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MOVEMENT AND HABITAT USE BY GREAT BASIN CANADA GOOSE BROODS

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Abstract: We studied movements and habitat use by radio-marked female Great Basin Canada geese (*Branta canadensis moffitti*) and their broods during rearing seasons of 1983 and 1984 on the Columbia River in south-central Washington. Adult female geese used a mean of 8.8 ± 4.4 (SD) km of the Columbia River to raise their broods to fledging. Mean home-range size was 983 ± 822 ha. Movement rates of broods were not significantly influenced by age of goslings or measured weather parameters. Broods were relatively inactive at night and most mobile during late-morning hours. Broods preferred riparian habitats within 5 m of the shoreline over aquatic habitats. A shoreline pasture grazed by cattle was an important foraging habitat to local broods but did not attract broods from surrounding areas. Broods appeared to be most susceptible to human disturbance during the first few weeks following hatching, but older broods were relatively tolerant of repeated human disturbance.

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Because of its importance as a game bird and aesthetic value to nonconsumptive users, Canada geese have been studied extensively (Craven 1981). However, there is little published data available on movement and habitat use by broods from hatching to fledging (Ball et al. 1981:17). Information on brood movements and habitat use during the rearing phase would aid in management of Canada geese (Ball et al. 1981:55). Attempts have been made to examine brood movement and habitat use by color marking goslings (Geis 1956, Culbertson et al. 1971, Warhurst 1974) or equipping adults with neck bands (Martin 1964, Zicus 1981). Acquiring detailed information on brood movements and habitat use by these techniques can be difficult, because they require visual sightings of marked birds when they exhibit extremely secretive behavior. Radio-telemetry techniques can be of great value in studying brood ecology because they allow relocation of marked individuals at any time. However, only 1 published study has used radio-telemetry techniques on geese during the brood-rearing period (Lebeda and Ratti 1983), but only 3 goslings were marked in that study. We present information on movements and habitat use by radio-marked adult female Great Basin Canada geese and their broods.

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STUDY AREA

The study was conducted from April to September 1983–84 on 88 km of the Columbia River (Hanford Reach) that flows through and adjacent to portions of the U.S. Department of Energy's Hanford Site in south-central Washington. This was the last free-flowing stretch of the Columbia River in the United States upstream from Bonneville Dam. Flow velocities for the Hanford Reach ranged from 0.9 to 3.4 m/second. The area was characterized by a semiarid climate (16 cm annu. precipitation) and steppe vegetation, sagebrush (*Artemisia tridentata*)–grass (Daubenmire 1970).

Twenty-one islands (range = 2.7–135.0 ha) occurred in the Hanford Reach. These islands were located a few to several hundred meters offshore and provided important nesting and brood-rearing habitat for geese. A few islands were nearly devoid of vegetation; however, most had low-growing shrub and herbaceous ground cover (Hanson and Eberhardt 1971, DeWaard 1981). Most of the shoreline supported natural plant communities dominated by various species of forbs, grasses, and shrub willows (*Salix* spp.); trees were scarce. The only agricultural land that adjoined the river was a 4-km section of pasture, an orchard, and small grains on the eastern shoreline between Ringold Ranch and Richland. The pasture at Ringold Ranch had been used as a brood-rearing area for ≥38 years.

Public access by land was restricted on the southern and western shoreline of the river by the U.S. Department of Energy, which managed the Hanford Site, but most of the northern and eastern shoreline was open to the public. Public access was also prohibited on the northern 11 islands and was not allowed on the southern 10 islands during the goose-nesting season (Feb–May). The entire Hanford Reach was open to boat traffic, but most boating activities occurred on the southern 30 km of the river from Ringold to Richland. A hatchery for anadromous fish was located immediately upstream from the pasture at Ringold Ranch. In late May and early June a returning run of fish attracted fishermen, resulting in increased boat and shoreline traffic near the pasture and some disturbance of resident broods. Comparatively, little human disturbance of broods occurred north of Ringold.

