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AEC Research and Development Report

A COLUMBIA RIVER
CANADA GOOSE POPULATION,
1950-1970

August 1971

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A COLUMBIA RIVER CANADA GOOSE POPULATION, 1950-1970

By

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Ecosystems Department

August 1971

BATTELLE MEMORIAL INSTITUTE
PACIFIC NORTHWEST LABORATORIES
RICHLAND, WASHINGTON 99352

A captive flock of two-year-old western Canada geese photographed under refuge conditions. Courtesy of Paul Hart, Yakima Herald-Republic.

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A COLUMBIA RIVER CANADA GOOSE POPULATION 1950-1970¹

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INTRODUCTION

Throughout its existence, the U.S. Atomic Energy Commission has supported extensive efforts to assess the status of biological populations in the environs of nuclear plants. This report documents population studies of the Western Canada goose, Branta canadensis moffitti Aldrich, conducted since 1950 on the Hanford Atomic Energy Commission Reservation in southeastern Washington. A program of banding and nesting studies has been continued through 1970 for both radioecological purposes and as a contribution to goose management. Banding constituted the principal effort during the first three years, and detailed nesting studies began in 1953.

Hydroelectric development of the Columbia and Snake rivers has gradually inundated the nesting habitat of Canada geese to the extent that the Hanford population now occupies the only major remaining natural habitat on the Columbia. It will soon be unique for the entire

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Columbia and Snake river systems. Whether it will remain so depends upon a decision to build or not to build the proposed Ben Franklin Dam (Figure 1), which would inundate all but the lower four islands of the study area. An alternative proposal by the U.S. Army Corps of Engineers is to excavate a navigation channel in the unimpounded Hanford section of the Columbia River. This would also have an important influence upon the goose nesting potential.

Maintenance of local Canada goose populations in the Columbia and Snake river systems depends critically on nesting habitat. Since the bulk of nesting takes place on islands, success of any efforts to replace lost habitat seems likely to depend on our knowledge of the ecology of present populations. The present report is thus intended as a record of nearly 20 years of study, and a source of information for future management efforts.

Results of the first 4 years of comprehensive study (1953-1956) have been described in an earlier report (Hanson and Browning 1959) which contained fairly complete data on productivity. An important consideration in that study was to document continued normal fertility of the local goose population in the presence of extensive nuclear reactor activity. Substantial evidence was already at hand that argued against any environmental damage from reactor effluents, but continued long-term observations were made to confirm the initial findings. This report summarizes such information, and provides basic ecological information on one of the few undisturbed nesting populations of western Canada geese in the Pacific Northwest. Individual histories of each of

the 18 islands over an 18-year period of intensive study provide information useful in interpreting goose behavior in nest site selection as well as a record of population dynamics.

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THE STUDY AREA

The 88-km unimpounded section of the Columbia River within the USAEC Hanford Reservation lies between McNary and Priest Rapids Dams in southeastern Washington (Fig. 1, Table 1), at the southern edge

of the Columbia Plateau. Situated in the rainshadow of the Cascade Range 150 km to the west, the region receives about 16 cm annual precipitation about 40% of which occurs during winter months and another 40% during the goose nesting period, February through May. The climate is characterized by hot dry summers, windy springs, and mild winters. In this region the Columbia River flows eastward in a broad valley of about 150 m elevation between the Saddle Mountains and Rattlesnake Hills, which reach a maximum elevation of about 1100 m. These hills influence wind patterns so that they prevail from the northwest in the upper section of the study area and from the southwest in the lower section. Soils of the region are classified as river-wash dune sand and sandy loam (Kocher and Strahorn 1919), much of which was deposited by glacial outwash at the southwest end of the channeled scablands to the north. These soils are highly susceptible to erosion by wind and water. Sheer sand and clay loam bluffs of the Ringold Formation rise some 70-100 m above the north bank for about 11 km in the upper section of the study area (Fig. 2).

Cemented gravel and clay bluffs of the Ringold Formation form the eastern border of the river in the lower part of the study area. Clay layers result in a danger of earth slippage through percolation of irrigation water used to the north (Wahluke Slope of the Columbia River Basin irrigation project). One such slippage of about 800,000 m³ of earth recently occurred about 15 km west of the study area and another is imminent in the river bluffs of the lower section, near

Island 13. Such events may change river channels and influence suitability of nearby islands as nesting habitat.

The arid climate and light soils of the region support a steppe vegetation association (Daubenmire 1970:5; Franklin and Dyrness 1969: 143) dominated by big sagebrush, Artemisia tridentata, and bunchgrass, Agropyron spicatum.

The islands used by the nesting geese occur in 2 groups of 9 islands each, the lower section between River Miles 340-355, measured from the river mouth, and the upper section between River Miles 365-377. In addition, one island in each group (numbers 5 and 16) was not used by nesting geese because of low profile and lack of nesting cover. The islands vary in area from 2.7 to 135 hectares (ha), of which we classify about 60% as usable by nesting geese. In recent years, a prime consideration for determining the usable area has been the manipulation of river flow at the series of hydroelectric dams upstream from the study area, especially the Priest Rapids Dam. During the critical months of goose nesting (March and April) of 1961 through 1969, diurnal fluctuations of 1.5 to 2.5 m elevation in river level occurred at flow rates of 84,000 to 104,000 ft³ (2,350 to 2,910 m³) per second (cfs, cms), as measured at a USGS gauging station near Priest Rapids Dam (Table 2). Such fluctuations create a barren zone on the river banks since there are no local organisms adapted for an "intertidal" life. This area has been described as being "too wet for geese and too dry for salmon." Normal flow usually reached a maximum about mid-June with a daily

average discharge of about 380,000 cfs (10,640 cms); however, manipulations to facilitate the filling of John Day Dam during April 1968 increased flow from the normal 100,000 to 170,000 cfs (2,800-4,760 cms) within 1 day and maintained this rate for 4 days (Fig. 3). Artificial creation of early flood conditions conflicts with goose behavior which is synchronized to complete nesting before arrival of normal flood levels. A similar test manipulation of river flow, scheduled for 3 April 1970, with maximum rates of 295,000 cfs (8,260 cms) typical of late May discharge, was cancelled on protest of the Washington Department of Game that such a test would inundate most goose nests.

The annual inundation of the islands erodes their sandy soils, especially on the upstream parts. This exposes the cobblestone gravel substratum and maintains plant communities dominated by lupine, Lupinus sp., buckwheat, Eriogonum compositum, and absinthe, Artemisia absinthium (Figs. 4 and 5). Stabilized soil on the downstream sections of the islands supports steppe vegetation typical of the region, with some modification owing to inundation. Ryegrass, Elymus cinereus. (E. condensatus of earlier reports, Hansen and Oliver 1951:7; Hanson and Browning 1959:131), wheatgrass, Agropyron dasystachyum, and yarrow, Achillea millefolium lanulosa, were most important nesting cover on those downstream parts of the islands that were inundated but not subjected to scouring action (Figs. 6 and 7). The major nesting cover composition of the islands (measured by planimeter on maps drawn from aerial photographs and ground surveys) is given in Table 3. The 18

islands used by nesting geese had a total area of 620 ha, of which 415 ha (67%) was considered usable by geese. Nesting geese showed preferences for certain cover types, forming population clumps on several islands, such as Islands 1, 2, 6, 9, and 12. On islands with low nesting densities there was a tendency for geese to utilize scattered clumps of overstory vegetation, such as willow, Salix exigua; mulberry, Morus rubra, or other shrubs.

Little evidence of plant succession was observed during the study period. There had been no human occupancy of the islands for 10 years before the comprehensive study began in 1953, and the last major flood occurred in June 1948. The vegetation, thus, was fairly stable, with a few notable exceptions. Willow clumps on several islands in the flowing river section (Fig. 8) tended to die out at an age of 16-26 years as measured by annual ring counts. Currant, Ribes cereum, often became associated with such clumps then also died out and reduced favored nesting sites for magpies, Pica pica, tending to decrease predation on goose eggs. Willow flourished at the littoral zone on the upper edge of Island 20, in the upper limit of the McNary Dam impoundment. This represents a successional condition owing to change from moving to slack water and elimination of scouring action of flood waters. Rye-grass on Island 6 showed accelerated growth after 2 major fires during 1958 and 1967 reduced the plant cover and liberated minerals into the soil. This produced excellent nesting cover the second year following the fires, but the lack of cover the first year reduced nesting in that

section. Similar response occurred in wheatgrass, which had become stagnated by accumulated litter. This latter plant also produced more available green feed for geese during the autumn rainy seasons of each year following a fire than it had previously.

On Island 11, pioneer plants of currant and mulberry scattered through an absinthe-dominated community were browsed heavily by mule deer, Odocoileus hemionus hemionus, and thus retained a shrubby form attractive to nesting geese. This variation of "edge effect" was noted on other islands, where a driftlog or other outstanding object in an otherwise homogeneous environment supplied a nesting site.

Islands 12-17 were opened to public access in August 1965 with the restriction that they be closed during the goose nesting season (February-May) of each year, whereas there was no public access restriction applied to Islands 18-20 at any time during this study. In all cases where public access was allowed, desertion and destruction of nests increased owing to robbing nests, photographing birds, picnicking, or other human activity. Nest markers were often removed or destroyed, in spite of appeals through news media. We finally decided not to publicize the onset of goose nesting, and a lower rate of human destruction followed.

Clay and sandy loam bluffs form a 70-100-m sheer northern bank of an 11-km section of the study area. About 8 km of the bluffs were considered to be available for nesting geese, but only 5 km were used by about 1% of the nesting birds. Eroded shelves about 5 m above the river level were most often used, with the nests usually by a small clump of vegetation which had been shorn for nesting material. Most bluff nests were immediately opposite Island 6, suggesting that the geese avoided isolation or that bluff sites were occasionally utilized by the overflow of Island 6 nesters. However, the low utilization of bluffs in 1967 and 1970, when nesting on Island 6 was either destroyed or discouraged by predators, indicated a general lack of interest in bluff nesting sites. In any case, the bluff sites are likely to be endangered by slippage as a result of increased irrigation on the adjacent Wahluke Slope.

NESTING

Methods

Usually, nesting surveys were begun during the first week of April of each year, unless mild temperatures and early pairing of geese was noted. The bluffs bordering the river were surveyed by boat, the general location of a nest usually being indicated by the distant flushing of the gander. The islands were systematically searched by 2 men who walked each island in the same manner each time. Careful counts of paired geese were made during the first 2 or 3 surveys, prior to much of the hatching. As each nest was found, a numbered 6-ft. willow marker, similar to that used by Naylor (1953:36), was placed near the

nest and the status of the nest recorded. Incubated nests were characterized by the presence of the female, warm eggs with glossy appearance, and substantial amounts of down. Deserted nests often had a smaller number of eggs, lack of down, and showed definite impressions of each cold egg. Nests classed as destroyed were those with missing or broken eggs and scattered down. Successful nests contained the shells and membranes of hatched eggs, filoplumes from natal down, "pipped" eggs or goslings. All eggs remaining in successful nests after the departure of the brood were broken to determine their status. Those eggs with the yolk wholly or partially suspended in the albumen were classified as infertile after Kossack (1950:646), whereas fertile eggs contained embryos that died in various stages of development. Dead or abandoned goslings, generally the result of weakness, crowding, or lateness in hatching, were also recorded.

Weekly checks of nests were made until incubation terminated (about mid-May), unless remoteness of a few nests widely scattered over the 88-Km study area or the press of other studies made it infeasible to continue the survey. The records provided a basis for estimating the beginning of nesting and for selecting a date for banding, which was usually done 6-8 weeks after the major periods of hatching. In many cases, nests with unusually long incubation periods were repeatedly checked to document that aspect of goose behavior.

The Nesting Population

Initial pair identification usually occurred from 15 January to 1 February as wintering flocks broke up into breeders and unemployed geese (Hanson and Smith 1950:155 Collias and Jahn 1959:484-485). Separation of nesting pairs from family groups occurred earlier during years of unusually mild weather during January and nesting began in March. The Hanford goose population increased from about 200 (termed "territorial" although some immature birds may not have nested) pairs in 1950 to a 4-year maximum of about 300 pairs during 1953-1956 and then steadily declined (Fig. 9) to a low point of 200 pairs in 1964 and 1965, and has only slightly recovered in recent years. Census techniques remained essentially unchanged and were directed by the senior author throughout the study. The population fluctuations are analyzed in relation to band recovery data in a later section of this paper.

The unemployed portion of the population, presumably composed of geese less than 3 years of age (Craighead and Stockstad 1964), numbered about 140 during the first 6 years of study and then decreased at about the same rate as the numbers of pairs until 1960; during the last 10 years of study, their numbers fluctuated between 50 and 150 geese. Unemployed geese moved about the study area, making censusing difficult, and were often mixed with migrant lesser and Taverner's Canada geese (B.c. parvipes and B.c. taverneri). Band recoveries showed a considerable portion of the immature geese also migrated

into northern Canada, but it is not known whether this proportion remained constant in each cohort. Territorial pairs (Table 4) outnumbered nests on individual islands (Table 6), and thus about 20% of the pairs were also "unemployed", although not classified as such. Extra pairs often accompanied the gander of a nesting pair and appeared as solicitous of the goslings as the real parents.

