AN ABSTRACT OF THE THESIS OF

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Title: _Breeding Chronology, Habitat Utilization and Nest-site_

Selection of the Long-billed Curlew in Northcentral Oregon.

Abstract approved: _Robert G. Anthony_
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Breeding ecology of long-billed curlews in Umatilla and Morrow Counties, Oregon, was studied during the spring and summer of 1978 and 1979. The first curlews were observed in the study areas on 16 and 19 March of 1978 and 1979, respectively. Earliest clutch completion and onset of incubation was on 1 April of both years.

Ninety percent of the observed nests (N = 112) had a clutch size of four eggs. A mean incubation period of 29 days$\pm$12 h was observed for ten nests of known history. Mean hatching date was 14 and 15 May of 1978 (N = 45, range: 1 May - 2 June) and 1979 (N = 66, range: 3 May - 4 June), respectively. A fledged juvenile (able to fly over 100 m) was first observed on 9 and 10 June of 1978 and 1979, respectively.

Flocking of curlews became evident by mid-June of both years and most curlews had departed from the study areas by mid-August of both years.

Five habitats in which territorial curlews were observed were defined, and habitat utilization by adults and adults with broods were sampled along four transects. Both adults and adults with broods occurred in habitats at frequencies significantly different from availability. In general, a preference for habitats of low vertical profile and low vertical density (plant parts/volume/height) was observed. Habitats of tall, dense shrubs or weedy annual vegetation were generally avoided.

Nest density varied from 0 - 9 nests/40 ha. Highest mean and single study plot nest density occurred in annual grass habitat (cheatgrass (Bromus tectorum)/Sandberg's bluegrass (Poa sandbergii) association). Nest success was 0.69 in 1978 (N = 40) and 0.65 in 1979 (N = 61). Predators destroyed 10.0 (4) and 16.4% (10) of the nests located in 1978 and 1979, respectively. Eight of 14 (57%) nests depredated over both years were destroyed by mammalian predators; at least three (21%) were taken by corvids, crows (Corvus brachyrhynchos) and magpies (Pica pica). Nest predation rate was significantly lower in annual grass habitats.

Five significant discriminant functions were generated which defined structural differences between nest-sites and general habitat characteristics. Variables related to vertical stratification of vegetation were important for three of the habitats. Vegetative coverage variables were important discriminants in only one habitat,

bunchgrass. Overall, nest-sites were less complex above 5 cm than the habitats in general. Significant differences in nest-site structure among habitats were observed for 5 of 6 paired comparisons, indicating some plasticity in nest-site selection by breeding curlews. Nest density on the 40-ha study plots was negatively correlated with 17 of 21 significant variables. Highest negative correlations were with vegetative height and vertical density.

Breeding Chronology, Habitat Utilization
and Nest-site Selection of the Long-billed
Curlew in Northcentral Oregon

by

Geoffrey J. Pampush

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BREEDING CHRONOLOGY, HABITAT UTILIZATION AND NEST-SITE SELECTION OF THE LONG-BILLED CURLEW IN NORTHCENTRAL OREGON

INTRODUCTION

The long-billed curlew (<u>Numenius</u> <u>americanus</u>) is the largest North American shorebird and a conspicuous component of grassland avifauna. Formerly, the species bred in shortgrass and mixed grass habitats from coast to coast (Hall 1960). However the long-billed curlew and its congener, the Eskimo curlew (<u>N</u>. <u>borealis</u>), were intensively hunted with resulting near extinction of the Eskimo curlew and apparent drastic reduction in breeding long-billed curlew numbers. Concurrently, agricultural development of the prairies reduced the availability of breeding habitat. A continent-wide decline in breeding numbers was recognized (Jewett 1936, Dawson 1923, Sugden 1933, Bent 1962, Wickersham 1902) though quantitative data are not available.

Lewis and Clark mentioned the abundance of curlews along the Columbia River in April 1806 (Thwaites 1904). Dawson (1923) indicated that "wagonloads" of curlews were seen going down the Columbia River which implied a substantial hunting harvest since curlews generally are widely scattered and in low densities today.

Intensive livestock grazing in the late 1800's deteriorated range conditions throughout the Columbia Basin. Large tracts of native bunchgrass were stressed beyond recovery and the invasion of exotic cheatgrass (<u>Bromus</u> <u>tectorum</u>) resulted in a significant change in the vegetative structure of the shrubsteppe. Many sites formerly dominated by a sagebrush (<u>Artemesia</u> <u>tridentata</u>)-bluebunch wheatgrass

(<u>Agropyron</u> <u>spicatum</u>) association were burned and/or heavily grazed with fire killing the sagebrush, and cheatgrass, along with other seral species, replacing the bunchgrass. A plant community of low shrub cover and shorter grass resulted.

Throughout the 1970's, considerable discrepancy prevailed over the status of breeding curlews in the Columbia and Great Basins. Extensive agricultural development occurred in the Columbia Basin during the 1970's with over 100,000 ha of shrubsteppe vegetation converted to circle pivot irrigation systems in a five-county area alone (Muckleston and Highsmith 1978). Historical breeding curlew population numbers in this area were unknown, though many long-time residents believed that a drastic reduction in the breeding population has occurred as a result of the agricultural development (H. Curtis, pers. comm.). These changes in community physiognomy as well as protection of migratory birds from unrestricted hunting probably changed the abundance and distribution of breeding curlews in the Columbia and Great Basins.

Avian habitat preferences and utilization patterns are often intimately tied to structural features of the habitat (Cody 1968, Eiserer 1980, Hilden 1965, Wiens 1973). In order to predict how changes in habitat structure and overall availability might influence curlew breeding it was necessary to examine the relationship between structural features of habitat utilized by curlews and general features of the habitat available. In order to pursue this topic, I addressed two questions:

(1) Do curlews select particular habitats during the breeding cycle?

(2) Do curlews select a specific microhabitat for nest-site placement?

STUDY AREAS

The study areas lie within the Columbia River Basin in northern Umatilla and Morrow Counties, Oregon (Fig. 1). All study plots are within 25 km of the Columbia River. Gently undulating topography characterizes the study areas near the river with increasingly steeper slopes occurring further south. Elevation ranges along a continuous gradient from 95 m at the study areas to roughly 1500 m in the Blue Mountains, 80 km south of the study areas. Sandy soil occurs along the Columbia River, grading into more tuffaceous soil to the south.

The climate of the area is characterized by hot, dry summers and moderately cold, moist winters. The 30-yr mean annual precipitation for the study areas was 21.67 cm (Ruffner 1978). Only one other isolated region in Oregon receives so little annual precipitation.

Dominant plant associations[1] are primarily grey rabbitbrush (Chrysothamnus nauseosus)-cheatgrass or bitterbush (Purshia tridentata)-cheatgrass associations along the Columbia River with sagebrush-bluebunch wheatgrass associations within 10 km south of the Columbia River.

Most of the former native vegetation has been drastically changed by intensive grazing, burning, and attempted cultivation on the sandy soils in the areas. In general, the study areas are of

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[1]Associations are species groups recurrently observed by the author.

