (2)     | 2898        | 4768        | Nov        |
| 1997/98 | Nov (2), Dec (3), Jan (2), Feb (2) | 1809        | 2895        | Feb        |
| 1998/99 | Nov (6), Dec (3), Jan (5), Feb (3) | 10,411      | 18,197      | Jan        |
| 1999/00 | Nov (5), Dec (3), Jan (4), Feb (2) | 11,885      | 21,952      | Jan        |
| 2000/01 | Jan                                | 19,506      | 19,506      | Jan        |
| 2001/02 | Nov, Dec, Feb                      | 15,093      | 20,078      | Feb        |
| 2002/03 | Nov, Jan                           | 19,656      | 23,288      | Jan        |
| 2003/04 | Nov, Dec, Feb                      | 14,725      | 15,546      | Dec        |
| 2004/05 | Feb (2)                            | 17,780      | 24,460      | Feb        |
| 2005/06 | Nov, Dec, Jan, Feb                 | 14,508      | 20,287      | Dec        |

Bracketed figures indicate multiple counts.

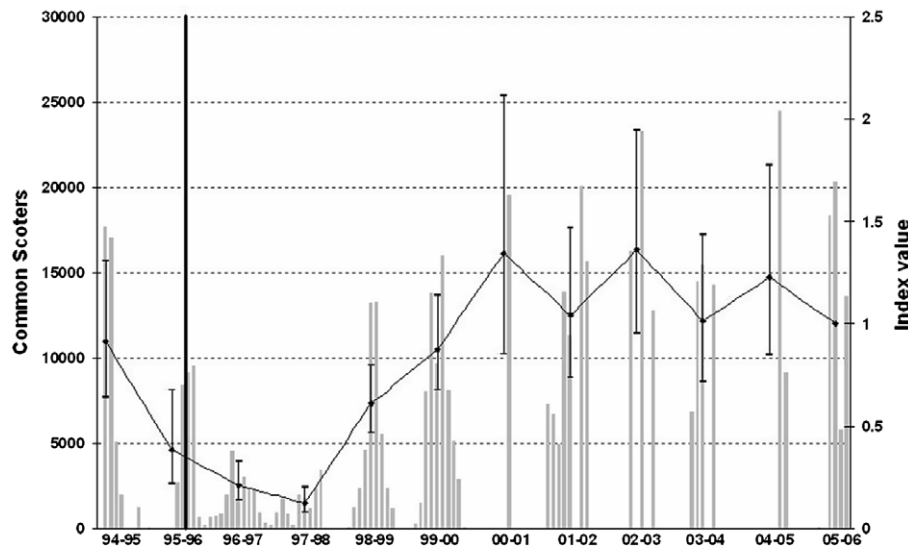


Fig. 2. Common Scoter numbers in Carmarthen Bay, 1994/95–2005/06. Mean monthly counts indicated by grey bars, index values (with 95% confidence limits) by bold line. Vertical grey line indicates occurrence of spill.

the trend in winter numbers at Carmarthen Bay (Fig. 2). Year ( $F_{11,23} = 6.30$ ,  $P < 0.0001$ ) but not month ( $F_{3,20} = 0.95$ ,  $P = 0.43$ ), was significant in explaining variation. Mean and peak counts for each winter were also derived (Table 1).

Analyses confirmed significant decrease in winter numbers during the period from November 1996 to February 1998 (the ‘immediate post-spill’ period) ( $F_{1,30} = 19.42$ ,  $P < 0.0001$ ); however, no significant difference existed between the pre-spill (before February 1996) and ‘new equilibrium’ (from November 1998) periods ( $F_{1,29} = 0.78$ ,  $P = 0.38$ ). The class variable ‘month’ again did not explain significant variation in counts ( $F_{3,29} = 0.84$ ,  $P = 0.48$ ), suggesting that monthly variation between winters was consistent.

In addition to changes in the index of Common Scoter numbers following the oil spill, patterns in distribution data collected on aerial surveys highlighted spatio-temporal changes within the bay. During the winter of 1997/98, the second post-spill winter, the relative density of Common Scoters was greater in the Rhossili area of Carmarthen Bay (Fig. 3). By the winter of 1998/99, when numbers of Common Scoter first returned to comparable pre-spill levels, the majority of birds were distributed in feeding areas in the north of the bay, a pattern which persisted in following winters (Fig. 3). By 2001/02, it was unusual to detect any substantial numbers of Common Scoters in the Rhossili area of the bay, especially beyond sea bed depths of  $>10$  m.