The numbers of territorial pairs on each island throughout the study period (Table 4) were usually fairly stable fluctuations although some island populations occasionally showed sharp fluctuations. Such changes seemed to be randomly distributed in time. This suggested that the cause was not an intrinsic feature of the goose population but was due to predation, harvest, or other mortality factors. Island 6 supported a stable population for about the first 15 years of study, and then suffered 3 periods of coyote predation that reduced the nesting population to 25% of its former level, and also reduced the number of nesting attempts to 20% of the expected number. The depressed populations on most islands usually recovered within a year to near the original levels.

A comparison of aerial census of territorial pairs with ground surveys was made during the 1966 nesting season to determine the feasibility of estimating the goose population from an aircraft. Counts were made a week prior to the first 2 ground surveys, using a Cessna 172 aircraft to circle each island twice at about 150 m above the terrain at minimal speed and full flaps. Results showed

aerial counts of territorial pairs to be fairly consistent, but we observed only 63% of the number seen by walking the islands (Table 5). The greatest disparity occurred at Islands 1, 2, and 6 and along the bluffs, largely because the females were concealed by nesting cover and their mates usually stationed themselves along the adjacent mainland shoreline rather than on an island. They joined in midriver when the females flushed from the nest and were then identified as pairs. Although a solitary goose was counted as a pair from the aircraft, it is apparent that many were overlooked; therefore, the aerial census method in this study was not considered sufficiently accurate to estimate the nesting population, but was advantageous in identifying the unemployed population.

Nesting Phenomena

Phenology

Initiation of nesting was estimated by backdating the hatching date of nests 5 weeks, assuming 1 week for laying the clutch and 4 weeks for incubation. These estimates are based on data of several investigations that reported egg-laying rates of about 1.5 days per egg (Kossack 1950:639) and incubation periods of 26 to 28 days (Kossack 1950:644, Collias and Jahn 1959:481, Hanson 1965:108). Hatching date of a successful nest was determined on the basis of (1) "pipping" of eggs 1 to 2 days before hatching (Kossack 1950:645), (2) brooding of young for 1 day after hatching before leaving the nest, and (3) selecting the median day between two survey periods that

bracketed a successful nest from which neither of the foregoing criteria were obtained. The distribution in time of 2,688 successful (hatched) nests showed that most nests were begun during the third week in March, but that there was some shifting in response to average daily temperature during the various years (Fig. 10). During years when February was warmer than the norm, such as 1958, 1961, 1965, 1968, and 1970, there usually was a larger number of early nesters. Those years also tended to have nesting starts extended over a longer period than most other years. Cold spring weather during early March, such as observed in 1955, 1956, 1960, and 1962, tended to delay nesting. As noted in our earlier report (Hanson and Browning 1959:132), most nests began when the average daily temperature at the Hanford Meteorology Tower remained above 5 C (40 F) for much of the time. The 1970 nesting season was the earliest of the study period, and was characterized by above-average temperatures in February and below-average temperatures in March and April. The temperature pattern was similar to that of 1967, yet nesting began one week earlier. This spread the nesting period from the beginning of 4% of the nests in late February through the hatching of the last 1% of successful nests during the third week of May, nearly 12 weeks. The 18-year average nesting period extended from early March until late May, also about 12 weeks.

The above data, combined with observations on nest desertion attributable to our survey activities, suggest that annual nesting surveys could be delayed until about the second week in April in

most years without missing any significant part of the hatching progression and probably would cause less nest desertion if delayed.

Location of Nests

Data were obtained from 3,824 goose nests during the 1953-1970 intensive study period, with complete information from 3,631. Forty-seven nests were classed as incomplete. The distribution of the complete nests by location is tabulated in Table 6. The ratio of nests to territorial pairs (Table 7) for all islands during the entire 18 years was 1.2 ± 0.07 (S.E.), with a range from 0.8 to 5.7. The lowest ratio occurred on Island 2, probably because it was so close to Island 3 that it was difficult to determine to which island the pairs should be credited. The highest average ratio occurred at Island 4, which usually supported 1 nest but was a favorite resting area.

The number of nests on individual islands varied over a wide range during the study, generally reflecting the considerable impact of predators. Island 6, for instance, supported 129 nests in 1957 and only 3 nests in 1970. Average annual total nests for the 18 islands throughout the 18 years of study was 209 ± 12 (S.E.), with an average density of 0.5 nest/ha useable area (Table 6). An additional average of 4 nests per year usually were found on the bluffs near Island 6.

Cover

The utilization of 7 major plant communities by nesting Canada geese during the period 1956-1970 is summarized in Table 8. These data differ slightly from the results obtained during 1954-1956 as reported earlier (Hanson and Browning 1959). Plant classification changed slightly, and Agropyron dasystachyum was incorrectly identified as Elymus glaucus in the earlier report.

We have tabulated the 7 most important native plant communities; in addition, the Russian thistle, Salsola kali, and driftwood each were utilized for 3% and rose, Rosa sp., and sagebrush, Artemisia tridentata, each for 2% of the nests.

An overall shifting in rank of cover types resulted from a decreased use of Island 6 in the later years of study and from increased use of Islands 1 and 2. Ryegrass grew on the stabilized soil on the lower portion of Island 6, especially on the raised berm that encircled the sheer edge of the island. This provided nesting geese with good cover, visibility from the nest, and a quick exit from approaching predators. These qualities attracted many geese during peak populations of 1953-1956 and accounted for the higher utilization of ryegrass at that time. The sharp decline in nesting that resulted when coyotes, Canis latrans lestes, invaded the island, reduced the number of nests in ryegrass cover and resulted in an apparent preference for lupine as nesting cover.

Comparison of the nesting cover used by the geese in terms of availability of the cover types (Table 3), indicated a preference for lupine and willow rather than wheatgrass and buckwheat, and an intermediate status or neutrality toward ryegrass, absinthe and yarrow. This may be somewhat misleading in view of an average utilization of lupine cover of 40% on Islands 1, 2, 10 and 20, which had an average lupine cover of 84%. On those islands, willow formed the cover for 26% of the nests although it occupied only 5% of the useable area.

Recurrent use of a nest site by individuals was noted in only the 1 case in which a partially albino goose nested at the same general location on Island 1 during 4 consecutive seasons. Many other nests were found at the same location as in previous years, suggesting "imprinting" of nest location.

Clutch Size

Average clutch size in 2,688 hatched nests was 5.5 eggs, with 90% of the clutches within the range of 4 to 7 eggs (Fig. 11). Nests that were inaccessible on the bluffs or that had hatched prior to their discovery were not included in the above tabulation. For purposes of estimating production of goslings all such nests were assumed to have contained 5 eggs that hatched, based on firsthand evidence in the nest or viewed with binoculars.

Average annual clutch size during the study period varied from a low of 5.2 in 1959 to a high of 6.3 in 1967, with an apparent correlation with the number of nests (Fig. 12). Two major features were apparent: 1) Average clutch tended to be lowest during the 1953-1956 period of maximum population and highest during the 1966-1970 period of lower population; and 2) average clutch tended to increase and decrease with the number of nests. Exceptions to this generalization occurred, of course, but the overall trend seems consistent. During years in which there was appreciable coyote predation on certain islands, there tended to be more clutches of 2 or 3 eggs. This may have represented more renesting attempts than usual or some physiological response to predation.

Fate of Nests

Seventy percent of the 3,824 nests observed during the period 1953-1970 were successful, 14% were deserted, 12% were destroyed by predators, 2% were flooded and 1% were incomplete (Fig. 13). Greatest nesting success occurred during 1961-1964, when 84 to 88% of the nests hatched. This period was bracketed by years of appreciable predation and nest desertion, which were probably interrelated.

Fate of nests on individual islands is summarized in Table 9. Nests on 5 islands (1, 12, 15, 17, and 18) showed outstanding success, with 84% of the nests being hatched, and on 2 islands (8 and 10) nests had markedly lower success than other islands.

Nest Desertion

Most deserted nests were abandoned after 3 or 4 eggs had been laid and before incubation had begun. After the geese were well into incubation, they sat tightly until flushed at close distance, often within a few meters if the observer approaching the nest gave the impression that the goose was unseen.

Observations during the 1953 nesting season raised the question of our contribution to nest desertion, and several attempts were made to evaluate this aspect of behavior during subsequent seasons. In 1954, Island 8, that had supported 13 nests during the previous season was surveyed on 6 April; 14 nests were found, of which 2 were not being incubated and contained 3 and 4 eggs. The island was left undisturbed for the next 3 weeks and was then surveyed on 27 April; 1 nest had been deserted, 1 was still being incubated and the remainder had been destroyed by coyotes or racoons (Procyon lotor excelsus). Four additional nests were found, 3 of which had been destroyed and 1 probably hatched. The single active nest was found destroyed the following week.

In 1958, the study on nest desertion was transferred to Island 6 to obtain a better sample size and to avoid the predation problem on Island 8. Only the lower portion of the island was involved, and the number of nests studied represented about half the nests on the island. Results of the study are summarized in Table 10, which shows the change in status of 59 nests surveyed on 2 consecutive days to record the influence of the preceding day's activities upon nesting behavior.

The first survey on 31 March revealed 23 active nests (Group 1, Table 10) on the lower area. These were divided into 2 groups, one of 16 for experimental purposes and one of 7 for controls. One week later, 10 of the 23 had been deserted and 1 had been destroyed. For no apparent reason, all the losses were in the experimental group selected for visit the following day (8 April), at which time no more desertion or destruction had occurred, nor did any appreciable change occur in those nests during the remainder of the season. In the control group, 3 of the 7 had been destroyed or abandoned by the end of the study. Final results from this first group showed (1) that two-thirds (15/23) of the nests visited during the initial part of the nesting season were deserted by the geese, (2) that 2 consecutive days' visits to the nests caused no appreciable desertion or destruction, and (3) nests visited most often had greater desertion and destruction rate (12/16) than those visited less often (3/7), but the difference was not significant by statistical (chi-square) analysis.

The second survey on 7 April found 22 more active nests (Group 2, Table 10) on the lower area and these were also divided into two groups, one of 9 for experimentation that were visited again the following day and then at weekly intervals, and one of 16 to serve as controls. The control group was not visited the second day but at weekly intervals; however, the clamor raised by the geese at our presence on the island may have frightened some of the incubating females to varying degrees. It was again noted that (1) most desertion occurred between the first

and second visits to the nests and (2) nests visited 6 times had a higher desertion-destruction rate (5/9) than those visited 5 times (4/13), although the difference was not statistically significant.

On a third survey (8 April), 11 nests were found that had not been marked the preceding day. Most of these contained only 1 or 2 eggs and were not being incubated, suggesting that they probably were renesting attempts of geese that had previously deserted nests. One week later, 6 of these 11 nests had been deserted and the remainder hatched. Again, desertion occurred in the week following the visit to the nests.

During the fourth survey (14 April), 7 more nests were found, 3 of which had been established within the week, 3 to 6 eggs laid and then abandoned, and 1 had been destroyed. During ensuing weeks, 1 of the 3 active nests was destroyed by a predator.

Comparison of the Control nests of Groups 1, 2, and 4 of the lower section with comparable samples on the upper section showed significantly less nest loss on the lower portion (35%) than on the upper portion (55%). The overall nest loss for all islands during the year was 52%, evenly divided between desertion and destruction.

Evaluation of renesting by deserting geese was complicated by inability to separate it from initial nesting of others. However, the data from the above study suggested that renesting could be interpreted as replacing the deserted nests after a 1- or 2-week delay following desertion of the original nest. For instance, the 11

nests in Group 1 that were deserted and destroyed between 31 March and 7 April were numerically equal to the 11 new nests (Group 3) found on 8 April; the 3 Group 2 Experimental nests found deserted on 8 April were similarly equal to the new nests (Group 4) found on 14 April; and the Group 4 nest found destroyed on 21 April may have been replaced by a single new nest found on 5 May. On the upper section of the island, the 7 nests deserted and destroyed from 31 March to 7 April were possible accounted for in the 9 new nests found on 7 April; the 3 of these nests found deserted on 14 April were equal to the number of new nests found on 21 April; and the 2 deserted and destroyed nests that resulted from the 6 new nests found on 14 April and which were lost between then and 21 April were possibly accounted for by 2 new nests found on 5 May. These conjectures also suggest that unsuccessful geese gave up nesting attempts after a second failure; subsequent discussion will show that the cause of nest failure was important in determining whether a renesting attempt would be made.

Further evidence for renesting may be found by comparing the periodicity of hatching (Fig. 14) to the nest losses presented in Table 8. The 18-year mean progression of nest hatching shows that 3% hatched from 9 to 15 April, 14% from 16 to 22 April, 40% from 23 to 30 April, 28% from 1 to 8 May, 12% from 9 to 16 May, 2% from 17 to 24 May, and 1% after 25 May. Assuming a symmetrical distribution of nest hatching with the 23-30 April value as the midpoint, the next weekly period (1-8 May) is twice as high as expected. The difference almost

exactly accounts for the nests lost by desertion and destruction, and at 1- to 2-week delays previously discussed. While it can be argued that such interpretation of the data is largely conjectural, the amount of data and long time span under consideration provide support for this interpretation.

