A preliminary study of the effects of disturbance on feeding Wigeon grazing on Eel-grass *Zostera*

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Wigeon at four different sites in Britain showed highly restricted bouts of foraging on inter-tidal *Zostera* beds. The feeding activity was closely tied to patterns of tidal inundation of this feeding resource and limited active feeding to four periods each of around two hours duration in every 24 hours, with little apparent difference between daytime and night-time foraging patterns. This represents far less foraging time than has been observed elsewhere. Observation of responses to disruptive disturbance of feeding Wigeon showed that birds would return to the feeding grounds if disturbed in the early stages of the feeding cycle, but that when the disruption occurred after the *Zostera* bed had been exposed by the tide, Wigeon abandoned the site altogether until the next tidal cycle. In situations where foraging opportunity is already highly restricted by natural environmental factors, additional disruption by human disturbance is likely to have considerable energetic consequences for the birds and could lead to the abandonment of the site.

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INTRODUCTION

It is axiomatic that birds foraging in inter-tidal habitats exhibit feeding patterns regulated by tidal inundation of their food supply. In the case of Wigeon *Anas penelope* foraging on inter-tidal eel-grass *Zostera* beds for instance, feeding usually ceases at high tide (Madsen 1988). However, with increasing human pressure on estuarine and other inter-tidal waters, particularly due to recreational pursuits, the question of how disturbance affects the patterns of feeding and roosting amongst estuarine waterfowl becomes ever more important. Birds disturbed whilst concentrated at high-tide roosts will suffer increased energy expenditure as they flee the cause of their disruption. However, birds interrupted from low-tide feeding areas suffer lost feeding time whilst also increasing energy consumption. On these occasions other feeding opportunities may already be highly restricted.

In this paper, an attempt is made to determine the total amount of time spent foraging by Wigeon feeding on inter-tidal *Zostera* at four intensively studied sites. A comparison of daylight and night-time foraging patterns is attempted to see if birds make up for lost daytime foraging under cover of darkness. Limited experimental disturbance was carried out to determine the effects of daytime disruption during the brief periods of intensive feeding which occurred.

STUDY AREA AND METHODS

Detailed activity budgets were compiled for feeding Wigeon at four different locations: Bruichnain (Beauly Firth, Highland Region), Udale Bay (Cromarty Firth, Highland Region), and two sites on the western and eastern shores of the Exe Estuary (Devon), Cockwood Corner and Cockle Sands respectively. Fieldwork was carried out at Bruichnain in winter 1984/85 and 1985/86, and at the Exe Estuary during the winters of 1988/89-1991/92 inclusive. All sites comprise discrete beds of *Zostera angustifolium* and Z. *noltii*, with greater or lesser extent of *Enteromorpha* and fucoids. Mapping of sites by aerial survey (Exe Estuary, see Bell *et al.* 1991) and ground survey (Moray Firth, see Fox *et al.* 1986) determined the extent of the *Zostera*-dominated mudflats as follows: Cockwood 25 ha, Cockle Sands 101 ha, Bruichnain 58 ha and Udale Bay 344 ha. Some observations from the Exe Estuary have already been reported in Bell *et al.* (1991) and the Udale Bay study was reported in Mudge (1989).

Field observations on the Exe Estuary and Moray Firth sites were made using $\times$ 20-60 telescopes, compiling