Approximately 200 pairs of geese nested on islands in the Hanford Reach from March to May (Fitzner and Rickard 1983). The local nesting population of geese was increasing during the study period (L. E. Eberhardt, unpubl. data) following a decline from 250–300 nests in 1953–58 (Hanson and Eberhardt 1971) to 100–150 nests in the 1970's (DeWaard 1981, Fitzner and Rickard 1983). Hatching began in early April and extended through mid-May; goslings fledged approximately 65–70 days later (Yocom and Harris 1965).

METHODS

We surveyed islands on foot on the Hanford Reach for active nests weekly. We attempted to capture adult females at nests that contained pipping eggs, recently hatched young, or in a few instances, at nests that had eggs that were within a few days of pipping. Eggs near hatching were identified by nest initiation dates, egg flotation techniques (Westerkov 1950), and characteristic vocalizations emitted by young just prior to pipping (Collias and Jahn 1959). Adult female geese were very protective of their nests at this time; therefore, chances of desertion caused by trapping activities were lowest. Females were captured at their nests with a 3- × 3-m monofilament drop-net suspended approximately 1.2 m above the nest (Eberhardt et al. 1986). The net was dropped remotely by a trigger mechanism consisting of a toy rocket ignitor, radio receiver, and transmitter. Captured adults were fitted with a back-mounted transmitter (Dwyer 1972) weighing 40 g (approx 1% of body wt), a 6.5-cm plastic neck band, and a USFWS leg band. Some females were tranquilized with a 50:50 mixture by volume of ketamine hydrochloride (100 mg/cc) and xylazine hydrochloride (20 mg/cc) immediately after capture (Smith et al. 1980) to reduce nest desertions resulting from capture.

We relocated all radio-equipped adult birds with broods twice a week throughout the rearing season. Most locations were obtained from boats; fixed-wing aircraft were occasionally used when large or unusual movements were made by marked birds. Location error was minimal be-

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cause the marked adult and its brood could usually be observed once the goose's general location was obtained. We plotted all locations on U.S. Geological Survey maps (scale 1:50,000) gridded with Universal Transverse Mercator Coordinates.

We recorded movements and behaviors (Eberhardt et al. 1989*b*) of broods of radio-equipped adults at 5-minute intervals for 3–8 hours at random times during daylight hours in the 1984 field season. Broods were selected for intensive monitoring such that all age classes were sampled; however, within a given age class broods were randomly selected. A strip-chart recorder was used to document general activity levels of 2 radio-equipped adult females. Changes recorded in signal strength were used to indicate activity.

During the 1984 rearing season, we systematically collected samples of terrestrial plants that were consumed by broods. These samples were analyzed for total nitrogen content by standard Kjeldahl procedures.

Estimates of home-range size for broods were computed by the minimum convex polygon (Odum and Kuenzler 1955), elliptical (Jennrich and Turner 1969), and harmonic mean (Dixon and Chapman 1980) methods. Because locations obtained during intensive monitoring periods were autocorrelated (Swihart and Slade 1985), only 1 location from each of these periods, in addition to biweekly locations, were used in calculation of home ranges. Home-range size estimates were compared using the Wilcoxon 2-sample test for broods using areas receiving intense versus little human use and for broods using agricultural areas versus nonagricultural areas.

We used multiple linear regression techniques to examine the influence of environmental variables on distance moved by broods. Environmental parameters used as independent variables included wind speed, barometric pressure, temperature, relative humidity, precipitation, and cloud cover. Hourly means for environmental parameters were obtained from a meteorological station located on the Hanford Site approximately 20 km from the center of the study area.

We made 3 separate analyses of brood habitat preference: different physiographic features (island shoreline, mainland shoreline, and water), areas with different potential for human disturbance (areas near and far from human habitation), and different vegetative features (agricultural and nonagricultural). Habitat use was estimated by the proportion of telemetry fixes falling into a particular habitat category. Availability was estimated by the proportion of a particular habitat occurring within an individual brood's home range. To reduce the problem of autocorrelation between fixes taken during intensive observation periods and still obtain reasonable sample sizes, the predominant habitat component used during each hour of observation was determined from 5-minute fixes and used in the analysis. Physiographic habitat preferences were evaluated by ranking usage and availability measurements (Johnson 1980). This method was selected because we were interested in the relative importance of islands to broods and this method permits statistical comparisons among components. We used Wilcoxon's signed-ranks test to test for preference or rejection of areas of different potential for human disturbance and areas of different vegetative components, because Johnson's (1980) method is inappropriate for analyses involving only 2 components.

