

Coastal pasture use by Long-billed Curlews at the northern extent of their non-breeding range

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ABSTRACT. The Long-billed Curlew (*Numenius americanus*), a declining species of Nearctic shorebird, winters as far north as Humboldt Bay, California, where it feeds principally in intertidal habitats but shifts to pastures with onset of seasonal rains. We studied variation in abundance and behavior of curlews in coastal pastures in relation to environmental variation that may influence the profitability of intertidal and pasture habitats as foraging sites. Curlews occurred in greater abundance in pastures during morning hours, when intertidal habitats were exposed for longer intervals during daylight hours, and coincident with greater rainfall. While using pastures, most curlews fed, and this proportion varied positively with intervals of lower tides in intertidal habitats. Pastures provide important foraging habitat for approximately one third of the 200–300 curlews wintering at Humboldt Bay, especially when inclement weather makes foraging in intertidal habitats difficult and increases food availability in pastures.

SINOPSIS. Utilización de pastizales por *Numenius americanus* en el extremo norte de su distribución no-reproductiva

Numenius americanus es un chorlo neártico que se encuentra en peligro de extinción. El ave pasa el invierno tan al norte como la Bahía de Humboldt en California en donde se alimenta principalmente en habitats marinos costaneros, pero cambia a pastizales con el comienzo de la temporada de lluvias. Estudiamos la variación en la abundancia y la conducta de las aves en pastizales costaneros asociada a variaciones ambientales (ej., lluvias) que pudieran influir el uso de la zona intermareal y de pastizales para forrajear. Los chorlos fueron mas abundantes en pastizales durante las horas de la mañana, cuando el habitat intermareal estuvo expuesto, durante las horas de luz, por largos periodos y que coincidía con una mayor cantidad de lluvia. Mientras utilizaban los pastizales, la mayoría de los chorlos se alimentaron, y esta proporción varió positivamente con intervalos de mareas bajas. Los pastizales estudiados proveen de habitat importante para el forrajeo de aproximadamente una tercera parte de los 200–300 individuos que pasan el invierno en la Bahía de Humboldt, particularmente cuando las inclemencias del tiempo hacen difícil el conseguir alimento en el habitat intermareal, pero incrementan la disponibilidad de comida en los pastizales.

Key words: habitat relationships, Long-billed Curlew, *Numenius americanus*, pastures

Most non-breeding shorebirds (suborder Charadrii) spend almost all daylight hours foraging to meet energetic requirements in the northern hemisphere, with some species continuing to feed at night (Puttick 1984; Colwell and Dodd 1997). While many of these shorebirds feed in intertidal habitats, individuals of some species benefit from use of pastures as secondary, or even primary, foraging areas (Townshend 1981; Kirby 1997), especially when intertidal food may become limited by winter storms, reduced prey accessibility, and prey depletion (Townshend 1981; Burger 1984; Goss-Custard 1985). In coastal northern California,

large numbers of shorebirds begin to use pastures only after the onset of autumn rains (Hoff 1979; Colwell and Dodd 1995, 1997). Rain increases the availability of earthworms (family Lumbricidae) to shorebirds by bringing them close to the surface (Townshend 1981; Edwards and Bohlen 1996), and by softening the soil, making probing by birds easier (Myers et al. 1980).

We studied Long-billed Curlew (*Numenius americanus*) use of coastal pastures in the Arcata Bottom, an area of approximately 2415 ha north of Humboldt Bay. The curlew is among the most imperiled species of Nearctic shorebird, with a declining population (Dugger and Dugger 2002) that is threatened by habitat loss throughout its range (Brown et al. 2001). Humboldt Bay, California, is an estuary of international importance to non-breeding curlews

