START

0007409

WILDLIFE MONOGRAPHS

(ISSN: 0084-0173)

A Publication of The Wildlife Society

THE ECOLOGY AND BEHAVIOR OF THE LONG-BILLED CURLEW IN SOUTHEASTERN WASHINGTON

by

JULIA N. ALLEN

FEB 1990
RECEIVED
EDMC

OCTOBER 1980 No. 73

FRONTISPIECE. Adult male long-billed curlew. (Photo by Mary M. Tremaine)

Battelle. F

INTRODUC
Objectiv
Status o
ACKNOWL.
TAXONOM
DESCRIPT
General
Physical
Vegetati
Weather
Specific
PROCEDU
Scientifi
Summar
Study A
Habitat
Weather
Observa
Nest Sta
Capturi
Censusi
Weights
Predati
Sex and
Data A
PLUMAGE.
MATUR
Plumag
Weights
Age at
DISTRIBU
Breedin
Winter
BREEDING
MAINTEN
Comfor
Resting
Feeding
LOCOMOT
AGONISTI
Mild In
Violent
INTERSPE
SEXUAL D
Boundi

THE ECOLOGY AND BEHAVIOR OF THE LONG-BILLED CURLEW IN SOUTHEASTERN WASHINGTON

Julia N. Allen

Battelle, Pacific Northwest Laboratories, Ecological Sciences Department, Richland, Washington 99352

CONTENTS

INTRODUCTION 6
Objective 6
Status of the Long-billed Curlew 6
ACKNOWLEDGMENTS 7
TAXONOMY OF THE LONG-BILLED CURLEW 7
DESCRIPTION OF STUDY AREA 7
General Description 7
Physical Features 8
Vegetation 8
Weather 9
Specific Study Sites 9
PROCEDURES AND METHODS 12
Scientific Names 12
Summary of Records 12
Study Areas 14
Habitat Analysis 14
Weather Data 14
Observations on Curlew Behavior 14
Nest Study 15
Capturing and Banding 15
Censusing 15
Weights and Measurements 15
Predation Study 16
Sex and Age Determination 17
Data Analysis 17
PLUMAGE, MORPHOLOGY, AND SEXUAL MATURITY 17
Plumage 17
Weights and Measurements 19
Age at First Breeding 21
DISTRIBUTION 21
Breeding Range 22
Winter Range 22
BREEDING POPULATION NUMBERS 23
MAINTENANCE BEHAVIOR 24
Comfort Movements 24
Resting 27
Feeding 28
LOCOMOTION 30
AGONISTIC DISPLAYS AND POSTURES 31
Mild Interactions 31
Violent Interactions 34
INTERSPECIFIC INTERACTIONS 34
SEXUAL DISPLAYS AND POSTURES 35
Bounding-SKK Flight 35
Ground-Calling 36
Scraping 36
Tossing 36
Courtship-Run 37
Shaking 37
Mounting 37
Copulation 38
Postcopulatory Behavior 38
MIGRATION AND BREEDING CHRONOLOGY 38
ARRIVAL AND TERRITORIALITY 39
DAILY ROUTINE 42
SOLICITATION AND INITIAL PAIR FORMATION 43
COURTSHIP, MATING AND PRELIMINARY NESTING 44
NESTING 45
Nest Site Selection 45
Nest Construction and Materials 46
Scrape Size 46
Nest Site Characteristics 46
Nest Density 48
EGG LAYING 49
Laying Behavior 49
Clutch Initiation and Laying Intervals 49
Clutch Size and Egg Description 50
Egg Losses and Renesting Attempts 50
INCUBATION 51
Behavior 52
Responses to Disturbances 54
Nesting Success 56
HATCHING 56
Behavior 57
BROOD PERIOD 58
Nest Departure 58
Brooding 58
Behavior 58
Territoriality 61
Responses to Disturbances 61
Accidents, Injuries, and Mortality 62
STAGING AND DEPARTURE 63
LITERATURE CITED 66
APPENDIX
List of Common and Scientific Names of Plants Mentioned in the Text 67

INTRODUCTION

The long-billed curlew *Numenius americanus* is the largest of the shorebirds, and yet is one of North America's lesser known bird species. Its life history, ecology, and behavior have, until recently, received little attention. The paucity of knowledge about the long-billed curlew relates to its isolated and heretofore remote ranges and to its status as a nongame species; nongame wildlife have only recently begun to receive management consideration from governmental agencies. The breeding range is restricted to scattered locations in the western United States, and parts of eastern Washington still provide suitable nesting habitat.

There is little published information on the distribution and ecology of the long-billed curlew, and until recently almost all of its known biology was based on fairly general works written around the turn of the century (e.g., Bailey 1904; Bent 1907; Cameron 1907; Dawson 1909; Dice 1918; Ferry 1910; Grinnell and Hunt 1929; Oberholser 1918; Shufeldt 1913; Silloway 1902, 1909; Wickersham 1902). More sophisticated long-billed curlew studies are becoming more numerous (e.g., Campbell 1972; Forsythe 1967, 1970, 1971, 1972, 1973; Graul 1971; McCallum et al. 1977; Sadler and Maher 1976; Timken 1969), but as was noted by Palmer (1967) and Pettingill (1968), there is still scant information on their breeding behavior.

Objective

The objective of this study was to examine in depth the nesting ecology and behavior of the long-billed curlew on a breeding area relatively free of disruptive human activity. Two summers of fieldwork were devoted to that end, and in 1976 a post breeding season survey of the major National Wildlife Refuges in Washington, southern Idaho, Utah, Nevada, California, and Oregon enlarged the scope by providing unpublished records of long-billed curlews in those areas. It is hoped this information will be useful to agencies or individuals responsible for the preservation of the long-billed curlew and its habitat.

Status of the Long-billed Curlew

At one time, the long-billed curlew occurred in large numbers over most of the prairie regions of the United States and southern Canada. However, by the early 1900s the species had already declined markedly. That reduction was a result of (1) overzealous sport hunters, who took advantage of the curlew's nature of returning to circle over wounded comrades, (2) market hunting (curlew wings brought 74¢ apiece in 1900, Stone 1901), and (3) the "reclamation" of vast areas of their former breeding range for farming and ranching (Wolf 1931, Sugden 1933). Today, curlews are restricted to scattered populations in the West. They are rarely encountered east of the Mississippi River, whereas formerly they were a common transient along the Atlantic Coast. The numbers observed on marshes, flats, and fields today represent a concentration in a restricted range rather than an increase in the number of birds (Sudgen 1933). Changing conditions in land use south of the United States where some curlews winter have undoubtedly also contributed to their reduced numbers. Long-billed curlews nest from southern British Columbia, Alberta, Saskatchewan, and Manitoba southward to Utah, New Mexico, and Texas. They no longer nest in Michigan, Minnesota, Wisconsin, Illinois, Iowa, eastern Nebraska, and Kansas (American Ornithologists' Union 1957, Oberholser 1918). They winter from California, western Nevada, Texas, and Louisiana southward to Baja California, Oaxaca, Mexico, and Guatemala, and also from South Carolina to Florida (American Ornithologists' Union 1957).

Other members of the genus *Numenius* in North America are the whimbrel *Numenius phaeopus*, the eskimo curlew *N. borealis*, and the bristle-thighed curlew

N. tahitiensis. On rare occasions, European curlews *N. arquata* may be sighted on the Atlantic coast, but they are displaced migrants and not native to the United States. It is interesting to compare the relative abundance of the whimbrel, eskimo, and long-billed curlews today with their status 100 years ago. At that time, the whimbrel was the rarest of the 3; today, it is the most common. The eskimo curlew is virtually extinct; the last confirmed sighting having been in 1972 (Iversen 1976). Possibly, the long-billed curlew can hold its own, but only if measures taken to preserve it are soon forthcoming.

Although the curlew is a protected species throughout North America, the process of habitat destruction continues at an ever increasing rate causing their numbers to decline. In both southeastern Washington and northeastern Oregon, an estimated 30,000 acres per year of curlew habitat are lost to cultivation (J. E. Kurtz 1976, Refuge Manager, Umatilla National Wildlife Refuge, Umatilla, Oregon 97882, pers. comm.). In view of that, public lands such as National Wildlife Refuges and the Department of Energy Hanford Site where curlews occur are bound to become arid islands of refuge in a sea of irrigated farmland. For the foreseeable future, lack of habitat protection threatens the survival of the long-billed curlew. Apparently, in response to this situation, the U.S. Department of the Interior (1973) has categorized the long-billed curlew as "status-undetermined," which means that it has been suggested as possibly threatened with extinction but sufficient information is not available to determine its status. More information is needed.

ACKNOWLEDGMENTS

This research was supported by the U.S. Department of Energy, Division of Biological and Environmental Research, under Contract DE-AC06-76RLO 1830, and by the Northwest College and University Association for Science under the NORCUS Laboratory Graduate Participant Program. Battelle, Pacific Northwest Laboratories, Ecological Sciences Department provided the use of their facilities and equipment on the Arid Lands Ecology Reserve, Hanford National Environmental Research Park.

I thank the personnel at Battelle who provided their assistance and cooperation. I also thank the U.S. Fish and Wildlife Service and those National Wildlife Refuge personnel who provided information from their Quarterly Reports.

I am indebted to Mary Tremaine for sharing her knowledge of long-billed curlews with me, and for suggesting techniques for making field observations and photographs of the birds. The pen and ink illustrations were drawn by Dick Fitzner.

TAXONOMY OF THE LONG-BILLED CURLEW

The long-billed curlew (family Scolopacidae, order Charadriiformes) is closely related to the snipe, sandpipers, and yellowlegs. In the early 1900s, considerable debate was going on concerning the status of the 2 races of the long-billed curlew and over correct names to be used (Bishop 1910, Grinnell 1921, Oberholser 1918, Ridgway 1919). Evidence presented points toward a smaller northern race versus a larger southern race, but there is notable size overlap between them. The American Ornithologists' Union (1957) distinguishes between the 2 in their checklist, accepting the names *Numenius americanus americanus* and *N. a. parvus*. The bird I studied in southeastern Washington belongs to the smaller race *N. a. parvus*.

DESCRIPTION OF STUDY AREA

General Description

The U.S. Department of Energy's Hanford Site comprises 1,476.3 km² or 147,715.5 ha of shrub–steppe vegetation at the southern end of the lower Colum-

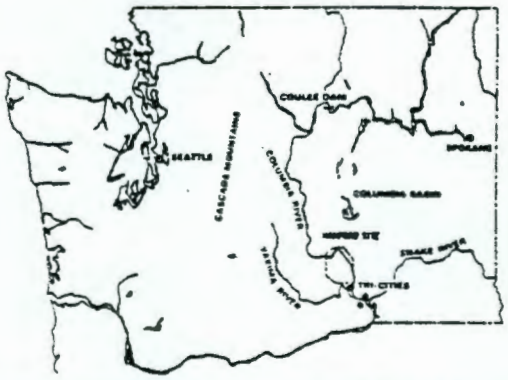

FIG. 1. Washington State showing Columbia River Basin and the location of the U.S. Department of Energy Hanford Site.

bia Basin in southeastern Washington (Fig. 1). Formerly in private land-holdings, the Atomic Energy Commission acquired the land in 1943 as a national security area that was closed to agriculture, grazing, and unofficial travel. For the most part, all of the original residential and commercial buildings have been removed and only remnant trees and concrete weir boxes stand as testimony to the irrigation that once serviced the area. Today, there are 12 controlled or limited access areas on the Hanford Site identified by area numbers (e.g., 300 Area, 200-E Area, 100-H Area, etc.). Each of those areas is totally enclosed by a high antipersonnel fence.

Physical Features

The most striking topographic feature of the Hanford Site is Rattlesnake Mountain which bounds the site on the southwest. For 5 km, the crest of the mountain is 1,100 m high. The northern slope drops steeply to 650 m and then eases down to Cold Creek Valley at 150 m. North of Cold Creek Valley, the land surface again rises to a plateau at about 225 m near the center of the Hanford Site. From there, the terrain slopes downward toward the Columbia River through a series of benches or terraces. The Gable Mountain–Gable Butte complex consists of 2 large basaltic rock outcroppings that rise to a height of 338.94 and 224.94 m, respectively, between the central plateau and the northern reaches of the river. The northern shoreline of the Columbia River is marked by the steep-walled "White Bluffs" rising 70–100 m above the bank for about 11 km; steep banks are also found along the eastern border of the river above the city of Richland. Two sets of dunes cross the Hanford Site. About 3,000 ha of active sand dunes form a belt 6.4 km wide immediately south of Hanford townsite to a point opposite Ringold on the eastern bank of the river. The second group of dunes focuses on the area between Horn Rapids on the Yakima River and the 300 Area, with the dune belt dying out to the northwest and southeast. The dunes trend northeastward.

The Columbia River is the largest body of water in the region and flows within the Hanford Site for 83 km. Twenty islands that range in size from 2.7 to 135.0 ha lie within that stretch of the river. The river is approximately 800 m across and flow is manipulated at a series of hydroelectric dams upstream. Other bodies of water include 4 small ponds on or near the centrally located plateau, Rattlesnake Spring at the base of Rattlesnake Mountain, and several flowing wells in the northeastern corner of the site.

Vegetation

Common and scientific names of all plants mentioned are listed in the Appendix.

Three major vegetational types (Fig. 2) occur on the Hanford Site west of the Columbia River (Cline et al. 1975): (1) the sagebrush–bitterbrush/Sandberg's bluegrass–cheatgrass type covers the low elevations in the eastern and southeastern parts of the site and occupies the sandiest soil short of dunes, (2) the sagebrush/bluebunch wheatgrass–Sandberg's bluegrass type is confined to the Rattlesnake Hills at elevations above 274 m, and (3) the vegetation that occurs as a broad zone between those 2 types is the

sagebrush/cheatgrass–Sandberg's bluegrass type. A general paucity of herbaceous cover tends to favor invasion by Russian thistle.

Although much of the Hanford Site was undeveloped at the time of its inception, several farming communities were displaced. The fields were left fallow and were soon invaded by cheatgrass. Notably enough, those abandoned fields, surrounded like islands by stands of native vegetation and isolated over time from human intrusion, provide the suitable nesting habitat for the long-billed curlew on the Hanford Site. Furthermore, the presence of a loose substrate in those fields seems to be an important factor in determining which areas are utilized by curlews.

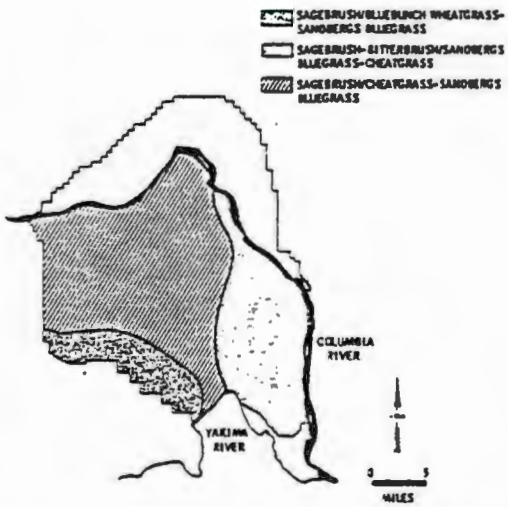

FIG. 2. Boundaries of the 3 major vegetational types on the Hanford Site, southeastern Washington.

Weather

The climate of the Hanford area is greatly influenced by the Cascade Mountain Range to the west. Annual precipitation at the Hanford Meteorology Station (at 223 m elevation near the center of the site) averages 16.5 cm but has ranged from about 7 to 30 cm during the past 30 years. On the average, 60 percent of the precipitation falls between October and February. Precipitation decreases after the 3 wettest months of November, December, and January, but increases again to a secondary maximum in June. June is also the month of the highest average wind speed, and only once in 7 years will it have even 1 day with a peak gust under 21 kph. December, on the other hand, is the month of lowest average wind speed and has an average of 10 such days. The climate of the Hanford region can thus be described as having windy springs, hot and dry summers, and moderately cold winters. July is the hottest and driest month, whereas January is the wettest and coldest month.

Temperatures during 1976 averaged 0.6 C cooler than usual. Total precipitation for the year was 46 percent of normal, making 1976 the driest year on record in the Hanford area. The spring and summer of 1976 were also windier and cloudier than normal. Even so, the spring growth of plants was for the most part unaffected, and the weather in general did not appear to be detrimental to successful curlew nesting.

The weather during 1977 was bizarre, with many months being substantially warmer or cooler than normal and with precipitation during usually dry months. Coupled with the shortage of precipitation in 1976, drought conditions persisted until August when sudden rains finally initiated the "spring growing season" for many plants. Consequently, when the curlews arrived in March many plants had not germinated or bloomed, including the cheatgrass. The only nesting cover in the fields was the dead vegetation from the previous year.

Specific Study Sites

Although the entire Hanford Site west of the Columbia River was surveyed for curlews, only 3 study sites were selected for concentrated behavioral observations (Fig. 3). (Because of its relative inacces-

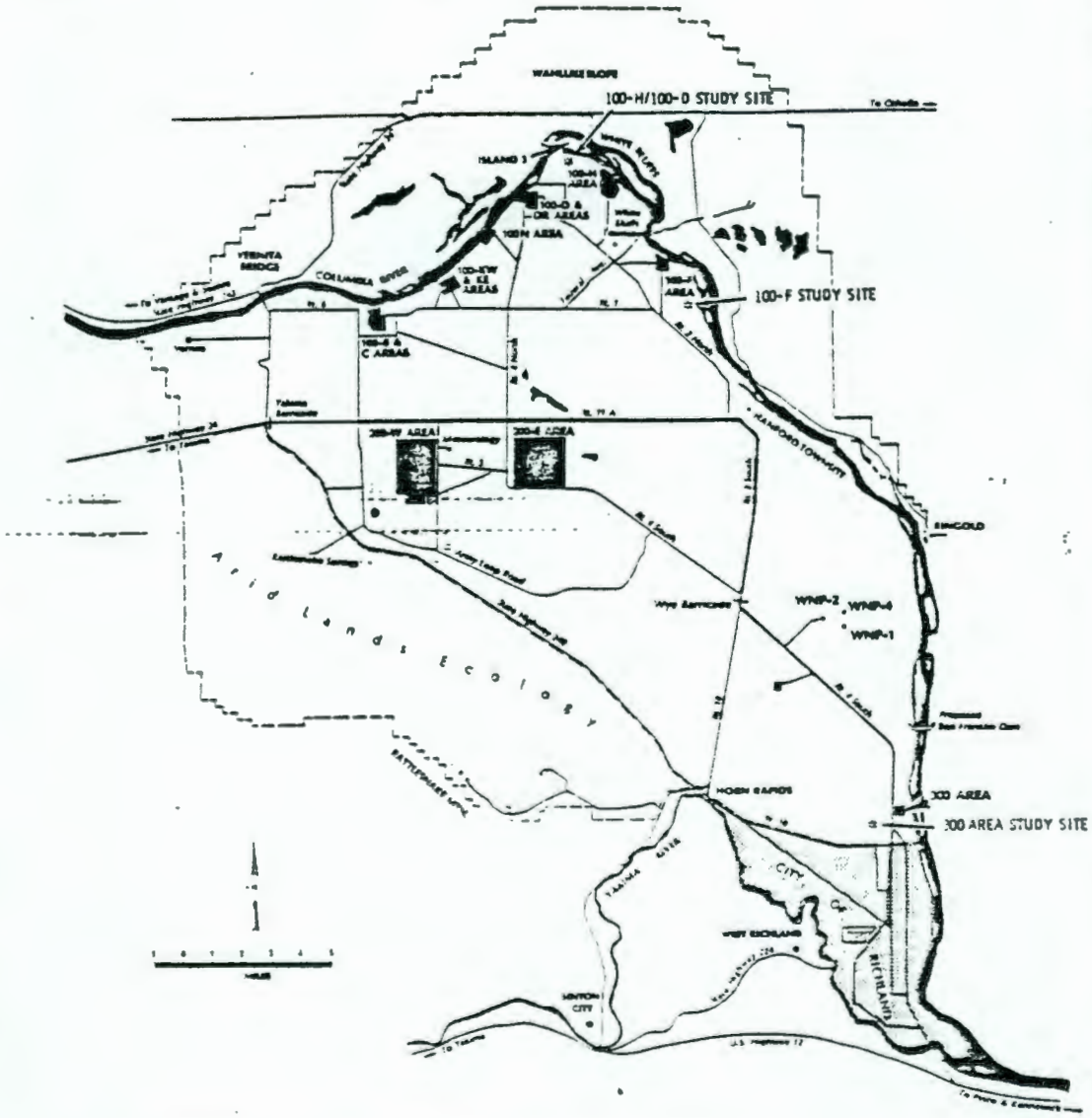

FIG. 3. The Hanford Site in southeastern Washington with asterisks (*) to show location of concentrated study areas.

sibility, the Hanford Site north of the Columbia River was not included in this study. However, groups of birds from the Wahluke Slope area north of the Columbia River are included under the topic of STAGING AND DEPARTURE.)

(1) The 300 Area study site was the primary study area. Located west of the 300 Area and approximately 0.8 km from the Columbia River, that site encompassed approximately 10.36 km² of sagebrush–bitterbrush/Sandberg's bluegrass–cheat-

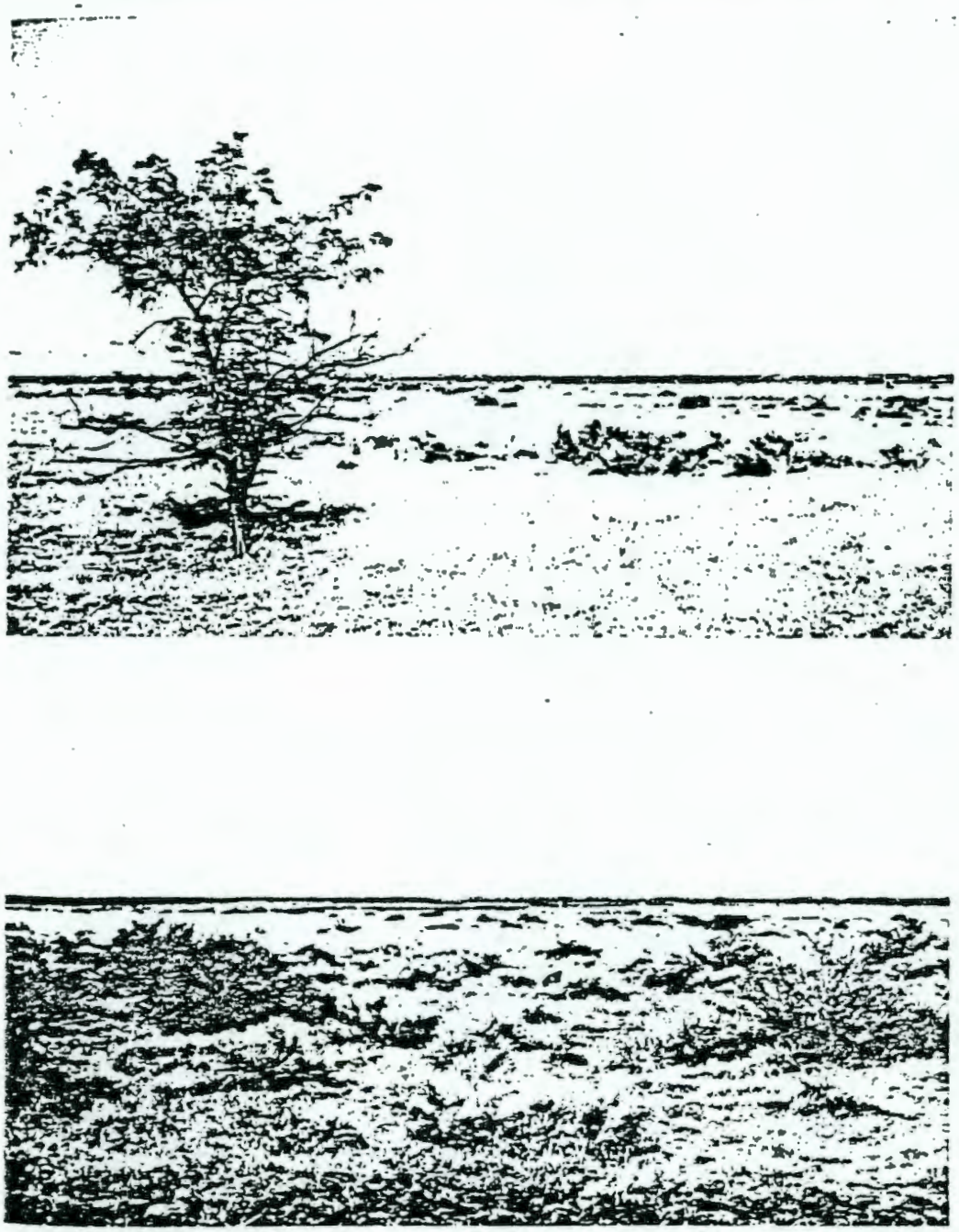

FIG. 4. Habitat at the 300 Area study site. Upper, South Field; Lower, Mosaic of shrub and field areas.