During the 1959 nesting season, another study of nest desertion was conducted, this time isolating all but Island 6 and the bluffs. A weekly census was made of Island 6 and bluffs to determine the number of territorial pairs, fates of nests and eggs, and hatching progression. After a majority of the Island 6 nests had hatched, all other islands were surveyed to determine whether similar fates had occurred to nests where our weekly visits were not made. Results (Table 11) were complicated by the presence of raccoons that destroyed 20 nests on Island 6 and apparently caused substantial desertion of many others. This so complicated the data that it was deemed inconclusive. The 1959 nesting data was, therefore, substantially underestimated because many of the vacated nests could not be found once the geese had left the islands.

The 1961 nesting survey was delayed until 19 April, or about 3 weeks later than usual. The Hanford goose population enjoyed its most productive nesting season of the study period as a result of a maximum number of nests, better than average clutch size, and very low rate of nest loss compared to other years (Table 12). Similarly, low desertion and destruction occurred in 1964, when the first survey was begun on 9 April.

Results of these studies indicated that about 20-50% of nesting females on an island were likely to desert their first nest if disturbed prior to or in the early stages of incubation, that most geese would attempt to renest, and that once well into incubation they were quite tolerant of disturbance by survey personnel. Early surveys caused more desertion than frequent visits.

Destruction of Nests

Coyotes were the most important predator on goose nests during the study because of their ability to reach any island of their choosing, and because their presence usually eliminated and/or prevented nesting on an island. Tracks, scats, evidence at nest sites and repeated observations of the animals searching islands provided conclusive evidence of their activities. Magpies, Pica pica, were important predators during 1953 on Island 3 (Hanson and Browning 1959:134), but, later were eliminated by poisoning and have not since been a major problem. Raccoons were occasionally a problem, but such instances were uncommon and usually restricted to a part of an island rather than denying the entire island to the geese as was the case with coyotes. Raccoons commonly patrolled the river bluffs, particularly during the goose nesting season. It appeared that their main interest was searching for young northern cliff swallows, Petrochiledon pyrrhonota, or cannon wren, Catherpes mexicanus, that fell from nests. Goose nests that were accessible were also destroyed.

No destruction was attributed to California gulls, Larus californicus or ring-billed gulls, Larus delawarensis, although 2 large colonies of those birds were present. Geese several times nested within the gull colony on Island 12 and usually were successful. This island had the lowest destruction rate of goose nests of all islands, and the gulls may have actually provided some protection by harassing mammalian predators.

Humans occasionally removed eggs from nests, broke eggs, or destroyed nest markers on the lower islands (18, 19, and 20) which were open to public access. The greatest damage from man, however, was through harassment caused by picnics, beach parties, photographing nests, and so on (Table 9). We originally publicized the beginning of the goose nesting season by public appeals (through news media) and recommended that people stay off the islands until mid-May; however, there was less destruction of nests when no publicity was used during later years of the study.

Magpie predation upon goose nests was usually greatest on Islands 3, 6, 8, and 14; all these islands had thickets of willow, hawthorne, rose, or currant that provided nesting and perching sites for magpies and thus exposed the goose nests to danger over a longer period of time. Although magpies or other animals may occasionally actively prey upon goose eggs, it became apparent during this study that most destruction was probably preceded by nest desertion, except in the case of coyotes. Several times during the study deserted nests

were left marked and rechecked to determine whether destruction ensued. This was often the case, especially where magpies were nearby. To quantitate this point during the 1959 survey of Island 6, all deserted nests were rechecked; of 29 deserted nests, 24 were subsequently destroyed by birds and mammals. Twenty-eight nests classed as "destroyed" (because there was no previous record of their desertion) were attributed to mammals (6), birds (8), or unknown cause (14). Bobcats, Lynx rufus pallescens, and badgers, Taxidea taxus neglecta, were seen on a few of those islands accessible through short, shallow water routes, but only one instance of possible badger predation was noted; the animal apparently ate the eggs and then dug a hole nearly 0.5 m deep through the bottom of the nest.

Coyotes were the most mobile and destructive of all predators on goose nests. Although we have championed a policy of uncontrolled animal populations in the study area, infrequent control of problem animals was necessary. Also, some control practices have been conducted on the Reservation boundary to placate stockmen and poultrymen who claimed it served as a coyote "reservoir." Limited coyote control was routinely practiced on the south and west sides of the Columbia River (Benton County) further upriver than Island 14; none was needed below Island 17 because of industrial and municipal complexes. Islands 1 through 14 had the largest fraction of nests destroyed during the study (Table 9), attesting to the presence of a substantial coyote population. A total of 451 nests were destroyed by predators during the study, many of them the direct result of coyotes, and 424 (94%) of these were on Islands 1-14.

The patterns of nest destruction showed that Islands 3, 8, 9, 10, and 11 were most often the victims of predators, and that 1955, 1957, 1958, and 1970 were years in which 6 or more of 10 islands that supported the majority of goose nests lost many of them to coyotes or other predators. The islands mentioned above are on the periphery of the best coyote habitat and are also easily accessible from the mainland, being separated by only short stretches of water. Coyotes swam to and from most of the islands during the study; and, on two occasions, were found swimming in midstream at locations where the Columbia River was 300-400 m wide and several meters deep.

The true impact of coyote predation upon goose nesting losses was not always reflected in the number of nests destroyed. Considerable desertion of nests resulted when a coyote invaded an island after nesting had begun, and the geese could not or would not renest. If the coyote was on the island prior to the nesting season, the geese often did not attempt to nest on that island or to move elsewhere to nest. A good example of the importance of the coyote as a deterrent to Canada goose production and an example of the apparent learning by geese was documented on Island 6 during the study. The first records of coyote predation on Island 6 occurred in 1959, when a coyote destroyed 42 nests and killed several incubating females. Most of the kills occurred at nests built near a wall of Russian thistles that had been "wind-piled" against the line of hawthorne trees along a portion of the north bank of the island. These losses of geese emphasize the

importance of visibility from the nest site as a survival factor for nesting geese. The second coyote incident occurred in 1965, when 1 animal (observed on surveys and from an airplane) destroyed 11 nests, killed 7 females, caused most of the desertion recorded at 28 other nests and prevented many geese from nesting; 8 nests were successful, an all-time low for the 13 years that the island had been studied. Only 47 goose nests were attempted during that year, which was about half the number expected.

Two coyotes swam to Island 6 in the autumn of 1966 and found sufficient food in the limited populations of cottontail rabbits, Sylvilagus nuttallii nuttallii, ring-necked pheasants, Phasianus colchicus, and small rodents, Perognathus parvus, Peromyscus maniculatus gambelii, and Microtus spp. to sustain themselves until the goose nesting season. They then destroyed 24 goose nests, caused 5 others to desert and only 1 nest, situated on a small isolated hillock, was successful. The coyotes then reverted to other foods and were still present in February 1968 when they were shot. The geese were very wary, however, and attempted only 52 nests during 1968; 47 of these were successful. The number of nests increased in 1969 and then was a complete failure in 1970. A coyote occupied the island prior to the nesting season, destroyed 2 nests and caused 1 to desert. This represented the minimal nesting effort on Island 6 during the entire study period. These observations strongly suggest that geese learned to recognize the predator; during the first encounter, the geese apparently defended their nests and several were killed. In the second encounter, the

coyote apparently came on the island shortly before we began our survey and had destroyed only a fourth of the nests and caused many others to desert. In 1967, the geese attempted to nest despite the presence of the 2 coyotes on the island, but were wary enough not to defend the nests to their death. By 1970, the geese apparently had learned that nesting was futile when a coyote was on the island and they made only a token attempt to nest.

Further evidence of geese learning not to defend nests from coyotes appeared on Island 8. We never found any evidence of nesting geese killed at that location, although coyotes routinely visited the island and destroyed goose nests.

Nesting losses from coyotes thus had to be evaluated from several standpoints. If the animal invaded the island prior to the nesting season and remained, most of the geese would not attempt to nest and the actual loss was best estimated from the long-term nesting history of the island. If the coyote came after nesting had begun and the geese had previous experience with coyotes, most of the active nests would be destroyed and the remainder deserted and subsequently destroyed; if the coyote intruded after nesting had begun and the geese were inexperienced with coyotes and defended their nests, several geese were likely to be killed and most of the nests destroyed. A second example of the last category was also recorded on Island 1 during the 1958 season; the coyote left the island shortly after destroying the geese and nests, however, owing to the lack of other food.

Records of coyotes taken in U.S. Bureau of Sport Fisheries and Wildlife, Wildlife Services Division programs in Benton, Franklin, Grant and Yakima Counties during the study period are presented in Table 13 (E. A. Peacock, pers. comm. 1970). Coyote control fluctuated with needs of people in a given county, availability of funds and other factors; these records, therefore, may not represent true population indices. Since mid-1960, selective control of coyotes based upon justifiable needs of individual cases has been the governing policy of the Division and undoubtedly influenced the recorded take of animals. The percentage of goose nests destroyed during various years showed no correlation with numbers of coyotes taken, particularly in Benton County, which is the source of most of the coyotes that invaded the goose nesting islands. The percentage of nests destroyed ranged from 11-13 during periods when about 400 coyotes per fiscal year were taken and also when 100 to 200 animals were taken per year. This emphasized the importance of individual animals as predators of goose nests in the study area.

Flooding

A few nests were lost by flooding during most years; but in 1956, a premature flood crest in the Columbia River that resulted in part from release of stored water behind Grand Coulee Dam destroyed 12% of the nests. In 1968, hydraulic manipulation to expedite the filling of the John Day Dam impoundment (see Fig. 2) inundated 2% of the Hanford goose nests.

Two remarkable behavioral events were recorded in connection with flood waters. In the first, a goose nested on Island 4 within 1.5 m of the water and in a situation where a vertical river rise of 0.3 m would inundate it. Two weeks later the river had risen sufficiently to barely cover the original nesting site; however, the goose had physically moved the nest, including 3 of her 4 eggs and the down and lupine nesting material, a distance of nearly 2 m in an attempt to escape flooding. She continued to incubate the nest but it was inundated the following week. The second example occurred on Island 2. A nest on a low part of the island would have been covered with water during the filling of the John Day impoundment; we moved the nest 10 m horizontally and 2 m in elevation in an attempt to save it. The goose accepted the change in location, reoccupied the nest and successfully hatched the eggs.

Most nests lost by flooding were on upper ends of Islands 2, 6, 8, and 9. These areas were of lower elevation than other sites occupied by nesting geese. Most consistent flooding loss was on Island 9, which has the appearance of a river gravel bar and which was inundated annually. Early annual inundation of Islands 5 and 16 precluded their use for goose nesting sites.

Fates of Eggs

Of the 3,631 nests from which complete histories were obtained, 2,688 were successful. The various categories into which the 14,796

eggs in those nests were divided include infertile, broken, and fertile eggs at different stages of development (Table 14).

Infertile eggs were of prime interest in this study because they provided a measure of reproductive performance of adults reared and resident in the environs of the largest nuclear reactor complex within the United States. The average fertility of adults studied by these means was about 97%, which is equal to or better than for geese from areas where there was no exposure to the very low amounts of radioactive contamination found at Hanford (Hanson and Kornberg 1956: 385, Davis et al. 1958:423, Wilson 1970:17). Fertility ranged from 95 to 99% throughout the study with no pattern with respect to time or location, indicating that neither the number of reactors operating during any one time nor the proximity of the geese breeding ground to the reactors had a measureable effect upon the production of infertile eggs.

Most broken eggs occurred in nests in the cobblestone gravel on the upstream ends of the islands. These nests often contained rocks of the same general size and shape of a goose egg and breakage occurred during normal incubation activities.

Among the fertile eggs that died during embryonic development, the first and fourth weeks predominated as critical times, corroborating the results from the first 4 years of study (Hanson and Browning 1959: 135). The 50 dead goslings found in successful nests probably resulted from delayed hatching, as none were found in hatched nests containing

broods. A few eggs that were within hours of hatching were found in nests abandoned by earlier hatched broods, and during the entire study period 2 live goslings were found as single orphans. Both died before they could be fed or placed with a brood of equal age. On a few occasions, geese were encountered at the critical period when part of the brood was dried and ready to leave the nest, and the remaining eggs were hatching. In such cases, the females usually ran a few meters with outstretched wings and the dry goslings attempted to follow. We usually placed these back in the nest and hurried away so the female would continue brooding the young until all eggs hatched. Usually, later observation showed that this was successful, but occasionally the young had to be returned to the nest several times.

Unusual Nesting Behavior

Forty instances of abnormal incubation periods owing to entire clutches being dead or infertile were noted during the study (Table 15). Two nests containing only rocks were incubated at least 7 and 26 days, respectively, and then abandoned.

During 1958, a second clutch occurred in the same nest from which a brood of 7 goslings has been raised a week previously. Three eggs were laid and incubated for 2 weeks and then deserted; all 3 contained dead embryos in the first week of development.