The assumption of normality was examined with both plots of the data and Kolomogorov D or Shapiro-Wilk statistics (SAS Inst., Inc. 1985). Nonparametric tests were used when the assumption of normality was rejected.

RESULTS

We captured and marked 41 adult female geese, 10 during 1983 and 31 in 1984. Only 15 of these females fledged at least a single gosling; the remaining females lost their entire brood ($n = 12$), deserted their brood as a result of our trapping activities ($n = 7$), or were not followed through the entire rearing season ($n = 7$). Analysis of gosling survival is presented in Eberhardt et al. (1989*a*). Desertion rates were not reduced ($\chi^2 = 0.00$, $P = 1.00$) by use of tranquilizers during capture; 17% of 18 tranquilized females and 17% of 23 nontranquilized females deserted their nests.

Movements

Seventeen of 19 radio-equipped adult females that lost their broods due to trapping ($n = 7$) or unknown natural causes ($n = 12$) left the study area shortly after the end of the nesting season in late May. These birds were not relocated within 80 km of the study area during subsequent aerial searches. In addition, nearly all un-

Table 1. Length of river used and home-range estimates for Canada goose broods on the Columbia River, south-central Washington, 1983–84.

Brood no.	No. relocations used to calculate home range	River length (km)	Home-range estimation technique: Minimum area (ha)	95% CI ellipse (ha)	Harmonic mean (ha) 75%	Harmonic mean (ha) 95%
090	19	10.3	2,405	4,146	2,830	5,367
157	23	2.8	234	471	336	678
186	43	10.5	436	387	1,291	3,657
303	52	8.6	891	764	989	2,246
311	20	5.0	388	478	290	700
427	25	14.8	2,145	5,833	1,475	2,853
495	26	18.1	1,782	2,803	2,809	5,608
586	19	6.0	595	1,491	633	1,137
599	19	4.9	278	479	362	790
629	23	15.3	1,437	4,851	768	1,538
651	23	10.0	611	898	634	1,217
715	22	6.1	477	987	601	963
728	21	6.8	592	1,378	528	1,011
828	26	6.0	278	670	326	449
855	21	6.5	489	1,105	613	948
$\bar{x}$ ± SD		8.8 ± 4.4	869 ± 716	1,728 ± 1,812	983 ± 822	1,939 ± 1,687

marked adult geese that were not accompanied by broods also left the study area in late May. Two marked adult females that remained on the study area after losing their broods late in the rearing season presumably molted locally. Band recoveries during fall and winter following marking were obtained for 6 of the 17 unsuccessful birds that left the study area (1 from Alta., 1 from B.C., 2 from Mont., 1 from northern Wash., and 1 local). Of the 5 adult females for which first-year band returns were obtained from distant areas, 2 had actually lost their broods and 3 deserted their brood or nest as a result of trapping efforts.

Radio-marked Canada geese used from 2.8 to 18.1 km of the Columbia River (Table 1) to raise their broods to fledging ($\bar{x}$ = 8.8 ± 4.4, n = 15). The relatively swift flow (approx 1–3 m/sec) of the Columbia River did not restrict brood movements to a downstream direction during our study.

Mobility of goose broods did not change significantly (Kruskal-Wallis, P = 0.15) with gosling age until they fledged (Fig. 1). However, broods that fledged and were flying to nearby fields to feed appeared to be less mobile while on the river than prior to fledging (Fig. 1).

Broods were relatively inactive during the night, based on strip-chart data for 2 adult females with broods (Fig. 2) and nocturnal radio tracking. Based on distance moved/30 minutes (Fig. 3), gosling movement rates increased during morning hours, reached a peak at midday, and gradually decreased in the afternoon and evening. Diurnal activity levels as determined by distance moved/time period and strip-chart recordings of changes in signal strength did not correspond. Broods were most mobile during late morning hours based on distance moved, which was when strip-chart recordings indicated that broods were least active. This apparent discrepancy probably reflected differences in the type of activity actually being measured by the 2 techniques. Changes in signal strength only reflected changes in radio orientation, and therefore, the strip-chart recorded all types of goose activity.