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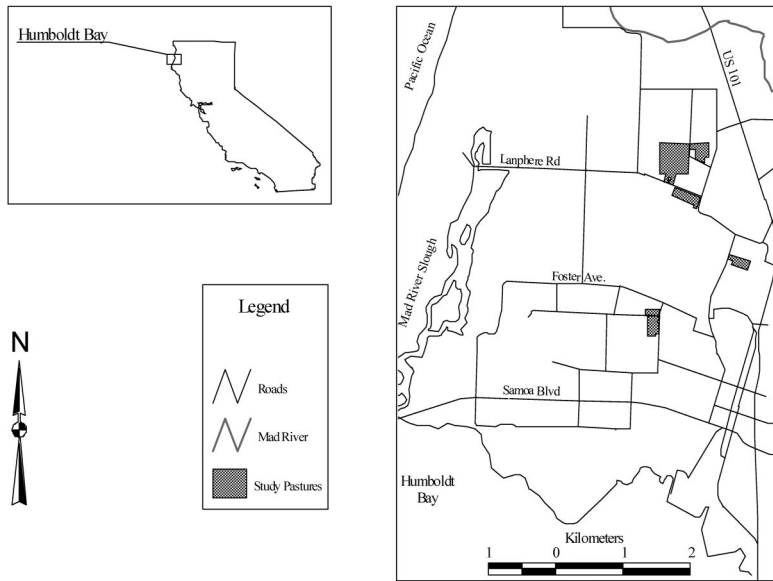


Fig. 1. Arcata Bottom study area.

(Dugger and Dugger 2002), and offers expansive tidal flats and saltmarsh, with pastures nearby. The Humboldt Bay region experiences mild temperatures and wet winters. Most winter days receive some rain, but substantial rainfall results from occasional storms (Barnhart et al. 1992).

Nocturnal foraging is common in some shorebirds (Dodd and Colwell 1996), including the Eurasian Curlew (*Numenius arquata*; Cramp and Simmons 1983), and is common in some terrestrial habitats (Shepherd et al. 2003); however, curlews appear to use pastures near Humboldt Bay only during daylight hours. Prior to this study we observed flocks (of usually <10 curlews) flying to pastures from the direction of the bay within 20 min after sunrise and returning to the bay shortly before sunset. Curlews also regularly arrive on intertidal territories at dawn and depart from them at dusk (Colwell and Mathis 2001).

We collected data on five factors that could affect curlew behavior: seasonality (day), time of day, tide height on Humboldt Bay, mudflat availability, and rainfall. We tested the hypotheses that these five factors affect the abundance and behavior of curlews using selected coastal pastures near Humboldt Bay. We predicted that abundance is positively correlated with tide height since rising tides would inundate inter-

tidal habitat, and with rainfall since rainfall can increase prey availability in pastures (Edwards and Bohlen 1996). We predicted that the proportion of birds feeding is correlated negatively with time of day since most birds should forage after nighttime fasting, and pasture prey may be more active during morning hours (Edwards and Bohlen 1996). We predicted that date would be positively correlated with both abundance and proportion of birds feeding if intertidal prey is depleted through winter.

STUDY AREA AND METHODS

Study area. We studied curlews on pastures of the Arcata Bottom (Fig. 1) from mid-October 1998 to early March 1999. The study area consisted of 25 non-randomly chosen pastures totaling ~37 ha. Study pastures occurred in five areas where we knew curlews regularly occurred and where landowners allowed access or where roads offered good observation points. These pastures were located either adjacent to or surrounded by residential developments in the City of Arcata.

Field observations. We scan-sampled (Altmann 1974) pastures beginning 13 October 1998. We performed scans during three periods on one day per week, at approximately 08:00, 12:00, and 16:00. We began scans at least 30

min after sunrise to allow curlews to arrive on pastures, and finished prior to sunset, before curlews departed. When heavy rain prevented three scans from being conducted on the same day, we completed scans on the next earliest day permitted by weather.