Figure 1. Location of study areas in northcentral Oregon.
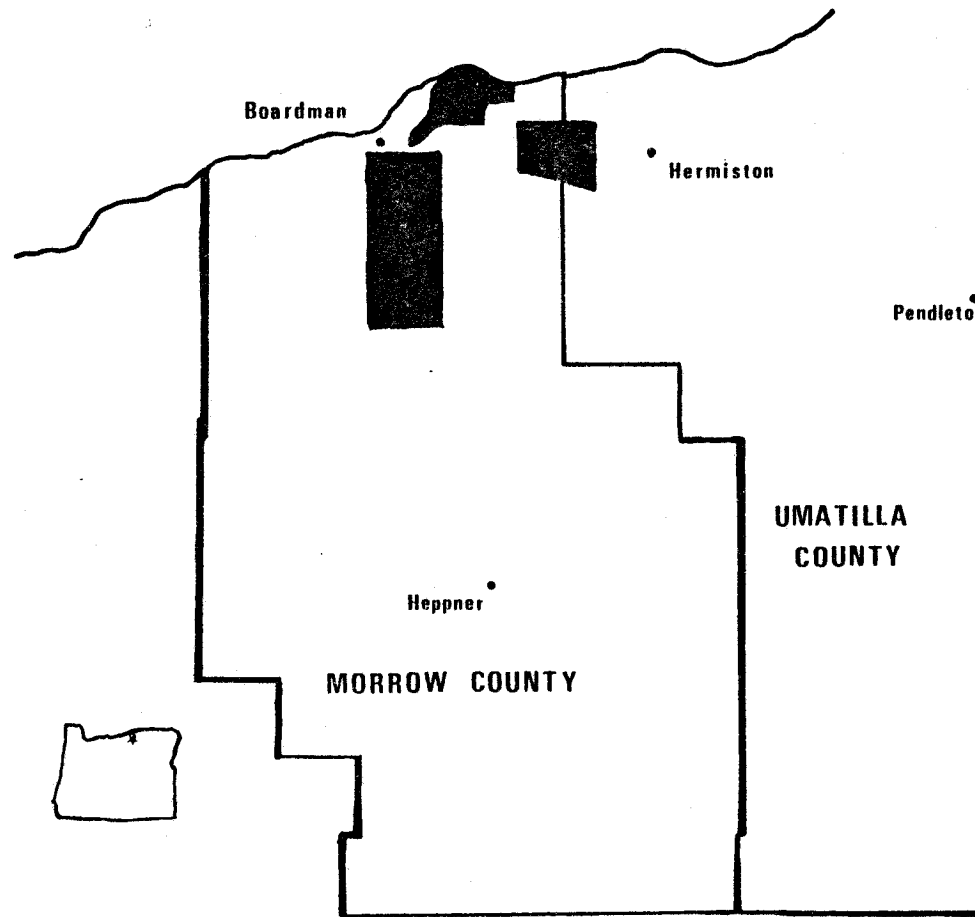
two habitat types[2]; sagebrush-needle and thread (<u>Stipa</u> <u>comata</u>) on the sandy soils grading into a sagebrush-bluebunch wheatgrass habitat type on the southern end of one study area.

Currently the study areas are dominated by a grey rabbitbrush-cheatgrass association with lesser amounts of needle and thread, snowy buckwheat (<u>Eriogonum</u> <u>niveum</u>) and patchy Jim Hill mustard (<u>Sysimbrium</u> <u>altissimum</u>). On the more tuffaceous sites, some patches of sagebrush-bluebunch wheatgrass are extant with snakeweed (<u>Gutier-rezia</u> <u>sarothrae</u>)-grey rabbitbrush-Sandberg's bluegrass-cheatgrass dominating the more disturbed sites.

Due to the extensive circle pivot agricultural development in the two-county area, potential study areas of adequate size were limited to federal landholdings. Three study areas were chosen for intensive investigation.

<u>Umatilla National Wildlife Refuge-(McCormack Slough)</u> - The refuge was established in 1968 primariy as mitigation for loss of Great Basin Canada Goose (<u>Branta</u> <u>canadensis</u> <u>moffitti</u>) habitat through a lease agreement with the U.S. Army Corps of Engineers. Formerly the land was heavily grazed with some parts cultivated. Currently the Fish and Wildlife Service maintains a cooperative farming program to provide forage for migratory waterfowl and to maintain wildlife diversity. Roughly 285 ha of a total land area of 1800 ha are farmed. The majority of the non-irrigated land on McCormack Slough is dominated by a grey rabbitbrush-cheatgrass

[2]Habitat types from Daubenmire, 1970.

association. Throughout much of this association, snowy buckwheat is subdominant with small patches of sagebrush and bitterbrush occurring. Cheatgrass is the ubiquitous, dominant grass species throughout the refuge. In some of the more stabilized areas, Sandberg's bluegrass codominates with crustose lichens and acrocarpous mosses covering the soil in the interstices between bluegrass clumps.

Umatilla Ordnance Depot - The Depot encompasses roughly 5,300 ha of a bitterbrush-cheatgrass-Sandberg's bluegrass association. The area is administered by the U.S. Army and serves as a military storage and supply depot. The depot is interlaced with a series of asphalt roads along which concrete-walled "igloos" are located, serving as storage structures. Approximately 1,000 "igloos" are systematically distributed over most of the depot excepting approximately 25% of the area which is free of man-made structures. The open areas generally surround the core of roads and igloos and form a 0.6 km wide band around the depot. From this band a number of study plots were chosen for investigation.

The U.S. Navy Boardman Bombing Range - The Bombing Range encompasses 20,300 ha and is used as a training site for U.S. Navy and Air Force bombers. Although the area is subjected to almost daily bombing during the curlew breeding season, a small central target area absorbs most of the training bombs. The study plots chosen for investigation were at least 3.0 km from the central target area.

The range's plant associations are variegated with a grey rabbitbrush-cheatgrass association dominating the sandy soils on the north end and a sagebrush-cheatgrass and rabbitbrush-snakeweed

association dominating the deeper soils on the south end of the range. Roughly 80% of the range has been and currently is grazed by sheep and cattle. Those areas are dominated by plant associations indicative of disturbed sites (i.e. cheatgrass, Jim Hill mustard, evening primrose (Oenothera pallida), tumbleweed (Salsola kali), grey rabbitbrush and snakeweed). Some smaller tracts of land on the Bombing Range, roughly 10% of the total area, have not recently been grazed and have escaped heavy disturbance. Robust stands of sagebrush-bluebunch wheatgrass are found within those tracts. Two major canyon systems contribute to the greater topographical relief on the south end of the range. The canyon slopes are dominated by sagebrush with occasional junipers and a fairly uniform distribution of cheatgrass. The flat ridges are dominated by a snakeweed-grey rabbitbrush-cheatgrass association over most of the southern end of the range.

From the above three study areas, five habitats were chosen for intensive investigation. These habitats were chosen because curlews utilized them in varying degrees and they were each structur-ally unique and contiguous with each other. Some less dominant plant species were common to two or more habitats but dominant plant species varied between habitats with resultant unique physiognomy in each habitat.

THE HABITATS: Annual grass habitat - This habitat is of uniform-ly low vertical profile. Cheatgrass is the dominant graminoid with scattered patches of Sandberg's bluegrass intermixed and few perennial shrubs (Table 1). Prickly pear (Opuntia polyacantha) was common in

some of the study plots along with tumbleweed and filaree (Erodium cicutarium). This habitat was grazed intensively by sheep on the Bombing Range.

Bitterbrush habitat - This habitat was dominated by a bitterbrush-cheatgrass association. The vegetative cover in the interstices between individual shrubs was generally sparse with cheatgrass, prickly pear, and other short forbs dominating these areas (Table 1).

Bunchgrass habitat - This habitat was dominated by fairly uniform stands of ungrazed, perennial bunchgrasses. Either bluebunch wheatgrass or needle and thread were prominent with few species of annual forbs occurring (Table 1).

Denseforb habitat - Dense annual vegetation dominated this habitat. Principal dominants were Jim Hill mustard, tumbleweed and tarweed with an understory of cheatgrass (Table 1). Grey rabbitbrush and snowy buckwheat also occurred in the habitat in low to moderate frequency. This habitat was not grazed by domestic livestock so residual vegetation remained between years.

Open-low-shrub habitat - High shrub coverage with little herbaceous vegetation in the interstices between shrubs characterized this habitat. The structure of this habitat was probably a result of cattle and sheep grazing on the heavier soils. The mean height of this habitat was considerably less than the bitterbrush habitat since it was dominated by the diminutive snakeweed and short grey rabbitbrush bushes. Cheatgrass and some Sandberg's bluegrass occurred in the interstices (Table 1).

Table 1. Quantitative description of the five habitats on the study areas. Means with standard deviations (in parentheses) are provided.