In 1961, a female hatched one gosling and then continued to incubate her other 3 eggs (all containing dead week-old embryos) for 3 more weeks and then deserted. No sign of the gosling was seen except for the shell membranes from his hatching. A similar record was made in 1966 when a female hatched 1 gosling and continued to incubate her other 5 eggs for several days, eventually hatching 4 of them. In both instances, the single gosling was apparently cared for by the adult male, who was not observed near the nesting site and presumed "babysitting". Similar behavior was observed by Sherwood (1965:125-126).

Occasionally, an increase in the clutch size occurred well after incubation had started. In 1970, for instance, a nest contained 2 additional eggs 1 week before the original 6 hatched. Both late eggs were fertile, but died after the nest was abandoned. We have no evidence as to the source of the late eggs.

Brood Rearing

Immediately after hatching and brooding, goslings were escorted by their parents to areas of riparian vegetation that supported concentrations of geese throughout moulting and growth of flight feathers. Five major brood rearing areas were used to varying degrees: Coyote Rapids, about 10 km upstream from Island 1; Wahluke, immediately adjacent to Islands 1, 2, and 3; Hanford, 5 km downstream from

Islands 8, 9, and 10; Ringold, adjacent to Island 12; and the mouth of the Yakima River, 5 km downstream from Island 20.

These areas had common properties of: (1) gently sloping shorelines, allowing easy access to and from the river; (2) freedom from boat traffic or else escape cover to provide sanctuary; and (3) abundant plant food in the form of pasture grasses (orchard grass, Dactylus glomerata, and alfalfa, Medicago sativa at Ringold) or semi-aquatic plants such as spike rush, Eleocharis macrostachya, sedges Carex spp., and bog rush, Juncus balticus. The close relationship of brood rearing areas to islands that were consistently utilized by nesting geese suggested that proximity to such areas was probably one of the requirements of a good nesting island.

A total of 434 broods were counted during the study to compare survival with age of goslings. These are summarized in Table 16, to which has been added the average number of young produced per nest at hatching. A 4% decrease in brood size was found during the first week of life (Class IA), no apparent further decrease in the age class of 1-2 weeks (Class IB), a 10% decrease between the second and third weeks (Class II), and a mixing of broods that produced larger and fewer broods after the third or fourth week of life (Classes III and IV). This mixing of families was noted only once in the Class IA broods, when a brood of 11 was accompanied by a Class II gosling, although 2 Class II broods numbering 28 and 11 goslings obviously represented 2 or more families. All these broods were escorted by

only 1 pair of adults. At the Ringold brood rearing area in 1970, 2 groups of geese were captured intact and each consisted of 30-40 goslings of various ages escorted by 5-6 adult birds. Brood mixing was probably more common than was apparent (Sherwood 1965:129).

In addition to the brood rearing areas, a favorite loafing area for moulting adult birds (<1 year) was the upstream end of the Hanford Reservation. Large groups of moulting geese, mostly unemployed sub-adults or unsuccessful nesters, remained on the riparian flatlands about midway between Priest Rapids Dam and the uppermost Hanford reactor area.

Mortality of goslings was not studied although some observations were made of their potential predators. One of the more chronic sources of loss was humans, who either maliciously harassed broods with boats or unthinkingly captured young that had been secreted by surprised adults. Coyotes were seen to chase broods that had gone ashore to avoid boaters, and a bobcat was seen to capture a gosling from a brood put ashore during banding operations. Two instances of hawks repeatedly swooping at goslings were noted; the first was a western red-tailed hawk, Buteo jamaicensis, that made repeated passes at adults and young of a family that scaled the river bluffs within the hawk's territory and the second was the apparent "play" of a marsh hawk, Circus cyaneus, that performed several "rolls" at a goose and her young in an alfalfa field. Neither hawk appeared bent on destruction.

POPULATION DYNAMICS

Banding Methods

Geese were banded each year from 1950 to 1970 except for 1966. The date for banding was predicated upon the hatching progression, coinciding with an age of 6-8 weeks for most goslings. This special time yielded best results in terms of survival of goslings after release and the retention of bands. Also, a majority of the adults (birds more than 1 year old) were flightless at that time.

Members of the State of Washington Department of Game, Bureau of Sport Fisheries and Wildlife, and AEC contractor personnel participated. The entire crew usually numbered 12-16 men in 4 outboard motor boats. Two methods of capturing the geese were employed, trapping and freebanding ("running them down"). Trapping was attempted from 1951 through 1954, beginning with the building of a V-shaped drive trap on the shoreline of a peninsula below Island 8 across which the geese fled during 1950 banding. However, in 1951 the geese fled across the next peninsula upriver and dispersed around the trap. The trap was accordingly moved the next year, and we fenced in the entire riverfront utilized by the geese. The levels of the river were lower in 1952 than in 1951 and the geese refused to cross a short stretch of slack water between a small island and the fenced riverfront. In 1953, the fence was moved to that small island, but the drive was only partially successful because the geese seemed wary of the island. Most of them had been herded down the Columbia River for some 30-40 km,

and the sudden confrontation with boats in their path of drift seemed to make the birds wary. The last trapping attempt was in 1954, when we attempted to take advantage of existing fences on an abandoned farm on the north riverbank near Island 1. In previous years, the geese had shown a preference for landing in this area and then running across cleared old fields in an attempt to elude the boats. This trapping location worked best of all attempts; but, unfortunately, was near a favorite watering location of range cattle. Several cattle were captured along with about 200 geese. The cattle stampeded through the holding pen with such force that most of the geese escaped through the gaping holes that remained. After this experience, it was decided to abandon trapping in favor of "freebanding".

"Freebanding" methods consisted of two boat loads of men equipped with aluminum salmon landing nets working down each shoreline of the river, attempting to push the geese ashore in areas where they could be run down and netted. The brood rearing areas previously discussed were most successfully handled by having all men and boats close in on one area at a given time. During the last 3 years of capturing geese, a new tactic of moving slowly but deliberately inwards and surrounding flocks of from 40 to 80 birds, mostly goslings escorted by a few adults, worked exceptionally well. All boats would make a frontal approach to the beach where the geese were loafing, then the birds were herded about 200 m into a farm pasture, where they were surrounded by the banding crew forming a circle of 150-200 m diameter. A second line of men stationed

themselves between the circle and the river to capture any birds that escaped the circle. Four men would charge toward the bunched geese, capture as many as possible, and split the flock into segments which were herded apart and held separate until captured birds were banded and released. The smaller flock would then be captured and banded and the main flock again split as many times as necessary to handle all birds effectively. This tactic proved almost completely successful under a variety of circumstances and cover types.

Although the "freebanding" method sounds as though it might be hard on the geese, only two geese were killed in the twenty years it was practiced; both mishaps occurred when goslings concealed in heavy grass were stepped on during pursuit of other geese. In addition, a bobcat captured one gosling as a direct result of banding operations. One advantage of the method was that entire family groups were often captured and released together at the same time.

Recovery of Bands

A total of 595 adults (birds more than 1 year old) and 1,602 goslings (locals) or juveniles were banded from 1950 through 1967, representing an average of 5.6 and 6.9%, respectively, of the adult and local bird populations available for marking assuming that all birds survived to banding (Table 17). This was obviously not the case, because the brood counts indicated a 14% mortality during the first 3 weeks of life; therefore, we banded about 8.1% of the surviving local birds during each year.

From the 2,197 banded birds, recoveries through December 1968 (when the summary used here was obtained from the Bureau of Sport Fisheries and Wildlife Bird Banding Laboratory) had totaled 490 or about 22% of those banded (Table 18). Adults contributed 29% of the recoveries, with slightly more of them having been recovered locally (within 50 mi or 80 km radius of banding location) than from distant points. Among juveniles, most of the direct (same year as banding) recoveries were near the breeding ground; the second-year recoveries were more distant; and, at the third year and over, the recovery pattern was nearly identical to that of adults.

Local Recoveries

Five main areas of band recoveries occurred within the 50 mi (80 km) radius of the banding location (Fig. 15). The area of greatest recovery was in the vicinity of McNary National Wildlife Refuge, which allows limited public hunting and attracted hunters on its periphery, and the Washington Department of Game's McNary Game Range, which has heavy hunting pressure. These areas are between the Snake and Walla Walla rivers and on or near the Columbia River in western Walla Walla County. Twenty-eight percent of the local recoveries occurred in this area, most of them juveniles. The second greatest recovery area was in southwestern Franklin County, where hunters using decoys in open fields near Islands 18, 19, and 20 that served as resting habitat for wintering Canada geese, accounted

for 14% of the recoveries, mostly adult birds. Northwestern Franklin County was nearly comparable to the last area, with 13% of the local recoveries; however, the age composition of the recoveries was nearly reversed, with locals being most heavily harvested. Central Grant County contributed 12% of the local recoveries, with third-year juveniles and adults being the main harvest, and 11% of the local recoveries were from eastern Benton County, where nearly equal numbers of adults and juveniles constituted the harvest.

A few birds of all age categories dispersed along the river systems of the region, but most of the birds remained on the sanctuaries or the Columbia River and flew to grain fields twice each day (usually) to feed. The tendency of the recoveries to lie in a northerly and northeasterly direction from the main resting areas was apparent and was in the opposite direction to that taken by the daily feeding flights of lesser and Taverner's Canada geese, which intermingle with western Canada geese on the resting areas.

A large part of the Hanford goose population apparently moved to the McNary Refuge during autumn months, an unexpected revelation of the band recoveries, whereas the remainder was more or less evenly distributed along the Columbia River between the Snake River and the old Hanford townsite. This distribution shifted prior to our aerial winter waterfowl census, largely because of hunting pressure.

Distant Recoveries

The pattern of distant band recoveries (Fig. 16) showed that the Hanford goose population did not perform a late season northward migration (molt migration) comparable to that reported in giant Canada geese (B. c. maxima) by Hanson (1965:78). About 75% of the young Hanford geese remained in the local area throughout their first winter, and the remainder emigrated southward through eastern Oregon, northeastern California, and down to the junction of the Sacramento and San Joaquin rivers in central California.

On the return northward the following spring, most of the young birds evidently continued on into northern Canada in the company of a few adult birds and most of the subadult birds. When the southward migration began the following autumn, most of the Hanford birds of all age cohorts returned through central Alberta and crossed the Continental Divide in the vicinity of Crows Nest Pass, at the juncture of the British Columbia-Alberta-United States borders. A few birds apparently joined Central Flyway flocks and continued southeasterly. The clustering of recoveries in southern Alberta is similar to that reported for the shortgrass prairie Canada goose population (B. c. parvipes) in a so-called "staging area" (Grieb 1970:13-17) that must be an impressive sight. Geese returning to their ancestral range moved through eastern Washington and many birds apparently wintered in southeastern Washington. The remainder of these geese emigrated southward through eastern Oregon

and stopped for considerable time in the vicinity of Klamath and Goose Lake areas of southcentral Oregon and Tule Lake, California, before moving on southward into central California. Another group of birds followed the Snake River into southeastern Idaho; we believe that most of these migrating birds return to the breeding ground at the age of 3 years on the basis of the fact that only 1 bird was retrapped on goose breeding grounds in California, and that may have been a wounded bird unable to return. A majority of the distant recoveries were from areas in which other nesting populations of the moffitti race occurred, (Jewett 1949:87; Yocom 1965:18; Hine and Schoenfeld 1968:6), and their intermixing and remaining with those populations is possible. A few recoveries were on the periphery of the dusky Canada goose (B. c. occidentalis) wintering range (Chapman, Henny and Wight 1969:8), but no major intermixing was indicated.

Survival Estimates from Banding Data

Recovery data for geese banded as juveniles or as adults are summarized in Tables 19-22. The data have been split into two sets, one containing essentially complete recoveries (birds banded 1950-1960) and the other more recent, incomplete recoveries (birds banded 1961-1967).

The "complete" data for geese banded as juveniles have been analyzed on a year-by-year basis, using a method attributed to Lack (Haldane, 1955). A correction for bias and statistical calculations follows results given by Chapman and Robson (1960) and Robson and Chapman (1961). The survival estimate is obtained from the equation:

$$\hat{s} = \frac{T}{n + T - 1}$$

where:

$$n = n_0 + n_1 + n_2 + \dots$$

$$T = n_1 + 2n_2 + 3n_3 + \dots$$

and n_0 represents first-year ("direct") recoveries, n_1 those in the second year, and so on.

A chi-square test (developed by Chapman and Robson 1960) was used to determine whether the first-year recoveries (n_0) were compatible with the remainder of the data. In the results for geese banded as juveniles (Table 23), there are a number of years in which the computed chi-square (1 degree of freedom) indicates the first-year recoveries were not in accord with the other recoveries. Such a result was expected, in view of the well-known greater vulnerability of juveniles to hunting. However, the actual situation is the opposite; as is evident from the

data in Table 19, geese banded as juveniles at Hanford from 1950 through 1960 had a much lower direct recovery than would be expected if they suffered a first year mortality equal to that of birds banded in later years.