9 9 2 1 2 4 9 3 2 0 6 4

EA STUDY SITE

entrated

he pri-
he 300
om the
passed
brush–
-cheat-

grass vegetation and former homesteads with a few remnant trees. Sandy, shrub covered ridges and small dunes are present and separate the relatively flat nesting fields (Fig. 4). The topography is gently undulating and broken and lacks well-defined surface drainage channels. In the spring, the ridges and dunes display a burst of flowers: long-leaf phlox, prickly-pear cactus, pale evening primrose, balsamroot, desert parsley, lupine, yarrow, fleabane, antelope bitterbrush, broadiaea, wallflower, and tarweed fiddleneck. Later in the summer, Russian thistle germinates in the fields and becomes more prominent.

The fields themselves are cheatgrass mixed with Sandberg's bluegrass with occasional patches of Jim Hill mustard. Variations of this include 2 fields with bluebunch wheatgrass sparsely distributed, and a field with gray rabbitbrush and big sagebrush sparsely distributed. The main vehicle entrance to the site is via a test well access road.

(2) The 100-H/100-D study site was between the 100-H and 100-D Areas directly adjoining the Columbia River. That location is markedly different from the 300 Area study site in physical appearance (Fig. 5). It is larger (approximately 15.48 km²), more open, and lacks the lushness of vegetation at the 300 Area site. The major vegetational type is sagebrush/cheatgrass–Sandberg's bluegrass. It is comprised almost exclusively of abandoned fields and orchards with only scattered areas of sparsely distributed shrubs (big sagebrush, spiny hopsage, gray rabbitbrush, and buckwheat). Most of the fields are cheatgrass–Sandberg's bluegrass; Jim Hill mustard is extensive in some areas and Munro globe-mallow is common, blooming profusely in the spring. There are 2 groves of trees along the river, several old fruit orchards, and individual trees planted at old homesites. The entire site is criss-crossed with old roadways, most of them originally abandoned by the Atomic Energy Commission. The surface is relatively flat and declines toward the river. The shoreline drops off abruptly near the 100-H Area, but it descends more gradually towards the 100-D Area where a large cobble beach of riverwash extends out along the water.

(3) The 100-F study site of approximately 5.18 km² was southeast of the 100-F Area along the Columbia River. Though not visited as frequently as the first 2 areas, it was used most consistently for observations during the brood period. There is 1 large main field of very dense cheatgrass, and a test well access road runs north and south through the site dividing the field. Along the northern edge is an old burn now covered with blackened big sagebrush stumps, Russian thistle, and grasses. Sagebrush/cheatgrass–Sandberg's bluegrass vegetation surrounds several smaller cheatgrass fields. Sand dropseed is very prominent in one field and asparagus continues to come up each year in another. Jim Hill mustard occurs over much of the site, and several trees grow along the river bluff. The topography is gently undulating with sandy ridges except for the fields leveled when originally farmed.

PROCEDURES AND METHODS

Scientific Names

Common and scientific names of birds follow the American Ornithologists' Union Checklist of North American Birds (1957), names of mammals follow Hall and Kelson (1959), and names of amphibians and reptiles follow Stebbins (1966). Plant identification and names follow Hitchcock and Cronquist (1973).

Summary of Records

In addition to the data collected in the field, I compiled all the available records for the long-billed curlew on the major national wildlife refuges in Washington, southern Idaho, Utah, Nevada, California, and Oregon. Census information was taken from the refuge quarterly reports for 1960 and 1970 to June of 1976. I also

FIG. 5. Habitat

100-H Area,
ally towards
arge cobble
out along the

approximate-
of the 100-F
ver. Though
s the first 2
sistently for
ood period.
f very dense
access road
h the site di-
orthern edge
with black-
Russian this-
/cheatgrass–
etation sur-
tgrass fields.
inent in one
s to come up
Hill mustard
and several
luff. The to-
g with sandy
veled when

THODS

nes of birds
ithologists'
erican Birds
follow Hall
s of amphib-
bins (1966).
mes follow
73).

ts

ected in the
able records
n the major
Vashington,
da, Califor-
rmation was
erly reports
1976. I also

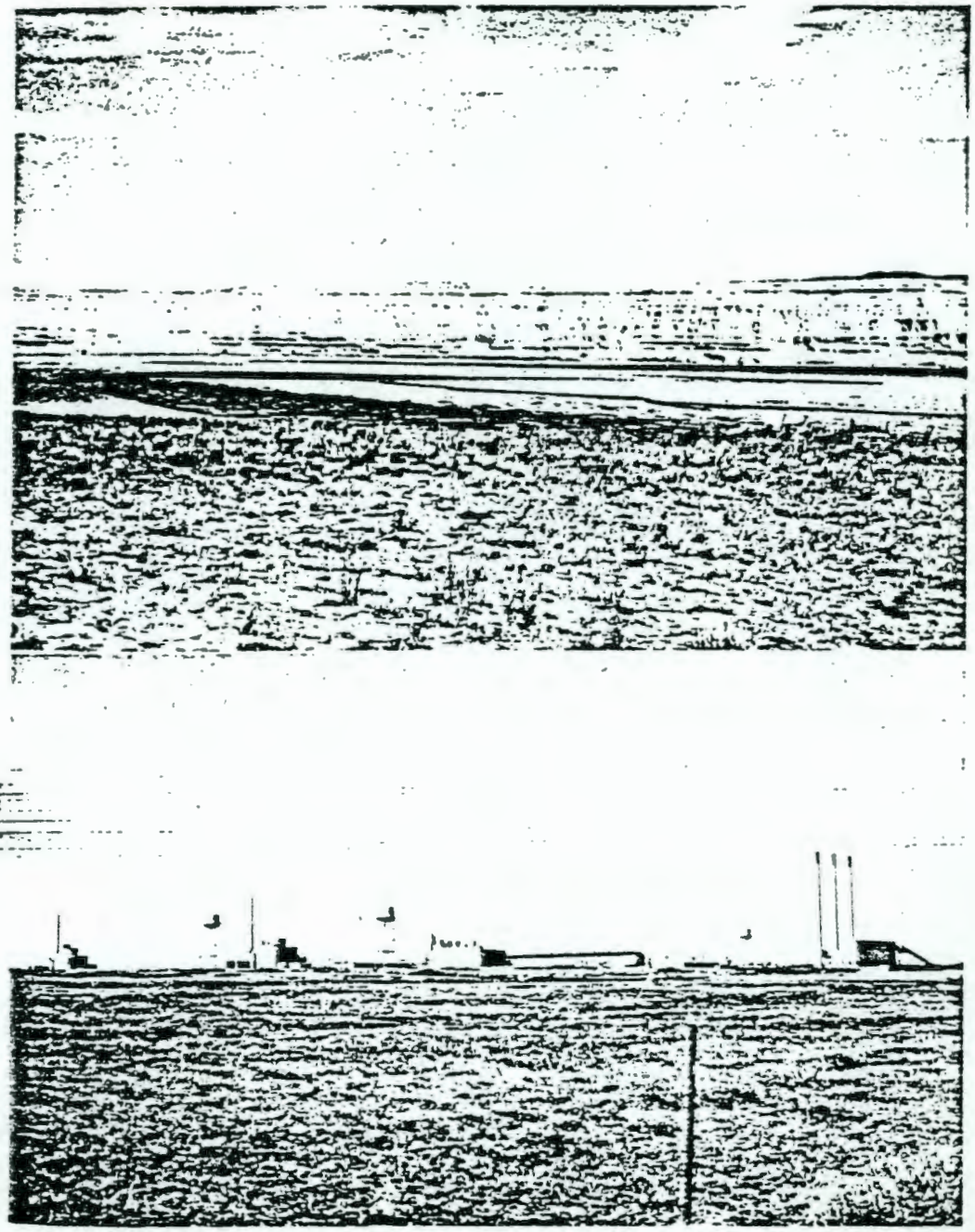

FIG. 5. Habitat at the 100-H/100-D study site. Upper, adjacent to Columbia River showing White Bluffs; Lower, vicinity of Study-plot Road territory showing 100-D Area.

drew upon communications with Hanford Site personnel, U.S. Fish and Wildlife Service personnel, and reports of private individuals.

Study Areas

The 300 Area study site was selected because it supports the highest density of nesting long-billed curlews on the Hanford Site. It also contains the major habitat types used by long-billed curlews in other southeastern Washington breeding areas.

Fieldwork started 15 March 1976 and covered the breeding seasons of 1976 and 1977. I visited the 300 Area study site daily from early March until mid-July when all the curlews were gone. I spent time at the secondary study sites on a rotating basis, the time of day, duration, and frequency of those visits depending upon the phase of the breeding cycle. Other areas of the Hanford Site were censused weekly or biweekly.

Descriptive details of the Hanford Site were developed from my field notes, U.S. Geological Survey maps, and Battelle, Pacific Northwest Laboratories' documents (Cline et al. 1975, Stone et al. 1972).

Habitat Analysis

Replicated 50-m transects were laid out in each of the major curlew utilization areas. The transect lines were chosen so as to characterize the nesting fields and the feeding habitats of each area. Canopy coverage provided by herbaceous taxa was measured by reading 50 2 × 5-dm plot frames systematically spaced at 1-m intervals on each line transect. From 100 to 300 plots were read in each area, depending on the variability and utilization. Canopy coverage for each taxon was estimated visually using a method developed by Daubenmire (1959). A modification of the method was to separate species into litter and live categories and to treat the 2 categories as separate "taxa" for analysis. Total live canopy coverage and total litter canopy coverage were also estimated. As classification numbers are often modified by individual investigators using that method, they are given here: 1 = 0–5 percent, 2 = 5–25 percent, 3 = 25–50 percent, 4 = 50–75 percent, 5 = 75–95 percent, and 6 = 95–100 percent. Frequency of occurrence was calculated as percentage of the total number of examined plots in which a particular taxon was present. All field data on habitat analysis were obtained between 6 and 13 June 1977.

Weather Data

Summarizations of the climatological data from the Hanford Meteorology Station at 223 m elevation near the center of the Hanford Site have been used.

Observations on Curlew Behavior

Observations, aided by 7 × 50 power binoculars and a 15–60 variable power spotting scope, were made in 2 ways. The first, and most productive prior to hatching, was from 6 stationary blinds placed in strategic locations that overlooked 8 territory nest fields on the 300 Area study site. The blinds were constructed of brown burlap and measured 1.2 × 1.2 × 1.5 m with a window on each side that could be pinned open or closed. At the 300 Area study site, my truck was always parked in the same location, and set pathways to the blinds were used. That routine was intended to reduce impact on the vegetation and to habituate the birds to my presence as much as possible.

The second means of observation was from a pickup truck parked along a roadway and was used during the entire 1976 breeding season. During 1977, it was used on all curlew areas other than the 300 Area study site and for all brood period observations. The majority of the behavioral observations were made in the open fields where the birds could be seen readily, and descriptions of displays are based on what was considered typical for the species.

Nest Study

After the long-billed curlews had started incubating at the 300 Area study site in 1976, the fields were searched systematically for nests. However, sitting and watching the birds proved less destructive to the grass cover and far more productive in locating nests. A nest location was first approximated using the surrounding features during nest relief, then approached and marked with a small white flag placed about 5 m away.

The eggs in each nest were weighed in a plastic bag using a 300-g spring scale and individually marked with a colored dot on the tip of the small end. The eggs were subsequently weighed weekly until hatching. By the identifying dots, I was able to study the fate of each egg, the hatching sequence within the nest, and the duration of hatching. After each examination, the area around the nest and along the approach route was sprinkled with paradichlorobenzene granules to mask my scent that might otherwise lead coyotes *Canis latrans* or other mammalian predators to the nest site. After hatching, the broken shells were collected from each nest. Eggs that failed to hatch were also collected.

During the 1977 breeding season, active nests were not approached and the nest fields were not traversed. Walking through the fields left scars for the remainder of the season and tended to disrupt behavioral patterns. At the end of the breeding season, scrapes were measured, photographed, and described.

Capturing and Banding

Standard U.S. Fish and Wildlife Service bands (size 5) were placed above the foot on all captured long-billed curlew chicks. A numbered, colored, plastic leg band (National Band and Tag Co., Newport, Kentucky) placed on the opposite leg was used to identify each individual bird, year, and place of origin. Most chicks were weighed, measured, and banded as soon as they hatched. Others were caught by hand later. I withheld marking the birds in any way that might adversely affect their natural camouflage and make them more susceptable to predation. Notes requesting band returns were sent to North American Bird Bander, National Audubon Society, The Murrelet, The Auk, The Wilson Bulletin, The Wildlife Society, and The Condor for publication. Flyers were also sent to Mexico and to all the national wildlife refuges in Washington, Oregon, Idaho, California, Arizona, Nevada, Utah, New Mexico, and Texas requesting information on band sightings.

Censusing

Censusing of long-billed curlews on the Hanford Site was done throughout the breeding season by making weekly road counts that consisted of stopping every quarter mile (0.4 km), walking a short way off the road, imitating a curlew call, and recording the number and sex of the curlews that responded. Birds were also counted at loafing and staging areas on a daily basis toward the end of the 1977 season. Also in 1977, 1 Columbia River census was made by boat in which the islands and shorelines between Vernita Bridge and Richland were searched.

Weights and Measurements

Each chick captured for banding was also weighed and measured. Small chicks were weighed in a plastic bag with a 300-g hand-held spring scale. Larger juveniles were weighed on a 1,610-g platform balance with their wings secured with Velcro straps. Measurements were taken on all birds with vernier calipers or a millimeter straightedge. The measurements are described here as some do not follow conventional methods. (1) *Length of tarsus* (tarsometatarsus) as measured diagonally from the point of the tibia/metatarsus joint behind, to the point of the metatarsus/middle toe joint (Fig. 6a). (2) *Length of exposed culmen* from the

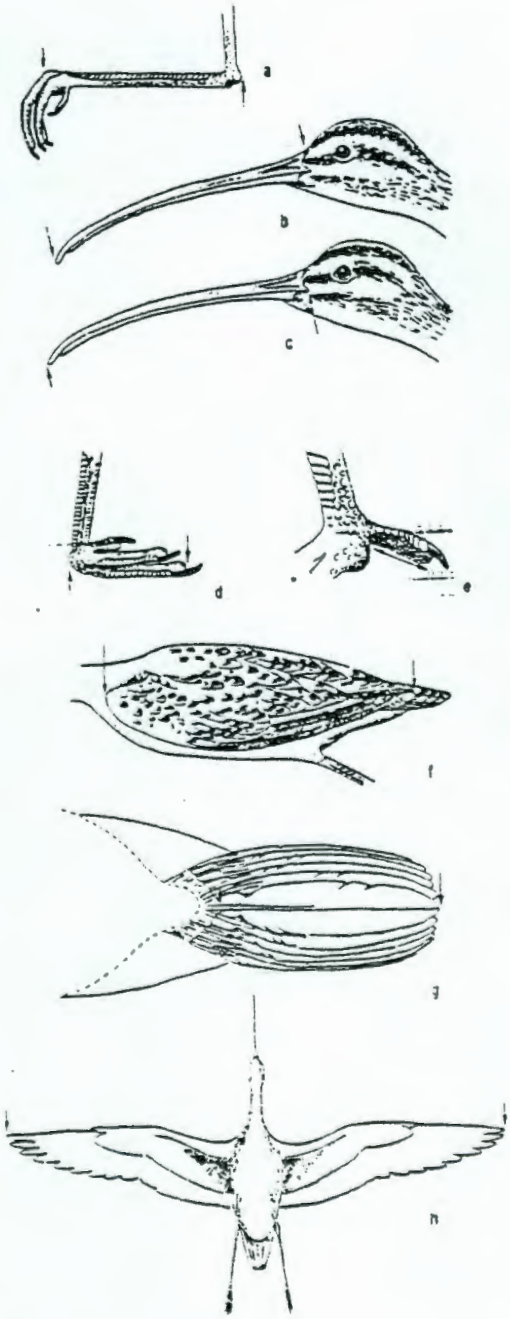

FIG. 6. Measurements of long-billed curlews. a, Length of tarsus; b, Length of exposed culmen; c, Length of bill from gape; d, Length of middle toe; e, Length of hallux; f, Length of closed wing; g, Length of tail; h, Extent of wings with feathers.

point where the feathers of the forehead end straight to the tip of the culmen (Fig. 6b). (3) *Length of bill from gape* as measured by the chord, straight from the tip of the maxilla to the corner of the mouth (Fig. 6c). (4) *Length of middle toe* as measured on the dorsal surface with the foot bent back from the point of the joint with the tarsus to the tip of the toe exclusive of the claw (Fig. 6d). (5) *Length of hallux* as measured along the ventral surface between the point of juncture with the tarsus and the tip exclusive of the claw (Fig. 6e). On older juveniles, wing chord and tail measurements were also taken. (6) *Length of closed wing* (wing chord) as measured from the farthest anterior point to the tip of the longest primary, without attempting to straighten the curve of the feather (Fig. 6f). (7) *Length of tail* as measured from the insertion point of the 2 middle rectrices to the tip of the longest tail feather when the tail is closed (Fig. 6g). Three chicks were recaptured at a later date and were again measured and weighed.

Four adult long-billed curlews were collected, weighed, and also measured as above. In addition, the *extent of wings with feathers* was measured as the distance between the tips of the outstretched wings from the farthest primary tip on one side to the farthest primary tip on the other by laying the bird flat on its back and grasping each wing at the carpal joint to spread the wings out along a ruler as far as possible without injuring the bird or flattening the wing quills (Fig. 6h). Study skins were prepared and placed in the Puget Sound Museum of Natural History, Tacoma, Washington.

Predation Study

Time-lapse cameras (Fitzner 1977) were set up in several blinds overlooking nests at the 300 Area study site to record predation. The cameras were mounted in rainproof boxes lined with foam, then mounted on wooden stakes inside the blinds. The cameras were set to take 1 frame every 60 sec. When the predator at

a nest site was not seen or filmed, the remaining evidence was examined for possible identification of the predator.

Sex and Age Determination

I judged sex of adult long-billed curlews by configuration and length of the bill in proportion to the head. In profile, the bill of the female is more than 3 times the length of the head; in the male, the bill is 3 times or less than the length of the head (Fig. 7). In addition, the bill of a male has a more perfectly symmetrical curve whereas the female bill is rather flat on top with a more pronounced curve towards the tip. That method of distinguishing sex was devised by M. M. Tremaine (1976, Ornithologist, P.O. Box 31152, Omaha, Nebraska 68131, pers. comm.) for curlews in Nebraska and is accurate and easy to use after a little experience. Also, the female of a pair is often up to one-third larger than the male, but is a difficult criterion to use unless both members of the pair are present for comparison. Juveniles (birds of the year) can be separated from adults by their noticeably shorter bill length.

Data Analysis

Program COVER (Sauer and Owzarski 1979) written specifically to handle habitat analysis data obtained with Daubenmire's (1959) method was used to combine the habitat data. That program provides the following: percentage coverage by species, relative coverage and species diversity, and frequency of occurrence. Weights and measurements were compared with *t*-tests.

PLUMAGE, MORPHOLOGY, AND SEXUAL MATURITY

Plumage

Adults

The plumage of adult long-billed curlews is well described by many authors

FIG. 7. Comparison of bill length of male and female long-billed curlews. Female in foreground.

(Bailey 1904, Bent 1962, Brooks 1920, Dawson 1909, Grinnell and Hunt 1929, Griscom 1939, Palmer 1967, Ridgway 1919, Suckley 1860, Wilson and Bonaparte 1831). Palmer (1967) and Ridgway (1919) made a distinction between nuptial and winter plumages, and both noted that in the winter plumage the under parts are darker or deeper pinkish in color. Bent (1962) reported the juvenile plumage to be somewhat more tawny than the winter adult plumage, especially below, and the streaks on the neck and the breast to be fewer and narrow. Suckley (1860) thought the overall rufous shade of the adult plumage to be more distinct in the young. On the basis of the 4 adult study skins in nuptial plumage I

TABLE 1.—WEIGHTS (G) AND MEASUREMENTS (MM) OF LONG-BILLED CURLEWS AT HATCHING, HANFORD SITE, SOUTHEASTERN WASHINGTON, 1976

Chick no.	Hatching date	Weight	Tarsus	Culmen		Middle toe
				From gape	Exposed	
1	11 May	52	47.1	27.0	20.3	33.8
2	11 May	51	45.3	27.0	20.2	34.4
3	11 May	50	43.3	25.3	20.7	33.8
4	11 May	56	44.3	26.0	19.6	33.5
5	11 May	51	45.2	25.2	18.5	33.5
6	12 May	50	43.6	25.3	20.6	35.8
7	12 May	44	45.1	23.9	21.5	37.7
8	13 May	56	45.2	26.5	21.3	35.4
9	13 May	52	46.5	27.8	20.3	35.1
10	13 May	53	42.8	24.8	19.0	34.8
11	14 May	47	44.2	24.5	19.5	38.0
12	14 May	50	42.5	24.7	20.2	35.9
13	14 May	49	44.7	26.2	21.5	36.9
14	25 May	48	46.7	25.8	21.1	36.0
15	25 May	50	43.8	25.2	22.0	35.7
16	25 May	50	45.5	26.5	22.3	35.5
17	29 May	45	39.7	23.2	18.5	30.6
18	29 May	47	42.5	26.5	20.8	35.0
19	29 May	46	40.4	23.5	22.1	34.2
20	29 May	47	41.6	25.6	21.9	32.4
23	3 Jun	53	48.5	28.5	24.5	37.0
24	3 Jun	46	46.5	30.0	25.0	37.1
Mean = SE		49.7 = 0.69	44.3 = 0.47	26.1 = 0.34	21.0 = 0.35	35.1 = 0.38

prepared and 4 juveniles examined during the postnatal molt, I found the following:

(1) the streaks on the neck were fewer and less pronounced (narrow and smaller) in the juvenile plumage than in the nuptial plumage (per Bent),
(2) except for a few lateral feathers, the breast of the juveniles was completely unstriped, unlike the adults that are conspicuously striped, and
(3) the juvenile plumage was more rufous or with a deeper pinkish-cinnamon cast than the nuptial plumage (per Suckley). If the adult winter plumage is a deeper pinkish or rufous than the adult nuptial plumage, then the juvenile plumage may be more tawny when compared at that time (per Bent).

Grinnell and Hunt (1929) reported that the female long-billed curlew has a much pinker flush over the body and wings than the male, and that as a rule the male shows more white on the wing coverts. I cannot pick out either characteristic in the 4 study skins I prepared (1 female and 3 male), and the sexes appear indistinguishable on the basis of plumage. In addition, my field observations did not reveal any sexual dimorphism in plumage. Individual birds could be identified by feather aberrations and/or variations in the feather patterns, but could not be used as a key to the sex of the bird.

Chicks

The downy young were described briefly by Allen and Kyllingstad (1949), Bent (1962), Palmer (1967), and Ridgway (1919) as basically buffy colored with irregular dark brown markings. According to Bent (1962), the buffy color varies from "warm buff" on the breast and flanks to "cream buff" on the face, upper parts,

TABLE 2.—WEIGHTS (G) AND MEASUREMENTS (MM) OF LONG-BILLED CURLEWS AT HATCHING IN UTAH (FORSYTHE 1973) AND COLORADO (GRAUL 1971)

Chick no.	Hatching date	Weight	Tarsus	Exposed culmen
Utah				
1	24 May 1966	56.6	35	22
2	24 May 1966	55.6	31	21
3	24 May 1966	57.6	41	21
Colorado				
1	3 Jun 1969	66.0	46.0	22.0
2	3 Jun 1969	62.0	47.0	22.0
3	3 Jun 1969	62.0	47.5	22.0

and belly, and to "cream color" on the throat with the crown even paler.

After banding several chicks at the 300 Area study site, I noticed what at first appeared to be 2 color phases in the newly hatched chicks. Of 6 broods, 3 chicks were entirely "cream colored" on the breast and belly and 10 were "warm buff" to varying degrees on the breast and belly. The 3 "cream colored" chicks were from separate nests. I thought this might indicate a difference in sex, but all 12 chicks from 5 broods banded at the 100-H/100-D study site were cream colored, and the probability is remote that all the chicks would be the same sex. If a larger number of chicks were examined, one probably would find a gradation of colors from one extreme to the other.

Weights and Measurements

The weight and measurements of 22 long-billed curlews at hatching are given in Table 1. Table 2 gives those measurements at hatching published by 2 other authors, but neither of them described their measurement procedures. I believe weight and exposed culmen measurements are comparable between us, but not the tarsus length because the wide variation suggests different measuring techniques. A Bonferroni *t*-test (Miller 1966) indicates that the weights from the 3 studies are significantly different from one another ($\alpha = 0.05$); the long-billed curlew chicks from Washington were significantly lighter at hatching than those from Utah or Colorado. On the other hand, an analysis of variance on the length of the exposed culmen does not show significant variation among the 3 groups ($\alpha = 0.05$).