Spatially explicit parameterised models (including sill and range parameters estimated from a robust exponential semivariogram) would not converge under any convergence criteria or meaningful categorisation of class variables. Instead, a reverse deletion method with GLMMs including no allowance for spatial autocorrelation was used. A significant effect of depth was found ( $F_{6,2369} =$

9.18,  $P < 0.0001$ ), as was a significant interaction between depth and year, suggesting that birds were at different depths in different winters ( $F_{31,2369} = 2.06$ ,  $P = 0.0005$ ). However, these significant effects should be treated with some caution as the random error from spatial autocorrelation remains unknown. Table 2 indicates that even accounting for such error, the significant interaction is likely to be acceptable: in 1998, 30% of the distribution occurred within depth contours  $>10$  m; in no other winter did more than 7% of the distribution occur within such sea bed depths.

Mean weighted centroids of average winter Common Scoter distribution in Carmarthen Bay underlined a strong pattern of change; in the immediate post-spill winter of 1997/98 (labelled with the latter winter only), the mean centre was some 7.5 km further south and in water 5–10 m deeper than that for 1998/99, and approximately 5 km from the nearest mean centre (2001/02) across all years. Mean centres for every winter other than 1997/98 lay at very similar locations and water depths (Fig. 4).

## 4. Discussion

### 4.1. Effects of the Sea Empress spill on Common Scoters

Marine oil spills can impact seabirds by affecting local population size, by altering reproductive success and by influencing habitat use (Murphy et al., 1995). It is clear from these results that following the *Sea Empress* spill, the local population size was temporarily reduced, as numbers fell from a peak of 17,650 in 1994/95 to a peak of 4768 in 1996/97, the winter following the oil spill. Direct mortalities (Hughes et al., 1997) alone cannot fully account for the discrepancy between counts made pre-spill and immediately post-spill and in the absence of risk – mortality estimates (e.g., Wilhelm et al., 2007) or drift-block