VARIABLE   HABITAT

VARIABLE	Annual grass	Bitterbrush	Bunchgrass	Denseforb	Open-low-shrub
annual grass coverage[1] (%)	.28 (.09)	.38 (.14)	.35 (.09)	.37 (.09)	.36 (.10)
perennial grass coverage[2] (%)	.02 (.03)	tr[3] (.01)	.18 (.09)	.02 (.09)	tr (.02)
bare ground coverage (%)	.40 (.14)	.36 (.16)	.30 (.18)	.26 (.08)	.36 (.10)
herb coverage (%)	.20 (.12)	.07 (.09)	.04 (.05)	.20 (.11)	.05 (.07)
shrub coverage (%)	.02 (.03)	.08 (.06)	.02 (.02)	.07 (.05)	.12 (.05)
effective height (cm)	24.80 (3.33)	32.90 (6.94)	29.60 (7.60)	32.00 (4.00)	28.00 (2.90)
overall vertical density	1.18 (.26)	1.42 (.36)	1.63 (.20)	1.66 (.23)	1.29 (.27)

[1] includes Sandberg's bluegrass (Poa sandbergii)

[2] Stipa comata and Agropyron spicatum

[3] trace - less than 1% coverage

METHODS

Upon arrival of the earliest returning curlews in 1978, (approx.
15 March) observations were initiated to determine the distribution
and abundance of curlews on the three study areas. Behavior was
observed throughout the prenesting phase of the breeding cycle to
determine movement patterns and habitat utilization of breeding
curlews. Most observations were conducted from a vehicle with 7 x
35 binoculars and a 20x spotting scope.

Systematic nest searching was begun in early April of both years.
Nest searching was conducted by spacing people roughly 5 m apart and
walking slowly, in a line, across the study plots. It was assumed
that a majority of fixed proportion of nests was found in each plot
by flushing the incubating adult.

During the early phase of the 1978 field season prior to nesting,
it was not possible to estimate breeding territory size or nesting
density. Also manpower was not readily available for nest searching.
Therefore, it was not until late in the 1978 season that reasonable
study plot size was established for comparison of nesting densities.

In 1979, 40-ha plots were established in each of the five
habitats with at least four replicates (24 plots total) of each
habitat (Fig. 2). These study plots were nest-searched from 7 April
to 2 May using the technique described above with the aid of 1,300
students. Each of the five habitats was nest-searched sequentially
with the replicate plots being searched under the same scheme (i.e.,
annual grass 1, bitterbrush 1, bunchgrass 1, denseforb 1, open-low-
shrub 1. annual grass 2...open-low-shrub 4). This scheme was adopted

Figure 2: Distribution of 24--40-ha study plots on the three study areas.

Umatilla NWR

2mi
3km
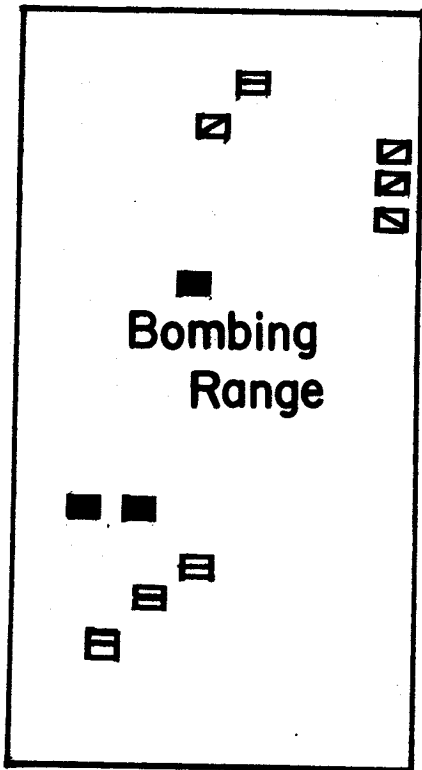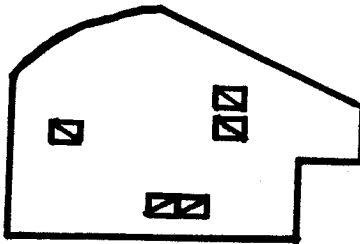
Annual grass
Bitterbrush
Bunchgrass
Denseforb
Open-low-shrub

Bombing Range
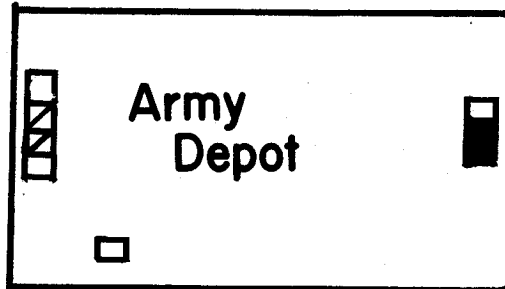
Army Depot

to avoid sampling bias toward a particular habitat since the onset of nesting could vary over a six-week period.

Nest density per plot, clutch size, fate of nest, type of predator depredating nest, number of addled eggs, and number of eggs hatched per clutch were recorded during both seasons.

Censusing and Habitat Utilization - A modified strip census technique (Hayne 1949) was employed to determine habitat utilization and preference patterns of adult curlews and adults with broods. Four predetermined census routes through the three study areas were sampled throughout the breeding cycle. The assumption was made that all adult curlews within 50 m of the transect road (except incubating adults) were included in the sample. Curlews flying over the transect strip were not included unless they were males performing "display-flights". Since "display-flights" were performed over relatively fixed areas, the males performing them within the 100-m census strip were included in the sample.

Since adult curlews attending young exhibit a strong defensive response by flying toward and swooping down toward intruders (predator, vehicle, or human on foot), the census strip was widened to 150 m on either side of the transect road when censusing broods.

All of the habitat included within the transect strip was classified according to the previously described scheme (annual grass, bitterbrush, bunchgrass, denseforb, open-low-shrub) and also included cropland on McCormack Slough. Percentage of each habitat occurring along the transect routes was calculated.

<u>Vegetative Measurements</u> - A series of measurements was taken to describe characteristics of vegetative structure of study plots and nest-sites. In each of the 40-ha study plots, ten--100-m random transects were established perpendicular to each other with compass direction of the first randomly chosen. Variables measured were as follows:

Vertical density---number of touches of plant parts within 5-cm height increments on a 6-mm diameter vertical rod (Wiens 1973).

Effective height---height at which 90% of a white board, 30 cm wide, was obscured by vegetation when viewed from 10 m at 1-m eye-level.

Coverage---estimate of canopy coverage of grasses, herbs and bare ground using Daubenmire's (1959) technique. This consisted of using a 10 x 50 cm (0.1 m^2) frame along the transect and estimating coverage by class.

Shrub coverage---estimated using line-intercept method (Piper 1973) by summing the number of meters of each 100-m transect inter-cepted by a shrub and dividing by 100.

Evenness and Diversity---these indices were computed from the vertical density measurements described above.

See Table 2 for complete list of variables measured or computed.

<u>Statistical Analyses</u> - Habitat utilization data were analyzed on two levels. First, a chi-square test for independence was employed to determine whether or not habitats were utilized in proportion to availability. Secondly, after chi-square testing, confidence intervals were constructed about the theoretical proportion in order to determine

Table 2. Description of structural variables measured
          at nest-sites and in study plots.