No difference (t = 0.38, P = 0.71) was detected in mean movement rates of broods using the lower 30-km segment of the Columbia River (Fig. 1), where human use was high, compared to the upper 58 km of the river, where human activities were infrequent. Multiple linear regression of environmental parameters and time of day on distance moved by broods/hour was not significant (P = 0.15, r^2 = 0.06).

Home-Range Size

Estimates of home-range size (including length of river used) obtained from various estimation techniques (Table 1) were significantly and positively correlated with each other (Spearman rank correlation, r range = 0.46–0.85, P range = <0.01–0.08), but generally not with sample

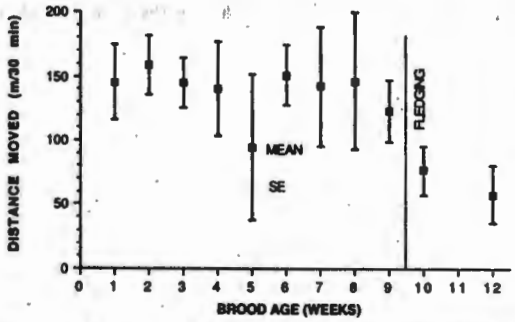

Fig. 1. Relationship between mean distance moved and age for Canada goose broods in south-central Washington, 1983–84.

sizes (r range = −0.15–0.46, P range = 0.09–0.77). The bivariate normal distribution did not appear to fit the observed distribution of locations for 13 of 15 monitored broods ($P < 0.10$) based on the Cramer-von Mises statistic (Samuel and Garton 1985). Therefore, the 95% confidence interval ellipse (Table 1) was probably not an appropriate home-range estimator (Samuel and Garton 1985). Mean home-range sizes for minimum convex polygon and harmonic mean (75%) estimators were similar (Table 1) but varied substantially among broods, with the largest home range being approximately 10× larger than the smallest. Home-range size for broods ($n = 3$) that used agricultural areas exclusively did not differ from those ($n = 10$) using natural rearing areas (river length, $P = 0.35$; min. area, $P = 0.50$; 75% harmonic mean, $P = 0.27$). Nor was there a difference in home-range size (min. area, $P = 0.08$; river length, $P = 0.39$; 75% harmonic mean, $P = 0.23$) for broods ($n = 9$) residing on the lower river where the level of human activity was high compared to broods ($n = 5$) on the upper river where human activity was low.

Habitat Use

Most geese used well-defined areas to raise their broods; however, some moved frequently and identification of specific rearing areas for these broods was difficult. Brood-rearing areas occurred throughout the study area and included islands, pasture, secluded side channels, main river channel, a 24-ha pond approximately 0.5 km from the river, and a ring-billed gull (*Larus delawarensis*) colony. Vegetation height in rearing areas ranged from 4 cm (gull colony) to >1 m (reed canary grass [*Phalaris arundinacea*]). Maximum number of broods observed in a single rearing area was 18 at the Ringold pasture. Generally, there were 8–10 broods in each of the more intensively used rearing areas, and broods used from 1 to 4 rearing areas (mode = 1, median = 2.5) prior to fledging. The first rearing area used by most broods (10 of 15) was in the immediate vicinity of the nest, although some broods moved up to 13.0 km to reach the first intensively used area. There appeared to be fewer suitable rearing areas in the upper 58 km than in the lower 30 km of the river. Four of 5 broods that fledged in the upper stretch and only 1 of 10 in the lower stretch moved >1 km to their first intensively used rearing area following hatching.