We recorded the number of curlews in each pasture and the number engaged in each of the following behaviors: foraging (walking, pecking, probing, or handling prey), roosting (sitting or standing with head tucked), alert (standing motionless with bill horizontal or raised), maintenance (preening, stretching, or bathing), and flying. The time we spent on each scan varied with pasture conditions and number of curlews. Small pastures with short vegetation were sampled more quickly (e.g., <1 min) than larger pastures with taller vegetation (e.g., 5 min). Likewise, pastures with large mixed flocks including Marbled Godwits (*Limosa fedoa*) or Whimbrels (*Numenius phaeopus*) required more time to sample than pastures with few or no birds.

Data summary and analyses. We used NCSS 2000 (Hintze 1999) to run multiple regressions on each of three dependent variables: curlew abundance, proportion of curlews feeding, and proportion of curlews roosting during each scan sample, and to compute 95% confidence intervals. We evaluated five independent variables for use in each regression: day, time of day, tide height, number of daylight hours tidal flats were exposed during the previous 72 h (hours exposed), and rainfall during the previous 72 h (rainfall). We used a 72-h period for hours exposed to magnify the effect of restricted availability of intertidal habitat. We used a 72-h period for rainfall to capture the effect of large periodic storms that might have been missed with a shorter period; the effect of those events could persist for several days in Humboldt Bay's cool and humid climate.

We used McHenry's Select Algorithm in NCSS 2000 to evaluate all subsets of independent variables for each regression. This algorithm selects the variables which provide the largest R^2 for each subset. We used the subset with the greatest number of independent variables that provided a relatively large gain in R^2 (i.e., if a subset of $n + 1$ variables only resulted in a small increase in R^2 relative to the subset of n variables, we used the subset of n variables).

We calculated day as the number of days from 13 October 1998, which corresponded to the typical beginning of the winter rainy season (Barnhart et al. 1992). We recorded time as the mid-point between start and finish of each scan period. We used data from the National Oceanographic and Atmospheric Administration (NOAA 1998, 1999), recorded at 6-min intervals on the north spit of Humboldt Bay, to calculate average tide height for the duration of the sample period. We used NOAA tide data and sunrise and sunset times to calculate the number of daylight hours that tide was below 1.2 m (the level at which intertidal feeding areas of curlews begin to be exposed at most sites in the bay; Danufsky and Colwell 2003). To calculate rainfall, we used hourly precipitation data collected by NOAA at Eureka, California, approximately 10 km south of the study area.

To meet assumptions of normality, we examined the relationship of each independent variable with each dependent variable for linearity and transformed independent variables when indicated. We examined collinearity diagnostics (eigenvalue and condition index) for evidence of multi-collinearity between variables in each model, and concluded that multicollinearity was not present. We consider all tests significant at $\alpha = 0.05$, and we present means \pm SD.

RESULTS

We conducted 57 scan samples on 21 days from 13 October 1998 to 8 March 1999. Four scan samples resulted in no curlews on any pastures in the study area. Although we selected pastures with a high likelihood of being used by curlews, three of the 26 pastures sampled were never used, and one pasture was used during only one scan, by one curlew.

Curlew abundance. The number of curlews ranged from 0–129, with a mean of 48 ± 38 ($N = 57$). The subset of variables used for the multiple regression included time, hours exposed, and rainfall. Neither tide nor day improved R^2 substantially enough to be included in the regression. The regression resulted in a significant model ($F_3 = 11.4$, $P < 0.001$, adjusted $R^2 = 0.36$), and curlew abundance correlated significantly with all three variables (Table 1). Abundance was greatest earlier in the day, during periods of greater diurnal exposure

Table 1. Multiple regression examining the effect of independent variables on Long-billed Curlew abundance in pastures of the Arcata bottom, from November 1998 to March 1999. Variables are ranked in order of descending magnitude of the standardized coefficient.

Variable	$\beta \pm 95\%$ confidence interval	SE	<i>P</i>	Standardized coefficient
Time of day	-137.18 ± 65.92	32.865	< 0.001	-0.450
Hours exposed	5.54 ± 3.22	1.605	0.001	0.389
Rainfall	5.16 ± 4.36	2.175	0.021	0.267

of intertidal habitat, and with more rainfall in the previous 72 h.