DENS   mean number nests per plot
ANGR   percent coverage of annual grass (Daubenmire 1959).
PERGR   percent coverage of perennial grass
TOTGR   percent coverage of all grass
BRGD   percent coverage of bare ground
HERB   percent coverage of herbaceous plants
CHNA   percent coverage by grey rabbitbrush (Chrysothamnus
              nauseousus)
ARTR   percent coverage by sagebrush (Artemsia tridentata)
GUSA   percent coverage by snakeweed (Guttierezia sarothrae)
PUTR   percent coverage by bitterbrush (Purshia tridentata)
SHRUB   mean coverage of all shrub spp. (by line intercept)
EFHT   height at which 90% of a white board is occluded by
              vegetation when viewed from 10 m at height of 1 m
FHDG   foliage height diversity of grass (based on 5-cm intervals)
FHDH   foliage height diversity of herbs
FHDS   foliage height diversity of shrubs
FHDTOT   foliage height diversity of all vegetation
FHEG   foliage height evenness of grass (based on 5-cm intervals)
FHEH   foliage height evenness of herbs
FHES   foliage height evenness of shrubs
FHETOT   foliage height evenness of all vegetation
HG25   mean vertical density (0 - 25 cm) of grass (Wiens 1968)
HH25   mean vertical density (0 - 25 cm) of herbs
HS25   mean vertical density (0 - 25 cm) of shrubs
HTOT25   mean vertical density (0 - 25 cm) of all vegetation
HG50   mean vertical density (25 - 50 cm) of grass
HH50   mean vertical density (25 - 50 cm) of herbs
HS50   mean vertical density (25 - 50 cm) of shrubs
HTOT50   mean vertical density (25 - 50 cm) of all vegetation
HGTALL   mean vertical density (50 cm) of grass
HHTALL   mean vertical density (50 cm) of herbs
HSTALL   mean vertical density (50 cm) of shrubs
HTOTALL   mean vertical density (50 cm) of all vegetation
HTOVRL   mean vertical density over all intervals of all vegetation

whether the expected values for each habitat fell within the range of significant effects. Because several parameters were being estimated simultaneously, a $(1-\alpha)$ 100 percent "family" of confidence intervals with an α of 0.10 was used (Neu et al. 1974).

Nest-site characteristics were analyzed in three ways. First, discriminant function analysis was employed to determine which structural variables were important in discriminating between nest-sites and habitat in general. Discriminant functions were generated for four of the habitats plus one with all nests and habitats pooled. One discriminant function was generated in each comparison and variables were added stepwise with a minimum α of 0.15 (F = 4.0). A varimax vector rotation was used since it is believed to highlight the variable in the function which loads most heavily without change in variable composition of the model (Nie et al. 1975).

Nest-site characteristics were compared between habitats with Hotelling's T^2 test, to determine whether or not nest-sites were structurally different between habitats. Because the number of variables used exceeded the capacity of the C.D.C. 3300 computer, factor analysis was employed to generate linear combinations of variables used for T^2 analysis. After factor analysis, univariate t-tests were conducted to determine which variables contributed most to the significant differences between groups.

Nest density was tested for correlations with 28 variables describing vegetative characteristics of the plots using the Pearson correlation coefficient (Nie et al. 1975).

Normality of the structural data was checked and non-normal data were transformed. All coverage data were recorded as percent and thus were arcsine transformed; vertical density data were log transformed.

RESULTS

Breeding Chronology - The first curlew was observed on the study areas on 16 and 19 March of 1978 and 1979, respectively (Fig. 3). Within two days after arrival, males began performing display-flights (See Allen 1980, pg. 35--Bounding SKK Flight). These display-flights were performed by paired and especially unpaired males. Frequency of display-flying was highest during the prenesting phase of the breeding cycle, and males performed these flights more or less syn-chronously in a given area. Males foraging in association with a female occasionally performed these display-flights during the pre-nesting phase. These may possibly have been incipient pairs which were not together during the previous breeding season. Most other males with females performed display-flights infrequently, if at all, which suggested that these were more firmly established pair bonds.

A distinct population component of "non-breeding" males was evident on the study areas and comprised up to 20% of the total population. These males defended relatively plastic territories which were often contiguous with the territory of a mated pair. Flight of a female or mated pair through its territory generally elicited a display-flight from a non-breeding male and these non-breeders performed display-flights into June, often soliciting for copulation with a female while she was away from her territory. On numerous occasions I observed non-breeding males performing display-flights over the territory of a mated pair, and occasionally directly over an incubating male.

BREEDING CHRONOLOGY
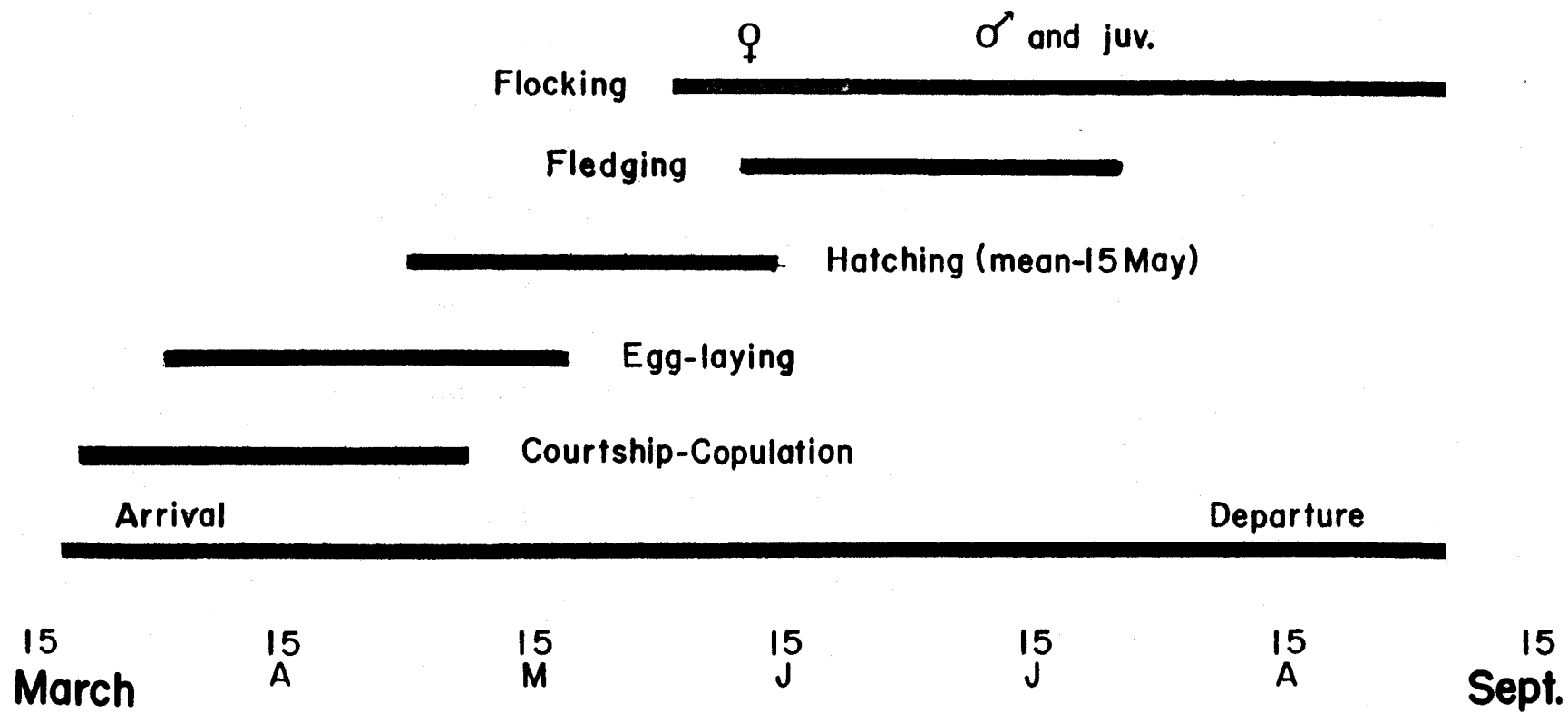
"Scraping" by adult males was first observed on 20 and 21 March of 1978 and 1979, respectively. "Scraping" appeared to function as the first step in a behavioral sequence culminating in copulation. Over the course of 3 - 10 days, females became progressively less evasive of the males' copulation attempts and finally submitted. The earliest "successful" copulation was observed on 26 March 1978. Earliest clutch completion and onset of incubation on the three study areas was 1 or 2 April (backdated 29 days from earliest hatching date) with a few clutches completed as late as 15 May. Renesting was not documented though the protracted clutch completion period suggested this possibility.

Ninety percent of the observed nests (N = 112) had a clutch size of four eggs, nine percent contained three eggs and one nest (1%) contained only two eggs. Net clutch size might be influenced by predators since an incomplete clutch may be unattended up to five days during egg-laying. Crows and magpies regularly foraged throughout the study areas and may have removed one or the only egg from the nest cup. Corvid depredated eggs were often found near tall shrubs.