Table 3 gives the weight and measurements of juveniles and adults. Forsythe (1973) reported the growth in length of

TABLE 3.—WEIGHTS (G) AND MEASUREMENTS (MM) OF JUVENILE AND ADULT LONG-BILLED CURLEWS, HANFORD SITE, SOUTHEASTERN WASHINGTON, 1976–1977

Bird no.	Hatching date	Sex	Age[1]	Weight	Wing chord	Tarsus	Culmen: From gape	Culmen: Exposed	Tail	Middle toe	Hallux	Wing span
21	3 Jun 1976	Unk	Juv	164	—	72.5	45.2	38.5	—	43.0	10	—
22	3 Jun 1976	Unk	Juv	187	—	73.0	47.2	39.7	—	43.4	10	—
25	7 Jun 1976	Unk	Juv	129	—	63.5	43.7	38.7	—	42.0	10	—
5[2]	19 May 1976	Unk	8 days	55	—	49.6	30.7	22.8	—	37.7	11	—
21[3]	10 Jun 1976	Unk	Juv	250	—	81.9	53.4	48.4	—	44.4	10	—
13[3]	14 Jun 1976	Unk	31 days	383	182	89.2	62.8	56.0	—	47.1	12	—
26	9 Jun 1977	♀	Ad	533.9	269	88.4	129	131	108	45.8	10	944
27	9 Jun 1977	♂	Ad	494.4	255	88.2	124	120	99	44.8	11	887
28	9 Jun 1977	♂	Ad	502.2	269	87.9	116	113	109	43.4	11	909
29	15 Jun 1977	♂	Ad	541.4	272	86.8	120	120	108	46.2	10	918
30	13 Jun 1977	Unk	Juv	308.3	163	89.4	59	54	62	43.0	11	—

[1] Ad = adult, Juv = juvenile chick of unknown age.
[2] Recaptured after banded as chick, see Table 1.
[3] Recaptured after banded as juvenile.

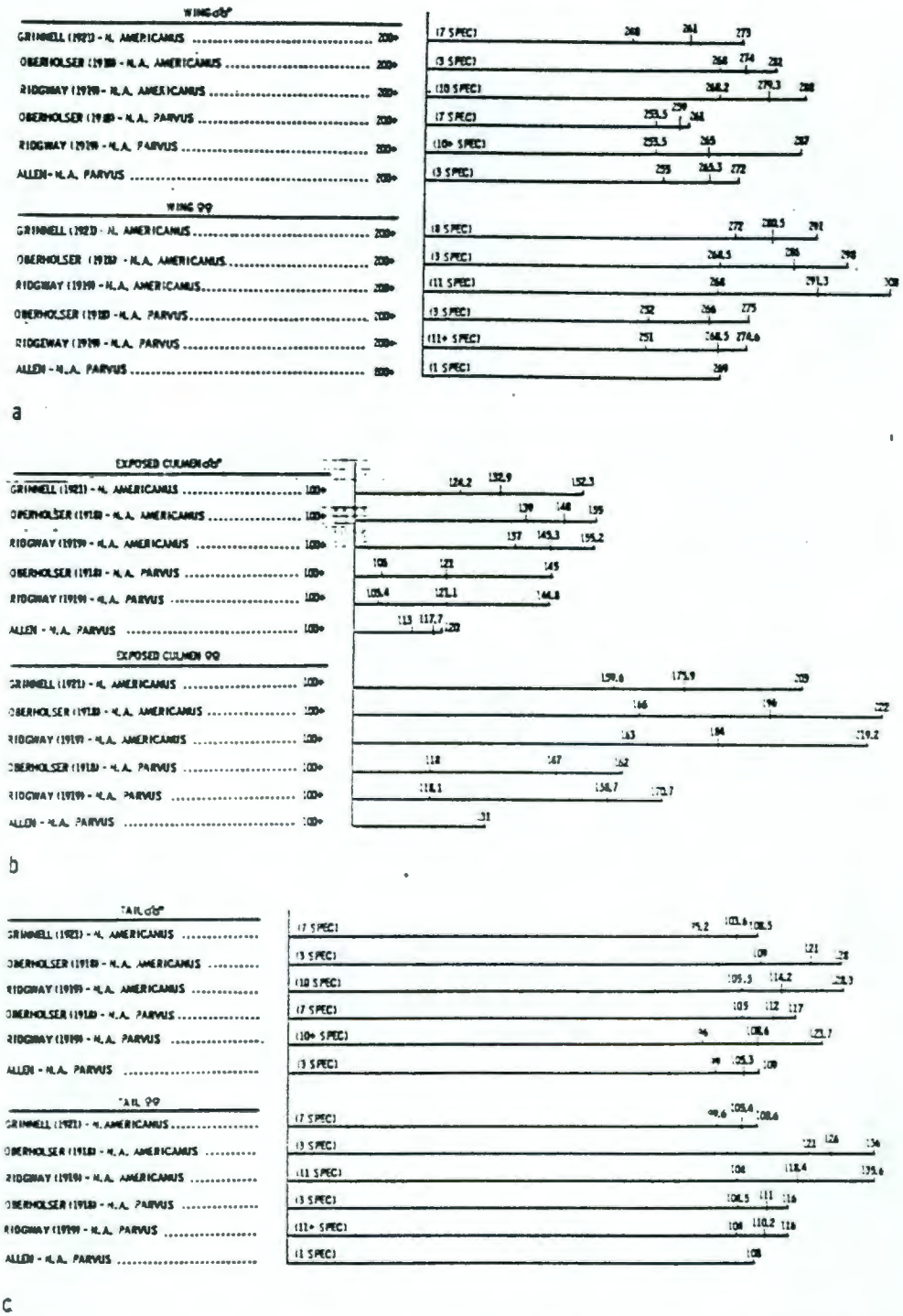

FIG. 8. Presentation of measurements (mm) of adult long-billed curlews. a, Wing chord; b, Exposed culmen; c, Tail. Values are maximum, minimum, and mean.

TABLE 4.—COMPARISON OF AVERAGE (MEAN ± SE) WEIGHTS (G) AND MEASUREMENTS (MM) OF ADULT MALE AND FEMALE LONG-BILLED CURLEWS FROM WASHINGTON (THIS STUDY) AND CALIFORNIA (GRINNELL 1921). FIGURES IN PARENTHESES INDICATE THE NUMBERS OF SPECIMENS

	Weight	Culmen	Wing chord	Tail
Males				
California (7)	693.0 ± 21.85	132.91 ± 3.59	261.0 ± 2.94	103.62 ± 1.72
Washington (3)	512.67 ± 14.54	117.67 ± 2.33	265.33 ± 5.24	105.33 ± 3.18
Females				
California (8)	815.64 ± 36.34	173.81 ± 6.11	282.63 ± 2.67	105.84 ± 1.09[1]
Washington (1)	533.9	131	269	108

[1] Only 7 specimens.

the exposed culmen, tarsus, and middle toe of chicks to be linear but not at equal rates. I do not have enough data points to determine linearity.

In the same format as presented by Grinnell (1921), Fig. 8 compares the adult measurements found by me, Grinnell (1921), Oberholser (1918), and Ridgway (1919). The latter 2 authors classified their specimens into subspecies on the basis of size, but as Grinnell (1921) pointed out, there is a significant degree of overlap between the 2, and most of the measurements are for migrants. The specimens from Washington tend to align more closely with the *N. a. parvus* specimens of Ridgway and Oberholser than with their *N. a. americanus* specimens. This is particularly apparent for exposed culmen, and the shortness of the bill in *parvus* as compared with *americanus* is the characteristic emphasized most.

Comparing the measurements of the 3 males from Washington (collected on their breeding grounds) with the 7 males (collected as migrants) measured in California by Grinnell (1921), those for body weight and length of exposed culmen differed significantly (t-test, $\alpha = 0.05$). Wing chord and tail measurements, however, showed no significant difference at the 0.05 level. Table 4 summarizes his data and mine. In summary, those weights and measurements confirm the placement of Washington bred long-billed curlews into the smaller, northern subspecies, *parvus*.

Age at First Breeding

I observed small flocks of birds that would pass through the nesting areas after nesting was well underway. Those small groups would frequent the areas adjacent to the territories for up to a week at a time where they would be seen walking and feeding leisurely as a group. They showed no migratory restlesssness. Occasionally, such a group would alight in one of the nest fields to feed, but were rarely driven out by the territory holders. In addition to this group behavior which is distinctive from that of migrants, the group members all appeared to have a shorter, male length bill. Taverner (1934) stated that the bills of curlews continue to grow for some time after apparent maturity. Possibly, the birds I observed were 1-year-old subadults that would not reach sexual maturity until the following year and whose bills were, therefore, not yet fully developed.

DISTRIBUTION

The present distribution of the long-billed curlew has not been adequately described; although common in parts of its range, its distribution and abundance throughout its range are poorly understood. Included in this section is information from national wildlife refuge records, that is tenuous at best but does provide distributional data on long-billed

FIG. 9. Locations of national wildlife refuges from which records were obtained.

curlews in the areas where it was collected.

Breeding Range

Western United States

National wildlife refuge records I have summarized show curlews during the breeding season on or near the following refuges (Fig. 9): Columbia, Saddle Mountain, McNary, Toppenish, Cold Springs, Umatilla, Deer Flat (Sand Hollow area between Ontario and Caldwell, Idaho), Minidoka, Malheur, Clear Lake, Upper Klamath, Lower Klamath, Tule Lake, Modoc, Sacramento, Colusa, Delevan, Salton Sea, Imperial, Havasu, Stillwater, Ruby Lake, and Bear River. Of those, nesting populations are thought not to occur at Imperial or Havasu, the birds being uncommon migrants. Although curlews are year-round residents in the Sacramento Valley (where Sacramento, Colusa, and Delevan are located), they are not known to nest (Manolis and Tangren 1975). Long-billed curlews are also present throughout the year in varying numbers in the Imperial Valley (Salton Sea), but again are not known to nest (McCaskie 1970).

Washington

Within the state of Washington, most of the curlew population is restricted to the Columbia River Basin. Fig. 10 shows the areas within and adjacent to the state where known breeding populations exist. Additional populations undoubtedly exist elsewhere in the state as well. The distribution of curlews on the Hanford Site is shown in Fig. 11.

Winter Range

Long-billed curlews do not winter in Washington, Oregon, Idaho, Utah, or Nevada. As previously noted, curlews are year-round residents in the Sacramento and Imperial valleys of California. Spring migrants apparently move northward up the western coast of Mexico and concentrate in the Gulf of California. The Salton Sea, just north of the head of the Gulf of California, is the last large body of water those birds find before they encounter the desert areas of eastern California. Spring and fall concentrations of long-billed curlews at the Salton Sea suggest that they are wintering in Mexico or farther south.

Stenzel et al. (1976) also identified a wintering population of about 40 birds on Bolinas Lagoon northwest of San Francisco, California, on the Pacific Coast. Forsythe (1970) observed wintering curlews in Texas at Aransas National Wildlife Refuge, Aransas County, and at Kingsville and Padre Island National Seashore Monument, Kleberg County.

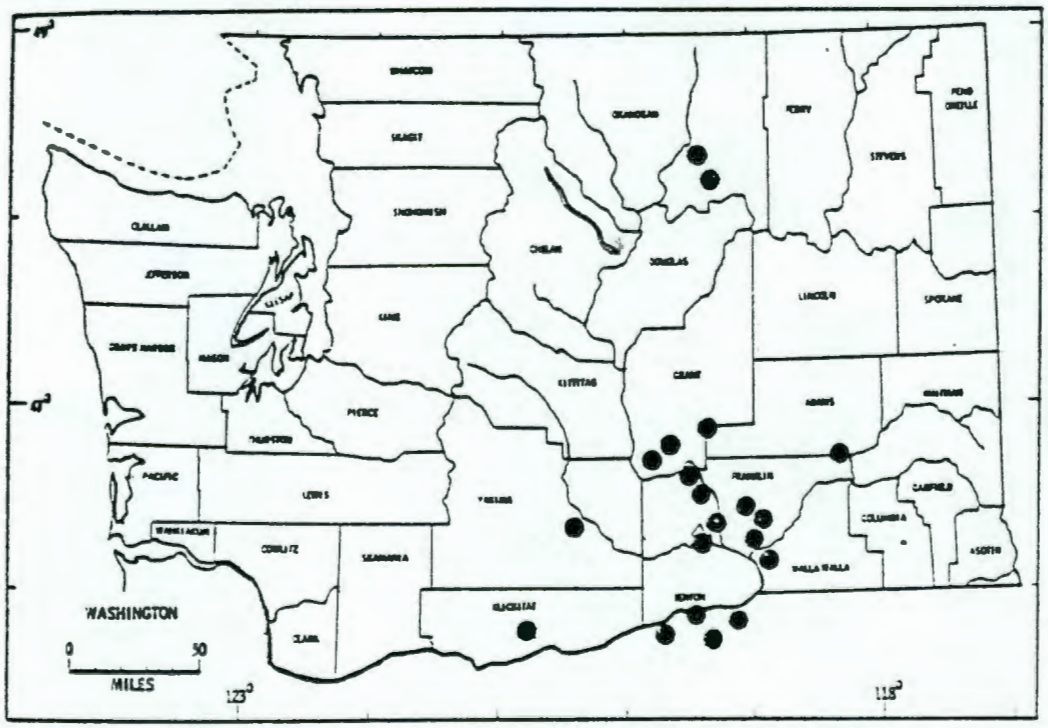

FIG. 10. Areas in Washington where curlews were recorded in 1976–1977.

Bystrak (1974) mapped the wintering areas of bird species summarized from Audubon Christmas Bird Counts nationwide (a 1971–1972 average in the case of the long-billed curlew). In addition to the Sacramento and Imperial valleys in California, he showed curlews in the San Joaquin Valley, the San Francisco Bay area, and along much of the coast. In Texas, the birds concentrate inland around Midland (Midland County), around San Angelo (Tom Green County), and in the area between those cities. The Texas and Louisiana Gulf Coast regions are shown to be very popular. The only other sightings shown are in Florida: Monroe County, the Tampa Bay area, the Merritt Island area, and around Jacksonville.

BREEDING POPULATION NUMBERS

The fact that no total census of long-billed curlews exists reflects formidable logistics of surveying a range characterized by widely scattered pockets of suitable habitat within forbidding terrain remote from centers of human habitation. Moreover, the pairs disperse widely during the breeding season and their characteristic shyness makes them difficult to locate. None of those factors has encouraged an effort to make a complete count.

McCallum et al. (1977) reported 73 sightings involving 226 individual curlews in 13 counties for 2 breeding seasons in Colorado, but whether that figure is the breeding population of the state or the sum of birds counted in 2 years is not clear.

The Hanford Site and adjoining Wahluke Slope together support a long-billed curlew population of approximately 300 birds during the breeding season. The Hanford Site west of the Columbia River has a resident population of approximately 100 birds. Of those, approximately 60

are paired, 20 are unpaired but territorial males, and 20 are unattached individuals.

MAINTENANCE BEHAVIOR

Comfort Movements

Comfort movements are those maintenance activities that aid in the care of the body and are not concerned with feeding, locomotion, or resting. Some of those movements differ in form from group to group and have been used in classification. For example, Simmons (1957), by using the method of head scratching as a character, placed the recurvirostrids near the charadriids rather than near the scolopacids. Many of the comfort movements exhibited by long-billed curlews are almost identical in form to those of other species, but have not previously been described.

Two-wing Flap.—The Two-wing Flap is a movement whereby the head and neck are stretched upwards and the angle of the back is increased slightly. Simultaneously, the wings are extended vertically into the air over the head to their full extent and fluttered briefly. The wings are then held extended in a pause (Fig. 12a). The bird rises on its toes, and commonly an individual will lift off the ground several centimeters while performing the fluttering phase of the movement. The Two-wing Flap was observed regularly in flocks of birds at loafing sites where it appeared to be preparatory for flight. It also appeared to signal impending flight to neighboring birds and thus was an aid in coordinating departure. The Two-wing Flap was also observed in birds on their territories, and in those cases it presumably functioned in stretching cramped muscles.

Two-wing Stretch.—The Two-wing Stretch (Fig. 12b) is a movement whereby the body is brought to a near horizontal position with the head and neck extended. Simultaneously, the wings are extended vertically into the air over the back and to their full extent. The bird stands squarely on both feet. The Two-wing Stretch is performed slowly and deliberately and lasts for several seconds. It does not appear to have any social significance and was most commonly observed following resting.

Wing and Leg Stretch.—Another form of stretch is the Wing and Leg Stretch (Fig. 12c). In that movement a leg is stretched backward, extended, and held as the wing on the same side is partially extended and stretched downward and backward adjacent to it. The stretch also does not appear to have any social significance. Only one bird at a time was observed to give the Wing and Leg Stretch, and when it was observed the birds were walking and feeding and merely paused briefly to stretch.

Scratching.—In the suborder Charadrii, 2 methods of head scratching are found. The scolopacids scratch directly (i.e., the foot is brought directly to the head) and the charadriids scratch indirectly (i.e., the bird lowers a wing and brings the corresponding leg over the shoulder) (Simmons 1961). Long-billed curlews scratch the head directly with the foot (Fig. 12d) and were never observed to use the indirect method. Scratching appeared to alleviate some irritating stimulus, and as such a stimulus was likely to be present at any time, another activity usually is interrupted for scratching purposes. The foot is used for scratching all parts of the head and those areas of the breast and neck the bird can reach. Other areas of the body are "scratched" with the bill, the tip of which is directed to the location of the stimulus and the mandibles move back and forth rapidly at the site. Some individuals tended to scratch more than others, possibly a reflection of the presence, absence, or abundance of ectoparasites the individual harbored.

Bathing.—A bathing bird (Fig. 12e) lowers itself into knee-deep water by bending the legs until the breast is at water level. The bird then wets itself by repeatedly rocking forward rapidly and submerging the head in a dipping motion. Simultaneously, the wings are quiv-

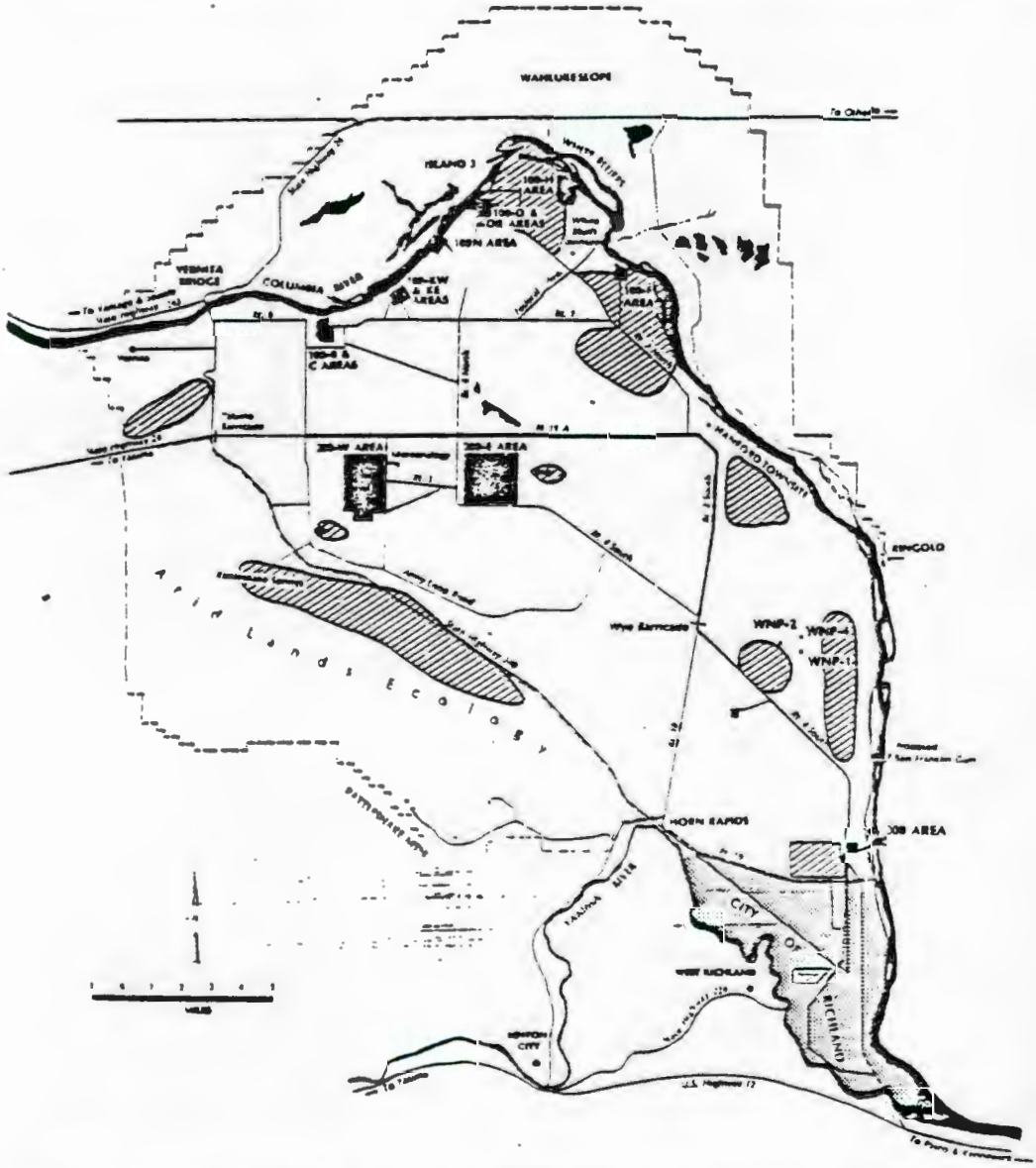

FIG. 11. Locations of areas on the Hanford Site, southeastern Washington, diagonally lined, utilized by long-billed curlews, 1976–1977.

ered slightly. Once wet, the bird briefly beats the water with its folded wings. This is done in a head-up position. Afterward, the bird stands, shakes off the excess water, moves to shallow water or to shore, and preens. Frequently during preening, the bird will extend and flap its wings several times. Bathing frequently was observed to be performed simultaneously by 2 or more birds at the same location. As bathing was a relatively uncommon activity, the sight of 1 bathing

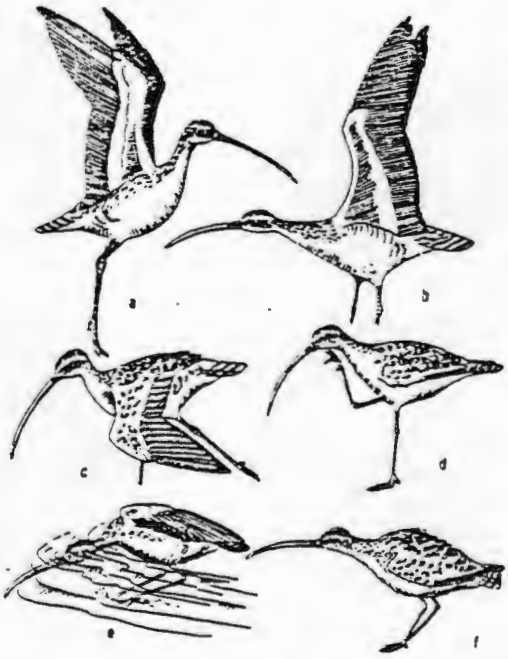

FIG. 12. Typical postures for comfort movements of long-billed curlews. a, Two-wing Flap; b, Two-wing Stretch; c, Wing and Leg Stretch; d, Direct head scratch; e, Bathing; f, Feather Shaking.

bird likely stimulated others to bathe. Solitary bathers, however, were also observed.

Preening.—Preening consists of manipulating and arranging the feathers with the bill. Oil is obtained from the uropygial gland with the bill and is manipulated into the feathers. While preening, birds frequently will rub the top of the head over the back and sides. This helps to spread the oil over the feathers and probably serves to preen the top of the head which cannot be reached with the bill. Preening birds usually stand on both feet with their feathers ruffled up. A pair will stand within a meter of each other, facing the same direction, and preen. During windy and/or hot weather, the birds seek the shelter of a large shrub for protection and shade. Complete preening of the body lasts a minimum of 5 min, but many times throughout the day the birds stop and preen one particular area briefly before proceeding with another activity. Preening was most commonly observed interspersed with feeding or preceded by feeding and followed by resting. In flocks of curlews loafing along the river, many birds are often observed preening simultaneously, demonstrating the social nature of the activity. In that situation, birds were sometimes observed preening while standing on one leg, and occasionally a bird would lose its balance resulting in a "hop-and-flap" sequence as the bird would attempt to recover equilibrium without putting the other foot down. A hop-and-flap consisted of a bird hopping a short distance to the side on one leg while simultaneously extending and flapping its wings several times.