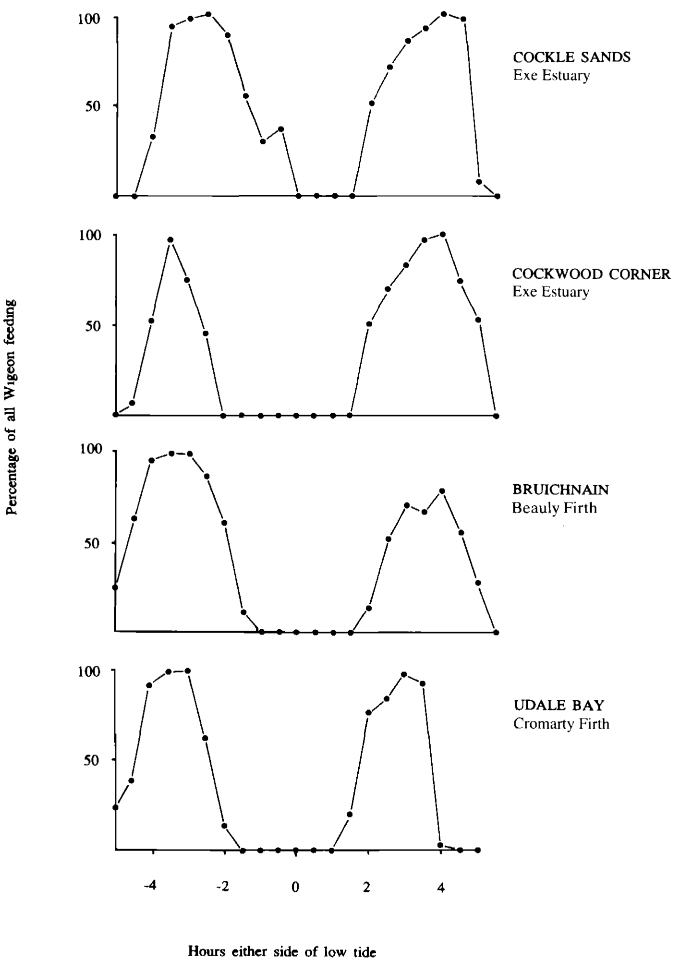

Figure 1. Percentage of Wigeon feeding on *Zostera* beds in the Exe Estuary, Devon and Moray Firth at different states of the tide. Plotted values are half-hourly means, standard error bars are omitted for clarity.

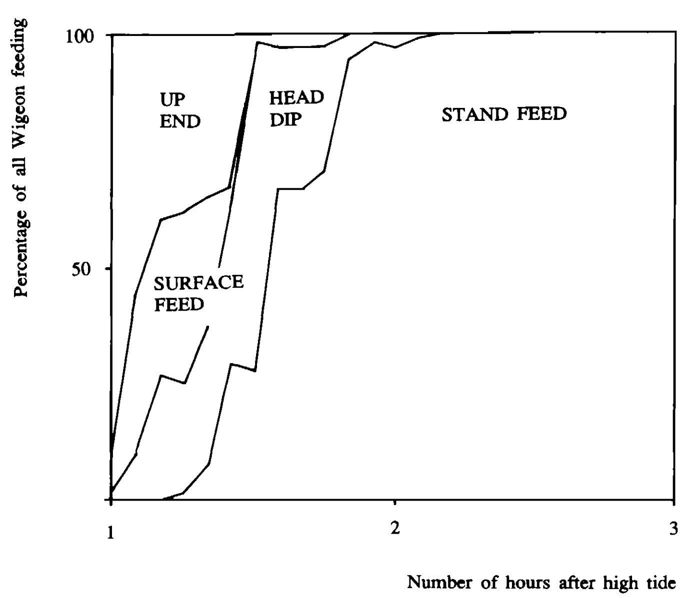

Figure 2. Typical plot of feeding techniques used by Wigeon on a falling tide from the Exe Estuary, October 1988.

activity budgets by instantaneous scan sampling throughout the entire flock at half-hour intervals (Alltman 1974, Martin & Bateson 1986). The proportion of the birds feeding, flying, swimming, walking, resting, preening, drinking, alert or in antagonistic interactions were recorded. In addition, more detailed observations were carried out at the Beauly Firth and Exe Estuary, where the proportion of feeding birds in different activities were scored every five minutes. The percentage of birds feeding by up-ending, head-dipping, surface dabbling and stand-feeding was recorded for each scan during the tidal rhythm.

In addition to recording feeding activity on the Exe Estuary Cockwood Corner, on a series of tides, six disturbance events were monitored to determine the difference in feeding activity between these and six undisturbed tidal feeding cycles. Cockwood Corner is a nature reserve, and human disturbance is reduced to a minimum by restricted access. This is in considerable contrast to Cockle Sands where unrestricted recreational activity takes place throughout the inter-tidal zone. The percentage of birds feeding was recorded at five-minute intervals throughout the tidal cycle for this phase of the investigation, but is summarised by mean percentage of birds feeding in the presentation of results. In the first instance, disturbance occurred through the presence of maintenance staff on the railway, which forms the upper boundary of the estuary behind the study area. The presence of such workers was sufficient to put Wigeon to flight from feeding areas during three observation sessions. However, on a further three tidal cycles, Wigeon were deliberately disturbed and the effects of this disruption compared with undisturbed feeding bouts. The total percentage of birds feeding was calculated for the time from when birds commenced swim-feeding until the time birds commenced standing to feed and from that time until the *Zostera* bed had completely dried out (the time when Wigeon normally abandoned feeding on *Zostera*). In bouts when disturbance occurred, the total percentage of birds feeding was calculated from the point of disturbance until the end of the phase under consideration in order to control for timing of disturbance in the cycle.