We have no explanation for this surprising result, other than an obvious conclusion that those juveniles somehow escaped much of the normal exposure to hunting. It seems difficult to support any explanation based on band reporting, in view of the persistence of the phenomenon over a considerable span of years. We believe the effect extends over all (or nearly all) years, but does not result in significant chi-square values in many years simply because juveniles are much more vulnerable to hunting. Thus, the two effects tend to cancel out in many years. Of course, sample sizes for most years are rather small, but the overall result seems quite adequately supported.

The data for survival estimates with direct recoveries deleted (Table 23) show no evidence of incompatibility of second-year returns with the remaining data, and have been combined to provide an overall estimate of survival as 0.601 per year. This estimate was obtained by summing data over all years, and using the "Lack" (or Chapman-Robson) equation given above.

Unfortunately, there are too few recoveries for geese banded as adults to provide estimates on a year-to-year basis. The combined data for birds banded as adults from 1950 through 1960 (Table 21) provide a survival estimate of 0.685 (variance, 0.00065, chi-square value 0.38.

As previously noted, the "adult" category includes birds 1 year of age and older. The standard errors for the two categories (banded as juveniles; banded as adults) are fairly small (roughly 0.023 and 0.025) relative to the difference between the 2 survival estimates (0.600 and 0.685), indicating a significantly higher overall mortality in the first few years of life. It should be noted we have discarded direct recoveries for juveniles in the estimates used here. Some simulation experiments (Eberhardt 1970) suggest that, when survival rates change to a new rate after being constant for the first 2 or 3 years, the estimates obtained by the Lack method will tend to most nearly reflect the first rate. We are thus inclined to suppose that survival rates may be on the order of 0.60 for the second year of life, and increase to something on the order of 0.70, perhaps soon after the third year, by which time young geese become part of the breeding flock. The data do not really support a satisfactory estimate for the first year of life.

The rather small samples make it difficult to judge whether there has been any overall trend in survival rate during the years of study. Individual estimates for the first 10 years (Table 23) do not suggest a pattern of change. Recoveries since 1960 (Tables 20 and 22) are as yet incomplete, and rather small in number. Using Haldane's (1955) method, we estimated the survival rate for geese banded as juveniles to be 0.636, and that for adults as 0.752. First-year recoveries were not used in forming estimates for juveniles. These estimates are subject to sizable variation due to the incomplete nature of the data.

A MODEL OF ISLAND GOOSE POPULATIONS

One effective way to appraise the data on population dynamics is to use it to construct a model of the Hanford goose population. Since it seems quite apparent that the 18 islands each have a fairly definite "carrying capacity" for nesting geese, we constructed the model to include each of the 18 islands as a separate entity (the Bluff areas were not included in the model). We have no way of knowing how faithful geese are to a particular island. One extreme case would be that in which each island has its own population, with no exchanges. This is, of course, not at all reasonable in view of the stable but very small populations observed on several islands. With the observed rates of about 70% nesting success and 30% annual adult mortality, such populations are not likely to persist without replacement from outside. On the other hand, a completely random redistribution of geese each year also seems unlikely, so we chose an intermediate and simple route -- surviving pairs always used the same island, but new breeders (3 year olds) were allocated to available breeding space in a random manner (once assigned to an island, they remained there).

The number of calculations involved in handling all 18 islands over 21 years (1950-1970) led to constructing the model as a computer simulation. To obtain as much realism as possible, the various events were structured on a probabilistic basis with mean (average) values derived from the observational data already described in this report. This means, of course, that the outcome of any given run of the model

is also a random variable. To obtain the expected (average) value of population size, one would either need to perform some rather detailed and complicated calculations or to run the model a large number of times and average the outcomes. However, we do not consider the expected outcome to be a matter of major interest as a consequence of our uncertainty about the values of certain parameters, survival during the first year of life being a prime example. We regard the model as being more important as a way of exploring various aspects of population dynamics of the Hanford Canada goose flock and appraising shortcomings of our knowledge about that population and the mechanics of its year-to-year dynamics.

As has already been noted, the basic element is the individual island population of adult geese. In the model, each island starts out with initial populations of the size listed for 1950 (Table 4) expressed as territorial pairs. "Output" data from a sample run of the model show that the 1950 data of Table 24 correspond to that of Table 4. Other initial values required are the number of 2 year olds (400) and 3 year olds (300) alive in the spring of 1950. These values were calculated to correspond with a "steady-state" population of 210 territorial pairs of adults, using average nesting success (70%), brood size (5), and survival rates (see below).

Beginning just before nesting, the first computer operation distributed 3 year olds over the various islands. A "carrying capacity" was assigned each island (Table 25). Values assigned were taken from

Table 4, and were usually the modal (most frequent) value, or if there were 2 modes, the numerically largest one during the period 1950-1965. "Space" available on each island was determined by contrasting the current population (territorial pairs) with carrying capacity. If population size equalled or exceeded carrying capacity, then no space was available, and no new recruits (3 year olds) were assigned that particular island. The total available space was compared with the number of 3 year olds and any surplus (Table 24) was removed. Presumably these individuals left the Hanford area. The remaining new recruits were randomly distributed over the islands (even though we recognize this is not the natural case), but with probabilities proportioned to the available space on each island. This permitted the population on a given island to exceed or remain less than carrying capacity even though there may have been an overall surplus of 3 year olds.

The actual situation probably is more complex than that of our model. No doubt total carrying capacity changes somewhat from year to year, and surely some surplus geese do nest in less favorable spots (and thus perhaps produce fewer young), while others may remain as unemployed geese and ultimately contribute to the populations or serve as a sort of safety factor. Another kind of density-dependent "compensatory" mechanism is undoubtedly the case of breeding by 2-year-old geese (reported by Craighead and Stockstad 1964:62 and Sherwood 1965:143). When there is a good deal of available nesting space on the islands,

2 year olds no doubt fill up some of this space and help return populations to higher levels. Since we have no data on these several mechanisms, our initial model does not include a variable carrying capacity, or utilize surplus or 2-year-old geese for breeding.

After the 3 year olds were allocated, reproduction was simulated. Each pair was randomly assigned to a "successful" or "unsuccessful" status, with probabilities for each island corresponding to the data of Table 9, with the exception of Island 6. Since this island has nearly half the total territorial pairs, and suffered some catastrophic coyote predation on nests, we initially assigned it 84% success, but reduced success to 50% in 1959, and to zero in 1965, 1967 and 1970 to correspond to observed coyote predation on nests. This gave an overall success of roughly 70% to correspond with that recorded in Table 9.

Each "successful" pair was randomly assigned a brood size with probability proportional to the frequencies of Class IA broods recorded during the course of the study. (These records were kept only from 1959 to 1970). The average simulated brood size value for "successful" pairs (Table 24) can be contrasted with the brood size data of Table 16.

The next operation simulated adult survival over the years. Each pair was randomly assigned as surviving or dying, with survival probability set at 0.685 to correspond to the estimates given in the section on survival estimation. We calculated survival for pairs rather than individuals as a matter of convenience, assuming that an equivalent calculation for individuals would be followed by pairing of the survivors. The above scheme excludes natural mortality from the

nesting season, except as it affects the percentage success in nesting. Presumably, percentage success might be decreased slightly to allow for natural mortality before nests are established, but such an adjustment does not seem feasible in view of the limited knowledge available on natural mortality and the difficulty in calculating what effect it does have on values recorded as percentage nesting success. As has been previously noted, adult pairs in the simulation remain on a given island as long as they survive.

Juveniles were assigned to a common pool and survived as follows: 0-1 years, 0.60; 1-2 years, 0.60; 2-3 years, 0.685. Rather than proceeding on an individual basis, which would be quite demanding of computer time in view of the substantial numbers involved, each age class survival for each year was treated as a binomial random variable depending on survival rate and number of individuals (actually a "pseudonormal" distribution substitutes for the binomial).

As has been previously remarked, the survival figures are one of the weak points in the data. We simply have no way of calculating survival from just after hatching to one year of age. We used a rate equal to the 1-2 year rate because band returns showed that Hanford juveniles apparently somehow escape much of the usual high first-year shooting losses. Very likely first-year survival should be lower than the value used, and probably survival from age 2 to age 3 should also have been decreased, perhaps to 0.60. On the other hand, we suspect geese older than 3 years very likely have a survival rate greater than that estimated

(0.685) and used. It seems clear that any significant decrease in survival rates will lead to decreasing populations, and a necessary compensation would then be more nesting by 2 year olds. This is undoubtedly best explored by a considerable number of simulation runs, with varying survival, and by incorporating 2-year-old nesting if space is available on the islands. It does seem that the year-to-year survival rate was fairly constant, as evidenced by our data from band recoveries (Table 23). We have thus held average values of survival rates constant over the course of the simulation. It may be noted that the survival rate for 0-1 years (0.60) actually starts with Class IA broods which (Table 16) have already suffered a small mortality.

The sporadic nature of coyote nest predation is an important variable which is difficult to handle realistically. For the several smaller islands quite regularly visited by coyotes, the observed overall proportion of successful nests provides a sufficient measure of predation. On Island 6, however, visits were not recorded, or infrequent, in the early years of the study, but of serious consequence in later years. Starting in 1965, there was some evidence that geese began to avoid the island, or were driven off by coyotes. We have, consequently, arbitrarily reduced the carrying capacity of Island 6 to 50 pairs from 1965 onwards, and increased that of Island 1 to 30 pairs beginning in 1962 to correspond with an evident shift in population on that island.

The data in Table 24 indicate that the simulated population produced an appreciable surplus in the late 1950's and early 1960's and again from 1965 to 1967 (the latter condition results from the arbitrary reduction of Island 6 carrying capacity to 50 pairs (see Table 26)).

Comparing the data in Tables 24 and 17, it appears that the simulated population fails to reach a maximum as rapidly as shown by the actual population. The actual population may well have had a larger reserve of "unemployed" geese to draw on -- quite clearly the recorded (Table 17) population of unemployed geese was much less than that necessary to maintain the population (age classes 1 and 2 of Table 24). The data (Table 4) suggest that in 1950 the Island 6 population may have been recovering from a low point, which might conceivably have been due to coyote incursions, just as observed in the late 1960's.

One of the interesting things about the simulated data is the considerable variability in average brood size. This, in conjunction with the effects of chance on survival, makes it unwise to try to interpret the results of any one simulation in detail. Quite clearly the effects of coyote predation in the 1960's (and reduction of Island 6 carrying capacity) resulted in decreasing the simulated overall population, but not to as low a level as was experienced by the actual population (Table 17).

Since survival in the first year is our major unknown, it seems worthwhile to exhibit some effects of reducing survival in that age-class.

The population trends with first-year survival reduced from 0.60 to 0.50 are shown in Tables 26 and 27. The data are based on an identical set of constants, so that the outcomes differ simply as a matter of chance. They do indicate, however, that reducing first-year survival to 0.50 may tend to hold the population just below or near the carrying capacity (about 300 pairs). Very possibly continued coyote harassment on Island 6 would result in a continued decrease in the population, perhaps to a point well past the "new" carrying capacity (about 250 pairs). As has been noted above, a realistic investigation of such a change needs to include some reproduction by 2 year olds when unused nesting space is available.

In general, the simulated individual island populations seem to be appreciably less variable from year to year than were the actual populations. Many reasons for the difference may be suggested. One is that, in the "real world," carrying capacity probably is not a rigid ceiling in any year, and surely varies from year to year. Using island populations (Table 28) corresponding to Table 27 (in which carrying capacity was not reached in the first 15 years) we contrast (Table 29) some measures of variability for the first 6 islands (actual and simulated data). The comparisons are limited to the first 15 years to largely avoid the further complication of coyote nest predation in the later years.

It seems evident that the simulations mostly have a smaller range and variance than do the actual populations. The one exception (Island 1) had a change in carrying capacity during the simulation (from 19 to

30 pairs). It may be noted, too, that the simulations tend to have a variance smaller than the mean, so that variability is less than that of the "Poissonian" situation one might intuitively expect. The higher actual variance of Island 6 populations probably is accounted for by the fact that the initial population was only about half the carrying capacity, so that there was a considerable growth in numbers during the simulation. Another possible contributory factor is "sampling error" in that some pairs may have been missed during the field counts while others may have been assigned to the wrong island.

Perhaps the most important contribution to larger variation in the actual populations may come from 2 other sources: 1) year-to-year fluctuations in weather and river flow conditions and their influence on survival of goslings, and 2) adults may not return to the same island each year, thus reducing the stability of individual populations. Other factors might also be considered, such as variation in the influence of our nest surveys and of predation on desertion rate.