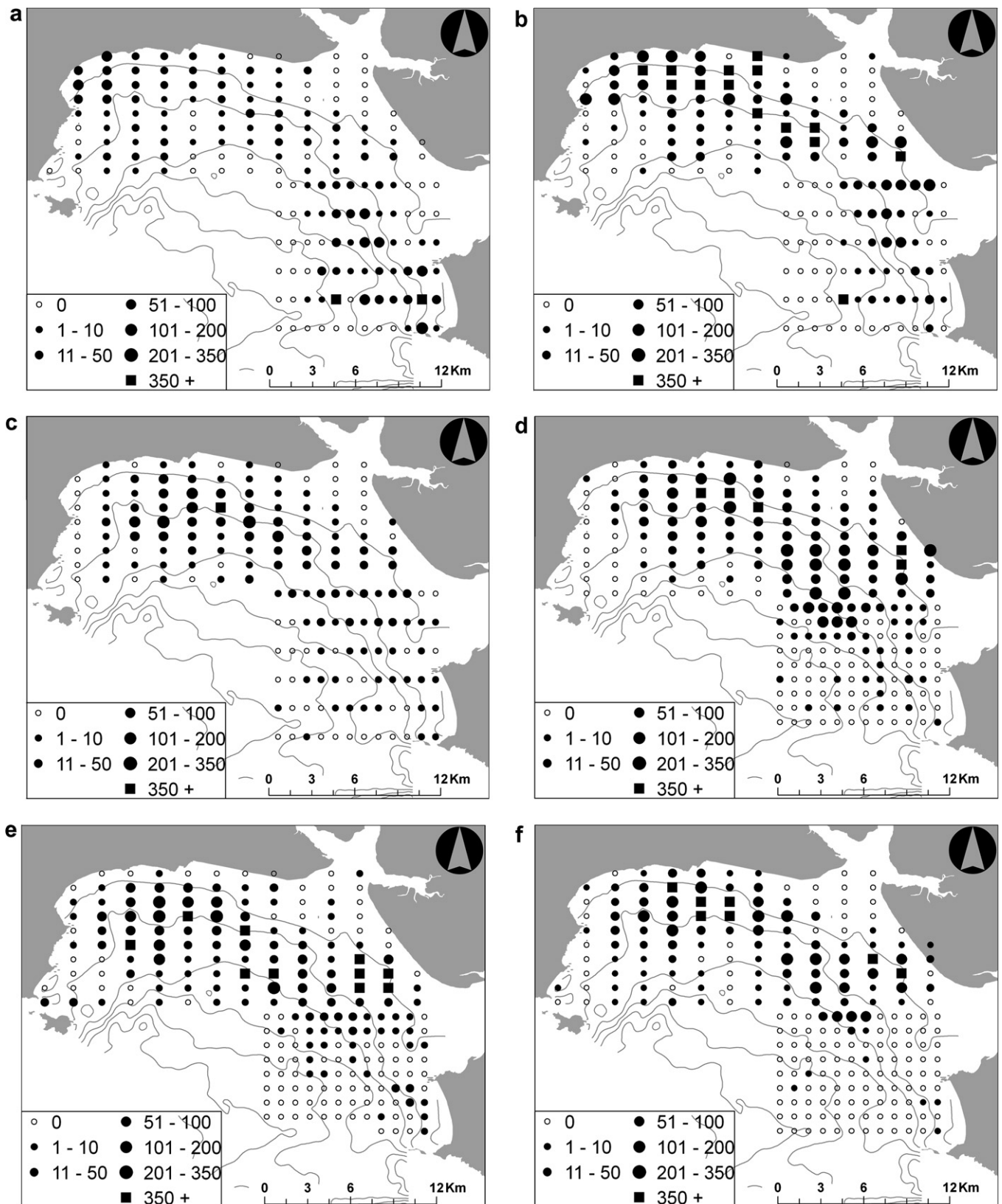


Fig. 3. Mean annual distribution of Common Scoters from aerial survey counts, January–March. (a) 1998, (b) 1999, (c) 2000, (d) 2001, (e) 2003 and (f) 2004.

experiments (e.g., Hlady and Burger, 1993; Heubeck et al., 2003) actual casualty figures were almost certainly higher

owing to an unknown number of deaths occurring without evidence of corpses appearing on land; other persistent

Table 2  
Average yearly (Jan–Mar) proportion of Common Scoter distribution within depth contours from aerial survey

|      | Depth (m) |      |      |      |      |      |
|------|-----------|------|------|------|------|------|
|      | 0         | 5    | 10   | 15   | 20   | 25   |
| 1998 | 0.14      | 0.32 | 0.25 | 0.17 | 0.11 | 0.02 |
| 1999 | 0.40      | 0.41 | 0.14 | 0.01 | 0.04 | 0.00 |
| 2000 | 0.03      | 0.52 | 0.42 | 0.03 | 0.00 | 0.00 |
| 2001 | 0.20      | 0.48 | 0.25 | 0.07 | 0.00 | 0.00 |
| 2003 | 0.02      | 0.67 | 0.24 | 0.07 | 0.00 | 0.00 |
| 2004 | 0.10      | 0.60 | 0.28 | 0.01 | 0.00 | 0.00 |

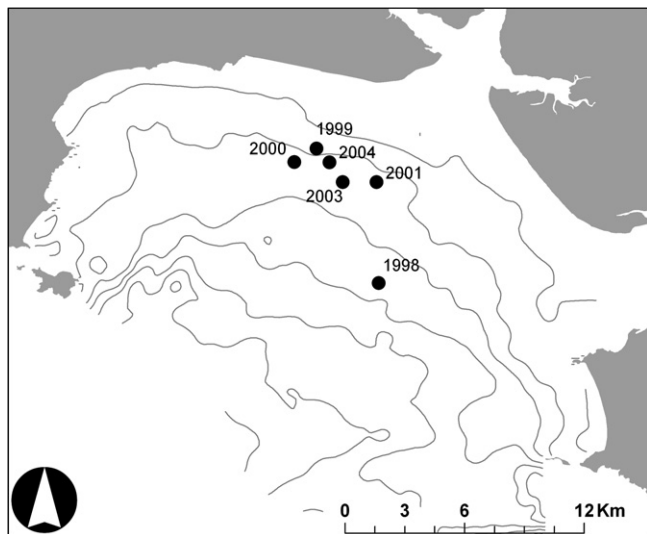


Fig. 4. Weighted centroids of mean winter Common Scoter distribution in Carmarthen Bay 1998–2004.

factors, including the consumption of contaminated prey, should be considered.

Habitat use also appears to have been affected; evidence that birds may have been displaced to less preferred feeding sites, at least in the winter of 1997/98, comes from the relatively large numbers of birds recorded on aerial survey in the previously and subsequently largely unused south east corner of the bay, off Rhossili. This area harbours a different prey community than that found in the commonly preferred west of the bay and the sea bed is at a relatively greater depth, suggesting that scoters were forced to feed on uncontaminated but energetically less profitable prey immediately post-spill (Woolmer et al., 2004). The distribution of a shallow water (<10 m) invertebrate ‘Venus’ community rich in bivalves and polychaetes spatially matches the ‘typical’ distribution of Common Scoters in Carmarthen Bay and is considered to provide the majority of the scoter diet at the site (Woolmer, 2003). Such communities are likely to be sensitive to oil spills, as shown following the *Exxon Valdez* spill (Jewett et al., 1999), but there have been few, if any, post-spill studies that have demonstrated these effects because sampling is difficult. The shallow water community in Carmarthen Bay, especially in the key scoter feeding areas in the north west of the bay that