Curlew behavior. Curlews mostly foraged ($74.6\% \pm 25.6$), followed by roosting ($10.9\% \pm 13.1$), maintenance ($5.2\% \pm 8.7$), alert ($4.1\% \pm 5.8$) and flying ($5.1\% \pm 15.8$). The subset of variables used for the multiple regression for proportion of birds feeding included day, hours exposed, and tide. Time and rainfall did not substantially improve R^2 and were not included in the regression. The regression resulted in a significant model ($F_3 = 5.14$, $P < 0.05$, adjusted $R^2 = 0.19$), and the proportion of birds feeding correlated significantly with all three variables (Table 2). The proportion of curlews feeding was greatest earlier in the survey season, during periods of greater diurnal mudflat exposure, and at lower tides.

The subset of variables used for the multiple regression for proportion of birds roosting included day, tide, hours exposed, and time. Rainfall did not substantially improve R^2 . The regression resulted in a significant model ($F_4 = 4.19$, $P < 0.05$, adjusted $R^2 = 0.20$), and the proportion of birds roosting correlated significantly with tide and day (Table 3). The proportion of curlews roosting increased at higher tides and later during the survey season. Although hours exposed and time substantially improved R^2 , they were not significant in the model.

DISCUSSION

Curlews were detected infrequently in previous studies on randomly selected pastures adjacent to Humboldt Bay (Gerstenberg 1972; Hoff 1979; Colwell and Dodd 1995; Long and Ralph 2001). We non-randomly selected pastures in order to reliably find curlews for this study. We detected curlews on 93% of surveys, indicating regular use of study pastures. We observed an average of 48 curlews using study pastures, or about half of the average number of curlews observed using pastures in the Arcata Bottom during low-tide winter surveys (Mathis 2000).

Contrary to our predictions, tide height was not related to curlew abundance on study pastures. Although we non-randomly selected pastures and inferences derived from these data may only apply to study pastures, this result is supported by Hoff's (1979) observation that curlews were not among the species he observed flying to and from pastures with rising and falling tides. In addition, Mathis (2000) observed an average of 99 out of 310 curlews in Humboldt Bay using pastures at low tide during bay-wide winter surveys. The regular use of study pastures independent of tide suggests that some curlews may use these pastures as primary foraging habitat, a pattern demonstrated for the Eurasian Curlew in England (Townshend

Table 2. Multiple regression examining the effect of independent variables on the proportion of Long-billed Curlews feeding (arcsin square-root transformed, and excluding observations with no curlews) in pastures of the Arcata bottom, from October 1998 to March 1999. Variables are ranked in order of descending magnitude of the standardized coefficient.

Variable	$\beta \pm 95\%$ confidence interval	SE	<i>P</i>	Standardized coefficient
Day	-0.003 ± 0.002	0.001	0.007	-0.433
Hours exposed	0.045 ± 0.037	0.018	0.019	0.372
Tide	-0.170 ± 0.127	0.062	0.009	-0.342

Table 3. Results of a multiple regression examining the effect of independent variables on the proportion of Long-billed Curlews roosting (arcsin square-root transformed, and excluding observations with no curlews) in pastures of the Arcata bottom, from October 1998 to March 1999. Variables are ranked in order of descending magnitude of the standardized coefficient.

Variable	$\beta \pm 95\%$ confidence interval	SE	<i>P</i>	Standardized coefficient
Day	0.003 \pm 0.002	0.001	0.002	0.497
Tide	0.135 \pm 0.093	0.046	0.006	0.392
Hours exposed	-0.025 \pm 0.026	0.013	0.058	-0.297
Time of day	0.364 \pm 0.479	0.238	0.133	0.204

1981), although further study with marked individuals would be required to establish this pattern at Humboldt Bay.