DISCUSSION

The Hanford Canada goose population is relatively young in historical terms. Early residents of the region stated that very few Canada geese nested on the Columbia River islands prior to establishment of the Hanford Reservation in 1943 (A. Borden, 1970). This is consistent with other reports of the adversity that has beset the Canada goose in its local history. According to Yocom (1961, 1962): "All evidence indicates that Canada geese did not nest along the

Columbia River from Kettle Falls, Washington, to its mouth nor along the Snake River, at least in Washington, prior to 1900," nor did archaeological evidence suggest that there was appreciable nesting in this area. Indians apparently decimated most nesting on the river systems until recent times and early homesteaders extirpated the populations in the eastern Washington uplands. Small flocks that prevailed in certain areas, such as those near Moses Lake and the pot-hole lakes of the channeled scablands (Dawson and Bowles 1909:828), furnished breeding stock that exploited nesting opportunities such as that created by the sanctuary of the Hanford Reservation. By 1948, Jewett (1949:93) estimated that there were "possibly between 75 and 100 pairs" along the Columbia River between Richland and Kettle Falls. Apparently, that was a conservative estimate in light of the 210 pairs counted on only the Hanford islands 2 years later. He also estimated that the number of nesting pairs on the lower Columbia River, between The Dalles and Pasco, was 66 in 1944 and about 125 in 1948. Hansen and Oliver (1951:4) reported about 600 pairs in the same area in 1950, further suggesting that Jewett's estimates were conservative but that the goose population had markedly increased. These estimates and our results for this period (Fig. 3, Table 4) suggest that the Hanford population rapidly increased from a few scattered pairs in 1943 to a relatively stable population of about 300 pairs by 1952. Similar increases occurred in other areas of eastern Washington

during this period as a result of changes in farming practices, reduction of rural human population, and increased food sources (Yocom 1961). The downward trend of the Hanford nesting population since 1958 is believed principally due to coyote predation; excessive hunting mortality is not indicated in the limited banding recovery information. The possibility of a compensatory influx of birds from adjacent nesting areas that were disturbed by hydroelectric dam construction and impoundments prompted the installation of artificial nesting platforms on Islands 14 and 15 during 1951 (Hanson and Browning 1959:31). The complete failure of the nesting platforms to attract nesting geese and the observation in our study area of only one distinctively neck-banded goose from the John Day Dam impoundment since that nesting area was inundated in 1968 is evidence that movement into another adjacent nesting area is not a simple matter. Nor was there any appreciable immigration of geese banded on other breeding grounds. The prompt pairing of "previously acquainted" breeding adults who have lost their mates (Sherwood 1967:350) and the pairing observations of Martin (1964:33) complement our observations that social organization in Canada geese is a complex and important phenomenon that has greater application than usually recognized. It may certainly control the mixing of breeding populations and may seriously retard the assimilation of displaced geese into a neighboring population to the extent that interim mortality factors may exceed permissible limits.

Territoriality in Canada geese, as in animals in general, is one of the most important and most complex factors regulating population performance. It almost certainly is involved to some degree in nest desertion where overcrowding occurs (Rienecker and Anderson 1960:486; Munro 1960:547) and may cause subordinate or surplus nesting geese to utilize unsafe habitat exposed to predators (Sherwood 1965:48). Overcrowding was not apparent during our study and nest desertion owing to territoriality did not occur during the peak years of nesting. Greatest nesting densities occurred on Islands 1 and 2 (7.1 and 3.4 nest per useable hectare, respectively) but varied as to years of maximum. Island 6, which initially supported about 35% of the total nests in any one season, yielded 0.9 to 12.0 nests/ha during the period 1954-1958. The overall density during the 18 years of intensive study was 0.5 nests/usable ha, equivalent to 1.2 nests/acre. This was considerably less than the 9.4-30.7 nests/acre reported by Munro (1960:548) in the upper Columbia Valley goose population in British Columbia and about equal to densities at Flathead Lake, Montana (Geis 1956:412). Hammond and Mann (1956:351) reported that a nesting density of about 16 per acre was the maximum tolerated by geese on Lower Souris National Wildlife Refuge (North Dakota) before increased friction and nest loss would occur. Personal observations made on the John Day Dam impoundment during the 1970 nesting season suggest that geese displaced from their past nesting or natal islands may colonize new nesting habitat in remarkable densities approaching the 56-60 nests per acre found by

Naylor (1953:90) in California. This condition will probably not persist. In addition to intraspecific friction, such densities present concentrated opportunities for predators to destroy large segments of the population.

Hanford geese frequently used the mainland riverbank adjacent to the islands as part of their territory, especially for the gander "stand." The territory for a pair on such Islands as 1, 2, 8, and 11 then extended for a short distance around the nest and the considerable distance across the river to the adjacent riverbank. Ganders often took up stations 20-25 m toward the water from the nesting female on islands with extensive littoral zones, such as Islands 3, 6, 9, 12, 17, and 19. Combinations of these arrangements thus allowed the best use to be made of the most preferred habitat and accounted for the relatively calm atmosphere that prevailed during the study. No strife between pairs was noted, even during the population peak, and prompted the conclusion that the Hanford goose nesting habitat was not completely utilized. Dropped eggs were encountered occasionally, but no significance was attached to these as indicators of strife or frustrated subordinate geese (Collias and Jahn 1959:505). "Nearest neighbor" distances were measured during 1968 and 1969 for 330 nests on the various islands (Table 30). The validity of such data in population analysis of nesting geese is questionable because of a tendency toward "clumping" of nests in response to vegetation (Martin 1964: Munro 1960:550), topography (Yocom, Buechele and Harris 1956:16) and other factors that encourage colony nesting (Kossack 1950:638).

Studies of individually marked geese under refuge conditions (Collias and Jahn 1959:503) suggested that 25% of the potential nesting population may not pair effectively. Our results indicated somewhat better conditions in the Hanford goose population. The 20% greater number of pairs than nests probably contained many sexually immature birds as well as subordinate pairs unable to secure and defend nesting territories. Nesting densities on individual islands supporting a majority of the nests varied over a threefold range, and yet the number of pairs per nest remained steady. Exceptions to this occurred on Island 6 during years in which coyotes invaded the island; on these occasions 20-40 pairs stayed on the island until mid-April or longer and then gradually disappeared, presumably to the "adult" molting area at the western boundary of the Hanford Reservation.

The desertion studies previously described indicate the difficulty of separating the various factors that enter into that aspect of goose nesting behavior. Islands 1, 12, 15, 17, and 18 had the lowest incidence of desertion. A review of their qualities showed that 1) their usable area was about 10-20 hectares; 2) vegetation was mostly comprised of low-growing species; 3) their pairs/nest ratios were 1.2-1.5; 4) they had experienced little or no predation problems; 5) they were situated near the middle of the river, requiring some effort on the part of coyotes to swim to them; and 6) the food base on the island was not sufficient to support coyotes for any appreciable time. Results of our study emphasize the importance of coyotes in not only destroying goose nests, but also in preventing the geese from nesting.

Various animals have either assumed important roles in other waterfowl nesting studies or have had little impact upon populations. Nesting losses to predation were of very limited importance in Utah (Williams and Marshall 1937:85) and in northeastern California (Miller and Collins 1953:385), but were appreciable and due principally to mammals in the Sacramento Valley in 1955 (Anderson 1957:89) and in Idaho (Salter 1958:7). Ravens (Corvus corax) and crows (C. brachyrhynchos) were important goose nest predators in Wyoming (Craighead and Craighead 1949: 58-59; Dimmick 1968:46) and California and ring-billed gulls were reported to be the main predators of goose nests and perhaps of week-old waterfowl on Tule Lake and Lower Klamath National Wildlife Refuges (California) in 1957 (Rienecker and Anderson 1960:503). California gulls, magpies and ravens were responsible for about one-third of Canada goose nest failures in a recent Utah study (Martin 1964:47). Coyotes and ravens were found by Sooter (1946:34) to be major predators affecting waterfowl production on Malheur National Wildlife Refuge (Oregon) during the period 1938-1943, although Sperry (1941: 52-53) during the same time reported that there were no documented cases of nest predation by coyotes, but cited reports of them molesting flightless young waterfowl. Munro (1960: 553) stated that "the Canada goose is not an important food source for any predator. Predation on Canada geese probably occurs only as a result of chance opportunities." Sherwood (1965:47) concluded that the limited numbers of safe nesting islands prevented growth of the Seney goose population, which was also subjected to coyote predation. He apparently felt that islands more than 200 feet offshore were relatively safe, whereas

most of the Hanford islands were farther offshore than that and in the middle of a large, swift river.

Predation is thus seen to be highly variable in importance with respect to time, geographical location, animal species involved and human interpretation. All of the animals cited above occurred in varying numbers within the study area but caused no major nesting losses except for coyotes and the isolated incident involving magpie predation on Island 3 during 1953. Desertion usually preceded nest destruction by animals other than coyotes, as shown by the 1959 study previously described, and is a product of physiological and behavioral factors that remain to be adequately described.

The prime objective of the intensive nesting study was achieved in the documenting of the long-term record of adult fertility as indicated by egg fertility. Results of our observations are compared with other studies conducted in areas where there were no Atomic Energy Operations in Table 31. The 97.4% fertility of Hanford adult geese is comparable to other populations, and we conclude that the nuclear reactor operations had no apparent deleterious effects upon the geese.

MANAGEMENT CONSIDERATIONS

In addition to the demonstration of no injurious effects upon the population by Hanford reactor operations, results of this study can also be applied to management considerations in the light of possible environmental changes and offer a base for other studies.

The Proposed Ben Franklin Dam

The specificity of geese for certain islands was clearly demonstrated by the behavior of birds driven from Island 6 by coyotes during several years. They refused to utilize adjacent islands or river bluffs which apparently had sufficient nesting territories to accomodate at least a portion of the displaced birds, and there were sufficient numbers involved that their presence on other islands would have been noted. This behavioral phenomenon was also observed in the John Day Dam impoundment, where most birds returning to their inundated nesting area appeared incapable or unwilling to accept their modified environment for some time (E. Bowhay, pers. comm. 1970) and tended to nest in unusual densities on a few islands thereafter. Such performances have particular application in assessing the probable effect of the proposed Ben Franklin Dam upon the Hanford goose population.

Inundation of the 14 islands used by 80% of the Hanford geese for nesting would be a major blow to the population by loss of nearly an entire age cohort. New nesting habitat created by the impoundment would subsequently be utilized in unusual ways that could result in considerable intraspecific strife and might attract appreciable predation. The light soils of newly created islands in the impoundment would probably erode under the influence of water and wave action similar to islands of comparable characteristics in the impoundment behind the John Day and McNary Dams; therefore, rip-rapping or other bulwarks should be added to the new islands to prevent such habitat loss. Construction of artificial islands from peninsulas should be guided by characteristics

of the most successful islands of the present natural habitat. A substantial nest base is the most essential factor, with visibility to have definite influences upon production (Williams and Marshall 1937:83; Williams and Sooter 1940:383; Williams and Nelson 1943:341).

The possibility of offsetting nesting losses by erection of artificial nesting platforms such as those used to varying degrees by other populations (Yocom 1952, 1956; Craighead and Stockstad 1961: 363-372; Dimmick 1968:41) is questionable. A few artificial platforms were tested at Seney, but were not used by the geese there (Sherwood 1965:91). Such installations are expensive, are alien to current nesting behavior, and probably require a gradual experience of adaptation by the geese rather than the abrupt environmental change that has prevailed in dam impoundments in the past. Placement of a few platforms to accomodate more than 200 territorial pairs in the midst of a traumatic behavioral experience would be tokenism. Sufficient time prior to inundation of the present nesting islands should be allowed for adaptation; the utilization of river bluff nesting sites by 1-3% of Hanford geese may represent a step toward platform nesting or at least an indication it might be encouraged. The specificity of geese for their ancestral islands attests to the complex behavioral response that one must deal with in such a situation and strongly suggests that considerable planning is necessary to successfully resolve the problems.

One of the most important considerations in evaluating nesting habitat loss would be replacement of brood rearing areas, particularly

near Islands 6 and 12. Several abandoned farms in the White Bluffs and Ringold areas should be irrigated and pasturage provided. Such areas would provide ideal brood rearing and banding sites and should be managed as such, with sharecropping a secondary consideration. Wintering geese would also use the areas extensively and provide conditions for study of goose family behavior during the reassembling of families following the nesting season. At the present time, wintering geese concentrate on the lower 3 islands of the study area, within the sanctuary of the City of Richland, and in the secured region between Island 1 and the west boundary of the Hanford Reservation. Autumn rains and the resultant sprouting of brome grass, Bromus tectorum, are prime factors influencing the distribution of the geese, which are subjected to considerable hunting pressure on the lower part of the study area and tend to move into the interior of the Hanford Reservation when sufficient green brome grass is available. During the winter of 1968, 80% of an estimated 50,000 wintering geese moved upriver as the sprouting brome provided food in the Hanford sanctuary. Irrigated pastures could thus be utilized year around and provide means of redistributing goose populations in response to management needs.

The Proposed Columbia River Navigation Channel

An alternative proposal by the Corps of Engineers to excavate a navigation channel in the Columbia River through the Hanford Reservation to provide barge transportation to the upper Columbia River if Ben

Franklin Dam is not authorized will have serious impact upon waterfowl habitat within the study area. Channeling of the river flow will allow coyotes easy access to many of the goose nesting islands now invaded sporadically, but the greatest concern would be the disposal of the estimated 6.3 million cubic yards (4.8 million m³) of gravel and rock to be removed to create the 76-m-wide x 4.3-m-deep channel. Deposition of this material along the riverbank would destroy brood rearing and resting habitat vital to the Hanford geese and to a variety of other wildlife. Approximately 200,000 wintering ducks and a few hundred geese utilize the margins of Islands 8, 9, and 10 and nearby mainland shoreline during winter months, exhibiting rather specific behavior in their selection of habitat. The navigation channel would thus drastically alter a section of river that contains prime nesting and resting habitat of considerable value underestimated by most governmental agencies.