RESULTS

Daytime feeding patterns

Feeding formed the predominant activity of Wigeon at all four sites as *Zostera* beds became exposed (Figure 1). Feeding behaviour was similar at all sites, with the ducks loafing in large rafts on the water adjacent to feeding areas at high tide. In these situations, birds roosted, preened and indulged in social interaction, but showed almost no feeding activity at all. In Udale Bay and Bruichnain, some feeding occurred on saltmarsh merse around high tide, but this rarely involved more than 15% of the entire flock. As the tide fell, Wigeon came to the *Zostera* beds to feed avidly until the water level had fallen below the lowest level of the *Zostera* beds. At this stage, the entire flock would flight to a favoured low-tide loafing area which at all four sites comprised the channel or mouth of a freshwater inflowing stream entering the estuarine complex above the mudflats. On the flood-tide, Wigeon would swim up towards the lower edge of the feeding areas and feed in shallow water behind the tide edge as it covered the eel-grass beds. At none of these sites were Wigeon observed to feed on eel-grass at low water or at high tide.

As the tide dropped, so feeding methods were modified to exploit the *Zostera* as appropriate (Figure 2). Initially, birds pecked floating blades of *Zostera* from the water surface where available; such feeding was clearly opportunistic and occurred at relatively low levels throughout the flock. The swimming Wigeon would then up-end as the tide receded, browsing bottom vegetation until water levels were shallow enough to permit feeding by dipping the head and eventually dabbling on the surface of the water. Ultimately birds stood to feed. Almost all the grazing at the sites appeared to be through grazing of above-ground parts of the *Zostera* and very little grubbing was observed.

The average feeding period of Wigeon was 2 hours 8 minutes at Bruichnain and 2 hours 7 minutes on the Exe Estuary.

Night-time feeding patterns

As part of a study of the effects of night shooting on feeding Wigeon (Mudge 1989), image-intensifying equipment was used to study Wigeon flocks at night at Udale Bay. Rough estimates of the number of night-feeding birds were comparable with daytime numbers. In all sites observed, there was no evidence of dusk flights away from study areas. Confirmation of the Wigeon remaining on the study area by day and night also came from records of radio-tagged birds (Mudge 1989), with 91% of birds present both by day and night on the *Zostera-feeding* beds and high-tide loafing areas during paired 24-hour studies. Although full activity budgets were not possible during the hours of darkness, comparison of 23 undisturbed night and 65 equivalent daylight periods in the Moray Firth showed no significant difference in the proportions of Wigeon hours spend feeding (Table 1; $F_{1,80} = 0.19$, $p>0.65$).

At Bruichnain domestic lighting permitted some casual observations of feeding birds at night, when birds were only ever seen feeding during the same phases of the tide as during the day. However, such observations were never obtained on a regular enough basis to provide reliable data. Similarly, observations using image-intensifying equipment on the Exe Estuary showed that Wigeon were using the *Zostera* beds during the same state of the tide as during the day. Hence, all the evidence suggests that on the four study areas, Wigeon feeding activity at night is dependent on tidal state in precisely the same way as during the daylight hours.

Total diurnal feeding budget

If we therefore assume that the mean feeding period during the night is the same as during daylight, and

Table 1. Mean percentage of Wigeon-hours spent in undisturbed major activities on the Moray Firth study sites in relation to day/night and tidal states (data from Mudge 1989)

	Number of observations	Feeding	Flying	Swimming	Resting	Other
HIGH TIDE						
day	19	24.2	0.6	5.5	69.3	0.5
night	11	11.4	0.3	9.9	78.4	0.0
EBB TIDE						
day	14	89.0	1.5	5.4	3.5	0.7
night	4	96.6	0.0	3.4	0.0	0.0
LOW TIDE						
day	19	44.5	0.6	8.4	45.5	0.9
night	1	0.0	0.0	0.0	100.0	0.0
FLOOD TIDE						
day	13	88.5	0.4	5.0	6.1	0.1
night	7	95.3	0.2	2.1	2.5	0.0

Table 2. Comparison of percentage time spent feeding by Wigeon on Cockwood Corner *Zostera* bed on the Exe Estuary during disturbed and undisturbed ebb tides. Birds were disturbed at two different stages of the falling tide, (i) during the early stages where feeding takes place predominantly by swimming and (ii) during the later stages when the eel-grass is exposed and Wigeon feed by walking. Differences between disturbed and undisturbed cycles are significant for both times of disturbance (swim-feed $F_{1,7}$ = 20.0, p<0.01; walk-feed $F_{1,7}$ = 738.05, p<0.0001)

Tidal stage at which Wigeon were disturbed	(i) early Swimming	(ii) late Walking	
	% of time spent feeding		Comments
Disturbed	34.2		Wigeon flew to channel before drifting back to commence feeding at the bottom of the *Zostera* bed
Disturbed	16.7		As above, but c.40% of Wigeon left feeding area altogether
Disturbed	48.0		As above, but only c.15% of Wigeon departed feeding area altogether
Disturbed		3.9	All Wigeon departed and most did not return to feed within tide cycle
Disturbed		0.0	All Wigeon left feeding area and did not return during tide cycle
Disturbed		0.0	As above
Undisturbed	79.4	89.6	
Undisturbed	88.5	94.6	
Undisturbed	78.8	89.9	
Undisturbed	75.0	80.0	
Undisturbed	69.8	94.0	
Undisturbed	53.6	88.7	Some disturbance caused by train

given four bouts of feeding on all ebb and flood stages of the c.24-hour tidal cycle, the mean feeding period was 8 hours 32 minutes.