Feather Shaking.—Feather Shaking is a generalized ruffling of the feathers brought about by shaking of the body while standing on both feet with the head and neck extended out in front (Fig. 12f). As a comfort movement, Feather Shaking was closely associated with preening and resting, and both of those activities were commonly preceded and followed by it. During cold or rainy weather, the birds would stop and shake frequently, presumably to enhance heat retention. Feather Shaking was also observed in the morning after the birds stood up from roosting for the night and after bathing as previously noted.

Other Comfort Movements.—Bill shaking (not to be confused with Shaking behavior discussed under SEXUAL DISPLAYS AND POSTURES) consists of a violent shake of the head, usually only once. Birds were observed to stop momentarily, shake the head, and often scratch the head before proceeding. Therefore, this movement may be in response to some irritating stimulus. Additionally, a male would sometimes shake his bill following a prolonged and unsuccessful mating attempt.

Foot shaking consists of rapidly shaking a foot and was observed in 2 types of situations. First, the movement was per-

formed as a leg was being raised into the one-leg resting position and was presumably to remove debris. Second, shaking of the trailing foot was seen occasionally while a bird was walking and feeding, and appeared to rid the foot of debris or entanglement in the vegetation.

Feather arranging movements, such as the shaking of the tail or lowering of the tail, are often observed especially after bathing or when a bird is preening. Shaking of the tail was also sometimes performed by one or both members of a pair following a courtship/mating sequence and by participants at the conclusion of an agonistic interaction. In addition, a bird would often shake its tail while walking and feeding.

While resting or walking and feeding, birds occasionally were observed to raise their feathers in a way that produced the same visual effect as Feather Shaking. However, the plumage would often be held in the raised position for a minute or so before the bird would resume its usual profile.

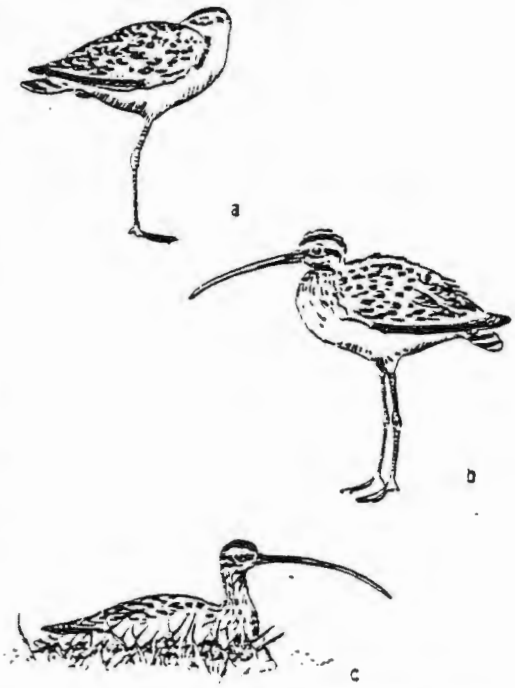

FIG. 13. Resting postures of long-billed curlews. a, Bill-back; b, Hunch-down; c, Sitting.

Resting

The basic characteristic of resting is a lack of or a minimizing of activity that probably results in minimal expenditures of energy. The most common behavior that can be included in resting is sleeping, but unfortunately it is not always possible to tell if a bird is, in fact, sleeping. Consequently, no attempt was made to differentiate sleeping from resting. I considered as resting (1) all birds in one of 3 resting postures and (2) birds that were stationary and preening at very low intensities. Birds preening at low intensities were considered as resting because preening frequently immediately precedes and follows resting, and the transition from one to the other is difficult to identify. Also, when birds were mildly disturbed while resting they frequently preened before resuming their rest.

Curlews rest facing into the wind so that in any given area, all resting individuals are found facing the same direction. On their territories, they will seek wind protection and/or shade behind any available shrubs, even though such a position appears to block their view in at least one direction.

Resting long-billed curlews assume several distinct postures. In terms of energy expenditure, the different postures probably are roughly equivalent and I was unable to associate the different postures with particular situations or time intervals except that during inclement weather only the hunch-down posture was observed.

In the bill-back position, the bill is placed under the scapulars; the legs may be in either of 2 positions. In one, the bird stands on both legs, whereas in the other the bird stands on 1 leg with the other tucked under the breast (Fig. 13a). In the one leg method, the leg is brought up into position sometimes before and sometimes after the bill is placed on the back. When the head is turned around,

the wing on the opposite side is lifted slightly to allow the bill to slip under the scapulars, but there was no correlation between the direction the head was turned and the leg that was raised. When resting in that position is terminated, the head is turned forward before the leg is lowered.

In the hunch-down posture (Fig. 13b), the bird stands on both feet facing forward with the head and neck retracted into the shoulders. The feathers are often fluffed up, particularly during inclement weather. Often too, the tail is dropped below the level of the primaries.

Long-billed curlews often employ another method of resting in which they sit on the ground with both legs tucked under their breasts. While sitting (Fig. 13c), the bird usually faces forward with the neck semiretracted. Less frequently, the bill is turned back and placed under the scapulars. Curlews are likely to rest sitting on hot days, and migrants most commonly rest in that position.

Feeding

Like other waders, long-billed curlews are opportunists, feeding on whatever foods are available. Consquently, one expects considerable differences in the diets of birds at different localities or at different times of the year.

On their breeding grounds, long-billed curlews appear to feed entirely by day. They feed within and throughout their territories as well as elsewhere on the Hanford Site and in the irrigated fields nearby. Prior to incubation, a pair will feed together with one following the other or both wandering in separate directions and eventually rejoining. Commonly, I saw them 50 m or more apart when feeding in the open fields. Usually, visual contact is maintained, but vocal communication also plays an important role especially in the shrub areas; a soft "Curlee Curlee" or "Wheet Wheet" call is used. When too great a distance is reached, one bird, usually the male, will fly over to the other and land nearby, then continue feeding. Once incubation has begun, the unattending individual feeds alone when on the territory.

Analysis of the different habitat areas used for feeding has revealed that at the 300 Area study site the partially exposed dune areas and ridge areas had the greatest variety of plant species. Those areas were also the most preferred for feeding.

In an attempt to be consistent with other authors, I have assigned the feeding movements of curlews to 2 categories: (1) pecks, in which only the bill tip touches the substrate, and (2) probes, in which the bill is partially or fully inserted into the substrate.

Pecks form a large proportion of the feeding movements, but their significance is not always easy to assess. They are used to obtain prey on the substrate surface; however, most pecks do not result in any obvious capture. Curlews "walking-and-feeding" within a territory are in constant motion as they zigzag across an area with bill pointed diagonally downward, pecking here and there, and heads bobbing. Occasionally, they may be seen to walk with head held high then to run rapidly, sometimes for several meters, ending with a peck (or a probe) for prey that presumably has been seen. Hunting by sight has also been reported by Burton (1974), Stenzel et al. (1976), and Hibbert-Ware and Ruttledge (1944).

Probes commence directly in front or diagonally to one side. As the bill is inserted in a burrow or hole during a probe, a great deal of movement involving the head and neck and the legs and feet may be seen as the bird maneuvers to locate the prey. Vigorous side-to-side, forward-and-back, and up-and-down movements of the head are used in those endeavors, and oftentimes a bird will appear to stand on its head with tail tipped skyward in its effort to capture a prey item. Turns of up to 180° with the bill inserted full length into the ground are common. Subterranean prey items are gripped in the bill

tip and extracted before being swallowed. Curlews walking and feeding in a field probe into existing holes or crevices as they come upon them and at the bases of grass clumps. They give particular attention to thick patches of vegetation, often probing in them repeatedly. In sandy soil they walk along pecking and probing in the loose substrate, sometimes violently stabbing into holes and other times calmly exploring depressions that may indicate a submerged beetle or a rodent cache. Most searches are concentrated around the bases of small forbs and shrubs, and each bird makes many exploratory probes for each successful catch.

Stenzel et al. (1976) described a "pause probe" used by long-billed curlews to obtain prey in submerged areas. On 2 occasions, I observed a similar "pause probe" technique used to capture prey from burrows in the fields. The bird walked along, then stopped suddenly and posed with the tip of its bill at the opening of a burrow or with its bill inserted into the burrow. It froze in that position for several moments, presumably until detecting some movement below, then made a quick thrust into the burrow. Most attempts were fruitless and others were aborted as presumably no prey was detected. After each one, the bird moved on to another burrow and repeated the sequence.

Another technique for obtaining prey is to climb up into the bases of shrubs and poke among the branches with the bill. Where Munro globe-mallow occurs, the birds pay particular attention to it. An individual may circle a plant several times poking among the branches, presumably gleaning insects from the foliage.

After capture, the passage of small prey items up the bill is effected by rapid, small opening and closing movements of the mandibles, accompanied by backward jerks of the head as it is gradually raised. Larger items are conveyed to the mouth and swallowed by fewer and more violent movements with the bill near the horizontal.

Prey Species

Long-billed curlews were observed to eat large black beetles and also other smaller insects that could not be identified from a distance. Superficial examination of excreta samples revealed an abundance of adult tenebrionid and carabid beetle exoskeletons. Other insect parts were also present but could not be so easily identified. Subterranean insect larvae probably constitute an important fraction of the diet judging from the amount of time spent probing in loose substrate.

Timken (1969) and Sadler and Maher (1976) reported long-billed curlew predation on altricial nestlings of lark bunting *Calamospiza melanocorys* and horned lark *Eremophila alpestris*, respectively. Horned larks are very common on the Hanford Site, but I never observed a curlew preying on a nest.

Regurgitated Pellets

Many wading birds regurgitate pellets that contain the undigested hard parts of their prey. These can be useful in studying the diet, and several authors have done so with curlews (Goss-Custard and Jones 1976, Hibbert-Ware and Ruttledge 1944, Stenzel et al. 1976). According to Hibbert-Ware and Ruttledge, the number and size of the pellets are cyclic and vary with the time of year and with changes in diet. Their field observations showed that when food changed from insects and grains to that of earthworms and other soft foods utilized during the winter and spring months, the pellets diminished in number and size to a marked degree. This suggests that pellets are rare or absent during the breeding season.

On the Hanford Site, long-billed curlews were not observed to regurgitate pellets, and no such pellets were found in roosting or loafing areas even though

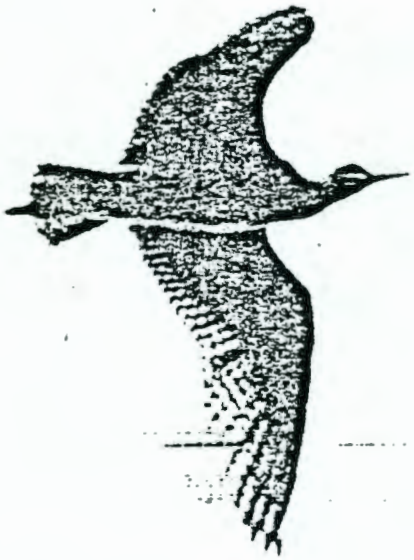

FIG. 14. Normal flight posture of the long-billed curlew.

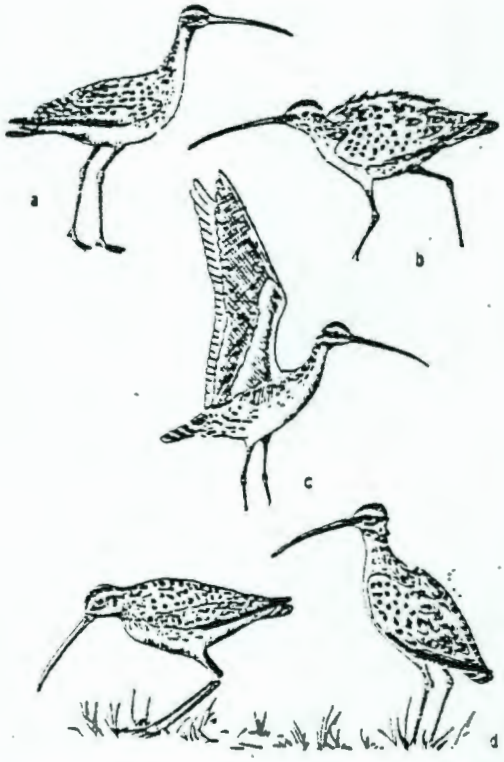

FIG. 15. Postures of long-billed curlews used in aggressive interactions. a, Upright; b, Crouch-Run; c, Wing-Raising; d, Appeasement, appeasor on left, opponent on right.

their diet is highly insectivorous throughout the breeding season.

LOCOMOTION

In normal flight, the neck is held slightly folded in a manner somewhat analogous to that of herons, but not as extreme (Fig. 14). Hamilton (1975), in comparing the American avocet *Recurvirostra americana* and the black-necked stilt *Himantopus himantopus*, reported distinctive neck positions for each species. The long-billed curlew holds its neck in a manner similar to the stilt but with a more pronounced fold.

When taking off, curlews customarily use their legs to obtain the necessary spring. The legs are brought up to the flight position soon after take-off and are lowered just before landing. When landing, the birds swing upwards with the wings momentarily fluttering high overhead before touching down. This puts them into a stall and allows them to drop gracefully to the ground. Or they may run a meter or so with the wings raised before coming to a halt. In both forms, the tail fans out as the bird touches down. If alighting in shallow water, curlews hover with their legs dangling and lower themselves gingerly. Other types of specialized curlew flights are discussed later.

I never observed long-billed curlews to swim, and wading was not common except when bathing. Most of the locomotion occurs on the ground where the birds walk or run. Running was normally observed during agonistic interactions. The exact postures used during walking, running, or wading are determined by the other activities being performed simultaneously.

AGONISTIC DISPLAYS AND POSTURES

I have categorized agonistic intraspecific interactions as mild (in which no physical contact occurs between individuals) and violent (in which physical contact between individuals does occur). Although agonistic interactions are common during the prenesting season, they become infrequent once nesting has begun and do not erupt again until the brood season. Throughout this paper such terms as aggression, aggressive, and aggressor refer to offensive behavior.

The Upright posture used during such interactions is characterized by the birds standing immobile with the angle of their backs above the horizontal and with their necks extended and their heads raised high (Fig. 15a). It is often held for several minutes before other postures are assumed. Frequently, when 2 birds are interacting, both will assume an Upright posture, or as one bird approaches another the other will assume an Upright posture.

During intraspecific interactions, the orientation of the bodies of the interacting birds is very important to them. If the birds face each other, it indicates aggression or a tendency to attack. Facing away (or looking away) indicates appeasement. Interacting birds frequently stand parallel to each other with their heads either facing the same or opposite directions. The bodies' parallel relationship between combatants probably is advantageous since such a position would enable either individual to strike with its wings or feet. Attack or retreat are equally possible from the bodies' parallel position.

Mild Interactions

Mild interactions occur most commonly while a bird is stationary or while it is running or walking on land. But they also occur in flight. Frequently, one bird will pursue another that is also in flight. Aerial pursuit is generally and for the most part one bird chasing another, but often intricate patterns of dives, swoops, turns, and twists are performed as 2 birds fly around a territory. Flying sequences are commonly initiated following other agonistic interactions, and the birds may make numerous short flights from place to place before the sequence is terminated. In general, aerial pursuit continues until the individual being chased is driven away.

Hovering.—Hovering is a form of aerial behavior used by an aggressive male and may function in locating an opponent hiding on the ground. The male flutters overhead on rapidly beating wings in a way resembling the hovering of an American kestrel *Falco sparverius* or a belted kingfisher *Megaceryle alcyon*. The hovering is of short duration (20 sec or less) and concludes with the aggressor landing near the opponent.

Crouch-Run.—A display often used during mild interactions is the Crouch-Run. In that display, the head is lowered, the back is held at an angle below the horizontal, the body feathers are raised, the tail is fanned, and the bill is directed out in front (Fig. 15b). The bird crouches down with the wings slightly raised from the body. This display is directed at another bird and is accompanied by movement toward the other bird, either by walking or (more frequently) by running. It is used by an aggressive bird and is a running threat that serves to lessen the distance between the aggressor and its opponent. The Crouch-Run was observed to be used when the opponent was within about 10 m of the aggressor. The display shows an attack tendency and usually was continuous with an attempt to peck (or stab) the opponent, followed by a return to an Upright posture.

A stationary form of the Crouch-Run is often performed when the opponent is at close range, e.g., when a territorial bird is joined by an outsider. In such cases, the aggressor assumes the Crouch-Run posture, aiming its bill at its opponent, but without the accompanying movement toward the opponent.

The opponent's response to the Crouch-

Run varies. Departure of the intruder usually results from a stationary Crouch-Run or from a walking approach. A running approach concludes with (1) flight of the intruder, (2) flight of the intruder and subsequent pursuit by the aggressor, (3) the intruder running or fluttering out of immediate striking range in which case the threat would be repeated, (4) the intruder assuming an appeasement posture thereby delaying or aborting a peck by the aggressor, or (5) violent interaction of some kind.

Upright-Run.—The Upright-Run is a running threat commonly used by an aggressive bird to pursue an opponent or to lessen the distance between it and its opponent. It replaces the Crouch-Run at distances of more than about 10 m. The Upright-Run is essentially an Upright posture put in motion and may terminate in any of the other mild or violent displays described herein, depending upon the situation and the response of the opponent.

Concealment.—Concealment is a display in which the aggressor approaches its opponent, then suddenly flops down in the grass and disappears from view. The bird assumes a position with the head and neck low, the bill resting on the ground, and the body flattened. The opponent often appears unable to locate the concealed individual and will walk back and forth across the area as if searching for him. When the opponent approaches the concealed bird, the concealed individual suddenly springs up at it in a Crouch-Run posture, then instantly drops back into the grass out of sight. The opponent stands and watches as the aggressor repeats the display, the aggressor each time moving closer to the opponent. Eventually, either the concealing bird will spring up and proceed with the Crouch-Run or the opponent will depart. However, the sequence is often prolonged and sometimes results in violent interaction.

Supplanting.—Supplanting is another form of mild interaction in which an aggressive bird flies or runs to the position of another bird. If the nonaggressor fails to defend its position and flies or runs away, Supplanting has been effected and the relinquished position will be assumed by the supplanter. If, however, the nonaggressor does not respond and remains in the immediate area, ground pursuit by the aggressive bird or violent interaction may result.

Wing-Raising.—In Wing-Raising (Fig. 15c), the bird essentially maintains an Upright posture but with the wings raised over the back. It is a standing threat display performed by an aggressive bird and directed at another bird in close range. Wing-Raising is commonly associated with Supplanting and the Upright-Run and also functions as a means of establishing individual distance between flock members at loafing sites. Abbreviated Wing-Raising, in which the wings are only partially raised, is more common than the full display and often precedes the full display. The intruder's response to Wing-Raising usually is to depart or to move further away.

Feather-Raising.—Feather-Raising is a generalized raising of the body feathers that results in a visual effect similar to that of Feather Shaking. The pose is held for several moments at a time, and the tail is often fanned simultaneously. Feather-Raising is usually terminated with Feather Shaking after which the usual profile is resumed. Feather-Raising was observed in a few instances among males. Under the circumstances involved, 2 males were competing for a female and each time all 3 birds came together the males would perform Feather-Raising.

Territorial Boundary Display.—Territorial Boundary Displays involve 2 neighboring territory holders near the territorial line. Both birds assume an Upright posture and make a series of short dashes directly towards or parallel to each other. Each dash, or charge, is followed by an abrupt halt and violent grass pulling or displacement pecking in which chunks of duff and litter are snatched up in the bill, "chewed" into little pieces, then dropped. Sometimes,

rather large pieces of sagebrush or dead flowering stalks of Jim Hill mustard are picked up in the bill and carried for short distances. Each time a bird halts and strikes the ground with its bill, its tail simultaneously fans out. In addition, the tips of the wings are often dropped below the level of the tail. Some birds carry their wings in that manner throughout an entire encounter while others drop them only when making a charge. Still others never seem to drop them. The position varies with the individual and with the intensity of the encounter.

Neither bird crosses the territorial boundary line nor comes within 1 m of its opponent in most cases. During such interactions, the birds almost always walk with their heads turned at an angle towards one another; looking away by one individual triggers a charge on the part of its opponent. When one bird initiates a charge, the other stands Upright and watches. When a charge is directly towards an individual within close range, that individual takes a stance facing the aggressor. The sudden halt at the end of such direct charges is sometimes accompanied by a swinging to the side instead of displacement pecking, so that the birds wind up standing perpendicular to each other. Occasionally, both birds run at one another simultaneously and either halt and snatch up debris, or turn to the bodies' parallel position when they reach the boundary line.

Occasionally, a Territorial Boundary Display erupts into violent interaction. When it does, it usually is from a bodies' parallel position in which one bird sidles up to the other, raises its wings, and flips up to attack the opponent with its feet. Often, however, the opponent moves away sideways rather than fight.

As a display progresses, the opponents move along the boundary line. Eventually, their paths begin to diverge and they begin displacement feeding. One individual may turn and surge back to the line in an Upright-Run after the other has moved some distance away, but then will again turn and also wander away. The display ends when the paths of both individuals have diverged to a point where neither shows further aggression.

Appeasement.—Appeasement by a bird may be indicated by a general crouched posture in which the bill is pointed diagonally downward, the neck is retracted, and the bird turns at an angle sideways and away from its opponent (Fig. 15d). In response to a running threat, an appeaser will often remain stationary in that posture, but then "duck" down suddenly when the aggressor approaches as if in a reflex-like response to an expected blow. Other times an Appeasement-Run will result in which the same basic posture is maintained, but the bird runs away. Invariably, the aggressor pursues in either the Crouch-Run or the Upright-Run posture, and such chases are often protracted as those being pursued usually are unwilling to leave. An Appeasement-Run was never observed to terminate in violent interaction, probably because of the nature of the display, but in all cases, intruders were eventually driven away.

Appeasement is also indicated by sitting or lying down. That behavior was observed in females as a response to male aggression. The female would sit down with the body flattened in a posture similar to that assumed for incubation. Her head would either be low, with the tip of the bill resting on the ground, or hunched down but still in the upright position. The male's response was either to stand and watch or to walk back and forth in front of her. The female usually remained sitting for less than a minute, and immediately upon rising remained crouched. Feather Shaking usually was performed by the female before proceeding with another activity.

The Bill-Down Display probably serves an appeasement function, presumably minimizing the threatening potential of the bill. The body is held with the long axis parallel to the ground. The neck is retracted and the head is in line with the body. The bill chatters and is directed downward, perpendicular to the ground.

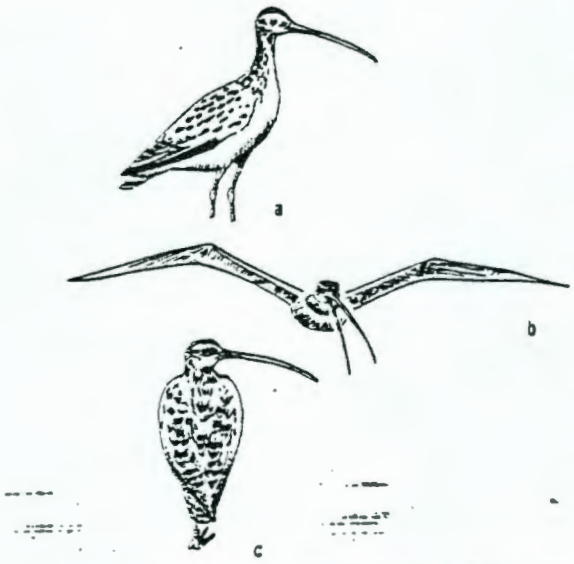

FIG. 16. Interspecific interactions of the long-billed curlew. a, The Alert-Attitude; b, Arc Display; c, Enticement-Run.

In that position, some birds remain still but others make little jerking movements forward and back with the bill, while still others make very slow rhythmic movements forward and back with the bill. I made many observations of the display involving pairs, but only 1 between nonpaired birds. In the latter case, a female ceased a running threat toward an intruding male when he demonstrated the display. Since all observations of Bill-Down Displays involved birds close together in pairs, perhaps the display serves to reduce aggressive tendencies in the mate that permits the 2 birds to remain close to each other.

Violent Interactions

Violent interactions involve actual physical contact with an opponent. The wings, the bill, and the feet are all used as weapons by fighting birds. But although such interactions are sometimes prolonged, an injury was never observed to result. Violent interactions are similar in many respects to mild interactions, but neither participant in a violent interaction initially shows any indications of appeasement; rather, both birds demonstrate a definite tendency to attack.

The most common position for fighting is facing front to front. The birds attack each other stabbing with their bills, clawing with their feet, and striking with their upraised wings, often flapping 0.5 m or more off the ground as they clash in a noisy ruckus. Violent fighting may also be side to side. In that position, the feet are the primary weapons though the wings are upraised and the bills may also be engaged. Sideways encounters last only a few seconds as one bird either moves away or both birds turn to the front-to-front position to continue the fight.