were comparatively heavily contaminated (Fig. 1), underwent drastic damage immediately following the spill: dead and moribund shellfish were washed on to the shore and high concentrations of hydrocarbons were found in many bivalves (Law and Kelly, 2004), including likely scoter prey (e.g., *Chamelea gallina*; Woolmer, 2003), though no detailed quantitative benthic data are available. However, scoter corpse stomach analysis (Hughes et al., 1997) suggested that the diet of beached birds was related to behavioural responses of benthic organisms, leading to reliance on traditionally unlikely prey items (e.g., Egg-shell razor *Pharus legumen*).

#### 4.2. Methodological considerations

Due to the absence of baseline aerial survey data, it was necessary to use land-based counts of Common Scoter to construct an index of abundance in Carmarthen Bay. Although only a proportion of the bay is visible by this method, the visible range includes the key Common Scoter feeding zones (<10 m deep) and so the index at least reflects changes in important foraging habitats. However, aerial survey data can be used to support treatment of this index as a surrogate for the whole bay; for example, Cranswick et al. (1998) combined aerial and ground survey count totals to form sum total ‘whole bay’ estimates of 6240 and 5103 in January and February 1998 respectively. Although these combined estimates are larger than the average ground counts used in our analysis, the totals are still extremely low in comparison to those pre-spill; it may be, however, that by 1997/98, numbers of Common Scoter in Carmarthen Bay had increased in parts of the site not contributing to our assessment of numerical change, implying a pattern of more gradual recovery than suggested by the index. Regrettably, the same procedure cannot be applied to pre-1998 data owing to inconsistent aerial survey methods.

We do not consider the assessment of change overly impeded by the relative lack of pre-spill data; our strict criteria of including only whole bay surveys excluded three partial ground counts ranging from 12,000 to 17,000 in December 1994 and January 1995 (Stewart, 1995). Furthermore, although an anomalously low count of 2688 scoters was recorded prior to the oil spill in January 1996, it is possible that practical considerations, such as bad weather, contributed. Additionally, a total of 10,631 birds was recorded in March 1996 immediately following the spill, confirming that numbers were still high around the time of the event. Direct mortality of at least a further 4700 birds washed ashore indicated an estimated 15,000 scoters were present at or shortly after the time of the spill (Stewart et al., 1997). Finally, despite stringent attempts to control for spatial autocorrelation in analysis of distributional changes in aerial survey data, no model would reach convergence using sill and range parameters (estimated from a robust exponential semivariogram); we cannot therefore rule out influence of this random variable in our conclusions.

#### 4.3. Status of Common Scoter in Carmarthen Bay

Common Scoter numbers in Carmarthen Bay recovered fully in the third winter after the oil spill, with birds returning to areas in the north that were previously affected by oil and were known to be favoured prior to the accident (Stewart, 1995). The implication of these changes is that the ecosystem at large, or at least that part of it supporting Common Scoters, had also sufficiently recovered (Moore, 2006). This is an important distinction, as there is no evidence to suggest that birds wintering in Carmarthen Bay represent a single sub-population. It seems more plausible that the relatively consistent numbers of Common Scoter now present in the bay represents a turnover of individuals, the net result being that the carrying capacity of the site is reached on a regular basis. The observed recovery of Common Scoter numbers is thus likely to be a reflection of a response to ecosystem recovery, rather than a recovery of the wider population of the species. Density-dependent population effects resulting from temporary habitat loss may have led to emigration (Goss-Custard et al., 1994), leading Carmarthen Bay to be largely avoided in favour of other feeding sites within the UK or the rest of Europe (e.g., Liverpool Bay, where large numbers of Common Scoter are now known to be present in winter: Smith et al., 2007).

Perhaps because of turnover, Common Scoter numbers have subsequently remained at a high level, whilst distribution patterns signal consistent selection of feeding areas that were formerly contaminated by oil (Law and Kelly, 2004). The significant depth effect found in this study and the relative distribution of scoters implies that, where possible, scoters were distributed in shallow waters <10 m deep. The significant depth by year interaction of winter distributions of scoters between 1998/99 and 2003/04 and the relative proportions of winter distributions in waters >10 m deep, suggests that the Rhossili area, characterised by steeply sloping depth contours, was only temporarily used as a foraging site during the immediate post-spill period, and that the 'traditional' feeding grounds in the north west of the bay, and at Pembrey (Cranswick et al., 1998), were again preferred in later winters; high densities of Common Scoters are correlated typically with areas of high abundance and biomass of prey, especially bivalves (Woolmer et al., 2004; Kaiser et al., 2006).