A mean incubation period of 29 days $\pm$ 12 h was observed (range: 28 - 31 days) for 10 nests of known history. Mean hatching date was 14 and 15 May of 1978 (N = 45, range: 1 May - 2 June) and 1979 (N = 66, range: 3 May - 4 June), respectively.

A fledged juvenile (able to fly over 100 m) was first observed on 9 and 10 of 1978 and 1979, respectively. During this same time

period, many adult females disappeared from the study areas leaving the adult males in attendance with the broods.

Flocking became evident in mid-June of both years with peak numbers occurring in July on Carty Reservoir near the Bombing Range. A flock of 500 curlews was observed from mid through late July 1979 on the reservoir mudflats (R. Klein, pers. comm.). During this time period large flocks were observed foraging on grasshoppers on the Bombing Range in the snakeweed-cheatgrass flats. Based on bill lengths and wing and tail-feather development, it appeared that no adult females remained in the flocks and that at least 80% of the birds were juveniles. By mid-August most curlews had departed from the vicinity of the study areas.

Nest Density and Success - Nest density varied considerably between habitats and between plots within habitats (Table 3). Highest mean nest density and highest single study plot density occurred in annual grass habitat. Nine nests were located in one 40-ha plot in a gently sloping, cheatgrass dominated swale. No other study plots within annual grass habitat supported such a high density. Nest density was not uniformly high throughout the annual grass habitat, and curlews nested in low densities in all other habitats. The greatest density observed in any other plot (other than in annual grass) was in bunchgrass habitat (3 nests/40-ha). This particular plot adjoined several hundred hectares of annual grass habitat, and the dispersion of nest-sites within the bunchgrass plot was linear along the short-grass-bunchgrass interface. The presence of annual grass habitat apparently influenced nest-site placement.

Table 3. Observed nest densities for long-billed curlews
          in the five habitats in 1979 (N=45).

HABITAT	MEAN DENSITY PER 40-ha PLOT	RANGE
Annual grass	3.6	2 - 9
Bunchgrass	1.4	0 - 3
Denseforb	1.3	0 - 2
Open-low-shrub	1.0	0 - 2
Bitterbrush	0.5	0 - 1

Nest success was high during both breeding seasons. Including both predation and abandonment, nest success (Mayfield 1975) was 0.69 in 1978 and (N = 40) and 0.65 in 1979 (N = 61). Predators destroyed 10 (4) and 16.4% (10) of the nests located in 1978 and 1979, respectively. Four nests were abandoned in 1978 and two in 1979. Cause of nest abandonment was unknown.

Nest predation rate was significantly higher than expected in habitats other than annual grass (X^2 = 6.36, $p < 0.05$), suggesting that either predators were more dense or nests were more vulnerable in non-annual grass habitats.

Eight of 14 nests (57%) depredated over the two-season study were destroyed by mammalian predators. Corvids (crows and magpies), were responsible for at least three of 14 (21%) of the nest predations.

Depredation rate of partial clutches was immeasurable and may have occurred at rates higher than calculated daily depredation rate during incubation. Egg shells were frequently found alongside tall shrubs during nest-searching, suggesting that corvids were responsible for the depredation.

Habitat Utilization--Adults - Adult curlews utilized habitats in proportions different from availability on all three study areas ($p < 0.05$)(Table 4). The annual grass habitat was highly preferred along the two transects which had the highest density of curlews (Bombing Range North, 1.88 km/curlew and Army Depot, 2.48 km/curlew). Annual grass habitat was used roughly in proportion to availability along the other two transects.

Table 4. Habitat utilization of adult long-billed curlews along four transects in northcentral Oregon during spring 1979.

TRANSECT	HABITAT	NUMBER OF ADULTS OBS.	PRECENT USE	% AVAIL.	CONFIDENCE LIMITS
Bombing Range South (x^2 = 20.4, P < 0.05)	Annual grass	10	.09	.08	.03-.15
	Bunchgrass	9	.08*	.17	.02-.14
	Denseforb	2	.02*	.15	.00-.05
	Open-low-shrub	74	.70*	.59	.60-.80
Bombing Range North (x^2 = 53.4, P < 0.05)	Annual grass	122	.55*	.33	.47-.63
	Bunchgrass	14	.06*	.12	.02-.10
	Denseforb	77	.35*	.44	.27-.43
	Open-low-shrub	7	.03*	.11	.00-.06
Army Depot (x^2 = 500.3, P < 0.05)	Annual grass	177	.76*	.20	.70-.82
	Bitterbrush	26	.11*	.39	.06-.16
	Bunchgrass	27	.12*	.05	.07-.17
	Denseforb	4	.02*	.36	.00-.04
Umatilla Rufuge (x^2 = 176.5, P < 0.05)	Annual grass	26	.11	.09	.07-.15
	Denseforb	27	.12*	.54	.08-.16
	Cropland	177	.77*	.37	.73-.81

* Denotes a statistically significant difference in use of habitat from expected based on availability.

Cropland was highly preferred along the Umatilla Refuge transect though the particular field utilized varied with changes in vegetative structure. Curlews used cropland as long as the vegetation was low profiled (or the ground fallow) and ceased use when the vegetation grew beyond 30 cm tall. Wheat, potatoes and alfalfa comprised the cropland and the alfalfa was recurrently available for utilization by curlews, depending upon haying schedule.

Bunchgrass on the Army Depot and open-low-shrub on the Bombing Range South were both slightly preferred. However the bunchgrass tract was contiguous with an irrigated pasture and annual grass habitat in which two nests were located. The proximity of these two habitats may have influenced use of the bunchgrass habitat in this area. The open-low-shrub habitat comprised 59% of the available habitat on the Bombing Range South which, coupled with low curlew density, may have influenced the slight preference for this habitat. Even though the open-low-shrub habitat was dominated by snakeweed along the transect, it is a much shorter shrub than rabbitbrush or bitterbrush with mean effective height (EFHT) of 16 cm.

Denseforb and bitterbrush habitats were avoided wherever they occurred along the transects. Bunchgrass was avoided on the Bombing Range North and South transects. Open-low-shrub was avoided on the Bombing Range North. In general, curlews preferred habitats of low vertical profile or low mean vertical density and avoided habitats of greater vertical profile or high mean vertical density.

Adults with Broods - Although adult females generally abandon their mates and broods prior to fledging of the young, adult males generally

remain with the brood until the young are able to fly. Habitat utilization patterns of pairs or males alone with broods were similar to adult habitat utilization patterns. (Tables 5 and 6).

Along three of four transects, broods occurred in habitats at significantly different frequencies than expected (p < 0.05)(Table 5). Annual grass habitat was preferred along all three transects. Chicks foraged extensively on grasshoppers (Orthoptera) which grazed on Psoralea in the annual grass habitat.

Habitats of greater height and vertical density were avoided by the broods. Bitterbrush habitat was avoided on the Army Depot even though the interstices between shrubs were very similar structurally, to the adjacent annual grass habitat. The vertical component of this habitat appeared to influence habitat utilization. Denseforb habitat was avoided on all three transects, even though grasshopper densities appeared as high in this habitat as in annual grass. Denseforb habitat had the highest mean vertical density of all five habitats (4.42) and second greatest effective height (behind Bitterbrush habitat). Curlew chicks often struggled to get through the dense annuals (Sysimbrium, Amsinckia) and adults probably had limited visibility when in the habitat.

Cropland was used by broods on a periodic basis along Umatilla Refuge transect. Median hatching date roughly coincided with first alfalfa cutting on Umatilla Refuge. Immediately prior to swathing, alfalfa fields were unused by curlews. However, swathing provided a habitat of low vertical profile and unveiled an abundance of invertebrates. Curlews opportunistically exploited the alfalfa

Table 5. Habitat utilization of adult long-billed curlews with broods along four transects in northcentral Oregon during spring/ summer 1979.