Broods used riparian habitats more frequently than aquatic habitats (78% of 3,073 locations). The river was used by broods primarily as an escape route when disturbed and for moving to new riparian feeding sites. Most terrestrial locations (66.7%) of broods were within 5 m of water; only 7% were farther than 50 m from water. Intensive use of habitat immediately near the shoreline by broods was probably due to the lush forage near the waterline and presence of predators. Coyotes (*Canis latrans*), the most common predator on nesting geese in the study area (Hanson and Eberhardt 1971), were observed attempting to capture goslings along the mainland shoreline. Fifty-seven percent of locations of broods on islands ($n = 1{,}302$) were >5 m from the shoreline, and only 43% of locations of broods on the mainland ($n = 1{,}252$) were >5 m from the shoreline; these differences were significant ($\chi^2 = 7.9$, $P = 0.005$). Evidence of coyotes was present on only 4 of the larger islands in the study area.

Amount of time goslings spent in water varied significantly with age ($\chi^2 = 150.9$, $P < 0.001$). Greatest deviations between observed and expected frequencies in this analysis were for goslings <1 week old, which spent considerably less time in water than expected, and 9-week-old goslings, which spent more time in water than expected.

There was a significant difference ($T^2 = 119.4$, $P < 0.01$) in the use of major physiographic features (e.g., islands, mainland, and water) by goose broods. Shoreline habitat of islands was preferred and water was avoided based on multiple comparison tests ($P = 0.05$).

Eight broods residing in the lower stretch of the river had access to shoreline areas within their home ranges that were adjacent to human

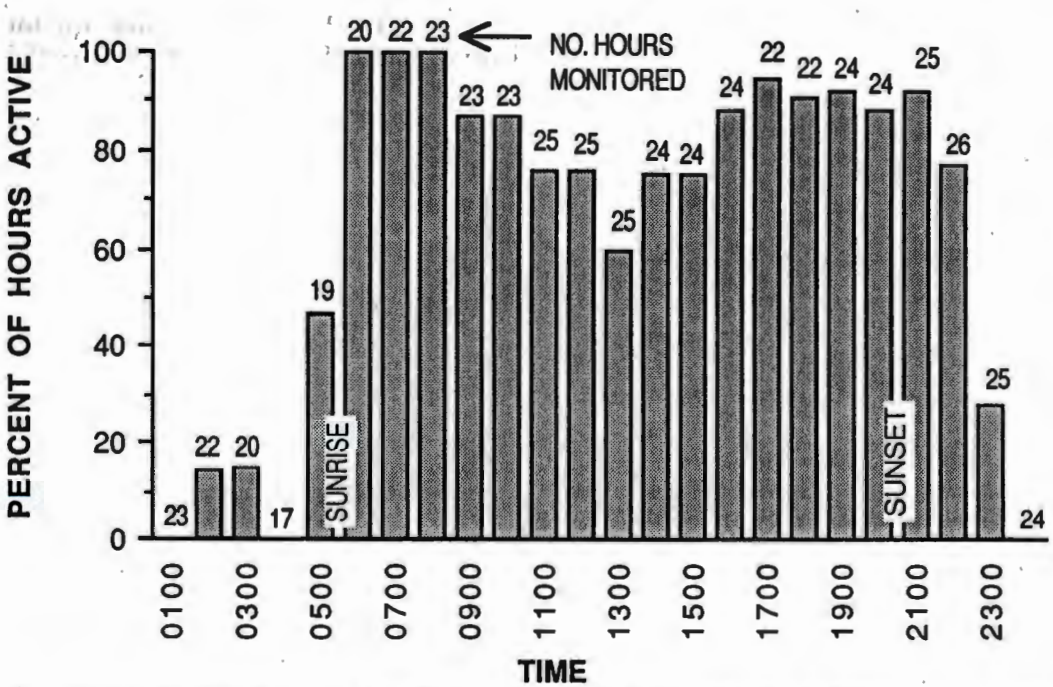

Fig. 2. Twenty-four-hour activity pattern of 2 adult female Canada geese with broods based on recorded changes in radio-transmitter signal strength, south-central Washington, 1984. Data are presented as percent of monitored hours that females were active when their broods were between 1 and 9 weeks old.

habitation. These broods showed a significant avoidance of such areas ($P = 0.02$) and concentrated their activities in portions of their home ranges that were comparatively free from human disturbance.