In conclusion, therefore, the effects of the oil spill on local Common Scoter numbers and distribution, and by implication the ecosystem itself, appear to have been short-lived, unlike the after-effects of some other oil spills, which have persistently affected marine ducks for many years (e.g., *Exxon Valdez*; Peterson et al., 2003).

#### 4.4. Seabirds as indicators of environmental change

Predatory birds, often highly mobile and at the top of trophic webs, can in many situations act as indicators of the 'health' of the wider ecosystem (Furness and Greenwood, 1993; Furness and Camphuysen, 1997). Addition-

ally, birds are generally easily visible, and receive much attention through both conservation efforts and amateur birdwatching. As such they attract greater survey effort (and consequently experimental power) whilst simultaneously achieving a resonance with the general public as recognisable and evocative indicators. Bird numbers and breeding parameters are potentially good measures because they are highly sensitive to changes in food supplies, accumulation of contaminants and trophic changes (Diamond and Devlin, 2003; Fernandez et al., 2005). Some seabirds, such as scoters, may be particularly effective at revealing lethal and sub-lethal effects of marine oil pollution, because they are more likely to encounter both surface oil and contaminated food resources whilst feeding in their shallow-water foraging habitats. Changes in the accessibility of food resources following oil spills are believed to have contributed to shifts in distribution of marine birds (Castège et al., 2004), underlining the insight gained from measuring both bird abundance and distribution.

For large numbers of Common Scoter to return to visible feeding areas of Carmarthen Bay in the third winter after the spill, and for aerial surveys to detect birds in previously contaminated offshore locations, food resources appear to have recovered sufficiently to support the birds. However, as baseline pre-spill data do not exist, there is no direct evidence of recovery of scoter food resources. Nevertheless, amphipods are known to be sensitive indicators of oil contamination (and are consequently often used in toxicity testing); in Milford Haven, close to the site of the spill, a clear pattern of recovery in these taxa was evident by 1998 (Law and Kelly, 2004), sustained after a slightly longer post-spill period of five years (Nikitik and Robinson, 2003). As well as acting as sensitive indicators of infaunal benthos, amphipods are a likely component of scoter diet (Woolmer et al., 2004) and therefore their recovery within similar time scales to that of the Common Scoter is pertinent.

Following the *Amoco Cadiz* spill, densities of *Ampelisca* spp. amphipods took 15 years to return to pre-spill levels (Dauvin, 1998), and amphipod abundances remained lower than reference conditions for six years in shallow subtidal sea grass beds affected by the *Exxon Valdez* spill (Jewett et al., 1999). Whether the apparently rapid recovery of invertebrates at Carmarthen Bay is due to the comparative scale of the initial impact, the regenerative capacity of the ecosystem or the subsequent management of the spill, including recovery of oil and dispersant spraying policy decisions (Law and Kelly, 2004), is unclear.

A program of scoter monitoring is now established in Carmarthen Bay and further changes in Common Scoter numbers can be used to indicate the underlying condition of the site, which has been designated as the UK's first marine Special Protection Area (SPA) on the basis of non-breeding Common Scoter numbers. The results of the present work emphasise the importance of long-running monitoring in order to assess the condition of wildlife resources and evaluate anthropogenic influences.

## Acknowledgments

This work was supported by the Countryside Council for Wales as part of projects FC 73-02-123/53/62/316/338. Aerial and ground fieldwork was undertaken by Dean Bolt, Ian Bullock, Richard Schofield and Rob Taylor, in addition to some of the authors. Niall Burton contributed extensive and helpful advice, Mark Rehfisch commented on an earlier draft and Steve Freeman, Sarah Jackson, Stuart Newson and Niall Burton provided statistical advice. Barry Stewart, Peter Hayward and WWT supervised and supported PhD studentships and research that contributed to this study. Andy Woolmer contributed valuable comments for an earlier report. James Dargie has managed and archived data from the projects this paper is based upon. Thanks to Ravenair for pilotage and Bill Cooper of ABP Research for data to support a complementary project. Tony Fox, Ivor Rees, Maggie Hill, Mandy McMath, Blaise Bullimore and Mike Camplin all provided support and comment over the years and the Environment Agency Wales provided a financial contribution in the first year of aerial surveys. Andy Webb offered helpfully comment on an earlier draft.

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