Opening the Columbia River to Public Access

There is currently mounting pressure by several agencies to obtain public access to the entire stretch of the Columbia River, which is now closed between Island 11 and the western end of the Hanford Reservation. So far as nesting Canada geese are concerned, such access would be seriously detrimental unless strictly controlled from February through June. Our experience during this study showed that human disturbance materially reduced nesting on islands, especially where repeated visits

were made by pleasure boaters. Increased incidence of wildfire probably would result from public usage and could have considerable impact upon nesting, as shown by our results, especially if it occurred during the nesting season. Wildfires resulting from lightning strikes occasionally occur during summer months within the Hanford Reservation but have rarely been observed on the river islands; fire danger is, therefore, related to human activities on the islands.

Opening the Columbia River within the Hanford Reservation to public access probably would extend the hunting and fishing activities now available to the public through the Ringold extension of the McNary National Wildlife Refuge. Shoreline hunting and fishing are now allowed on the north side of the river within the restricted area from Island 11 to the old Hanford Ferry landing and this activity displaces wintering waterfowl upriver into the secured area near Island 8, 9, and 10. Further harassment of the waterfowl by opening the river to public access would probably decrease waterfowl hunting opportunities and success by driving the ducks and geese from an important resting area. A few hunters on the lower 16 km of the study area each year effectively clear the river of ducks and geese, which move upriver into the sanctuary of the Hanford Reservation or downriver into the closed area of Richland city limits. This had greatly reduced the waterfowl hunting opportunities that formerly existed when the Columbia River Waterfowl Closure prevented waterfowl shooting within 0.4 km of the Columbia River in this region.

In addition to public harassment of geese during the nesting and hunting seasons, we have noted that pleasure boaters have gradually driven the birds from most of the lower study area during the brood rearing season. Several observations and reports of harassment account for the withdrawal of the geese into the Yakima River delta below Richland, where shallow waters restrict boat traffic and riparian vegetation provides food and shelter. Luxuriant growth of willow, Salix amygdaloides, should be curbed, however, because it is usurping more habitat than is advisable. Proper management of the delta area could enhance its value as a brood rearing habitat and its adjacency to a public highway provides esthetic interest.

Development of Nuclear Power Plants

The proposed construction of a nuclear power reactor "park" within the Hanford Reservation for supplying electricity to metropolitan areas would affect Canada geese by creating microclimates of heat near reactor outfalls or cooling towers. These might be beneficial by stimulating growth of aquatic biota along shorelines, by providing ice-free loafing areas, and by promoting the growth of green grass in areas of warm, moist air during winter months. Environmental and radiological health considerations would be an integral feature in an industrial development and these should include comprehensive studies of nesting and other wildlife in the reactor environs. Such studies would have important implications in the future expansion of nuclear power generators and should transcend this study.

Increased Hunting Pressure

Hunting mortality is often the greatest single factor controlling a Canada goose population (Hanson and Smith 1950:149; Craighead and Stockstad 1956:211; Martin 1964:70). Band recoveries during our study showed that the Hanford goose population provides a substantial number of birds to hunters over a large area and thus deserves consideration in the face of greater future harvest. Opening of the Hanford Reservation to public access would probably result in exposing the Hanford geese to greater hunting mortality whether or not hunting per se would be allowed within the Reservation. A balance must be obtained between the extremes of protecting the birds to the point that they become unwary and thus more susceptible to hunters (Hanson and Smith 1950:126-127) and driving them away from their ancestral wintering grounds. The implications of the latter possibility are not known and need further study for a realistic approach to management of the population. Movement of the geese in response to food availability, weather conditions, hunting pressure, and sanctuary is probably as important to the future of the Hanford population as that reported for geese in Montana (Craighead and Stockstad 1956:228).

Certain areas should be kept as sanctuaries, especially Islands 18, 19, 20, and nearby Nelson Island within the City of Richland, and an area comprised of 1 km on either side of the Columbia River from Island 6 to Coyote Rapids (about 20 km of river).

Improving Current Production

Several management techniques can be instituted under the present habitat conditions within the study area that will increase Canada goose production:

1. A predator control program conducted by the U. S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife Division of Wildlife Services and currently funded by the Atomic Energy Commission should include a regular coyote control campaign on Islands 6, 8, 9, 10, and 11 at the optimum and on Island 6 at the minimum. Results of this study leave no doubt of the possible impact of even 1 coyote upon the Hanford goose production.
2. Vegetation control on certain islands and brood rearing areas would increase production. Currant and willow thickets on Islands 8 and 14 are important magpie cover and promote predation on goose nests. A dense growth of chokecherry, Prunus virginiana, and other shrubs on Island 13 is utilized by magpies and may explain the lack of goose nests on that island, although the number of nests involved has been too few to realistically measure predation by magpies there. The encroachment of willow upon brood rearing habitat at the Yakima River delta should be checked in the near future because it is now accelerating. This could be accomplished in cooperation with State and Federal Agencies, and should

possibly include cooperation with the City of Richland.

Island 20 and Nelson Island, both within Richland city limits, should be treated to diminish willow growth that is now encroaching on important resting habitat. Occasional burning of stagnated vegetation on Island 6 may be a useful tool for opening up nesting and feeding areas.

3. Cooperative agreements should be made with private landholders whose property is heavily used as brood rearing areas, especially at Ringold, to allow maximum utilization and protection of pasturage. These areas could also be used advantageously for banding geese.
4. Placement of driftwood or other objects for nesting cover would increase utilization of several islands. Suggested locations are Islands 2, 3 (north arm), 4, 5, 7, 9, 10, and 18. Discarded automobile tires on such islands have been used by nesting geese, but are not esthetically acceptable.
5. The Corps of Engineers and Public Utility Districts associated with hydroelectric dams upstream from the study area, especially Priest Rapids Dam, should avoid discharges of 137,000 cfs (3,836 mps), as measured at the Priest Rapids stream gauging station, during the period mid-March to mid-May. This was the rate at which we noted flooding of nests during our study.
6. Annual nesting surveys should be delayed until mid-April to avoid causing desertion, as discussed previously.

7. Behavioral studies should be initiated, using this study as a background, for better definition of certain observations reported here. Carrying capacity of habitats, desertion rates, renesting, brood rearing phenomena, movements of family groups, role of various wintering areas in maintaining the Hanford population, response of geese to various management policies and other aspects of Canada goose behavior are but a few of the opportunities that may be based upon this long-term study. Such studies should start while the information reported here is cogent and applicable.

SUMMARY

Nesting and banding studies of a Western Canada goose population resident within the Hanford AEC Reservation in southeastern Washington were conducted during 1950-1970. Objectives of the studies were to determine population dynamics, and to assess possible effects upon geese resident near the largest nuclear reactor complex within the United States.

Intensive nesting studies were conducted during 1953-1970, usually beginning during the first week of April and continued at weekly intervals thereafter until the end of the annual nesting season (about mid-May). The nesting goose population increased from about 200 pairs in 1950 to a maximum of 300 pairs during 1953-1956 and then declined to about 200 pairs in 1964-1970. Unemployed geese, presumably less than 3 years of age, numbered 50-150 each year. The number of pairs associated with each island used by nesting geese was fairly constant until serious coyote predation on geese and their nests apparently forced a population shift during the later years of study.

Goose nesting began when average daily temperatures of 5°C (40°F) were reached, with most of the nests begun during the third week of March. The 18-year average nesting season extended through 12 weeks, and began earlier in those years when February was warmer than the norm for the region.

All nests on 18 of 20 islands utilized by nesting Canada geese in the 88 km (55 mi) of unimpounded Columbia River were individually marked

and their nesting history recorded. During the 18 years, information was obtained from 3,824 goose nests, with complete data from 3,631; or, an average of 209 nests per season with a density of 0.5 nest per hectare usable habitat. The geese utilized 7 major plant communities for nesting cover, but showed a preference for lupine and willow.

Of the 3,824 nests, 70% were successful (hatched), 14% were deserted, 12% were destroyed by predators, 2% were flooded, and 1% were incomplete. Several studies of nest desertion were made and we concluded that about 20-50% of nesting females on an island were likely to desert their first nest if disturbed prior to or in the early stages of incubation. Renesting occurred after a 1-or 2-week delay, and unsuccessful geese usually gave up nesting attempts after a second failure. Eggs in deserted nests were often eaten by various animals, and gave the appearance of having been "destroyed". Lowest incidence of desertion occurred on islands of 10-20 hectares usable area, with low-growing vegetation, a pairs/nest ratio of 1.2-1.5, and little or no history of predation problems.

Coyotes were the most important predator of geese and their nests during the study, and often completely eliminated nesting on an island, to which they easily swam. Evidence was obtained that the geese gradually learned to recognize the coyote as a major predator to be avoided. Magpies and other animals were occasionally important goose nest predators, but not as serious nor as constant as the coyote. Human disturbance and destruction of goose nests was of major consequence on islands open to public access.

Most of the 2,688 successful goose nests hatched during the last week of April and first week of May; 88.7% of the 14,796 eggs contained therein hatched, 6.4% contained dead embryos in various stages of development, 2.6% were infertile, 2.0% were broken or missing, and 0.3% produced goslings that died in the nest. Two single orphan goslings, hatched after the goose and her other young had abandoned the nest, were found alive during the study. Forty histories of abnormal incubation periods, due to completely dead and/or infertile clutches, varied from 30 to > 86 days (compared to a normal incubation period of 26-28 days). Two nests that contained only rocks were incubated at least 7 and 26 days, respectively, and then abandoned.

Goslings were escorted by their parents to 1 of 5 major brood rearing areas with gently sloping shorelines, freedom from boat traffic or with escape cover, and abundant pasturage. Counts of 434 family groups indicated that brood size decreased by 4% during the first week of life, remained steady in the 1-2 weeks age class, decreased by 10% between the second and third weeks and was characterized by extensive mixing that produced larger and fewer broods after the third or fourth weeks of life. In 1970, two intact groups of geese captured on a brood rearing area each consisted of 30-40 goslings of various ages escorted by 5-6 adult geese.

A total of 490 band recoveries from 2,197 geese (1,602 goslings and 595 birds >1 year old) banded from 1950 through 1967 were analyzed for population parameters. Adults (>1 year old) comprised 29% of the sample, with slightly more of them recovered locally (within 50 mi or 80 km of

banding location) than from distant points. Juvenile band recoveries were mostly local during the first autumn following banding, were more distant the second year, and were identical to adult recovery patterns thereafter. Local recoveries were concentrated in 5 major areas of hunting pressure and in different patterns than substantial wintering flocks of northern migrant Canada geese (B. c. parvipes and B. c. taverneri) that intermixed with local and migrant moffitti populations. Distant band recoveries showed that Hanford geese did not perform a late season northward migration (molt migration) comparable to that of the giant Canada goose (B. c. maxima). Most young geese remained in southeastern Washington throughout their first winter, migrated northward into Canada the following spring, and returned through central Alberta in their second autumn. Considerable intermixing with Central Flyway flocks of the shortgrass prairie Canada goose population (parvipes) occurred in southern Alberta, and some Hanford geese dispersed over the range of that subspecies. Most of the geese, however, returned to the Pacific Flyway and migrated southward through eastern Washington, Oregon, and into central California.

Survival rates estimated from band recoveries were 0.60 for the second year of life and 0.70 for mature (≥ 3 years) birds. Hanford juvenile geese showed a much lower direct band recovery than expected, suggesting that they somehow escaped much of the normal exposure to hunting that decimates young birds. First year recoveries of geese banded at >1 year of age were too few to permit satisfactory estimates of survival.

Nesting and banding recovery information were used to construct a model of Hanford island goose populations to appraise the data and to fit various parameters. Computer simulations had a smaller range and variance than did the actual populations, suggesting several contributory factors for further investigation.

Several management recommendations based upon the results of the study are made, dealing with the possible implications of inundation of the Hanford goose breeding grounds by hydroelectric dam impoundment, excavation of a Columbia River navigation channel as an alternative to the dam, opening the Hanford reach of the Columbia River to public access, construction of a nuclear power reactor "park" at Hanford, increased hunting pressure, and techniques for increasing current production. The prime objective of the study was achieved with the demonstration of 97.4% fertility of Hanford nesting geese over an 18-year study period, which was equal to or better than fertility reported in other studies of Canada geese in areas not supporting nuclear reactor operations.

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Table 1. Completion dates of Columbia and Snake river dams that affected Canada goose nesting populations in the Pacific Northwest Region.