Earthworm density in pastures peaks in late winter (Leeman 2000), near the end of the study period. We predicted that if there were a reduction in intertidal prey during this study, the proportion of curlews feeding in study pastures would increase through the study period. Contrary to this prediction, the proportion of curlews feeding in study pastures was greater early in the survey season (i.e., fall). This result may be explained by the availability of intertidal habitat, which varies seasonally at Humboldt Bay. Fall diurnal low tides are higher than at any other time of year (Dodd and Colwell 1996). If curlews cannot meet their energetic requirements by feeding in intertidal habitats, they may feed in upland habitats, such as pastures (Shepherd et al. 2003).

While curlew abundance on study pastures did not vary significantly with tide height, the proportion of birds foraging and roosting did vary. A larger proportion of curlews roosted and a smaller proportion fed at higher tides. While curlews are known to use high tide roosts at Humboldt Bay, dynamics of local curlew movements between bay mudflats, roosts, and pastures are not well understood. During this study curlews moved between study pastures and in and out of the study area. Based on data from Mathis (2000), the study area on average only included approximately one half of curlews using pastures in the Arcata Bottom. The change in behavior with tide could possibly be explained by some level of curlew exchange between study pastures, other pastures, and the bay, with bay curlews using pastures as high-tide roosts. If this occurs, a small increase in the number of roosting birds at high tide could

reduce the proportion feeding without significantly influencing abundance.

We also found that curlew abundance and the proportion of birds feeding on study pastures increased during longer periods of diurnal mudflat exposure. These data suggest that some curlews may not be able to meet their energetic requirements on the bay during longer periods of exposure, and move to pastures to continue feeding. Intertidal organisms, which experience more intense avian predation pressure during daylight hours and are at greatest risk of desiccation during diurnal low tides, reduce activity and seek refugia during extended periods of diurnal mudflat exposure (Raffaelli and Hawkins 1996) and may be less available to curlews. Also, curlews may have moved to pastures to benefit from flocking. Benefits could include reduced vigilance and increased foraging success, as shown for the Eurasian Curlew (Abramson 1979). Curlews on intertidal habitats are widely dispersed (Mathis 2000), but in this study curlews on pastures tended to flock (mean flock size, 24).

As predicted, curlew abundance was higher on pastures in the morning and during periods of increased rainfall. This is likely a result of improved prey availability, which can influence shorebird behavior (Puttick 1984). Earthworm activity would have been greatest in the morning, since many species of earthworms are more active at night and in early morning hours, and rain increases earthworm activity near the soil surface (Edwards and Bohlen 1996). Rainfall can affect shorebird behavior in several other ways. Small-scale movements by shorebirds are known to occur in conjunction with precipitation brought by winter storms (Colwell and Dodd 1997), and rainfall can reduce a shorebird's foraging efficiency on intertidal habitats

by directly interfering with its ability to detect surface movement of prey (Goss-Custard 1984; Pienkowski et al. 1984). Colwell and Mathis (2001) found that for some curlews using the Elk River estuary in Humboldt Bay, presence on territories was negatively correlated with recent rainfall, and they suggest that these curlews moved to pastures.

Conclusions. Coastal pastures are an important habitat for curlews in the Humboldt Bay region. Although curlews are infrequently found on randomly selected pastures, an average of 99 out of 310 curlews observed in Humboldt Bay used pastures at low tide during winter surveys (Mathis 2000). Throughout this study we observed an average of 48 curlews in study pastures irrespective of tide, with a larger proportion feeding at lower tides. In light of this data and previous studies we suggest that curlews do not randomly use pastures. Factors influencing pasture use by curlews are not well understood and deserve further study. Study pastures were situated adjacent to or within residential development, which tend to spread from the edges, and are therefore more at risk for conversion to residential development than other pastures. If individual curlews use different strategies to survive winter at Humboldt Bay (e.g., specialize on pastures or use both the bay and pastures), the loss of these pastures would affect them disproportionately to other curlews in the Humboldt Bay population.

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