Daytime feeding disturbance

A comparison of the disturbed and undisturbed tidal cycles are shown in Table 2. Although sample sizes are small, it would seem that Wigeon disturbed during the early phase of feeding on the bed will swim back into the *Zostera* feeding area, such that although the percentage time spent feeding is significantly reduced, feeding does resume. Disturbance later on in the tidal cycle, when Wigeon are standing on the exposed mud to feed, invariably causes the entire flock to abandon the *Zostera* bed completely until the following flood tide.

DISCUSSION

Wigeon at the sites studied are restricted in both time and space in their access to the inter-tidal feeding resource. *Zostera* tends to exhibit discrete areas of growth on the upper shore, and this feeding resource is rendered inaccessible by the twice daily inundation by sea water. Madsen (1988) demonstrated that this inhibited feeding at high tide, but that in his Wadden Sea study area, Wigeon fed throughout the entire period that the *Zostera* was exposed. This pattern has also been observed during the daytime period by ADF at Lindisfarne (north-east England) and at Strangford Lough (Northern Ireland).

However, in the study sites described here, this was not the case; Wigeon fed for approximately two hours after the exposure of the top edge of the *Zostera* beds and then ceased feeding until the flood tide began to cover the beds again. Campredon (1984), in Golfe de Morbihan, France also found that the feeding activity in Wigeon grazing on eel-grass flats occurred in two bursts only, before and after high tide, at least during October and January.

The constancy of the time spent feeding before flighting to loaf and drink in freshwater creeks was striking, and the causes of this will form the basis of another analysis to be reported elsewhere. The important feature of these studies is that for some reason the Wigeon are not feeding for the entire time the *Zostera* is exposed by the tides, and that makes the birds more vulnerable to disturbance during the short bursts of intensive feeding activity than may be the case elsewhere. At the study sites described here, Wigeon fed for approximately 8.5 hours per 24-hour period, considerably less than the observed c.13 hours in Denmark (Madsen 1988) and 14 hours by Mayhew (1988). In the latter study, Wigeon fed on terrestrial *Agrostis/Lolium* grass swards, but using the same methods, Madsen (1988) found Wigeon feeding on *Zostera* ingested less material in weight than grass-grazing birds, but with a greater feeding efficiency. The daily calorific intake in both populations were similar (630 Kj/bird/day Mayhew 1988; 592 Kj/bird/day Madsen 1988).

It would therefore appear that Moray Firth and Exe Estuary Wigeon feed for very much less time in undisturbed circumstances than in other studied situations. If Wigeon are disturbed on the water (at least sufficiently to initiate flight from the feeding area) the time spent feeding is reduced by one half to one third of the normal time spent feeding in each tidal cycle. When disturbed whilst stand-feeding, all Wigeon put to flight and deserted the feeding area altogether, usually not to return, losing up to a quarter of the total potential feeding opportunity in each 24-hour cycle.

Wigeon are relatively inefficient grazers, relying on rapid throughput of relatively poor quality forage, and are considered to require long periods of feeding to meet daily energy requirements. Eight hours of foraging per day are considerably fewer than reported from other studies, including Madsen's (1988) study of a Wadden Sea eel-grass site. The effects of disturbance on these feeding patterns are significant, further reducing foraging duration. Cockwood Corner is a refuge site on the Exe and because of its situation, bounded by a main railway line, is subject to hardly any direct disturbance (except during periods of railway maintenance). Hence, under normal conditions, the Wigeon suffer relatively little disruption of feeding cycles. At other sites, Wigeon numbers exploiting eel-grass beds have shown dramatic declines in situations where disturbance has been implicated, as at Strangford Lough and Lindisfarne (Fox *et al.* 1990). In these situations, we have no information on the frequency or intensity of human disturbance at these sites, but we might speculate that an inability to achieve daily energy requirements because of persistent disruption to already restricted feeding opportunities may lead to abandonment of a site, as appear to have occurred at both Lindisfarne and Strangford. More site-based research is required from *Zostera* feeding areas where Wigeon numbers appear to be declining.

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