TRANSECT	HABITAT	NO. OF BROODS OBS.	% USE	% AVAIL.	CONFIDENCE LIMITS
Bombing Range South (X^2 = 1.25, P < 0.05)	Annual grass	2	.06	.08	
	Bunchgrass	4	.12	.17	
	Denseforb	6	.18	.15	
	Open-low-shrub	22	.65	.59	
Bombing Range North (X^2 = 81.9, P < 0.05)	Annual grass	99	.64*	.33	.55-.73
	Bunchgrass	4	.02*	.12	.00-.05
	Denseforb	27	.17*	.44	.10-.24
	Open-low-shrub	24	.16	.11	.09-.23
Army Depot Transect (X^2 = 400.1, P < 0.05)	Annual grass	159	.74*	.20	.67-.81
	Bitterbrush	37	.17*	.39	.11-.23
	Bunchgrass	10	.05	.05	.02-.08
	Denseforb	8	.04*	.36	.01-.07
Umatilla Refuge (X^2 = 17.0, P < 0.05)	Annual grass	8	.28*	.09	.11-.45
	Denseforb	7	.24*	.54	.08-.40
	Cropland	14	.48	.37	.29-.67

* Denotes a statistically significant difference in use of habitat from expected based on availability.

Table 6. Summary of habitat utilization patterns by adults and adults with broods along four transects in northcentral Oregon.*

TRANSECT	ADULTS			ADULTS WITH BROODS		
	Preferred	Neutral	Avoided	Preferred	Neutral	Avoided
Army Depot	Annual grass Bunchgrass		Denseforb Bitterbrush	Annual grass	Bunchgrass	Bitterbrush Denseforb
Bombing Range North	Annual grass		Bunchgrass Denseforb Open-low-shrub	Annual grass	Open-low-shrub	Bunchgrass Denseforb
Bombing Range South	Open-low-shrub	Annual grass	Bunchgrass Denseforb	(Chi-square insignificant, P > 0.05)		
Umatilla Refuge	Cropland (alfalfa)	Annual grass	Denseforb	Annual grass	Cropland (alfalfa)	Denseforb

* Preference determined with "family" confidence intervals, $\alpha = 0.10$.

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fields for some period of time following cutting. When the alfalfa grew beyond approximately 30 cm tall, curlew use ceased, at least until the next swathing. On Umatilla Refuge, adults with broods remained in a given alfalfa field for up to three weeks although the annual grass habitat in which the pairs nested was contiguous with the alfalfa fields.

The bunchgrass habitat was avoided by broods on the Bombing Range North and used in proportion to availability on the Army Depot. The patchiness of needle and thread grass along the Army Depot transect provided microhabitat of annual grass interspersed with bunchgrass. Use of bunchgrass habitat was restricted to stands which were contiguous with annual grass habitat. Expansive stands of bunchgrass habitat were avoided by adults with broods.

The open-low-shrub habitat was used in proportion to availability on the Bombing Range North. This habitat comprised 11.0% of the available habitat and annual grass (33%) and denseforb (44%) habitats occurred in close proximity to open-low-shrub. This habitat may be particularly important in conjunction with annual grass habitat as a source of thermal cover during hot days before the young have fledged.

Nest-site Selection - Statistically significant structural differences between nest-sites and general habitats were found in four of five habitats (Table 7). When pooled nest-site data were compared with pooled habitat data, a significant discriminant function was generated which discriminated nest-sites from habitats in general. A significant discriminant function was not generated between nest-sites and habitat

for the bitterbrush habitat. Although ocular comparison indicated distinct differences, the small sample size of nests (N = 2) made statistical comparison futile. The bitterbrush habitat was generally avoided by curlews even when it was contiguous with annual grass habitat on the Army Depot.

For the annual grass habitat, the discriminant function correctly classified nest-sites and random transects for 74% of the cases (nests and random transects). Three significant variables loaded similarly in the model and all three were measures of vertical components of the habitat; effective height (EFHT), overall foliage evenness (FHETOT) and vertical density of herbs from ground to 25 cm high (HH25). Effective height (EFHT) and foliage height evenness (FHETOT) were greater in the habitat in general than at nest-sites, which indicated that the nest-sites were of shorter and vertically patchier vegetation than the habitat. Mean vertical density of herbaceous plants in the 0 - 25 cm height interval (HH25) was greater at the nest-sites than along random transects, reflecting the frequency of occurrence of standing dead tumbleweed plants and live Opuntia cactus that occurred in association with the nest-site microhabitats in the sandy soil.

For the bunchgrass habitat, the discriminant function correctly classified 54% of the cases. Three significant variables; total grass coverage (TOTGR), bare ground coverage (BRGD) and herb coverage (HERB), all coverage related, were included in the model. Total grass coverage (TOTGR) loaded most heavily with a higher mean value at nest-sites than along random transects. Though annual grass coverage constituted a significant component of the habitat (35%),

the differences between mean coverage values at nests and along random transects were small (37 and 35%, respectively). Herb coverage (HERB) was slightly higher at nest-sites than along random transects (6.0 versus 4.0%), due primarily to the occurrence of Phlox and Lupinus. Bare ground coverage (BRGD) was included in the model, but its inclusion is an apparent artifact of the computer analysis because the differences in means and standard deviations at nest versus random transects are negligible (means: 0.296 vs 0.297, S.D.: 0.067 vs 0.081, respectively).

The discriminant function for denseforb habitat correctly classified 87% of the cases with three variables (TOTGR, EFHT, FHDH). Effective height (EFHT) was the most important variable in the model with nest-sites having lower mean values than random transects (23.7 and 32.0 cm, respectively). Total grass coverage (TOTGR) and foliage height diversity of herb (FHDH) loaded similarly in the model and were lower for nest-sites than along random transects.

The denseforb habitat was compositionally similar but structurally quite different from annual grass habitat. Mean effective height at nest-sites was very similar for both habitats but mean effective height values for random transects between the habitats differed considerably (Table 7). Curlews chose nest-sites away from the taller, denser cover as evidenced by the inclusion of the herb height diversity variable in the discriminant model. Sysimbrim and Amsinckia, both annual herbs, occurred in highest frequencies where recent soil disturbance had occurred. Nest-sites were generally located in patches where the soil was more stabilized and cheatgrass-Sandberg's

Table 7. Discriminant function coefficients for comparisons between nest-sites and general habitat characteristics of long-billed curlews in northcentral Oregon. Means and standard deviations for variables at nest-sites and habitats are given in parentheses.

Variables in the discriminant models

HABITAT	TOTGR	BRGD	HERB	EFHT	FHDG	FHDH	FHETOT	HH25	HG50	HSTALL	Correctly Classified
Annual grass				-.52			-.64	55			74%
nest-sites				(22.2+2.8)			(.68+.16)	(.50+.31)			
habitat				(24.8∓3.3)			(.76∓.07)	(.38∓.22)			
Bunchgrass	1.48	.86	.97								84%
nest-sites	(67+.16)	(.30+.07)	(.06+.08)								
habitat	(55∓.12)	(.30∓.08)	(.04∓.05)								
Denseforb	-.51			-1.25		.58					87%
nest-sites	(.32+.08)			(23.7+3.5)		(.62+.08)					
habitat	(.40∓.09)			(32.7∓4.0)		(.72∓.26)					
Open-low-shrub				1.00							82%
nest-sites				(22.0+3.7)							
habitat				(28.0∓2.9)							
Pooled Data				-.89	.80		-.54		-.50	-.31	76%
nest-sites				(23.8+3.8)	(.60+.12)		(.70+.12)		(.80+.12)	(.02+.09)	
habitat				(28.9∓5.1)	(.62∓.16)		(.76∓.08)		(.15∓.18)	(.05∓.15)	

bluegrass dominated. Cheatgrass grew in dense patches in some areas within the denseforb habitat. Generally, the open, cheatgrass dominated areas where curlews nested were of lower plant biomass than the denseforb habitat in general. Edaphic and external (zootic or man-caused) factors probably manifested the patchy nature of this habitat which supported a lower density of breeding curlews than annual grass habitat.