Another attack maneuver is jumping, with wings raised, on the back of the opponent and delivering violent kicks with the feet while pecking with the bill. Oftentimes a back attack is preceded by running towards the opponent with wings raised over the back. Such attacks usually, but not always, result in a reciprocal back attack by the opponent and/or front-to-front fighting.

Pecking or attempting to peck is commonly performed by aggressive birds following a running threat. Avoidance or departure is the usual response of the opponent.

INTERSPECIFIC INTERACTIONS

Escape is the most usual reaction to disturbances outside the breeding season or away from the nesting territories. On the territories during the breeding season, reactions to man or predators are different. At either time, the Alert-Attitude (Fig. 16a), in which the alarmed bird stretches up to its full height with elongated neck, is the first response. The Alert-Attitude was named by Simmons (1955) who described it as a preparatory escape movement indicating "suspiciousness." That attitude is often accompanied with a strong "Wheet Wheet" call which alerts other curlews in the area

who then also assume the Alert-Attitude. The Alert-Attitude is held for a time and, if necessary, escape by flight or a threat or distraction display follows. Otherwise, previous activity is resumed as soon as the disturbance has passed.

Flying threats toward avian predators are often very elaborate. One or a few of the breeding birds fly to the level of the predator and fly at it with raucous cries of "Wheet Wheet" attempting to strike it on the back with their feet. The predator must usually twist and stoop to dodge the attacks which continue until the predator has departed.

The Chirping call signifies an intense response to a disturbance. I believe it to be the same vocalization as "cackling" and the long, rattling call, "que-he-he-he-he-he," mentioned by other authors (e.g., Bent 1962). The Chirping call is also believed to be the same as the "Ki-keck" call described by Forsythe (1970). That call is an alarm call given in response to ground predators and often attracts conspecifics.

Injury feigning to distract a predator involves movement away from a nest site with the toes just touching the ground, the wings flapping against the grass, the neck outstretched, and the head turned sideways watching the intruder behind.

A behavior known as Demonstration in waders is essentially an aerial and vocal form of reaction akin to the "mobbing" behavior of other groups (Simmons 1955). Demonstrating long-billed curlews circle an intruder, making short flights from place to place giving repeated "Wheet Wheet," "Curlee Curlee," and Chirping calls.

In the Arc Display, so named by Forsythe (1970) and also noted by LaFave (1954) and Silloway (1902), the bird (usually the male) flies rapidly straight at the intruder (Fig. 16b). When within several meters of the intruder the bird angles straight upward, then circles back to repeat the performance. The "Guaah Karee" call is given during this display. The "guaah" is a harsh guttural sound which has qualities similar to the caw of a raven *Corvus corax*. It is uttered, most commonly twice, when the bird is approaching. The "karee" sound begins harshly but then becomes more of a whistle; it is uttered as the bird reaches the peak of its climb and is followed by the "Curlee" call as the bird heads away. The Arc Display is a maximum intensity attack response and appears to serve to intimidate a predator and also to attract conspecifics to the site. Similar displays are performed by other large shorebirds (e.g., American avocet, Hamilton 1975; oystercatcher *Hematopus ostralegus*, black-tailed godwit *Limosa limosa*, European curlew, and whimbrel, Simmons 1955).

The Enticement-Run is used to lure a ground predator away from the nest or young. The performing bird lands about 10 m in front of the intruder, then runs along through the grass with head turned sideways enticing the intruder to follow. If the intruder gets too close to the bird, the bird flies further ahead, lands, and runs through the grass again. During that display, the body is horizontal and the head is held close to the body (Fig. 16c).

SEXUAL DISPLAYS AND POSTURES

Bounding-SKK Flight

In the Bounding-SKK Flight display, the bird rapidly flutters upward, rising almost perpendicularly, then sets its wings in a downward curved arch resembling an umbrella (Fig. 17a). In that position, it slowly glides back down, pinions motionless on the breeze, sometimes coming to within 0.3 m of the ground before rising again. The Soft "Kerr Kerr" call consists of a high-pitched and very melodious "kerr" note that tapers off at the end and is repeated in a series. Each time the call is repeated, the bird opens its bill only slightly and the sound is like that of wind blowing through a pipe. The Soft "Kerr Kerr" call begins as the bird reaches the peak of the flight and continues until it reaches the bottom. Sometimes, a bird performing bounding flight gives the "Hee-who" call intermingled

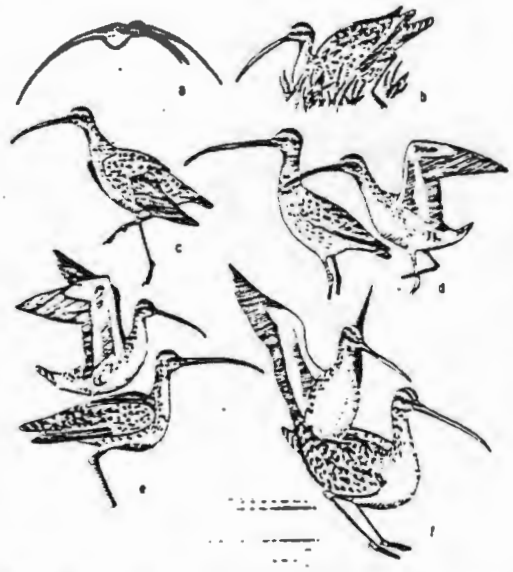

FIG. 17. Sexual displays and postures of the long-billed curlew. a, Bounding-SKK Flight display; b, Scraping; c, Courtship-Run; d, Shaking behavior, male behind female; e, Mounting prior to copulation; f, Copulation.

with the Soft "Kerr Kerr." The "Hee-who" call is another melodious call and consists of 2 drawn out notes, the second lower pitched than the first. The Bounding-SKK Flight display is a means of solicitation used by a male to advertise his unpaired status.

Although no other curlews have been reported to have this exact display with its accompanying call, some species do have aerial displays with similar elements. For example, the European curlew has a similar rising and falling flight with a high-pitched and flute-like call that is uttered on the descent (Bent 1962, Watson 1972). The whimbrel gives a call described as a very long-drawn "kewiu" that is uttered with scarcely opened bill and heard throughout the day (Bent 1962). Possibly, the call is similar to the long-billed curlew's Soft "Kerr Kerr" call.

Ground-Calling

In Ground-Calling the bird assumes an appeasement posture and utters a high-pitched and very melodious (yet mournful sounding) call that has several variations. The basic note is a long drawnout "whee" that fades in, rises in the middle, and then fades out. It is uttered with the bill only slightly opened and is repeated in a series. The following are variations on the basic "Whee" call: "whee," "whee-a-ee-a-ee," "wheer," "whee-a-ee-a-eer," "ee-a-ee-a-ee," and "eee." The "Hee-who" call is sometimes intermixed with the "Whee" call. Ground-Calling is performed by a male to attract a female for breeding. Occasionally, it is performed by a member of a well-established pair, but its function in such instances is unclear.

Scraping

Scraping is common among shorebird species that nest on the ground. In Scraping (Fig. 17b), the performing bird drops down onto its breast, wings slightly away from the body, with tail and wing tips pointed upwards. The bill is directed forward and diagonally downward as the feet are rapidly kicked backward alternately, pushing dirt up and out of the shallow depression (or "scrape") that is formed. The bird may rise and change position in the scrape frequently, each change usually involving a rotation of about 90 or 180°. Between scraping movements, the bird will commonly inspect the scrape with its bill and poke around in the bottom. Scraping produces nest bowls and many of them become scattered throughout a territory. Some of those sites are used repeatedly during courtship.

Tossing

Tossing is a nest-building movement that appears to be essentially the same as the Sideways Throwing Display described for other shorebirds and gulls (Graul 1973, unpublished dissertation, University of Minnesota, Minneapolis, Minnesota). During Tossing, the bird either stands with its back to the scrape and throws nest material along one side

of the body or alternately on each side, or it stands sideways to the scrape and throws nest material off to one side. The nest material is picked up in the bill then tossed into the scrape in repeated, quick movements. The act may also be performed while the bird is standing in the scrape.

Courtship-Run

The Courtship-Run (Fig. 17c) is a precopulatory running approach posture performed by the male. The neck is retracted unlike in the Upright-Run and the back is not at an angle below the horizontal as in the Crouch-Run. The head is held upright with the bill parallel to the ground and the body feathers in their usual position. As the male approaches the female, the wings may be raised partially with the primaries "flagging" in preparation for Shaking (see below) which follows immediately.

Shaking

Shaking is a precopulatory display performed by the male. During Shaking (Fig. 17d), the male assumes a position behind the female with the wings raised out to the side and the primaries "flagging." The tail of the male is cocked upward, the neck is outstretched, and the angle of the back approaches the horizontal. The footwork of the male is elaborate as he moves back and forth behind the female on either side of her tail, violently shaking his head and bill out in front. As he shakes, the bill of the male ruffles the shoulder feathers of the female. His head bobs up and down such that his bill traces a U pattern, moving first down one side of her shoulders and then down the other. The female stands erect, looking around. Occasionally, the female will move a few steps ahead, but for the most part she stands still.

As shaking progresses, the movements of the male become more frenzied. The wings are raised gradually until they are bent in a position above the back where they are fluttered in a jerky fashion. The male moves closer to the female straddling her tail, and climbing movements are made with the feet. His bill at that point ruffles the neck feathers of the female alternately on each side, and she has assumed a more horizontal body posture, though with head and neck still upright and looking around.

The Shaking call is given by the male throughout the Shaking display. It is difficult to describe but sounds like an evening chorus of Pacific treefrogs *Hyla regilla* around a pond. It also has a squeaky characteristic. When a bird is giving the call, the mandibles are not visibly separated but rather vibrate against one another. Forsythe (1970) briefly mentioned a "Sou" call he thought might be associated with copulation attempts. His description of the behavior of the birds at the time the call was heard corresponds closely with the Shaking behavior I observed, but his phonetic "sou sou sou" rendition does not.

Mounting

At the height of his Shaking frenzy, the male mounts the female by fluttering onto her back. At that point, he flexes his legs until he is resting on his tarsi with each foot cupped over a shoulder of the female (Fig. 17e). While on the female, the males makes very rapid "marking time" movements with his tarsi and feet such that his body vibrates or oscillates from side to side. Simultaneously, he holds his wings above his back and moves them in a way that helps to maintain his balance. The male's tail is cocked upwards and the head and neck are upright with the bill pointed diagonally downward.

The female stands with both feet squarely underneath. Her head and neck are also upright, but her bill is parallel to the ground and her back is horizontal. From the front, her trunk appears somewhat dorsoventrally flattened, giving her an elliptical silhouette. As the foot shuffling of the male continues, he gradually pushes the female's wings apart with his tarsi such that her wing tips drop below

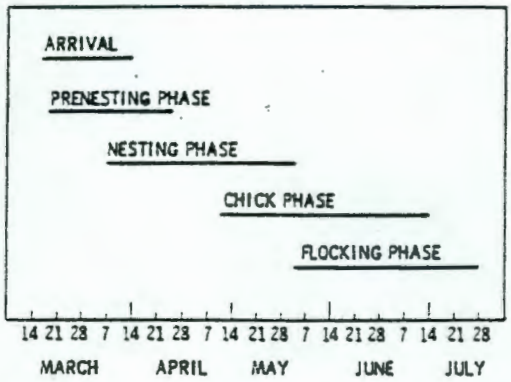

FIG. 18. Breeding chronology of the long-billed curlew on the Hanford Site, southeastern Washington, 1976–1977.

the level of her tail and one tarsus slips slightly underneath each wing. Mount time prior to copulation is about 60 sec.

The male continues to call after mounting and a rapidly repeated "wee" note is discernible. I believe the vocalizations heard during Shaking to be the same as those during mounting, the only difference being a certain amount of distortion caused by the action of the head during Shaking.

Copulation

The male's tail passes around the side of the female's just prior to dismounting. His tail drops under one of her wings as she tips slightly forward (Fig. 17f). Copulation is brief (about 2 sec); the male falls backwards as his tail is pressed down, fanned, and his wings are fluttered. Simultaneously, the female "falls forward" a few steps moving out from under the male.

If a copulatory attempt fails, the male regains his position on the female's back with feet shuffling and tries to copulate again 5 to 10 sec later. Rarely, 3 or 4 attempts are made before coition occurs. Oftentimes, however, once an unsuccessful attempt has been made by the male, the female will no longer stand and moves out from under him before he can continue.

Postcopulatory Behavior

There are no postcopulatory displays as such. The female Whistles as soon as the male dismounts, shakes her plumage, and begins walking and feeding, occasionally pausing and Feather Shaking a second time. The male dismounts, stands briefly, preens, and then also begins walking and feeding or, less commonly, flies to another part of the field.

MIGRATION AND BREEDING CHRONOLOGY

The spring migration is a general northward movement, but actual routes have not been identified. My use of color bands was intended to provide information on migratory pathways, but no returns have been reported.

Small flocks and single birds sporadically pass through on their way to other areas after the long-billed curlews have started breeding on the Hanford Site, and as the season progresses, migrants and residents can easily be confused. The transients rest or feed in or near areas where the residents are established. When flying through a nesting area, migrants commonly give a characteristic "Whort Whort" call that is repeated continually by 1 bird at 2-sec intervals. The call appears to have the effect of advertising their migratory status and therefore dispells any agonistic displays by the territorial residents. Migrants not using the "Whort Whort" call give the "Wheet Wheet" call as they cross the territories. (Local pairs or individuals often fly over one nesting area on their way to and from their own. Those birds fly along established routes that do not cross directly over the nest fields.)

When migrants land in a territory during the day, they alight in the open field first. They walk and feed very rapidly and often cock their heads skyward. Their behavior conveys a certain restlessness or nervousness that is particularly apparent in those that are paired. Members of a pair move in unison remaining within 1

m of each other and, occasionally, 1 bird gives the "Whort Whort" call as they feed. Migrants usually linger in an area only briefly, commonly less than an hour during the day, but sometimes they stay to roost most of the night. Those that spend the night Whistle back and forth for about a half hour before departure at dawn. Fig. 18 summarizes the breeding chronology of the long-billed curlew on the Hanford Site.

Arrival dates were 17 March 1976 and 21 March 1977 for the Hanford area. At the Umatilla National Wildlife Refuge approximately 40 km southward, arrival dates were 21 March 1968, 14 March 1969, 24 March 1970, 13 March 1971, 20 March 1975, 15 March 1976, and 21 March 1977 for an average date of 20 March. For the years 1956–1971, Littlefield (1973) found the earliest and latest arrival dates at Malheur National Wildlife Refuge in southeastern Oregon to be 22 March 1970 and 17 April 1967, respectively. The average arrival date at Malheur is 28 March for that period. Malheur is approximately 335 km south of Hanford and one would expect curlews to arrive there first. Possibly, the 2 populations of birds follow different migratory routes.

The first eggs were laid on about 8 April in 1976 and on about 2 April in 1977. A few adults may have still been incubating in June, but most eggs hatched by the end of May. Chicks began appearing on 11 May during both years and most fledged by late June.

The fall migration of long-billed curlews commences before the onset of the driest and hottest months. Those pairs whose eggs have been destroyed head southward early. I observed 1 pair to stay 8 days on the territory after losing their nest, and M. M. Tremaine (1976 pers. comm.) found departure within 10 days for lost nests. The overall movement of the birds south is, therefore, more extended than the move north, and, in fact, the early migrants also appear to be more leisurely in their behavior. Small flocks or pairs frequent cheatgrass fields and may be seen resting or loafing in them for several hours at a time. The birds usually just sit, but occasionally 1 will stand and preen or wander nearby feeding. Now and again, 1 will cock its head and look skyward.

In 1976, no curlews were seen on the Hanford Site after 1 July. A late record was 1 bird in Richland, Washington, on 24 October 1976. Three curlews (2 at Leadbetter Point and 1 at Ocean Shores) were also reported by birdwatchers for the Washington coast in the fall of 1976, but long-billed curlews are considered rare migrants west of the Cascade Mountains. In 1977, a large concentration of long-billed curlews left the Hanford Site from 15 to 23 June, and the last bird was seen on 22 July. Late records for the year were of birds feeding in alfalfa fields east of Red Mountain adjacent to the Hanford Site the week of 20 August, and 2 curlews on the McNary National Wildlife Refuge on 24 August.

ARRIVAL AND TERRITORIALITY

First observations were of single birds (males), but within a week numerous individuals had arrived and adult females continued to trickle in through the first week of April. In Utah, Forsythe (1970) reported a period after arrival when small flocks would frequent plowed fields and pastures. That period would last for several weeks before agonistic behavior would increase, leading to flock breakup and the dispersal of pairs to their territories to breed. On the Hanford Site, however, flocks of adult birds were not observed to remain intact after arrival, but rather the birds were first seen dispersed on their territories. Only on 1 occasion was agonistic behavior observed among members of a group that resulted in group breakup.

Forsythe (1970) and Wolf (1931) both reported that the birds seem to be paired on arrival, and Wolf (1931) also believed them to be mated on arrival as he never observed mating. Territories at Hanford were first occupied either by pairs or, and

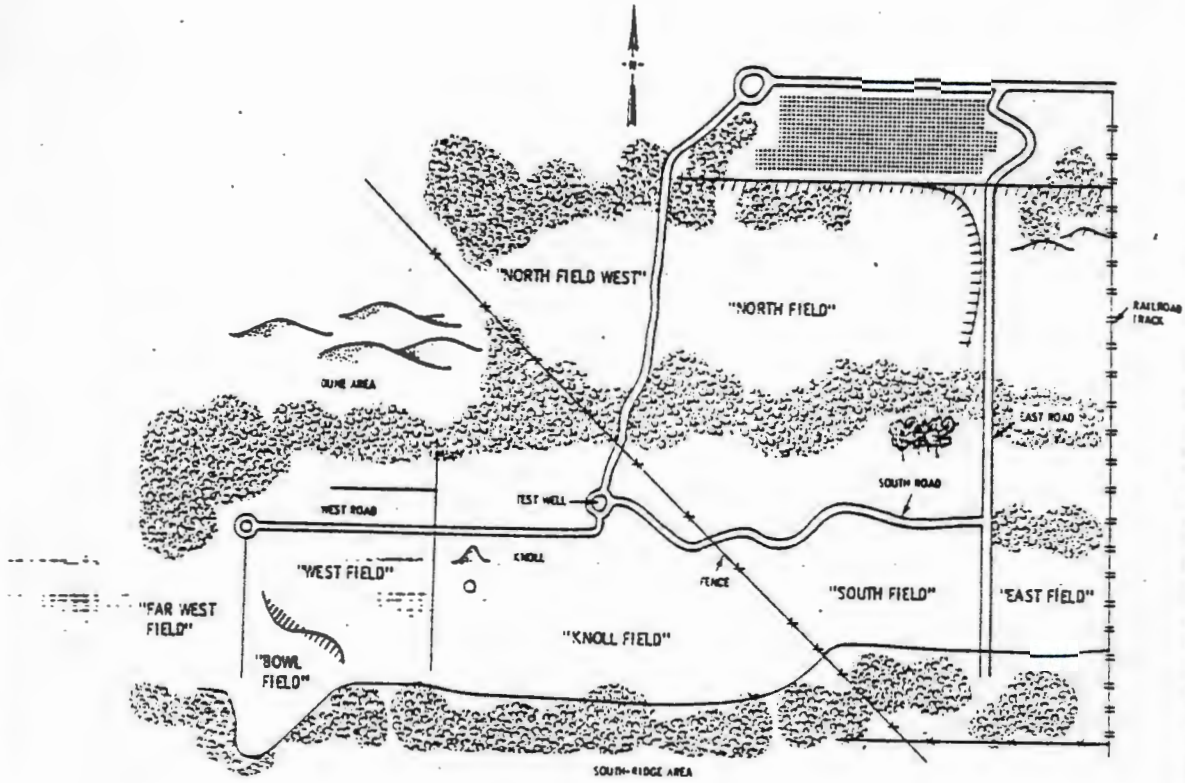

FIG. 19. 300 Area study site showing locations of the central territory nest fields of long-billed curlews, Hanford Site, southeastern Washington, 1976–1977.

equally as commonly, by unpaired males. In addition, courtship behavior, call advertising, and territorial behavior were observed as soon as the birds arrived.

Fig. 19 shows the locations of the central territory nest fields on the 300 Area study site. Territories were identified and named according to their relative position or to a prominent feature within them. The map also shows the location of areas and structures mentioned in the text.

Initial territory size varied with topography and habitat on the Hanford Site. They were smallest at the 300 Area study site where topography and habitat are the most varied, and the substrate is also very sandy. There, each territory consisted roughly of a nest field with an adjoining shrub area. Most of those nest fields were about 2 ha in area, with the smallest about 0.4 ha. Total territory size was only about 6–8 ha. Nesting territories were largest at the 100-H/100-D study site where the features are more uniform. There, and at the other nesting areas as well, "nest fields" as such do not exist because the habitat is so open. Instead, certain "nest areas" within the territories can be defined. In those relatively flat and open habitats, the territories were about 20 ha in area.

The same territories were used in 1976 and 1977, and I believe them to be historical in nature with previously defined boundaries. As such, I have taken the liberty of referring to them as territories even though the boundaries are not always defended against conspecifics. An increase in the number of birds in 1977

over 1976 did not result in a reduction of territory size but rather in an increased utilization of marginal areas, and some birds seemed to not nest at all. Conceivably, territory size had already been reduced to a minimum. In 1976, all the territorial males at the 300 Area study site acquired a mate for the breeding season. But in 1977, a shortage of females left almost half of them unpaired. In addition, many males holding marginal territories in 1977 were unpaired for the season.

Apparently, at least some birds may return to the same territories in subsequent years. This is based on identifiable plumage characteristics and on behavioral idiosyncracies of the birds seen from one year to the next. Head markings in particular were recorded for members of each pair, and in at least 3 cases, birds with the same markings returned the following year. However, I do not know how common such head patterns are in the general population.

Agonistic encounters between early arrivals were common. The few birds would range over large overlapping areas covering parts of several territories though each bird or pair could be associated with 1 territory in particular. Boundaries were not necessarily defended, especially not by unpaired males against neighboring paired females, until more birds had arrived. Once all the territories were occupied, paired birds would often tolerate the association of other birds in areas outside the actual nest field, but unpaired males were more defensive of their entire territory and would give aerial pursuit to any male intruders not accompanied by a female.

Territorial defense usually was performed by the male. Supplanting was the most commonly effectual means of evicting trespassers from territories but the Crouch-Run followed by aerial pursuit was also observed frequently in that endeavor. Following a flying chase, the territorial bird would return to the field with a loud Whistle and sometimes briefly perform Bounding-SKK Flight before alighting. Additionally, the Upright-Run, Wing-Raising, and Concealment were used to drive away trespassers, and violent interactions would erupt occasionally.

Variations occurred in the initial reaction of territorial birds to trespassers and depended in part on the stage of the breeding cycle and on whether the territorial individual was present when the trespasser first arrived. Paired males were more tolerant of outsiders in their territories for longer periods of time after mating had occurred. If a territorial male or pair returned to the territory to find an intruder present, the male usually would fly directly to the site of the intruder and proceed with agonistic displays. If a territorial male or pair was already present when an interloper arrived, an Upright posture was assumed by all individuals and was held for several moments before another posture (e.g., Crouch-Run) was assumed, or previous activity (e.g., feeding by the female) was resumed.

Defense of territorial boundaries for the most part involved Territorial Boundary Displays between neighbors, though violent encounters were not uncommon. Territorial Boundary Displays were consistently observed to occur only along those stretches of the boundary line that separated one nest field from another, and in those "zones," the line corresponded to a physical marker of some kind (e.g., a dead furrow, a road, a coyote path, a fence line, a ditch). Elsewhere, a certain amount of flexibility existed in the territorial lines. Those neighbors whose nest fields did not adjoin were never observed to engage in Territorial Boundary Displays with one another.

A Territorial Boundary Display was initiated when a neighbor provoked an encounter by entering the display zone and walking along the line. The other neighbor then flew or ran over to the zone and took up a position opposite his opponent, oftentimes sidling towards him and sometimes with the far wing raised overhead. Encounters most commonly involved just the males, but prior to the onset of incubation both members

of a pair were often present though usually only one member of each pair was directly involved in the interaction. Encounters usually were either male-to-male or, more rarely, female-to-female. Only 1 male-to-female interaction was observed. When 2 paired males were interacting, the females either stood and watched or more commonly, continued to walk and feed. When 2 females were interacting, however, the males assumed an appeasement posture and performed displacement feeding while slowly but continually walking around about a 1-m^2 area. They displayed that behavior until the Territorial Boundary Display between the females ended. With the passing of time on the territories, the intensity of interactions between neighbors gradually lessened to the point where full displays were rarely observed. Entering the zone by a neighbor still provoked an encounter, but the birds often remained farther apart and engaged only in displacement feeding.