Six broods that fledged young and had access to agricultural lands (primarily the pasture at Ringold) within their home ranges showed a clear preference ($P < 0.05$) for those habitats. Mean percentage of this habitat in the terrestrial component of these broods' home ranges was 2.4%. The Ringold pasture was fertilized regularly and the level of crude protein content in pasture grasses (21.0 ± 3.7 [$\bar{x}$ ± 95% CI], n = 7) was significantly higher ($t = 3.42$, $P = 0.007$) than in forage species used by broods in other areas on the study site (13.7 ± 2.0, $n = 24$).

The pasture at Ringold, which received heavy use by local broods, did not appear to attract broods from surrounding areas, based on movement of marked adults with broods and total number of broods present in the vicinity of the pasture. Only 2 of 23 radio-equipped adult females that hatched young on islands outside the immediate vicinity (>3 km) of the pasture moved their broods there. These broods moved from islands located 5 and 11 km distant. Neither of these movements was excessive when compared to mean river distance used by broods prior to fledging ($\bar{x}$ = 8.8 km) (Table 1). In addition, the maximum number of broods present ($n = 18$) in the vicinity of the pasture was considerably less (35.5 and 56.3% in 1983 and 1984, respectively) than that known to have hatched on adjacent islands, which also indicates that the pasture did not attract broods from more distant nesting areas.

Distance between the pasture and nesting habitat does not appear to be a significant factor in limiting pasture use because only 16.7% of broods in 1983 and 30.5% in 1984 hatched within 8.8 km ($\bar{x}$ river distance used to raise broods to fledging) of the pasture were actually observed in the vicinity of the pasture.

Human Disturbance

Broods avoided areas of human habitation in their home ranges; this was particularly true during the first few weeks following hatching, when broods appeared to be most sensitive to human disturbance. Typical response of adults and young goslings if approached from the water was to run inland and hide in the vegetation.

Drive-trapping of radio-marked adult fe-

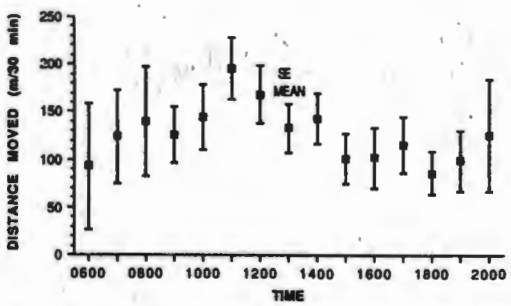

Fig. 3. Diurnal activity patterns of Canada goose broods (<9 weeks old) based on mean distance moved/30 minutes, south-central Washington, 1984.

males and their broods between the ages of 6 and 10 weeks did not appear to influence subsequent movements or integrity of these birds. Of 15 attempts to capture radio-marked adults and their broods (Eberhardt 1987), only 1 resulted in an unusual movement following capture attempts. This particular adult female and brood, which had a history of extensive movements, moved 6.2 km upstream following the second capture attempt in 5 days. Drive-trapping did not affect brood integrity based on changes in brood size following capture attempts, despite the fact that broods were often separated during drives. Of 7 broods that were disturbed by capture attempts and for which subsequent brood counts were available, only 1 changed in size (increased by 1) following capture. Three unsuccessful attempts were made to capture 1 adult female and her brood over a 10-day period with no apparent effect on the brood's integrity.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Movements

First-year band recoveries in Canada and northern United States from marked females that lost their broods on our study area indicated that at least some of the unsuccessful geese probably joined a northern molt migration by subadults and unsuccessful nesters (Krohn and Bizeau 1980:21, Ball et al. 1981:46). This is the first reported evidence of a molt migration in the west by adult Great Basin Canada geese that have lost their broods, although Zicus (1981) noted similar movements in the midwest by the same (Palmer 1976) or a closely related subspecies, the giant Canada geese (*B. c. maxima*). Hanson and Eberhardt (1971:31) suggested that large numbers of subadults and unsuccessful breeding adults molted in the northern portion of our study area; however, we did not observe such concentrations.

The amount of river used by broods during this study was on the same order of magnitude as the area used by color-marked Great Basin Canada geese with broods in other locations (Geis 1956, Martin 1964:23) and for other subspecies of Canada geese (Warhurst 1974:56–57, Zicus 1981, Lebeda and Ratti 1983).