For open-low-shrub habitat, a discriminant model with only one variable, effective height (EFHT), correctly classified 82% of the cases. Mean effective height for nests and random transects was 22.0 and 28.0 cm, respectively. The dominant vegetative element contributing to the difference in effective height was snakeweed. This shrub-dominated habitat supported a low nesting density even though its mean effective height differed from the shortgrass habitat by only 3.5 cm. Nest-sites in open-low-shrub habitat were character-ized by lower shrub coverage than random transects (8.0 vs 11.0%) but the difference was not statistically significant.

For the pooled habitats and nest-sites, a discriminant function was generated which included five variables, all related to vertical stratification, and correctly classified 76% of the cases (Table 7). Effective height (EFHT) loaded most heavily in the model followed closely by foliage height diversity of grass (FHDG). This model indicated that over the pooled habitats, curlews selected nest-sites of shorter and less complex vegetation than available in the habitats in general. Also, the vertical distribution of vegetation at nest-sites was "patchier" than in the pooled habitats, as indicated by the

inclusion of the foliage height evenness (FHETOT) variable. This indicated that curlews may be selecting vertically "patchy" nest-sites possibly as an anti-predator strategy to aid in crypticity.

Comparisons Between Nests among Habitats - Comparisons of nest-sites among habitats revealed statistically significant differences for 5 of 6 paired comparisons by Hotelling's T^2 analysis. The small nest sample size in the bitterbrush habitat (N = 2) precluded use of these data for comparison.

Seven variables in the annual grass/bunchgrass comparison pair contributed significantly to differences ($p < 0.0001$). All seven variables were related to vertical stratification of the vegetation with effective height, diversity, and vertical density all higher at nest-sites in the bunchgrass habitat (Table 8). For nest-sites in the annual grass/denseforb comparison, mean values for bare ground coverage (BRGD) and grass foliage height diversity (FHDG) were statistically different ($p < 0.001$). Bare ground coverage was higher at nests in annual grass habitat whereas grass height diversity was higher at the denseforb nest-sites.

In the comparison of the annual grass/open-low-shrub pair, only two variables (BRGD and HH25) were significantly different ($p < 0.05$). Mean bare ground coverage (BRGD) and annual herb vertical density in the 0 - 25 cm height interval (HH25) were greater at annual grass nest-sites.

For the bunchgrass/denseforb nest comparison, three variables were significantly ($p < 0.0001$) different (FHDG, HG25, HH25). The differences were related to vertical stratification and diversity.

Table 8. Comparison of nest-site characteristics between habitats for long-billed curlews in northcentral Oregon.

NEST-SITES IN HABITATS COMPARED	RESULTS OF HOTELLING'S T^2 TEST BETWEEN GROUPS ($P < 0.05$):		VARIABLES CONTRIBUTING TO SIGNIFICANT UNIVARIATE T-TESTS:
	Significant --	not significant	
Annual grass/Bunchgrass	X ($P < 0.0001$)		EFHT, FHDG, FHDTOT, HG25, HH25, HTOT-25, HG50, HTOVRL
Annual grass/Denseforb	X ($P < 0.0001$)		BRGD, FHDG
Annual grass/Open-low-shrub	X ($P < 0.05$)		BRGD, HH25
Bunchgrass/Denseforb	X ($P < 0.0001$)		FHDG, HG25 HH25
Bunchgrass/Open-low-shrub	X ($P < 0.001$)		HG25, HG50, HTOVRL
Denseforb/Open-low-shrub		X	

Grass was denser and more diverse at the bunchgrass nest-sites whereas annual forb density at the 0 - 25 cm height interval was greater at the denseforb nest-sites.

For the bunchgrass/open-low-shrub nest comparison, three variables were significantly (p < 0.001) different between habitats (HG25, HG50, and HTOVRL). All three variables were measures of mean vertical density of vegetation and nests in the bunchgrass habitat had a higher mean grass vertical density from 0 - 50 cm and a higher overall vertical density. The results of these pairwise comparisons indicated that curlews selected nest-sites with considerable structural variability from one habitat to the next. These differences may be a reflection of inherent differences between habitats and interpretation of these results must be made in light of reproductive success rate among the various habitats over time.

Nest Density Correlation - Nest density on the 40-ha plots was negatively correlated (p < 0.05) with 17 of 21 variables (Table 9). The three highest negative correlations (r ≥ -.30) were with effective height (EFHT), mean vertical density from 0 - 25 cm (HTOT25), and overall mean vertical density (HTOVRL). Eleven of the remaining 14 negative correlations were with variables relating to vertical stratification of the vegetation. A high negative correlation was found between nest density and shrub coverage (-.27) and a lower negative correlation for both annual grass (ANGR, -.16) and total grass coverage (TOTGR, -.16). Foliage height evenness of annual herbs

Table 9. Correlation of nest density (nests/40 ha) of long-billed curlews with habitat characteristics of plots within five different habitats in northcentral Oregon.

VARIABLE	R
ANGR	-.16
Pergr	-.07*
TOTGR	-.16
BRGD	.16
Herb	.14
Shrub	-.27
EFHT	-.31
FHDG	-.13
FHDH	.11
FHDS	-.26
FHDTOT	-.23
FHEG	.03*
FHEH	.20
FHES	-.24
FHETOT	.02*
HG25	-.22
HH25	.03*
HS25	-.21
HTOT25	-.30
HG50	-.17
HH50	-.03*
HS50	-.17
HTOT50	-.21
HGTALL	.02*
HHTALL	-.09*
HSTALL	-.15
HTOTALL	-.16
HTOVRL	-.32

* nonsignificant (P > 0.05)

(FHEH, .20) bare ground coverage (BRGD, .16), herb coverage (HERB, .14), and foliage height diversity of herbs (FHDH, .11), were positively correlated with nest density.

Generally, correlation of the structural variables with nest density indicated that curlews nested in highest densities in plots with shorter, less complex vegetation.

DISCUSSION

North American curlew (N. tahitiensis, N. hudsonicus, N. borealis
and N. americanus) breeding ecology is relatively unknown compared
to the confamilial calidridinae. As with most other Scolopacids,
the curlews breed in open, essentially two-dimensional habitats.
Bristle-thighed curlews (N. tahitiensis) bred in western Alaskan
tundra dominated by grey reindeer moss and black lichens with weathered
rock fragments protruding through the vegetation. (Allen and
Killingstad 1949). The Eskimo curlew (N. borealis) bred along the
Bering Sea in the "barren grounds"; treeless tundra (Bent 1962).
Whimbrels bred in muskeg community near Hudson Bay, Manitoba (Skeel
1976).

The long-billed curlew is the most southerly breeding curlew
and breeds in several habitats continentally. Most literature
describes the curlew in mixed-grass and shortgrass habitats (Baileey
and Neidrach 1965, Bicak 1977, Davis 1949, Graul 1971, King 1978,
McCallum et al. 1977, Sadler and Maher 1976). In the Columbia and
Great Basins, curlews breed in mixed-grass meadows, annual grassland
(cheatgrass and/or medusahead (Taeniatherum asperum) dominated),
saltgrass (Distichylis stricta) - greasewood (Sarcobatus vermiculatus)
associations and occasionally in agricultural or crested wheatgrass
habitats (Pampush 1980).

Hubbard (1973) speculated that the long-billed curlew had its
evolutionary origins in one of several North American refugia result-
ing from the extensive glaciation of the Pleistocene. Two congeners,

<u>N</u>. <u>arquata</u> and <u>N</u>. <u>madagascariensis</u> are considered possible palearctic differentiates of the long-billed curlew (Hubbard 1973).

The long-billed curlew's center of geographic origin is questionable although the Great Plains, as Johnsgard (1978) implies, seems likely. This speculation seems credible since the long-billed curlew breeds in shortgrass habitats throughout its range and short-grass and mixed-grass prairie are predominant communities of the western Great Plains. In contrast, the Columbia Basin fostered expanses of grassland historically but the vast majority was bunch-grass-dominated (Daubenmire 1970). Curlews avoided the bunchgrass habitat in this study and were infrequently observed or reported in bunchgrass habitat in a breeding status survey in the Columbia and Great Basins (Pampush 1980). Curlews were reported breeding along the Columbia River by the Lewis and Clark expedition (Thwaites 1904) which predates significant human influence on vegetation structure. Habitat composition and structure at the site of the earliest recorded observations are unknown, though lithosolic sites dominated by Sandberg's bluegrass were probably extant at the time and may have been preferred curlew breeding habitat.