DAILY ROUTINE

Each day begins approximately one-half hour before dawn with repeated volleys of Whistling as individual birds call out one after another from their roosting sites. "Curlee Curlee" and "Wheet Wheet" calls may also be heard but Whistling is the most common. Periods of quiet are interspersed with such rounds of Whistles, but the vocalizations continue until the birds begin their other daily activities.

During about the first 2 weeks following arrival, the birds are very active on their territories. There is rarely a peaceful moment during the day as calls ring incessantly across the fields, birds fly back and forth across their territories, solicitation and courtship begin with a frenzy, and agonistic encounters occur frequently. Unpaired males are particularly vocal, and the majority of their time is spent maintaining a visible profile. Paired and unpaired birds alike frequently move in and out of their nest fields all day long.

Courtship displays are most frequent during the early morning hours from dawn to about midmorning, but commonly continue through the morning and into early afternoon during the initial period. Courtship activities by one pair appear to stimulate courtship activities in neighboring pairs (social facilitation) as frequently 3 or 4 pairs will be courting within sight of each other. Solicitation for a female by unpaired males also begins in the early morning, but continues throughout the day. All reproductive activity is, however, stifled during inclement weather as the birds tend to stay in the shrub areas where there is more protection.

After about the first 2 weeks, but still prior to incubation, daily activities become more routine. Territorial pairs usually are in their nest fields only during the early morning, late afternoon, evening, and night. During the day, they feed quietly in the shrub areas within their territories, occasionally coming out into the open for maintenance activities or to pursue an intruder, or they are gone from their territories entirely, having moved to other areas to feed. Courtship displays in pairs are performed almost entirely during the first few hours of light. Paired birds have developed patterns for feeding, courtship, and mating that they follow routinely. The unpaired males continue to maintain a high profile as before, though perhaps with a little less vigilance, and tend to be much less routine in their activities. As the season progresses and a mate is still not obtained, solicitation becomes more intense with each passing female.

All birds usually leave their territories once a day for several hours (less for unpaired males) during the heat of the day to feed in irrigated fields or in other areas of the Hanford Site, and/or to loaf on islands in the Columbia River. The daily departure of a pair from their territory is often preceded by "Wheet," "Curlee,"

and "Curlee Wheet" calls for up to 10 min while the birds walk and feed. Actual departure is initiated by the female, who takes off quietly or calling "Wheet Wheet." The male assumes an Alert-Attitude, then follows calling "Curlee Curlee" and catches up with the female in flight. Commonly when a territory is unattended, neighboring birds will trespass flagrantly.

Curlews return to their territories in late afternoon and frequent the fields until they roost for the night. Occasionally, courtship behavior was observed during the afternoon/evening period, but was not common.

At dusk, the birds become very quiet on their territories as they walk and feed through the fields, and eventually none are heard. As twilight nears, they stop and assume an Alert-Attitude often listening and watching for several minutes. Then just at dark, they fly quietly to their roosting area (up to 200 m away) and disappear from sight. The same part of the field is used for roosting each night and members of a pair roost 10–50 m apart. Whereas territorial birds roost in their fields, migrants stopping over often use the areas of transitional vegetation bordering the fields.

By searching roosting areas covered with unusually thick stands of cheatgrass, I was able to find oval-shaped depressions in the grass with curlew excreta at one end. The narrowness of the ovals indicated that the birds do not flatten out on the ground when roosting as they do when concealing. I had no way of ascertaining the head position during roosting.

SOLICITATION AND INITIAL PAIR FORMATION

Solicitation or call advertising by unpaired males is seen in the form of Bounding-SKK Flights and Ground-Calling. Those displays serve to attract a female and are important in initial pair formation along with the Scrape Ceremony.

A male exhibits Bounding-SKK Flight most commonly flying in a path around the perimeter of his territory or in a figure-8 pattern over the nest field, but at times no particular pattern can be discerned. If a female is in his territory, a male usually will orient his display around her. Bounding-SKK Flights may last up to one-half hour, but sequences usually are shorter. Frequently though, the birds will remain on the ground only a minute or 2 between sequences. When a male completes a series of flights, he Whistles as he lands.

Bounding-SKK Flights become particularly intense whenever a female passes through a nesting area. At such times, all the unpaired males rise up and perform the display over their respective territories. If the female is unpaired, she usually alights in the nest field of one of the soliciting males but often does not stay there. Instead, she wanders from territory to territory walking and feeding. Once she leaves a male's territory, he becomes less intense in his solicitation, landing frequently and spending more time on the ground. For reasons not apparent to me, a female would eventually remain in one territory and tolerate the association of that male for up to a day, then move to a neighboring territory and male. She might switch back and forth more than once before a pair bond was formed and she remained with one of the males. A male persists with Bounding-SKK Flights throughout the first day of his association with a female, and some were observed to continue the displays for up to 3 days. With each succeeding day, however, the displays became shorter and fewer and usually were performed only when transients passed through the area or in association with other pair formation behavior.

As a form of call advertising, Ground-Calling is performed by an unpaired male within sight of a female who is either associated with another male or who has recently arrived but is in a neighboring territory. The soliciting male walks slowly through his field in an

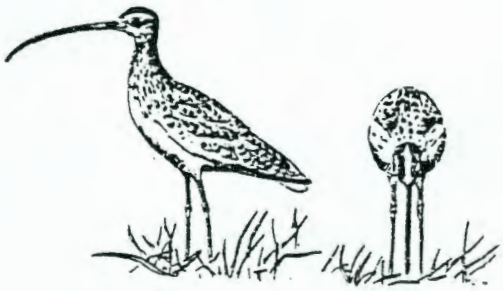

FIG. 20. Scrape ceremony of the long-billed curlew showing Bill-Down Display and orientation of the male.

appeasement posture giving the "Whee" call. Ground-Calling usually is interspersed with bouts of Bounding-SKK Flight; it is also an integral part of the Scrape Ceremony.

The Scrape Ceremony is performed many times during pair formation and involves ritualized Scraping. Initially, the Scrape Ceremony is preceded by Bounding-SKK Flight, after which the male takes up a position across the field from an unpaired female in his territory and performs Scraping behavior while Ground-Calling. Between Scraping movements he stands in the scrape and calls repeatedly. The female walks directly toward the male, often moving rapidly. When she is within about 10 m, her pace slows and the male assumes the Bill-Down Display posture and continues Ground-Calling softly. The female then approaches the scrape and steps into it as the male moves out sideways still maintaining the Bill-Down posture. The female commonly Whistles as she enters the scrape. The male takes up a position with his body oriented perpendicular to, and almost always behind the female (Fig. 20). Once out of the scrape cavity, the male usually ceases to call. During initial Scrape Ceremonies, the female often displays a certain amount of aggressiveness towards the male and directs pecking "intention movements" at him. The Bill-Down Display of the male appears to dissipate those aggressive tendencies, though the male may be observed to flinch in response to them.

While standing in the scrape, the female may change her direction many times, and each time the male will reposition himself accordingly to maintain the original orientation. Also, while standing in the scrape, the female may inspect it with the tip of her bill, make Tossing movements, or perform Scraping herself. Sometimes, the female Whistles during the course of those activities. However, she remains in the cavity only briefly before stepping out, though she usually stands for a time close by before walking away. Once the female has vacated the scrape, the male slowly raises his bill and then his head as if testing the female for aggressiveness before assuming another posture.

Scrape Ceremonies may be repeated by the male numerous times throughout the first day of association with a female such that it seems all of her time is spent walking back and forth across the field in response to his calls. Some males stop only briefly during the day to rest or feed or drive out an intruder.

At that stage following the ceremonies, the male usually performs Bounding-SKK Flight and the female begins walking and feeding. Gradually, this leads into the next phase in which precopulatory displays follow each Scrape Ceremony, and the pair bond becomes well established. Birds that arrive already paired begin their courtship activities at the next phase.

COURTSHIP, MATING, AND PRELIMINARY NESTING

Throughout this paper terms such as "courtship" and "courting" refer to events leading to copulation. After initial pair formation, the Scrape Ceremony becomes a precopulatory display. Scraping behavior eventually becomes disassociated with mating and appears to be the mechanism for designating the most favorable potential nest locations.

The basic Scrape Ceremony is described in the preceding section in its context with pair formation. The Scrape Ceremony is the same when performed as a precopulatory display with 1 addition. the male demonstrates Tossing behavior while calling the female over to the nest. Tossing behavior is widespread among shorebirds but its role in courtship is uncertain.

Following the Scrape Ceremony when the male raises his bill and head, he also slowly raises his wings out to the side, "flagging" the primaries. In that position he "cautiously" moves around behind the female and begins Shaking.

Initially, the female is unreceptive to the advances of the male. She does not tolerate Shaking behavior, and either turns in a Crouch-Run posture and pecks at the male or runs away. The male often pursues, chasing along behind, or circling one way and then another in an effort to take up a position behind her tail without being struck or grabbed. Once the female is receptive to Shaking, Shaking lasts for about 30—45 sec before the male attempts to mount. More time is required, however, before the female becomes tolerant of Mounting behavior.

Eventually, the female permits Shaking and Mounting, but runs out from under the male before copulation occurs. She then turns in a Crouch-Run posture and threatens the male. The male usually does not persist with courtship at the time, but tries again later. At that stage, some Scrape Ceremonies are followed by Tossing by the male (instead of further courtship). The Tossing often begins while the female is still standing in the scrape and continues until after she has walked away. In addition, mating attempts are sometimes made without the preceding Scrape Ceremony. At such times the Courtship-Run is displayed by the male followed by Shaking. The point at which the Scrape Ceremony (with Tossing behavior) changes from a precopulatory behavior to a nest site selection behavior is vague. A gradual process closely associated with the courtship/mating sequence is involved.

The final phase occurs when the female will tolerate the entire sequence of behavior from precopulatory displays through coition. Once that phase is reached, the Scrape Ceremony becomes isolated from courtship displays which are then preceded by the Courtship-Run. (The Scrape Ceremony will be discussed further under Nest Site Selection.) However, a male may still be unsuccessful at his first mating attempt each day, and therefore repeated courtship displays still occur. I did not observe more than 1 copulation in a pair on any given day, though some males would attempt 2 or more.

NESTING

Nest Site Selection

Scraping activities result in several scrapes, usually in one general area of the nest field with 2 or 3 occasionally being found within 8 m of one another. Most of those scrapes are used repeatedly during Scrape Ceremonies and one of them becomes the nest, but the means by which the actual site is selected is not clear.

Once Scraping behavior has become distinct from courtship behavior, each Scrape Ceremony is followed by the male Tossing while the female wanders away. Once the nest site is selected, Scrape Ceremonies cease but Tossing continues as the method for lining the nest cup.

Commonly, during the process of nest site selection, a bird was seen Tossing and missing the scrape altogether as a result of either misorientation or standing too far away from the site. Presumably in the latter case, the material tossed towards the scrape might be picked up later and tossed into it. Even with repeated use and Tossing oy the male, however, the scrapes were never substantially built and usually were devoid of nesting material when they were abandoned.

Subsequent Scraping behavior undoubtedly removed material previously placed in the bowl.

During nest site selection, the female often performed Scraping and Tossing during the Scrape Ceremony, and I suspect that her behavior ultimately determined which site would be used. During that period, females were observed to start scrapes and perform Scraping behavior without the accompaniment of the male. A male was never observed to respond to Scraping initiated by a female, but rather continued with his present activity. On the other hand, neither did the female call to the male or otherwise appear to be trying to attract his attention.

Nest Construction and Materials

The nest is initially formed as a scrape during a Scrape Ceremony. The bowl is made deeper with subsequent Scraping and with repeated bill poking. Improvement in the form of added nest material by Tossing is made throughout the laying period.

The nest cup is lined with whatever material is available in the immediate vicinity. Cheatgrass leaves and culms are the most common and are used along with rabbit pellets, small stems and twigs, seeds, Canada goose *Branta canadensis* excreta, and miscellaneous litter. Occasionally, a small stone was found in a nest along with the eggs. Considerable differences were noted in the amount of care taken to construct the nest. Some nests contained sparse amounts of insulating material and bare soil could be seen in the nest bottom. Other nests had thick bottoms and walls that afforded more protection to the clutch. Generally too, nests were more substantial where nesting material was locally abundant than where nesting material was scarce.

Incubating birds often picked up nearby material and placed it in the perimeter of the nest using the same nest building movements as in Tossing, except that the bird is in a sitting position. That activity is essentially the same as the Side-ways Building movements discussed by Graul (unpublished dissertation) for the mountain plover *Charadrius montanus*. Incubating individuals also reach out and pick up material, then drop it directly in front of the breast in a forward and back movement. As a result of these nest building activities, the brim of the nest becomes slightly elevated above the surroundings. Eventually, the area surrounding some nests becomes completely denuded of vegetation and litter.

Scrape Size

Fifty-nine scrapes were measured for depth and diameter (major and perpendicular axes). Depth in millimeters (58 scrapes) was $\bar{x} = 46.04 \pm 10.67$ SE with a minimum of 23 mm and a maximum of 66 mm. Diameter in millimeters (118 measurements) was $\bar{x} = 201.16 \pm 37.04$ SE with the smallest measuring 130 × 130 mm and the largest 275 × 245 mm. Those measurements are similar to those reported by Graul (1971) for 1 nest (diameter 190 mm and depth 45 mm) and by Silloway (1902) for 1 nest (major axis about 220 mm, minor axis about 153 mm, and depth about 51 mm). The variation in scrape diameter probably is a reflection of the size of the bird that made the scrape. Depth probably varies with the extensiveness to which the scrape was frequented.

Nest Site Characteristics

Evidence is accumulating that birds base their choice of habitat on features of the environment such as slope of the ground and structure of the vegetation rather than on the plant species present (Wiens 1969).

Vegetation Type

All nest fields were of a general cheatgrass community of 1 of 2 types. The first type was a cheatgrass/Sandberg's bluegrass association and the second type was cheatgrass with no accompanying blue-

TABLE 5—TOTAL COVERAGE (%) AND FREQUENCY OF OCCURRENCE (%) OF *BROMUS* AND *POA* IN 2 TYPES OF NEST FIELDS, HANFORD SITE, SOUTHEASTERN WASHINGTON. ALL VALUES ARE MEANS ± SE

	Bromus/Poa association		*Bromus*	
	Total coverage	Frequency of occurrence	Total coverage	Frequency of occurrence
Bromus tectorum	6.7 ± 2.2	72.7 ± 15.7	13.6 ± 1.6	93.5 ± 5.8
total *Bromus tectorum*	65.4 ± 10.9	100 ± 0	92.2 ± 2.8	99.5 ± 0.5
Poa sandbergii	16.6 ± 4.2	81 ± 7.9	—	—
total *Poa sandbergii*	4.6 ± 2	56.3 ± 18.5	—	—

grass. Table 5 summarizes total percentage coverage and percentage frequency of occurrence of cheatgrass and Sandberg's bluegrass for those types. Various forbs and/or shrubs in very minor quantities were associated with both types. Other cheatgrass communities (e.g., those that include a preponderance of Jim Hill mustard) and other grass communities (e.g., bluebunch wheatgrass stands) were not utilized by curlews for nesting.

Of 21 nest fields (or areas) identified, 6 (29%) were cheatgrass and 15 (71%) were cheatgrass/Sandberg's bluegrass. On the Hanford Site, all areas with cheatgrass/Sandberg's bluegrass fields in them were utilized by curlews, whereas many areas of just cheatgrass were never used.

In the nest fields, the average height of cheatgrass was less than 100 mm. Cheatgrass culms are robust, leafy, and spreading (as opposed to erect) and the panicle is dense and drooping. It covers the ground much more effectively than Sandberg's bluegrass (see Table 5). Sandberg's bluegrass has very slender erect culms that rise from a tuft of very fine short basal foliage. It averaged about 200 mm in height in the nest fields, noticeably taller than the cheatgrass, but due to its fineness probably did not present a visual barrier to the birds. In addition, where cheatgrass and Sandberg's bluegrass were associated, the grass clumps were more widely spaced with mosses and lichens in between, and the cheatgrass did not reach the density found in areas of pure stands (see Table 5).

The effects of grazing on breeding bird density and diversity in a prairie community were evaluated by Cole and Sharpe (1976). They found that both species diversity and total density were increased for their grazed study site in part because long-billed curlews were absent from their ungrazed study site. Work done by M. M. Tremaine in Nebraska (1976 pers. comm.) supports those observations that long-billed curlews may be restricted to such grazing areas. Wolf (1931) confirmed a preference for short grass.

In summary, long-billed curlews probably select sites because of the shortness of the vegetation and also the spacing of the grass clumps. Because they rely on camouflage for protection of the eggs and themselves during incubation, the short grass presumably allows for better visibility of approaching danger and the irregular pattern of the grass clumps complements their cryptic coloration.

Slope of the Ground

Long-billed curlews usually select relatively flat areas for nest sites, but some nests were found in locations where the ground is uneven; e.g., on top of a dead furrow (3 nests) or on a roadside furrow (1 nest). Wolf (1931) stated that the ideal location is on a slight rise of ground, and Graul (1971) found the nest he observed at the edge of a large valley adjacent to a gently sloping hill. I found 3 nests on a slight rise of ground, but most nests were toward the southern edge of the field regardless of slope. In fields with an east–west major axis, the nest was located in either the east quarter or the west

TABLE 6.—A COMPARISON OF THE DISTANCE (CM) TO THE NEAREST CONSPICUOUS OBJECT BETWEEN DIFFERENT SCRAPES OF THE SAME BIRD. O INDICATES THAT THE SCRAPE WAS AGAINST A CONSPICUOUS OBJECT, AND NA INDICATES NO OBJECTS IN THE VICINITY OF THE SCRAPE

Bird no.	Scrape No.					
	1	2	3	4	5	6
1	O	NA	NA	NA	NA	NA
2	O	O	O	5.5	300	NA
3	NA	NA	NA	NA	NA	NA
4	O	41	NA	NA	NA	NA
5	NA	NA	NA	NA	NA	NA
6	O	O	28.5	—	—	—
7	136	120	71	246	—	—

quarter. On the 100-H/100-D study site, the overall slope of the ground is downward to the Columbia River to the north, and so a southerly nest site gave the bird a sweeping view down the field. But on the 300 Area study site, the direction of slope in each field is variable and the advantages of a southerly location are not readily apparent.

Proximity to Conspicuous Objects

Silloway (1902) found several nests beside piles of dried cow manure, and Sugden (1933) included a photograph of a long-billed curlew nest adjacent to a pile of horse manure. Cameron (1907) noted that curlews look so like "buffalo chips" as to be easily mistaken for them at a little distance. In areas heavily grazed, and therefore covered with only scant vegetation, the selection of a site next to a manure pile would seem advantageous by making the incubating bird less conspicuous.

On the Hanford Site, distances from scrapes to the nearest conspicuous object were measured. The most common objects were old big sagebrush limbs, rocks, bare dirt mounds, and dead furrows. Other items were a steel cable, a horse manure pile, a rusty 5-gallon can, an old tumbleweed, and a large bunchgrass. Twenty-two nests (37%) were within 1 m of an object, 18 nests (31%) were within 30 cm of an object, and 16 nests (27%) were against an object.

Individual birds were not consistent in selecting scrape sites in relation to conspicuous objects (Table 6). However, I was unable to make comparisons between the nest sites chosen by the same bird in different years, and individuals may be more consistent in their final choice. Of 59 scrapes, 14 were used as nests and 9 of the 14 were near a conspicuous object. In general, though, conspicuous objects are in short supply in the cheatgrass fields on the Hanford Site. Surface rocks and sage stumps were removed when the land was farmed, and there are no grazing livestock to provide manure piles. Those objects present are widely scattered and some nest fields appear to be without any at all. Therefore, the tendency to select a nest site close to a conspicuous object may be limited by the availability of such objects.

Presence of Other Curlews

The presence of long-billed curlews in an area undoubtedly serves to attract conspecifics to the site and increases the probability of obtaining a mate, in addition to the survival value afforded in a group situation. Territorial behavior spaces the birds over a given area, but even though definite boundary lines are established, nests in neighboring fields were never adjacent. The nearest neighbor nesting distance was 250 m at the 300 Area study site. However, in particularly favorable habitat, there is a tendency for pairs to nest within sight of one another. Nests in other areas were 500 m or more apart which concurs with Forsythe (1970) who found nests about 462 m apart.

Nest Density

Sadler and Maher (1976) estimated approximately 1 pair of breeding curlews per 6 to 7 km² of suitable habitat in Saskatchewan. Nesting density is much higher on the Hanford Site. Fifteen ter-

tories were identified at the 300 Area study site that encompasses only 10.36 km². The 5.18-km² 100-F study site supports at least 3 territories, and the 100-H/100-D site (15.48 km²) supports at least 10.

Differences in nest density can be attributed to differences in habitat and to territoriality. Each territory must have suitable areas for nesting and chick rearing that include adequate food, cover, and shelter. The 300 Area study site supports the highest nesting density of curlews because the habitat there is prime. Such is not the case at the other study sites, and consequently the nesting densities are lower. The prairies of Saskatchewan where curlews occur are much more vast than the area at Hanford, and, therefore, one expects to find differences in breeding density.

EGG LAYING

Laying Behavior

The behavior of 3 females was observed during egg laying and was similar in each case: the female approaches the nest to within a meter, stands alert momentarily, then steps into the bowl. She first inspects the nest looking and poking around with her bill, and sometimes tosses or pulls additional material inside. Once that is completed, the female settles into the bowl and sits quietly. After the egg is laid, the female rises from the nest and begins Tossing while still standing in the bowl. Eventually, she steps out of the nest but continues tossing behind or to the side for 5–10 min. Time spent on the nest in the 3 cases observed was 13, 25, and 87 min. The final egg in the clutch was laid during the 87-min observation, and the onset of incubation may have influenced the extended time spent on the nest.

Once laying has started, both birds become very attentive and return to the nest numerous times throughout the day. During such visits, the bird usually steps into the nest bowl and stands over the eggs, sits down, or alternately stands and sits. When standing over the eggs, the female usually assumes a body posture essentially the same as that described for Appeasement. On 2 occasions, a female was observed to be calling softly while standing in that position. The Bill-Down Display is performed by the female when and if the male approaches her while she is standing in the nest bowl, and terminates as soon as he moves away. Males were never observed to stand over a nest for any length of time, but females would often do so for up to 30 min. Either bird might sit on the eggs for 1–2 hours during a visit.

Tossing behavior is closely associated with nest attentiveness and occurs along with repeated visual and tactile inspection of the bowl and its contents while the bird is in or around the nest. Tossing is also performed just before a bird steps out of the nest and again before it moves away from the site.

Courtship continues during egg laying, but mating attempts were observed to be successful only on those mornings when an egg was not laid. The laying of the last egg in a clutch was observed in 1 pair, and in that case the last copulation was seen the day before.

Clutch Initiation and Laying Intervals

Dates for the laying of first eggs were calculated by backdating at hatching, allowing 28 days for incubation (Graul 1971) and 6 days for laying. Most clutches were initiated within 2.5 weeks of when the first clutch was started. In 1977, 1 clutch was initiated unusually late, 23 May.

Eggs were laid in the early morning hours (within 2 hours of dawn) on alternate days. I was able to record the interval between the laying of 2 eggs (the first and second) in only 1 case, and it was 47 hours and 25 min. Graul (1971) reported a case of 3 eggs being laid over 4 days

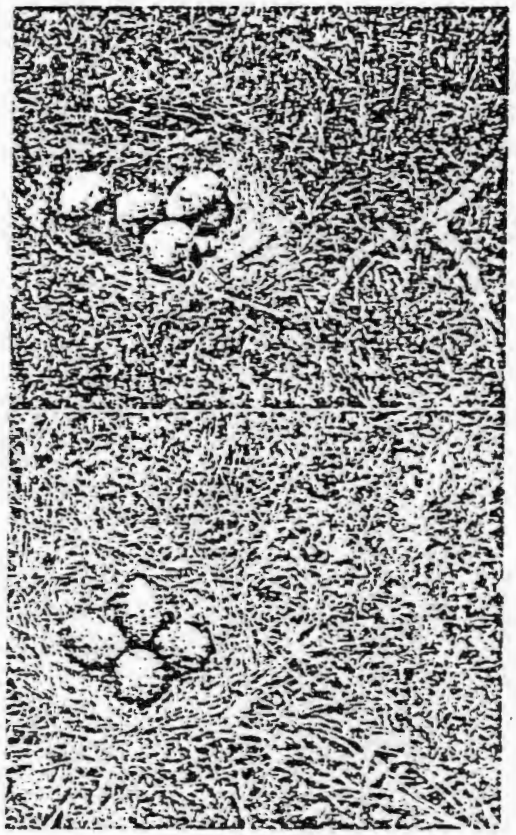

FIG. 21. Nests of long-billed curlews with complete clutches. Upper, Proximity to a conspicuous object; Lower, Usual arrangement of eggs.

and a minimum laying period of 5 days. Forsythe (1970) observed egg laying at 2-day intervals.