Because of physical size differences between 1- and 9-week-old goslings, we found it surprising that movement rates did not vary significantly with age. One possible explanation for this is that several species of waterfowl have evolved the capability to move extensive distances at an early age to reach suitable rearing habitat (Bellrose 1980:241, 273, 300). However, high movement rates of young goslings during our study did not appear to be related to the necessity of reaching adequate rearing areas, because the first rearing area used by most broods was in the immediate vicinity of their nests.

Habitat Use

We observed that goslings <1 week old spent less time in water compared to older goslings. Joyner (1977) noted that downy ruddy ducklings (*Oxyura jamaicensis*) responded to chilling by leaving the water. Probably, the relatively cold temperatures of the Columbia River (7 C), the early stage of plumage development, and perhaps an incomplete development of thermoregulation capability were contributing factors to the relatively short periods of time young goslings spent in the water. Why 9-week-old goslings spent more time in the water than expected is unknown, but these goslings were at or near fledging, a time when many behavioral changes occurred (Eberhardt et al. 1989*b*).

Canada geese used a wide variety of habitats to raise their broods to fledging. Desirable characteristics of brood-rearing areas include gently sloping shorelines, freedom from human disturbance, abundant foods, and a location in proximity to nesting sites (Hanson and Eberhardt 1971:30). Because broods were seldom found more than a few meters from water during our study, a maximum shoreline: water interface is an additional desirable characteristic of rearing areas.

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One of the few management techniques used for geese during brood rearing is the provision of irrigated pastures for foraging (Ball et al. 1981:55). The pasture on our study area was a preferred foraging site for nearby resident geese. Broods using the pasture spent nearly twice as much time feeding when they were in the pasture compared to when they were in nonpasture habitats (Eberhardt et al. 1989*b*), probably because of high quality pasture forage. Despite this, the pasture did not appear to attract adult females and broods from distant areas. Limited attraction of Ringold pasture to nonresident broods indicates that distance between the pasture and other nesting islands precluded significant brood movement, densities of broods at the pasture were at or near carrying capacity for the area, social factors prevented nonresident geese from using the pasture, there were sufficient brood-rearing areas of adequate quality available to geese elsewhere on the Hanford Reach, or a combination of the above factors.

Up to 18 broods were observed in the vicinity of the pasture. Whether this number reflects an upper limit for carrying capacity of this area is unknown. These broods used an area of approximately 4 km^2, which represents a density less than that observed under other natural and refuge conditions (Warhurst et al. 1983:1122).

Canada geese demonstrate a propensity to nest and raise their broods in the same areas where they were hatched and raised (Sherwood 1967). Fidelity to natal rearing areas may have restricted pasture use on our study area. There were numerous other intensively used rearing areas on the Hanford Reach. Whether these areas were of comparable quality to the pasture as rearing sites is unclear; however, concentration of feeding activities in the pasture by resident broods and high protein content of pasture forage indicate a high quality habitat. Over all foraging times, however, for broods using the pasture and broods residing in nonpasture areas were identical; both spent approximately 52% of their time foraging (Eberhardt et al. 1989*b*). Quality of the pasture as a rearing area may have been reduced by temporary, heavy fishing pressure in late May and early June near the adjacent fish hatchery. Of 7 resident radio-marked females with broods approximately 4–5 weeks old, 4 moved away when human activity increased; 3 of these broods did not return following a decline in fishing activities in mid-June. There was not, however, a noticeable decrease in total number of broods in the Ringold area in response to fishing, but only a general, temporary decrease in pasture use. Many broods appeared to acclimate to the heavy boat traffic and continued to use the pasture.

Impact of human disturbance on goose broods has been reported to range from little (Geis 1956) to one of the more frequent sources of mortality (Hanson and Eberhardt 1971:31). During our study, broods avoided areas of human habitation within their home ranges, particulary during the first few weeks following hatching. However, the presence of goose broods in many metropolitan parks, occasionally at nuisance densities, indicates that goose broods can tolerate a fair amount of human disturbance.

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