<u>Habitat Utilization Patterns</u> - In this study, an overall preference for habitats of low vertical profile and low vertical density was evident. Nesting adult curlews often foraged away from the territory while not incubating. Both non-incubating adults and adults with broods foraged in cropland both on the study areas and adjacent to them. Short or freshly swathed alfalfa was used extensively as a foraging area even though no nesting behavior was

ever observed in this habitat. Skeel (1976) observed whimbrels regularly foraging away from the defended territory and monogamous calidridine sandpipers often exhibit similar foraging patterns during the incubation period (Jehl 1973, Miller 1979, Holmes 1971). Although foraging often occurred at a distance from the defended territory, curlews regularly foraged in the annual grass habitat throughout the breeding season. Both 1978 and 1979 were years of high grasshopper (Orthoptera) population levels and curlews were often observed foraging on them. During these two breeding seasons, a preference for a particular habitat was not obvious, but rather a preference for habitats of certain structural characteristics. Some pairs which nested within 300 m of alfalfa fields were observed brooding young in the annual grass habitat throughout the brood-rearing period. However, during breeding seasons of low grasshopper population levels, I suspect foraging patterns would be different.

Nest Density and Success - Curlews nested in highest densities and had highest nest success in annual grass habitat. The mean nest density of 3.57 nests/40 ha in annual grass habitat compares closely with the density Skeel (1976) observed for whimbrels near Churchill, Manitaba. She observed 17 nests over a 166 ha study area (4.10 nests/40 ha) in hummock-bog habitat--the habitat in which the whimbrels had highest nest success over two seasons of observation. The hummock-bog habitat was of dense vegetation and was the most heterogeneous of the three habitats Skeel observed whimbrels nesting in. She attributed the high density and success in the structurally more complex habitat to the advantages of greater

crypticity in denser vegetation. Primary whimbrel nest predators were jaegers (Stercorarius sp.), species which forage from the air. In contrast, long-billed curlews in this study nested in highest densities and were most successful in the simplest, most open habitat available. Since eight of 14 nests depredated were destroyed by mammalian predators and nest predation was significantly higher in habitats other than annual grass, it appears that curlews in north-central Oregon are adapted to breeding in habitats of low shrub cover and of low vertical profile. Mammalian predators, particularly coyotes, may be utilizing shrubbier habitats more than open habitats. Small rodents (Perognathus) occurred in much higher densities in shrub-dominated habitats than cheatgrass-dominated habitats on the Bombing Range (G. Green, pers. comm.). Therefore, the density of potential prey may be influencing mammalian predator foraging patterns and a ground nesting bird nest may have a greater probability of predation in these habitats.

Crows and magpies also forage extensively in shrub dominated habitats. Though my observations are not quantified, I suspect that these corvids forage significantly more in shrub-dominated habitats than in annual grass habitats and may, therefore, pose a greater threat to curlew nests in shrub-dominated habitats.

Curlews produced a "bob-white" vocalization when broadwinged hawks (Buteo sp.), prairie falcons (Falco mexicanus) or golden eagles (Aquila chrysaetos) appeared over the breeding "colony". Also, group mobbing occurred in response to alarm calls given by a curlew reacting toward a predator. On two occasions during the

incubation period, I observed up to 15 curlews standing around a badger (Taxidea taxus) and occasionally making aerial swoops toward it. These anti-predator behavioral patterns suggest some advantages of loose "colonial" nesting and apparently confer some advantage to a breeding pair, as evidenced by the higher nest success in annual grass habitats.

In this study, broods occasionally foraged within the previously defended territorial boundary. However, emigration was more common and communal use of foraging areas with occasional brood mixing occurred. These behavioral patterns suggest that the function of territoriality in curlews may be to space out to avoid predation while maintaining the advantages of loose coloniality as Soikelli (1967) hypothesized for calidridine sandpipers.

Nest-Site Selection - Comparison of nest-site characteristics among habitats in this study indicated that curlews were relatively plastic in nest-site selection though a preference for structurally simple habitats was evident. Grassland ecosystems are characterized by climatic variability and unpredictability (Wiens 1974). With yearly variation in precipitation/temperature regime, the structure of an annual grassland may vary considerably between years. Although significant differences were evident between nest-sites and habitats in general, the structural tolerances of the species probably have not been fully identified in analysis of one breeding season's data.

Nest-site selection is presumably adaptive if some survival or ultimate reproductive advantage is conferred to the breeding pair. In attempting to understand nest-site selection of a species, other

environmental factors must be considered (sociality, philopatry, individual past reproductive patterns) besides the learned or innate psychological factor involved.

In comparison of nest-site and habitat characteristics, variables related to vertical stratification of vegetation were important factors in the discriminant analysis. Vegetative height and foliage diversity were lower at nest-sites than in the habitat in all cases except one. Herbaceous plant vertical density from 0 - 25 cm was higher at nest-sites in the annual grass habitat which probably resulted from the occurrence of the dense Russion thistle and Opuntia cactus that grew in association with cheatgrass patches. The cactus and Russian thistle plants were generally considerably shorter than 25 cm, although the variable does not discriminate finely enough to illustrate dispersion of vegetation within the 25-cm interval.

The inclusion of overall foliage height evenness (FHETOT) in two discriminant models (annual grass and pooled habitats) indicated that curlews selected nest-sites with vertically patchier vegetation than occurred in the habitats in general. Crypticity of eggs and plumage suggest that predation has been a strong selective force and the vertically uneven distribution of vegetation around nest-sites may enhance adult survival or nest-success. Nesting adult mortality was low over the two years. Only 6 of 101 nests were abandoned and adult mortality was possible in only 3 cases. Cause of abandonment was unknown although 4 of these nests were incubated into June and daytime high temperatures (30°C) may have influenced abandonment. Although these results were based on one breeding

season and annual vegetation may vary markedly from year to year, vertical patchiness may be a key stimulus in nest-site selection. Bicak (1977) found that curlew nest-sites in Nebraska had greater vertical biomass at the 5 - 10 cm height interval than did the shortgrass habitat in general, but he did not examine relative vertical dispersion (evenness) of vegetation.

Results of disciminant analyses in the bunchgrass habitat indicated that coverage variables were most important in discriminating between nest-sites and the habitat in general. These results must be considered in light of nest density and nest success. Curlews avoided expanses of bunchgrass habitat on the Bombing Range even though it was contiguous with annual grass habitat in which a high breeding density occurred. Therefore, bunchgrass may be a sub-optional breeding habitat and individuals breeding in this habitat may be expressing a psychological reaction to a complex of environmental factors (dominance, age, site-familiarity, etc.) which results in behavior contrary to individuals of greater "fitness".

The avoidance of native bunchgrass habitat is perplexing because it was the climax dominant community prior to the arrival of European man on the study areas (Poulton 1955). Intensive grazing and burning eradicated the bunchgrass and sagebrush and left prime conditions for the subsequent invasion of annual cheatgrass, an exotic.

Curlews currently breed in high densities in cheatgrass-dominated habitat where bunchgrass formerly dominated. The question of former breeding numbers and dispersion in the Columbia Basin is perplexing although various habitats probably supported curlews prior to the

advent of European man. Sandberg's bluegrass-dominated sites and saltgrass habitat around playas support breeding curlews in limited numbers throughout the Basins. These habitats may have fostered breeding curlews prior to the invasion of cheatgrass and the dispersion of breeding curlews may have changed after cheatgrass became well established.

In order to more fully understand the breeding ecology of long-billed curlews, long term study of marked individuals is necessary. Available data suggest that curlews are long-lived (up to 32 years in N. Arquata, Boyd 1962), realize low annual recruitment, and tend to be philopatric (R. Redmond, pers. comm.). This conservative reproductive strategy may be geared toward reproductive success in the "average year" as Parmalee and Payne (1973) have hypothesized for calidridine sandpipers in the Arctic.

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