Clutch Size and Egg Description

All nests in which incubation was initiated contained 4 eggs (Fig. 21). That is the number reported as the usual clutch size for long-billed curlews (e.g., Bent 1962, Sugden 1933, Wolf 1931).

The eggs are well described in the literature from the early 1900s when oology was popular (e.g., Bent 1962, Shufeldt 1913). Those descriptions indicate a considerable variation in shape, prevailing ground color, and spotting. I also found that to be true, though most of the eggs had either a light beige or a pale bluish-green ground color with chocolate colored markings. The dark markings can be bold, large blotches or fine, small specks, or mixtures of the 2 (Fig. 22). However, unlike what Bent (1962) reported, there was a tendency for the markings to be heavier and more numerous at the big end of the egg. I have no evidence that individual females tend to lay eggs with a distinctive pattern, and single clutches contained eggs that had both ground colors.

Two eggs weighed soon after laying weighed 73 and 71 g. Table 7 summarizes the egg weights from 4 clutches and groups them by week.

Egg Losses and Renesting Attempts

Coyotes and black-billed magpies *Pica pica* were the major predators and were particularly adept at locating nests, especially if I had previously approached the nests. Ravens and Pacific gopher snakes *Pituophis melanoleucus catenifer* were probably next in importance; badgers *Taxidea taxis* may also have been effectual.

If the nest is located by a ground predator, the birds' initial response is Demonstration, followed by displacement feeding some distance away while calling a rapid "Whee-whee-wheet." No attempt is made to drive the predator away from the nest. Flying threats are directed toward avian predators that enter the territory, and a curlew will not hesitate to drive a black-billed magpie or a raven away from the nest should it be located. If a black-billed magpie pecks one of the eggs in the nest, the curlews abandon the entire clutch (4 observations), but as a raven may fly away from the nest site with an egg (2 observations), possibly the curlews continue to attend any that are left behind. Pacific gopher snakes are common on the Hanford Site, and in the sandhills region of Nebraska, bullsnakes *Pituophis melanoleucus sayi* are a major predator and raid nests for the eggs of

birds like the American avocet and the long-billed curlew (Tremaine 1975). Consequently, though I have never actually observed such, I suspect Pacific gopher snakes are predators on the curlew nests at Hanford. Their impact, however, is difficult to ascertain.

If eggshells remain in the nest after it has been destroyed, as usually is the case following predation by a black-billed magpie, the female curlew will often remove them in the same manner as shells are removed following hatching (see Hatching). An aberrant form of shell removal is also often displayed in which the female picks up and crushes the shells between her mandibles, dropping the fragments in and around the nest.

In 1977, 5 nests that had been located during the egg laying period were destroyed prior to the onset of incubation. Three of those losses were attributed to coyotes and 2 to black-billed magpies. Only 2 nests were found during that period in 1976 and both were destroyed by black-billed magpies.

Long-billed curlews do not appear to renest once their first attempt has been thwarted. However, I did observe 1 female lay 1 egg in a second scrape following the destruction of the nest by a black-billed magpie. The nest contained only 1 egg at the time of destruction, which was presumably the first one laid. The egg laid in the scrape was also pecked by a black-billed magpie and no further laying attempts were observed.

INCUBATION

The incubation period for the long-billed curlew has been reported once by Graul (1971) as 27 days and 14 hours (±9 hours) between the laying and hatching of the last egg. As the start of incubation was unknown for all the successful nests I observed, I was unable to verify those data.

Observations at 2 nests indicate that the male initiates incubation on the morning following the laying of the last egg. Both male and female long-billed

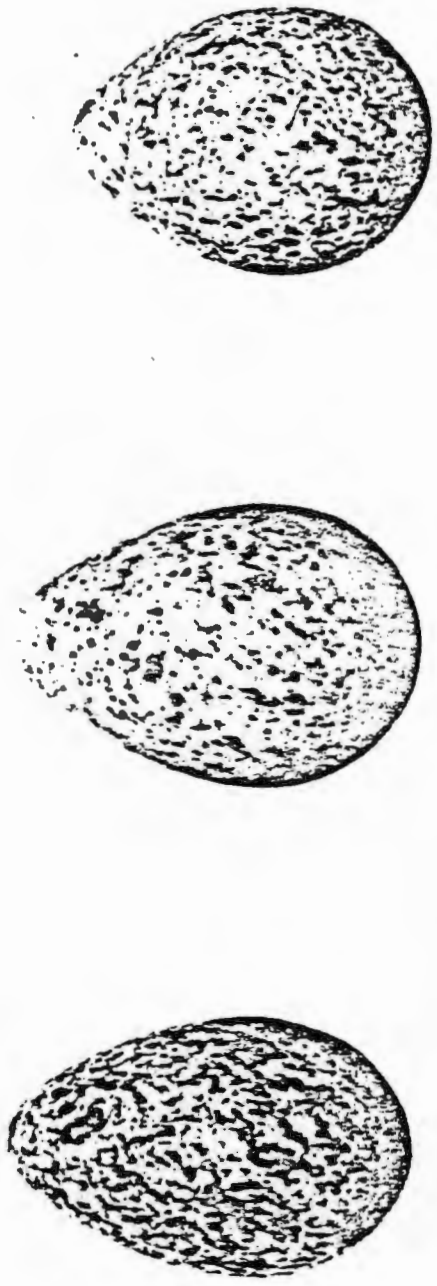

FIG. 22. Examples of eggs of the long-billed curlew showing variation in shape and markings.

FIG. 23. Normal incubation posture of the long-billed curlew.

curlews share in incubation duties, but it takes a day or 2 for them to establish a routine of nest relief where the female sits during the day and the male sits at night. Prior to that time, they may exchange places several times during the day, and the male may actually incubate more than the female. On 1 occasion during that early adjustment period, a female was observed to supplant the male from the nest by performing Wing-Raising. Also during those first few days, the birds tend to fly off the nest at the slightest disturbance. Once the incubation phase is underway in an area, the fields are much quieter and only the unpaired males and transient individuals participate in exchanging Whistles at dawn. The birds remain relatively quiet unless disturbed.

Behavior

The normal daytime incubation posture is an alert, head up position (Fig. 23). During inclement weather, however, the incubating bird modifies its posture and sits with its head low, often below the level of the grass. Birds using that low posture frequently raise their heads up, look around, then sink back down. In the evening, just before dusk, the male ducks his head presumably in that same low position. I was unable to observe the birds at night but assume the male remained low on the nest throughout. Shortly after dawn, the male may slowly raise his head and assume the normal head up position used during the day, or he may remain low on the nest until relieved by the female, popping his head up in response to her calls. In hot weather, the attending bird sits with head held high and pants.

During the day, the incubating adult adds nest material to the rim of the bowl in an idle manner, though such activity is sometimes more pronounced at nest relief time. The incubating bird also frequently repositions itself to face a different direction on the nest. Sometimes the bird accomplishes that by nestling around while remaining seated on the nest. More commonly, the bird rises, pokes in the bowl with its bill (presumably to rearrange or rotate the eggs), and then turns to face a different direction. Occasionally, the breast feathers are preened at that time. Sitting down again however, usually is protracted as the bird repeatedly attempts to settle over the eggs. The incubating bird usually is quiet, though Whistling from the nest is common at nest-relief time (see below). Whistles are also occasionally exchanged between neighbors, and a sitting bird will Whistle at a trespassing curlew if its mate is not present to defend the territory.

To rise from the eggs, the incubating bird tips forward onto its breast bringing its legs up behind, then pushes itself up and back with the tip of the bill until the feet are regained. When settling onto the eggs, the bird first lowers itself onto the breast with the wings slightly away from the body. The rear is then lowered as the bird simultaneously squirms into position and adjusts the wings individually.

During the day when the female is incubating, the male may or may not be present on the territory. Some males leave for only 1–2 hours, spending most of the day feeding within the territory, while others are gone until nest relief time and leave the female to fend for herself. When the female is relieved in the afternoon or evening, she usually leaves immediately for the river or another feeding area and does not return until dusk.

TABLE 2.—EGG WEIGHTS (G) OF LONG-BILLED CURLEWS AT VARIOUS STAGES IN INCUBATION,[1] HANFORD SITE, SOUTHEASTERN WASHINGTON

Egg	First week	Second[2] week	Third week	Pipping
Clutch A				
1	68	64, 65	63	
2	66	62, 64	63	
3	66	64, 63	64	
4	68	64, 64	64	
Clutch B				
1		74, 71	67	66
2		70, 68	64	64
3		70, 68	63	63
4		73, 71	67	67
Clutch C				
1		63	59	58
2		65	61	60
3		65	61	61
4		64	62	59
Clutch D				
1			67	61
2			60	58
3			62	58
4			65	62
Mean ± SE	67.0 ± 0.58	66.6 ± 0.82	63.3 ± 0.61	61.4 ± 0.89

[1] Weights are grouped by week of incubation calculated by backdating.
[2] Clutches A and B were weighed twice during the second week.

[illegible] departs again in the morning before [illegible] to incubate for the rest of the [illegible]

Nest Relief

Nest relief occurs about the same time each day for any given pair unless the birds are disturbed. For example, nest relief by one pair was delayed 2 hours one morning because a Swainson's hawk *Buteo swainsoni* was perched in a tree near their nest. The female curlew wandered up and down the field displacement feeding and watching until the hawk left. The morning exchange period was either between 0500 and 0630 or between 0900 and 1013. Evening exchange periods were not as clearly defined but were observed between 1700 and 1930, although on one very hot day a male was observed to relieve the female at 1343. The female immediately flew to a shady spot between 2 big sagebrushes and rested there for 20 min before departing.

Typically, at changeover time the incoming bird flies into the nest field and Whistles as it alights. The incubating bird answers the call with a Whistle from the nest. The incoming bird then walks or flies to within about 15 m of the nest. The incubating individual flies directly off the nest as its mate approaches, and lands elsewhere in the field. Departure from the nest is generally in the same direction each time, and on 1 occasion a male was observed to rotate 180° on the nest before flying off. The incoming bird approaches the nest along a particular route and settles over the eggs. The eggs usually are left exposed for less then 60 sec. However, a disturbance at that time will cause the relieving bird to delay its approach, and in hot weather that could kill the embryos. The bird that has been relieved preens its breast feathers and

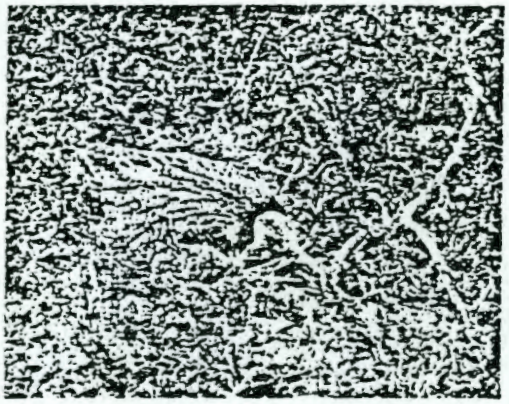

FIG. 24. Incubating long-billed curlew concealing on nest.

stretches its wings with a Two-wing Stretch or a Two-wing Flap before beginning another activity. On 1 occasion, a male preened, then flew very rapidly low to the ground around a small area, swooping up and down while tipping from side to side as if chasing butterflies. I could not resist the thought that the male's extraordinary behavior was a result of pure delight at being freed from the nest even though he was probably only stretching cramped muscles.

Responses to Disturbances

Responses to Human Intruders

Responses to human intruders are described separately from other disturbances because I did not observe other ground predators approach nest sites, though I presume the responses are similar.

If a human enters a nest field when the nonincubating bird is nearby, the nonincubating bird assumes an Alert-Attitude and usually gives the Chirping and/or "Wheet Wheet Wheet" call. If the intruder does not leave immediately, Demonstration interspersed with displacement feeding and the Alert-Attitude ensues, and sometimes the Enticement-Run is performed. As the intruder approaches within 10–15 m of the nest, the nonincubating bird ceases with those displays and stands or displacement feeds, calling a soft, rapid "Whee-whee-wheet" or "Curlee Curlee."

The bird on the nest maintains normal incubation posture even when its mate or neighboring birds are Chirping. It assumes a concealing posture, lying motionless as tight to the ground as possible with the bill resting on the ground (Fig. 24), only after the intruder comes within sight or its mate flies up nearby calling "Curlee Curlee." As long as the intruder is a potential threat to the nest, the incubating bird maintains that posture and the nonincubating partner continues calling. When no further calls are heard from the nonincubating partner or it Whistles an "all clear," the sitting bird slowly raises its head and looks around. If the nonincubating mate is not present when an intruder appears, the bird on the nest may remain low for half an hour or more after the intruder has gone before slowly rising up. I commonly observed such delays following my approach to a blind though eventually some birds habituated to my routine and would pop their heads up within minutes after my disappearance into the blind.

Incubating females usually do not flush when approached unless the intruder comes within about 2 m. The males, however, sometimes vacate the nest before an intruder is close enough to locate it. Several authors (e.g., Graul 1971, Sugden 1933, Wolf 1931) have touted their ability to approach an incubating bird and stroke it on the back or lift it off the nest, particularly near the end of the incubation period. I was never able to do that and believe the reason was because I originally located the nests by searching the fields and flushing the incubating birds. Once a curlew was flushed from the nest, a sensitivity threshold seemed to be broken and the bird subsequently flushed at the first sign of approaching danger. Such behavior may attract a predator to the site that might otherwise have gone unnoticed.

When flushed from the nest at close range, the incubating bird bursts forth with a loud squawk, then feigns injury for 10–20 m before performing the Enticement-Run and calling "Wheet Wheet." The bird eventually takes flight and, joined by its mate, Demonstration interspersed with the Enticement-Run and displacement feeding is performed. Neighboring birds that are not incubating gather nearby and add their voices to the ruckus.

Once the intruder has departed, the attending bird often takes up to an hour to settle back on the nest. During that time, the bird preens or feeds and may return to the nest several times to inspect the contents. The bird may settle over the eggs, then fly off again a few minutes later only to wander back and resettle. That period is crucial for the eggs during hot weather. The male often returns to the nest first even when it is not his turn to incubate, and if the disturbance occurred in the middle or late afternoon he usually remains on the nest through the night. If the disturbance occurred in the morning, the female usually relieves the male within several hours.

Responses to Other Species

An incubating bird responds to the presence of a potential avian predator (Swainson's hawk, red-tailed hawk *Buteo jamaicensis*, marsh hawk *Circus cyaneus*, ferruginous hawk *Buteo regalis*, great horned owl *Bubo virginianus*, raven) by crouching low on the nest as described previously. The nonincubating bird responds with flying threats (marsh hawks excepted; see below) or performs the Arc Display if the avian predator is perched near the nest.

Cameron (1907) reported seeing nesting curlews make flying attacks on marsh hawks. At the 300 Area study site, a pair of marsh hawks commonly hunted over the dune area and parts of the nearby fields, but the curlews usually ignored them. Black-billed magpies are a persistent threat to nesting long-billed curlews, but a pair can usually keep them from their eggs if not otherwise distracted. An incubating curlew does not conceal in response to a black-billed magpie, but the nonincubating bird will pursue one on the ground with the Crouch-Run, or in flight. Though gulls (*Larus* spp.) routinely fly over the 300 Area study site, they are ignored by the curlews and themselves show no interest in the nesting shorebirds unless a disturbance at a nest site creates a ruckus that then attracts them.

One or 2 coyotes commonly cross through the nesting fields daily, sometimes passing within a few meters of a nest. The incubating bird conceals as the nonincubating bird flies to a vantage point Chirping. The nonincubating bird then displacement preens or displacement feeds while calling "Curlee Curlee" off and on until the coyote departs. Neighboring birds may also fly to vantage points to watch the coyote, calling "Curlee Curlee." When a coyote is passing through an area, its movements are easy to follow merely by listening to the chain of curlew Chirping calls that results as it moves from one territory to another. A Townsend's ground squirrel *Citellus townsendii* was observed once in the vicinity of a long-billed curlew nest but the incubating female showed no aggression even though the squirrel came with 4 m of her.

Responses to Other Disturbances

Airplanes elicit the same response in incubating long-billed curlews as do avian predators, but nonincubating birds assume the Alert-Attitude and cock their heads skyward to watch. If a plane is between 15 and 30 m off the ground, all of the nonattending birds in the area begin calling a loud and shrill "Wheet Wheet," then fly up in alarm. Once the airplane has passed, they return to their fields Whistling as they land, and those on the nests pop their heads up again. Unusual sounds also cause an incubating bird to duck down on the nest, and the whistle

of a nearby train invariably elicited that response.

Nesting Success

Nesting success was good in 1976 (no losses were observed) and poor in 1977. All nests I had located prior to hatching were destroyed by predators, including all but 2 at the 300 Area study site. The success of the predators in 1977 is attributed to insufficient nesting cover that resulted from the dry winter of 1976. Additionally, coyotes were thought to be more abundant in 1977 than in 1976, but that is subjective.

Time-lapse film from 1 nest shows a coyote approaching and eating the eggs. The coyote was originally passing by about 5 m away, but then spotted the concealing curlew and turned to investigate. In a year of normal grass growth, a coyote would be unable to spot a concealing curlew at 5 m.

During the incubation period, coyotes appear to be the major predator, but other potential predators include badgers, Pacific gopher snakes, and black-billed magpies. At 1 nest, trampling by feral horses appeared to be the cause of destruction, but such damage may be offset by the benefits gained from grazing during years of overabundant plant growth. No losses by adverse weather were noted.

Behavior Following Nest Loss

Curlews abandon the nest once the eggs are damaged or destroyed. Once a nest is abandoned by a pair, they gradually become less and less responsive to predators and disturbances. The territory is still defended against conspecifics for a week to 10 days following the destruction of the nest, but the birds spend more and more time each day away from it. Finally, they depart and presumably migrate south.

Immediately after the predator leaves the nest, the curlews approach and if any eggshells remain in the nest they are removed. The birds at that point are hypersensitive to any disturbance and direct intensive flying attacks toward potential predators. Demonstration and displacement feeding are performed. Within several hours, the birds begin walking and feeding or rest in the field near the nest. In time, the male begins Ground-Calling and then Scraping and Shaking, all intermixed. Incomplete Scrape Ceremonies and Tossing behavior are also performed; the Bill-Down Display, however, was never observed. The female is not receptive to renewed courting by the male but she does perform Scraping at several different sites of her own. That behavior lasts for up to 3 hours, interspersed with brief periods of maintenance activity and standing around. Eight hours after one nest was destroyed, the pair finally left the nest field and flew toward the river.

HATCHING

Starring of an egg commonly appeared 3 to 4 days prior to hatching, and a hole usually developed 1 to 2 days before the chick emerged. "Clicking" noises from inside the egg were heard in pipped eggs up to 53 hours prior to hatching.

Forsythe (1967) described the hatching of the long-billed curlew. He observed that the pip hole was started approximately one-third the distance from the large end of the egg, then was progressively enlarged until the chick pushed out the large end and emerged by splitting the remaining shell into 3 roughly triangular pieces. I did not observe the complete hatching process, but did find the pip hole to be started as he described (Fig. 25). I also collected several shells as soon as the chicks were free. In each, about half of the large end and one side were missing whereas the rest of the shell was intact, indicating a slightly different method from that Forsythe found.

Presumably, the eggs were rotated throughout incubation as a result of pok-

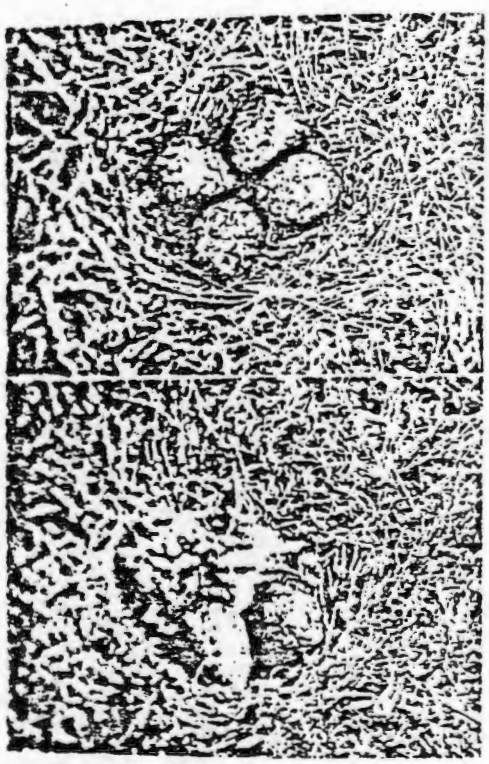

Fig. 23. Hatching of long-billed curlew chicks. Upper, Pipping; Lower, Downy chick.

[illegible] and shuffling by the adult bird, but during hatching they maintained a relatively stable position, usually with the [illegible] area upward. This would seem advantageous, making it easier for the chicks to switch to air breathing.

Hatching usually was synchronous within a nest, all the chicks being hatched within 5 hours, and seemed to occur at any hour of the day or night. Hatching was also synchronous within an area, unlike what Forsythe (1970) observed in Utah. In 1976, hatching on the 100 Area study site was 11–14 May (5 nests), at the 100-H/100-D Area it was 25 May to 2 June (4 nests).

Behavior

Long-billed curlews, like many other birds, become especially attentive at hatching time and both members of the pair remain present once the eggs are starred. Once hatching had actually begun, the female appeared to assume all incubation duties as she was invariably on the nest when checks were made, even at dawn when previously the male was in attendance. During hatching, however, it was not unusual to find both adults off the nest for short periods of time for reasons I was unable to ascertain.

Responses to Intruders

Hatching of the young seems to elicit a protective response in the adults that is not seen previous to that time. Arc Displays are directed at human intruders as are Demonstration and Enticement-Run displays, and, therefore, presumably at other ground predators as well. Avian predators that fly over or perch within the territory are confronted with the same flying threats, and marsh hawks are attacked at that stage for the first time. Conspecifics attracted to the site join the ruckus though do not perform the Enticement-Run or the Arc Display. If the nest has not been disturbed on previous occasions, the female remains concealed over the eggs during the male's displays unless discovered; then she too Demonstrates and performs the Enticement-Run. As soon as the intruder retreats, she or the male returns to the nest immediately.

Eggshell Removal

Adults remove eggshells soon after hatching by grasping them in the bill and flying several hundred meters before alighting and dropping them. Each shell is dropped in a different spot and not always in the same direction from the nest. Graul (1971) observed the male (short-billed individual) perform that function. At 2 nests where I observed the behavior, the females removed the shells.

FIG. 26. Brooding posture of the long-billed curlew.

Chick Behavior

Chicks generally dry out completely within 3 hours of hatching but even before they are dry they begin to toddle out of the nest alone, resting in the grass and returning to be brooded for short periods. Within a few hours, coordination of the young improves substantially, and those that hatch first often wander too far from the nest before the others are ready and become lost. At 2 sites, I was unable to find the first hatched chick within a 10-m radius of the nest. Newly hatched chicks do not follow or respond well to the calls of the adults, and once mobile may run from the nest when there is a disturbance instead of concealing. Upon approaching a nest soon after hatching, I would usually find the chicks resting in or just outside the bowl. When handled, the chicks would often cry in distress, giving the "Squee" call which would throw the adults into a frenzy of displays at close quarters. One chick called "Peep Peep" and "Hee-who" while resting in the nest prior to being banded. During the first 24 hours, the chicks slowly peck at the ground and at various objects and appear to start feeding by the second day.

BROOD PERIOD

Nest Departure

If the last chick hatches in the morning or very early afternoon and the weather is favorable, the entire brood is likely to leave the nest that afternoon. If the last chick hatches later in the afternoon or evening, the brood usually stays at the nest until the following day, leaving about midmorning when the temperature has risen sufficiently for the chicks not to require brooding. In rainy or cool weather, the brood may stay in the nest for up to 24 hours (1 observation). If the site is disturbed during hatching, the chicks are moved away from the nest prematurely, often before the youngest are fully mobile.

At the time of departure, the male stands watch some distance away in the direction they intend to move as the female gives a low call while standing near the nest. At the 300 Area study site, the chicks were moved directly to the south ridge area (Fig. 19), and the male took up a position on top of the first ridge overlooking the field and the rest of the ridge area. Normally, the chicks return and are brooded at the nest site at night for several days following the hatching and the site is defended during that time (M. M. Tremaine, 1976 pers. comm.).

Brooding

Brooding is accomplished by the same posture used in incubation or by the adult standing with the wings dropped down with the young standing beneath (Fig. 26). Young are brooded regularly at different times during their first few days by both sexes, particularly during the cool early morning hours. I do not know the age of the young when brooding terminated, but I never observed chicks being brooded after they were about 2 weeks old.

Behavior

Shading

The chicks spend most of their time walking and feeding even during the heat of the day, though when small they frequently rest for short periods in the

shade of a shrub or a large forb. Sometimes the chicks crawl up into such plants, presumably gaining the additional advantage of the cooling effect of the wind. I never observed adults shading their chicks, but on the Hanford Site the chick rearing areas all include plant species large enough to provide shade so adult shading is not necessary. The adults also seek shade during the heat of the day, but one bird always maintains a lookout.

Brood Movements

Long-billed curlew family units do not keep together the way some other shorebirds do, e.g., killdeer *Charadrius vociferus*. The chicks wander independently and often become widely separated. The older they get, the more independent the chicks become and the farther apart they wander. One juvenile of about 3 weeks of age was found approximately 563 m from its parents and a sibling. On another occasion, the 2 chicks in that same brood were separated by approximately 305 m. One parent was with each chick and neither could see the other. The adults can determine the general direction of travel by the male flying 50–100 m ahead and disturbing, while the chicks and the female wander towards him walking and feeding. If the chicks are wandering in the preferred direction on their own, the adults may merely follow along behind them. If the adults remain in 1 localized area, the chicks will center their activities there but may range 100 m out and back.

The adults maintain a close watch, usually 50–100 m apart with the chicks somewhere in between. Daily brood movements were of 2 patterns, presumably a function of the habitat available. At the 300 Area study site, the chicks were moved from the fields into the south ridge area, where at first they were found in different locations each day. Then sometime within the first 2 weeks, chick rearing areas were selected and each brood could be found daily in 1 specific area. Detailed observations were not made on broods in the south ridge area because the topography and vegetation inhibited sightings. At the 100-H/100-D and 100-F study sites, the broods followed a daily routine of moving toward the river from their nest area in the early morning, feeding in the fields along the bluffs during the day, and then heading back toward their nest area in the late afternoon and evening. The chicks and adults would then roost for the night in or near their nest area.

FIG. 27. Male long-billed curlew perching in shrub.

Perching

Long-billed curlews commonly alight in big sagebrush, antelope bitterbrush, trees, or on top of dried tumbleweeds, dirt mounds, rocks, stumps, fence posts, utility poles, rails, etc. (Fig. 27). Silloway (1909) discovered a male curlew that used a solitary fence post as a vantage point for guarding his home. Though that behavior may be seen at any time during the breeding season, it is particularly ad-

vantageous during the brooding period when the adults are protecting their flightless young. At the 300 Area study site where the chicks are reared in shrub vegetation that averages about 1.2 m high, the adults cannot possibly spot intruders at a distance while standing on the ground. Hence, at least 1 adult perches in the top of a suitably tall shrub. Occasionally, a bird was observed to assume a bill-back resting posture while perched in a shrub, but that may have been a displacement activity. In chick rearing areas where shrubs are not predominant, the adults perch on whatever is available. Those areas along the Columbia River have scattered trees and I have seen curlews land in them as high as 8 m off the ground when disturbed by an intruder. From such vantage points, the parent curlews keep close watch over the fields until all danger has passed.

The birds touch down gracefully when alighting above ground and the wings are fluttered overhead until balance is obtained. Sometimes it is a rather lengthy process if the branches of a particular bush are flimsy and the weight of the bird is too great for them. Some birds are often persistent and keep trying for several minutes, breaking numerous branches before selecting another perching site.

Roosting

The chicks are still downy when they are no longer brooded at night. They continue walking and feeding after sundown until the female calls them with the "Wheet" call toward the roosting area. Soon after sundown, the male flies from the field but I was never able to observe where he went. At twilight, each chick disappears into the grass while the female stands alert. At dark, she flies low across the field and also disappears. I made 1 observation of chick behavior on the first night following their abandonment by the female. The chicks were alone with the male and 15 min after sundown began to follow after him. The male responded by flying from place to place around the field as the chicks ran first one way and then another in an attempt to keep up, but the male always landed too far away. Finally, it got so dark I could no longer see the chicks and presumably they sat down in the grass.

Feeding

The chicks walk and feed in a manner similar to the adults except that they more frequently run after insects and probing was not observed. They pay particular attention to Munro globe-mallow plants when they are available, poking among the foliage and tugging at the leaves.

Flapping-Jump

The downy young were frequently observed to perform a movement I have termed the Flapping-Jump, in which they would make short dashes, simultaneously flapping their wings and jumping up and down as if attempting to fly. The behavior occurred when the chicks were crossing an open area such as a road, and each chick in turn would do the Flapping-Jump for a few seconds before going on.

Fledging

The females usually abandon their broods when the chicks are 2 to 3 weeks old, though it is not unusual for 1 to remain until fledging. After the females depart, only the males care for the chicks. Two young broods were found in which only the female was caring for the chicks and in those cases the male had presumably been killed.

About 31 days after hatching, the juveniles and attending adult(s) change their daily routine and begin moving cross country away from their nesting area. The feather development of chicks of known ages captured prior to that wandering period appeared to be within 18

to 11 days of completion. On that basis, long-billed curlews fledge at 41–45 days. Watson (1972) reported that Eurasian curlews fledge in 35–42 days.

Once the birds start moving they may travel over 2 km a day, and tracking them through the shrubby areas to make observations was not feasible since the adults at that stage no longer fly up at the first sign of disturbance. As a result, I have no data for that period and was not able to watch the process of "learning" to fly. However, on 21 July, I watched 1 juvenile flying from the Columbia River after loafing for several hours on an island. A strong breeze was blowing and the bird had considerable difficulty making headway, but eventually it was able to land on top of the bluffs above the river. After resting for 7 min, the bird again took off and with great difficulty disappeared over the horizon headed northeast. An adult bird could have easily negotiated the climb over the bluffs in even a strong wind.

Territoriality

Pairs with young spend a considerable amount of time evicting other long-billed curlews from the vicinity of the chicks. The area defended by the parents, however, is a minimum distance from the chicks themselves rather than the entire "territory" as was the case prior to hatching. Therefore, as the chicks move so does the area defended. The interactions with conspecifics usually are mild but violent encounters are also common.

The interlopers become increasingly problematic through June. Their numbers increase as do the size of the groups as these birds without chicks are flocking, and migrants from other areas start to arrive. In the late afternoon and evening, they move into the fields to feed and roost for the night. They appear to be attracted by the presence of other curlews and usually try to land with the parent birds and their young. Commonly, such intruders are very persistent and hesitate to leave, resulting in prolonged Appeasement-Run behavior. If a group flies in and lands near the chicks, the male or female threatens or pecks each bird one at a time and often repeatedly before the entire group departs. The chicks appear not to be bothered by the adult interactions and ignore the intruders.

Responses to Disturbances

At the first sign of approaching danger, adults with a newly hatched brood give a mixed series of Chirping, "Curlee Curlee," and "Wheet Wheet" calls. Demonstration is then performed by the female while the male remains with the chicks, though flying to a vantage point. If the intruder continues to approach, then the male also Demonstrates, and sometimes the Enticement-Run is performed. The Arc Display is performed if the intruder is very close to the young; e.g., when a human is searching for the chicks.

When an avian predator flies over the chick rearing area, the adults pursue it intensely. Occasionally, a raptor will perch near the chicks or will be perched in an area where the adults are trying to take the chicks. In such situations, the adult curlews repeatedly perform the Arc Display. On 2 occasions, I observed parent curlews flying at a perched red-tailed hawk for over 35 min. Perching raptors, however, rarely appear to be annoyed by the aerial displays of long-billed curlews, and ultimately the curlews resort to chick removal as a solution.

The chicks usually do not conceal promptly in response to the adult alarm calls, but they do conceal if both adults leave the immediate area. Their cryptic coloration serves them well as they crouch flat and motionless on the ground (Fig. 28), making them difficult to locate. The adults call them up with a soft "Wheet" call when the danger has passed.

As the chicks get older, they wait to conceal until they actually see the intrud-

FIG. 28. Long-billed curlew chick concealing.

er approaching. Also, those older more experienced chicks tend to hide when possible with at least the head under a shrub or forb, this often involving a run to a suitable point. As they run, they turn their heads to watch the intruder and hold their wings out to the side. I located a chick that had crawled into a small depression, covered with grass and broken Jim Hill mustard stems. Another was located 13 cm off the ground in a big sagebrush. Corresponding roughly with the change in chick behavior, long-billed curlew adults gradually stop performing threat displays and give only alarm calls in response to disturbances.

The older the chicks get, the more they run before concealing, and often I could approach within 10 m before losing sight of them. Chicks within 1–2 weeks of fledging would conceal, then just as I was reaching for them they would jump up and take off running. Once in hand, the chick would give a call similar to the adult "Guaah" call.

When a chick is first captured by a human, the adults Demonstrate and perform the Arc Display. After the chick has been in hand for several minutes, it usually ceases to give its alarm note and the adults displacement feed or assume the Alert-Attitude nearby. As soon as the chick is released the adults begin again with their Demonstrations. The chick runs away: younger ones usually conceal in the nearest shrub if one is available; older ones run until they are out of sight of the intruder. The adults fly to a vantage point and keep watch until the intruder has departed.

Accidents, Injuries, and Mortality

Two fledglings were involved in collisions with man-made structures. One was found dead, presumably having flown into a utility wire. The other was found stunned after an apparent collision with a car; it recovered and was released.

Three chicks were captured that were suffering from some kind of injury. The first was about a week old and had a fractured tibiotarsus. The chick was found in an emaciated condition and died within 2 hours. The second was 2–3 weeks old and had 2 cheatgrass florets lodged in 1 eye. The eye was completely closed, but after I removed the florets the bird was able to partially open it. The eye appeared normal when the same chick was recaptured 1 week later. The third case involved a 4–5 -week-old chick. It had an unidentified grass floret embedded in the feather shaft of 1 primary, and that primary had not emerged as fully as the others. I removed the floret before releasing the bird.

Mortality is highest in chicks under 1 week of age and seems to level off after that. A very unusual situation is to see a pair of adults with more than 2 young in their care and most adults have none. The chicks are lost most frequently at night when observations are made with difficulty.

Many of the causes of chick mortality are uncertain, but predation is no doubt partly responsible. R. E. Fitzner (1977, Research Scientist, Battelle, Pacific Northwest Laboratories, Richland, Washington 99352, pers. comm.) found the remains of 1 downy chick and 1 adult at a Swainson's hawk nest, feathers from 3 juvenile or adult birds in ferruginous hawk castings, and feathers from 1 juvenile or adult bird in a great horned owl casting. I saw a black-billed magpie carry off 1 chick that was less then 24 hours old. I

suspect coyotes are of primary concern, though I never actually saw one take a chick.

Some chicks may perish early by wandering too far from the nest too soon or by not being able to keep up with the adults and other brood members. A disturbance at hatching time resulting in chick removal most certainly increases chick losses in this way. One chick less than 2 days old was found dead in a nest field, presumably of exposure. Exposure during the heat of the day or at night may cause mortality.

Adverse weather conditions are undoubtedly stressful for the chicks. The nights are still cool when the chicks are downy and June is wet and windy. I have watched chicks walking and feeding for hours at a time in a high wind while it rained continuously. Cold, wet, windy nights must certainly take their toll. The wind also poses a problem for the adults when a predator approaches because they cannot fly at it effectively.

Many broods are still on the ground after the flocking phase is well underway. Those chicks that hatch late in May will still be downy after the bulk of the adults has departed, and that absence of conspecifics which would otherwise provide additional eyes and ears to guard against predators may also contribute to chick mortality.

In 1976, no estimate of fledging success was made. In 1977, 9 juveniles remained along the river after the main congregation of long-billed curlews from the Hanford Site and the Wahluke Slope had departed. I was unable to estimate age or ascertain the sex of the birds at the staging area because the staging island is too distant from the mainland.

STAGING AND DEPARTURE

Staging and departure were not observed in 1976. In 1977, the first small flocks were observed in the fields in early June.

Flocks spend the heat of the day resting in fields or loafing on the upstream tips of islands in the Columbia River. A spit on the south side of Island 3 between 100-H and 100-D Areas serves as the primary loafing and staging area for curlews from the Hanford Site and the Wahluke Slope.

Birds usually arrive at Island 3 in the morning between 1000 and noon. They arrive singly or in groups, some of which include up to 100 birds by mid-June. Time on the island is spent resting, preening, and occasionally bathing. The majority of the birds remain at the site until late afternoon or evening, usually leaving between 1600 and 1800; all are gone by 2000.

As the daily departure time grows near, "Wheet Wheet Wheet" calls and bouts of Two-wing Flap movements ripple through the flock. The birds become more restless, shifting about calling "Wheet Wheet Wheet," and groups begin to leave for the fields where they roost for the night.

Each group leaves in a flurry of Two-wing Flap behavior. A few birds lift off first, calling "Wheet Wheet Wheet," and are joined immediately by others. Their flight is erratic as they are buffeted by the wind, but eventually they rise up and fly away in strong, even flight though in no particular formation. Often shortly after taking off, individuals were observed to dive straight down, twisting back and forth, then to swoop up just before hitting the water as if they were playing in the wind.

The curlews apparently can identify the other birds that roost in their area because each group lifts off together and heads in a particular direction. When several groups leave simultaneously there doesn't seem to be any confusion among group members as to which way to go or with whom. However, when a group initiates its departure, other birds may also fly up to join them but then return to the flock.

As the flocking phase progresses, the birds arrive earlier and leave later each day; the flocks also become larger. A peak population of approximately 250 birds

was present on 17 June, following which their numbers decreased to merely a few stragglers by the end of the month. In July, only a small group of juveniles was present.

During that period of flock reduction, groups of up to 30 birds were observed to leave Island 3 at the usual daily departure time, but instead of heading out in one particular direction they began milling around over a nearby field, calling "Wheet Wheet Wheet" continuously as they spiraled upwards. I watched those groups through binoculars until they went up so high that I could no longer see them. Presumably those birds migrated from the Hanford Site and southeastern Washington.

A CURLEW'S FAREWELL

I tried but I can try no more
  I cried but I can cry no more
I failed to bring a young chick's cry
  Into this world.

Time now bids me say farewell
  The sun is setting and I must go
But I will come again next year . . .
  and try
  Until I die.

9 2 1 2 4 9 3 2 1 1 8

LITERATURE CITED

ALLEN, A. A., AND H. KYLLINGSTAD. 1949. The eggs and young of the bristle-thighed curlew. Auk 66:343–350.

AMERICAN ORNITHOLOGISTS' UNION. 1957. Check-list of North American birds. Fifth Ed. Port City Press, Baltimore, Md.

BAILEY, F. M. 1904. Handbook of birds of the western United States. Houghton, Mifflin and Co., Boston, Mass. Pp. 101–102.

BENT, A. C. 1907. Summer birds of southwestern Saskatchewan. Auk 24:407–430.

———. 1962. Life histories of North American shorebirds. Dover Publications, Inc., New York, N.Y. Pp. 97–109.

BISHOP, L. B. 1910. Subspecies of North American birds. Auk 27:59–63.

BROOKS, A. 1920. Notes on the Limicolae of southern British Columbia. Condor 22:26–32.

BURTON, J. K. 1974. Feeding and the feeding apparatus in waders: A study of anatomy and adaptations in the Charadrii. Brit. Mus. Nat. Hist., London, Eng.

BYSTRAK, D. (ED.). 1974. Wintering areas of bird species potentially hazardous to aircraft. Natl. Audubon Soc., Inc., New York, N.Y.

CAMERON, E. S. 1907. The birds of Custer and Dawson counties, Montana. Auk 24:241–270.

CAMPBELL, R. W. 1972. Coastal records of the long-billed curlew for British Columbia. Can. Field-Nat. 86:167–168.

CLINE, J. F., D. W. URESK, AND W. H. RICKARD. 1975. Characterization of plant communities adjacent to the B. C. Cribs controlled area and Redox Pond areas on the 200 Area plateau. BNWL-1916, Battelle, Pacific Northwest Laboratories, Richland, Wash.

COLE, T., AND R. S. SHARPE. 1976. The effects of grazing management on a sandhills prairie community. III. Breeding bird density and diversity. Proc. Nebr. Acad. Sci. Affil. Soc. 86:12.

DAUBENMIRE, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Sci. 33:43–64.

DAWSON, W. L. 1909. The birds of Washington. Occidental Publ. Co., Seattle, Wash. Pp. 680–682.

DICE, L. R. 1918. The birds of Walla Walla and Columbia counties, southeastern Washington. Auk 35:40–51.

FERRY, J. F. 1910. Birds observed in Saskatchewan during the summer of 1909. Auk 27:185–204.

FITZNER, R. E. 1977. Time-lapse photography for field studies of raptorial birds. *In* J. T. Kitchings and N. E. Tarr (Eds.). Natl. Environmental Research Park Symp.: natural resource inventory, characterization, and analysis. ORNL-5304, Oak Ridge Natl. Lab., Oak Ridge, Tenn.

FORSYTHE, D. M. 1967. Egg teeth and hatching methods of the long-billed curlew. Wilson Bull. 79:340–341.

———. 1970. Vocalizations of the long-billed curlew. Condor 72:213–224.

———. 1971. Clicking in the egg young of the long-billed Curlew. Wilson Bull. 83:441–442.

———. 1972. Long-billed curlew with supernumerary hallux. Auk 89:457.

———. 1973. Growth and development of long-billed curlew chicks. Auk 90:435–438.

GOSS-CUSTARD, J. D., AND R. E. JONES. 1976. The diets of redshank and curlew. Bird Study 23:233–243.

GRAUL, W. D. 1971. Observations at a long-billed curlew nest. Auk 88:182–184.

GRINNELL, J. 1921. Concerning the status of the supposed two races of the long-billed curlew. Condor 23:21–27.

———, AND R. HUNT. 1929. Notes on water birds at Morro Bay, California. Condor 31:62–73.

GRISCOM, L. 1939. Long-billed curlew in Massachusetts. Auk 56:332–333.

HALL, E. R., AND K. R. KELSON. 1959. The mammals of North America. Ronald Press Co., New York, N.Y.

HAMILTON, R. B. 1975. Comparative behavior of the American avocet and the black-necked stilt (Recurvirostridae). Ornithol. Monogr. 17:1–9.

HIBBERT-WARE, A., AND R. F. RUTTLEDGE. 194[illegible]. A study of the inland food habits of the common curlew. Brit. Birds 38:22–27.

HITCHCOCK, C. L., AND A. CRONQUIST. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle, Wash.

IVERSEN, E. 1976. On the brink of extinction. Texas Parks Wild. March:24–26.

LAFAVE, L. D. 1954. Breeding of northern long-billed curlews at Sprague Lake. Murrelet 53:48.

LITTLEFIELD, C. D. 1973. Bird arrival dates on Malheur National Wildlife Refuge, Oregon. Western Birds 4:33–38.

MANOLIS, T., AND G. V. TANGREN. 1975. Shorebirds of the Sacramento Valley, California. Western Birds 6:45–54.

MCCALLUM, D. A., W. D. GRAUL, AND R. ZACCAGNINI. 1977. The status of the long-billed curlew in Montana. Auk 94:599–601.

MCCASKIE, G. 1970. Shorebird and waterbird use of the Salton Sea. Calif. Fish Game 56:87–[illegible].

MILLER, R. G., JR. 1966. Simultaneous statistical inference. McGraw-Hill Book Co., New York, N.Y.

OBERHOLSER, H. C. 1918. Notes on the subspecies of *Numenius americanus* Bechstein. Auk 35:188–195.

PALMER, R. S. 1967. The shorebirds of North America Vol. III. Pp. 183–184. *In* G. D. Stout (Ed.). The shorebirds of North America. Viking Press, New York, N.Y.

PETTINGILL, O. S., JR. 1968. An uncommon gathering of stateside shorebirds. Audubon 70:6–17.

RIDGWAY, R. 1919. The birds of North and Middle America. U.S. Natl. Mus. Bull. 50:390–395.

SADLER, D. A. R., AND W. J. MAHER. 1976. Notes on the long-billed curlew in Saskatchewan. Auk 93:382–384.

[illegible], R. H., AND S. L. OWZARSKI. 1979. Collection and analysis of vegetative cover data. PNL-[illegible], Pacific Northwest Laboratory, Richland, Wash.

[illegible], R. W. 1913. An introduction to the study of the eggs of the North American Limicolae. Condor 15:138–151.

[illegible], P. M. 1902. Some experiences of 1901. Condor 4:11–14.

[illegible] 1959. A problem in indeterminates. Condor [illegible]

[illegible], K. E. L. 1955. The nature of the predator attitudes of waders toward humans; with special reference to the role of the aggressive-, escape-, and brooding-drives. Behaviour 8:130–[illegible]

[illegible] 1957. The taxonomic significance of the head scratching methods of birds. Ibis 99:178–[illegible]

[illegible] 1961. Problems of head scratching in birds. Ibis 103a:37–49.

[illegible], R. C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Co., Boston, Mass.

[illegible], L. E., H. R. HUBER, AND G. W. PAGE. [illegible] Feeding behavior and diet of the long-billed curlew and willet. Wilson Bull. 88:314–[illegible]

[illegible], W. 1901. Report of the committee on the protection of North American birds for the year [illegible]. Auk 18:68–78.

[illegible], W. A., D. E. JENNE, AND J. M. THORP. [illegible] Climatography of the Hanford area. BNWL-1605, Battelle, Pacific Northwest Laboratory, Richland, Wash.

[illegible], G. 1860. Water birds. Pp. 245–246. *In* The natural history of Washington Territory and Oregon. Bailliere Brothers, New York, N.Y.

[illegible], J. W. 1933. Range restriction of the long-billed curlew. Condor 35:3–9.

[illegible], P. A. 1934. Birds of Canada. Natl. Mus. Can. Bull. 72:189–190.

[illegible], R. L. 1969. Notes on the long-billed curlew. Auk 86:730–731.

[illegible], M. M. 1973. Life at an avocet nest. Auk [illegible]

U. S. DEPARTMENT OF THE INTERIOR. 1973. Threatened wildlife of the United States. U.S. Fish Wildl. Serv. Res. Publ. 114:204.

[illegible], D. 1972. Birds of moor and mountain. Scottish Academic Press, London, Eng. Pp. 88–[illegible]

[illegible], C. W. 1902. Sickle-billed curlew. Auk [illegible]

[illegible], J. 1969. An approach to the study of ecological relationships among grassland birds. Ornithol. Monogr. 8:1–93.

[illegible], A., AND C. L. BONAPARTE. 1831. American ornithology. Porter and Coates, Philadelphia, Pa. Pp. 320–324.

[illegible], L. R. 1931. The breeding Limicolae of Utah. Condor 33:49–59.

APPENDIX

List of Common and Scientific Names of Plants Mentioned in the Text

GRAMINEAE

- Cheatgrass *Bromus tectorum* L.
- Sandberg's bluegrass *Poa sandbergii* Vasey
- Bluebunch wheatgrass *Agropyron spicatum* (Pursh) Scribn. & Smith
- Sand dropseed *Sporobolus cryptandrus* (Torr.) Gray

POLYGONACEAE

- Buckwheat *Eriogonum* sp. Michx.

CHENOPODIACEAE

- Russian thistle *Salsola kali* L.
- Spiny hopsage *Atriplex spinosa* (Hook.) Collotzi

CRUCIFERAE

- Jim Hill mustard *Sisymbrium altissimum* L.
- Wallflower *Erysimum asperum* (Nutt.) DC.

LEGUMINOSAE

- Lupine *Lupinus* sp. L.

POLEMONIACEAE

- Long-leaf phlox *Phlox longifolia* Nutt.

BORAGINACEAE

- Tarweed fiddleneck *Amsinckia lycopsoides* Lehm.

ONAGRACEAE

- Pale evening primrose *Oenothera pallida* Lindl.

MALVACEAE

- Munro globe-mallow *Sphaeralcea munroana* (Dougl.) Spach

LILIACEAE

- Asparagus *Asparagus officinalis* L.
- Brodiaea *Brodiaea douglasii* Wats.

UMBELLIFERAE

- Desert parsley *Cymopterus terebinthinus* (Hook.) T. & G.

CACTACEAE

- Plains prickly-pear cactus *Opuntia polyacantha* Haw.

ROSACEAE

- Antelope bitterbrush *Purshia tridentata* (Pursh) DC.

COMPOSITAE

- Big sagebrush *Artemisia tridentata* Nutt.
- Gray rabbit-brush *Chrysothamnus nauseosus* (Pall.) Britt.
- Green rabbit-brush *Chrysothamnus viscidiflorus* (Hook.) Nutt.
- Fleabane *Erigeron* sp. L.
- Balsamroot *Balsamorhiza careyana* Gray
- Yarrow *Achillea lanulosa* (Nutt.) Piper