Name of dam	Year of initial service	Gross head Meters (Feet)	Length of reservoir Kilometers (Miles)
<u>Columbia River</u>			
Bonneville	1938	18.0 (59)	72 (45)
The Dalles	1957	26.2 (86)	50 (31)
John Day	1968	32.0 (105)	122 (76)
McNary	1953	26.2 (86)	98 (71)
Priest Rapids	1959	25.6 (84)	24 (18)
Wanapum	1963	24.4 (80)	61 (38)
Rock Island	1933	12.2 (40) ¹	34 (21)
Rocky Reach	1961	28.3 (93)	68 (42)
Wells	1967	21.9 (72)	48 (30)
Chief Joseph	1955	53.3 (175)	82 (51)
Grand Coulee	1941	104.5 (343)	243 (151)
<u>Snake River</u>			
Ice Harbor	1961	29.6 (97)	51 (32)
Lower Monumental	1969	30.5 (100)	47 (29)

¹Original head was 15.5 m (51 ft) before Wanapum Dam was built.

Table 2. Columbia River flow rates and vertical fluctuation during the critical months (March and April) of Canada goose nesting. Measurements made immediately downstream from Priest Rapids Dam, 1961-1969.

Day	March		April	
	Flow MCFS	Diurnal Fluctuation ft.	Flow MCFS	Diurnal Fluctuation ft.
1	82.6	6.7	80.6	6.0
2	76.5	6.5	81.1	6.3
3	80.8	7.0	83.1	6.4
4	81.4	6.8	74.9	5.7
5	80.1	6.4	91.9	5.3
6	84.3	7.4	89.1	7.1
7	80.0	6.7	89.1	5.9
8	87.7	6.1	77.6	6.5
9	92.1	7.2	94.5	6.0
10	90.7	6.8	94.9	6.0
11	86.8	6.2	94.6	6.0
12	84.3	6.8	100.5	6.6
13	88.3	8.0	100.6	7.8
14	84.1	6.8	96.9	6.3
15	81.4	7.2	102.7	6.9
16	81.1	6.9	105.5	5.8
17	83.2	6.2	107.1	5.4
18	86.8	7.1	112.9	5.0

Table 2. (Continued)

Day	March		April	
	Flow MCFS	Diurnal Fluctuation ft.	Flow MCFS	Diurnal Fluctuation ft.
19	80.5	5.9	123.7	3.3
20	82.5	6.6	115.9	5.9
21	84.0	5.9	111.4	5.7
22	85.8	7.6	122.8	5.6
23	83.6	8.2	116.4	6.7
24	85.6	7.4	116.4	5.8
25	85.2	7.9	120.9	6.6
26	83.1	6.5	121.7	6.5
27	83.4	6.4	125.6	6.0
28	79.9	6.7	116.8	6.4
29	80.4	7.0	118.0	6.7
30	88.1	6.5	116.9	5.6
31	<u>91.7</u>	<u>7.7</u>	—	—
	$\bar{x}$ 84.1	6.9	103.5	6.1

Table 3. Percentages of types of vegetative cover on islands of the Hanford Reservation utilized by nesting Canada geese.

Island No.	Area (hectares) Total Usable		Species cover type composition by percentage of total cover							
			<u>Lupinus</u> <u>sp.</u>	<u>Elymus</u> <u>cinereus</u>	<u>Agropyron</u> <u>dasystachyum</u>	<u>Artemisia</u> <u>absinthium</u>	<u>Salix</u> <u>exigua</u>	<u>Achillea</u> <u>millefolium</u>	<u>Eriogonum</u> <u>composition</u>	<u>Miscellaneous</u>
1	7.3	4.5	80		6	<1	<1			13
2	9.1	7.4	95				5		<1	0
3	68.0	46.2	2	3			<1		60	35
4	2.7	1.3	76						24	0
6	135.0	106.0	8	51	34	<1	<1	5		12
7	6.8	1.6	2				1		12	85
8	57.0	35.4	18	1	39	18	16			8
9	11.3	6.5	1				2		97	0
10	4.0	1.4	93				7			0
11	20.8	15.7	11		58	7	8	2		14
12	41.5	24.1	10	6		43	1	22		18
13	67.0	31.2		<1		47	6	1		46

Table 3. (Continued)

Island No.	Area (hectares)		<u>Lupinus</u> <u>sp.</u>	<u>Elymus</u> <u>cinereus</u>	<u>Agropyron</u> <u>dasystachyum</u>	<u>Artemisia</u> <u>absinthium</u>	<u>Salix</u> <u>exigua</u>	<u>Achillea</u> <u>millefolium</u>	<u>Eriogonum</u> <u>composition</u>	Miscellaneous
14	63.2	49.4	8	38	5	37	<1		11	
15	17.9	10.4	26		20		2	4	46	2
17	33.9	21.3	23		51	6		2	18	0
18	24.5	16.5	21	<1	9				62	8
19	39.0	30.2	6		1	13	5	<1	39	36
20	10.8	6.0	69		13	13	5	<1	<1	0
		Mean	13%	18%	18%	14%	3%	3%	15%	16%

Table 4. Numbers of pairs of Canada geese on islands of the Columbia River during various years, 1950-1970.

Year	Island Numbers																		Bluffs	Total
	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20		
1950	11	14	23	0	53	4	6	8	2	10	12	6	5	5	17	10	19	5	Not Censused	210
1951	12	14	31	2	64	2	10	11	2	12	9	6	2	4	21	4	16	2	"	224
1952	15	18	30	2	87	1	14	11	4	14	22	12	3	6	34	8	14	2	4	301
1953	11	16	24	4	111	4	12	17	3	10	15	14	3	6	25	7	14	5	5	306
1954	16	18	22	5	110	2	13	9	2	8	16	8	2	5	27	10	15	5	6	299
1955	17	18	23	5	113	2	13	9	2	8	17	8	2	5	28	10	15	5	6	306
1956	17	18	23	5	113	2	14	9	2	9	17	8	2	5	28	10	15	5	6	308
1957	14	19	26	9	131	3	8	5	1	6	13	3	1	5	15	14	12	5	7	297
1958	19	18	21	10	103	0	8	7	1	9	15	1	3	7	29	13	14	5	6	289
1959*	15	16	20	4	96	2	11	8	1	7	14	4	2	5	24	9	13	4	5	260
1960	19	19	13	4	105	1	19	4	1	2	17	1	2	3	30	5	17	2	7	271
1961	18	16	17	5	104	0	10	4	0	3	14	0	0	3	23	7	8	2	10	244
1962	26	13	15	10	103	0	9	3	0	4	20	0	1	2	29	5	5	2	9	256
1963	28	11	14	7	126	1	7	5	2	6	17	0	6	2	35	4	7	2	7	287

Table 4. (Continued)

Year	Island Numbers																		Bluffs	Total
	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20		
1964	21	7	6	9	98	0	9	4	0	2	7	0	2	4	21	6	2	1	3	202
1965	14	6	12	5	25	2	12	3	0	7	14	0	1	3	26	5	2	0	10	147
1966	32	14	9	6	66	2	5	6	0	11	13	0	2	4	35	4	4	2	3	218
1967	30	15	15	8	27	3	7	9	1	10	27	1	8	4	33	4	5	1	6	214
1968	32	11	15	7	43	1	3	4	2	10	19	1	9	4	27	6	5	3	5	207
1969	34	5	13	2	67	0	7	4	1	16	30	4	13	6	17	3	9	10	7	248
1970	38	10	10	8	30	1	10	5	2	13	22	1	12	5	16	8	9	9	11	218
1953-***	386	234	278	109	1475	24	166	107	20	134	293	50	69	73	443	120	158	64	114	4317
1970 **	22	13	16	6	86	1	9	6	1	7	17	2	4	4	26	7	9	3	6	253

(Totals & Average)

* Year of special desertion study. Island 6 and Bluffs regularly censused, other populations estimated. See text for details.

** Does not include 1959 (year of special desertion study).

Table 5. Comparison of aerial and ground survey counts of the Hanford Canada goose population during 1966.

Method	Date	No. Pairs	Unemployed
Aerial	March 22	147	162
Ground	March 28-30	236	173
Aerial	March 31	133	115
Ground	April 4-6	219	86
Aerial Mean		140	136
Ground Mean		228	130

Table 6. Distribution of 3,824 Canada goose nests in the study area of the Columbia River each year, 1953-1970

ISLAND NO.	LOCATION																			BLUFFS
	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20		
USEABLE AREA (HECTARES)	4.5	7.4	46.2	1.3	106.0	1.6	35.4	6.5	1.4	15.7	24.1	31.2	49.4	10.4	21.3	16.5	30.2	6.0	TOTAL	
YEAR	NESTS																			
1953	13	16	18	1	79	2	10	12	3	12	13	7	6	0	25	5	14	4	7	247
1954	12	18	21	2	99	2	19	10	2	9	16	2	2	7	35	5	11	3	2	277
1955	11	17	22	1	98	2	11	11	3	7	8	7	4	4	28	8	6	2	3	253
1956	12	21	17	1	112	1	11	6	2	6	8	6	1	5	27	7	9	6	3	261
1957	13	16	20	2	129	0	13	7	1	6	14	2	0	5	16	12	11	5	4	276
1958	21	24	21	2	117	0	16	12	1	10	13	2	2	5	27	8	16	6	3	306
1959 *	14*	21*	10*	0*	96	0*	9*	2*	0*	4*	15*	0*	0*	6*	10*					193
1960	18	22	14	1	86	0	19	6	1	3	17	0	0	0	24	4	7	2	9	233
1961	16	25	15	0	100	1	13	5	1	4	18	0	0	3	21	5	5	3	5	240
1962	17	13	11	1	77	0	9	2	1	3	9	0	1	2	20	3	6	1	5	181
1963	16	10	10	1	80	0	5	5	0	4	10	0	2	2	22	3	4	1	3	178
1964	16	10	4	1	81	1	5	5	0	2	7	0	1	5	15	3	3	1	1	161
1965	21	9	10	1	47	1	3	1	1	6	7	0	0	2	16	2	1	0	3	131
1966	30	18	15	0	80	1	6	7	0	9	12	0	2	4	33	3	4	2	2	228
1967	32	20	18	2	30	2	10	4	1	8	20	1	2	4	30	1	3	1	3	192
1968	24	14	15	1	39	1	3	4	1	7	20	1	4	3	22	3	3	2	5	173
1969	23	15	8	1	52	0	2	3	0	10	20	1	9	5	11	3	3	2	3	171
1970	24	17	2	1	3	1	4	4	1	10	17	0	5	5	14	4	3	5	3	123
TOTAL	333	306	251	19	1405	15	168	106	19	120	244	30	41	67	397	79	109	46	70	3824
MEAN	18	17	14	1	78	1	9	6	1	7	14	2	2	4	22	4	6	3		209 + 12
PER HECTARE	4.1	2.3	0.3	0.8	0.7	0.5	0.3	0.9	0.8	0.4	0.6	0.5	0.5	0.4	1.0	0.3	0.2	0.4		0.5

* YEAR OF SPECIAL DESERTION STUDY. ISLAND 6 AND BLUFFS SURVEYED WEEKLY, OTHER ISLANDS SURVEYED AFTER MOST NESTING WAS COMPLETED; NESTING AND POPULATION DATA ARE, THEREFORE, UNDERESTIMATED.

Table 7. Average ratio of territorial pairs to nests on islands and bluffs of Columbia River, 1953-1970.

<u>Island No.</u>	<u>$\bar{x}$ Pairs</u>	<u>$\bar{x}$ Nests</u>	<u>Pairs/Nest</u>
1	22	18	1.2
2	14	17	0.8
3	17	14	1.2
4	6	1	6.0
6	87	78	1.1
7	1	1	1.0
8	10	9	1.1
9	6	6	1.0
10	1	1	1.0
11	8	7	1.1
12	17	14	1.2
13	3	2	1.5
14	4	2	2.0
15	4	4	1.0
17	26	22	1.2
18	7	4	1.8
19	10	6	1.7
20	4	3	1.3
Bluffs	7	4	1.8
Totals	254	213	1.2

(excluding Island 4)

Table 8. Vegetation cover types utilized for 3,757 Canada goose nests on the Hanford Reservation Islands, 1954-1970.

Island No.	No. Nests	Percentage of nests in vegetation cover types							Misc.	Totals
		<u>Lupinus</u> sp.	<u>Elymus</u> cinereus	<u>Agropyron</u> dasystachyum	<u>Artemisia</u> absinthium	<u>Salix</u> exigua	<u>Achilea</u> millefolium	<u>Eriogonum</u> compositum		
1	333	49		8	5	18			20	100
2	306	58				22		5	15	100
3	251	28	3	8	5	4		5	47	100
4	19	33		5		5		5	52	100
6	1,309	6	40	13	10	1	3		27	100
7	15	46				7	7	33	7	100
8	158	6	6	8	16	32			32	100
9	106	16				28		35	21	100
10	26	31				69			0	100
11	120	18		8	23	7	1		43	100
12	244	4	13	12	10	5	9		47	100
13	30		4		4	13	13		56	100
14	41	7		10	12	2			69	100
15	67	35		25	4			3	33	100

Table 8. (Continued)

Island No.	No. Nests	Percentage of nests in vegetation cover types								Totals
		<u>Lupinus</u> sp.	<u>Elymus</u> cinereus	<u>Agropyron</u> dasystachyum	<u>Artemisia</u> absinthium	<u>Salix</u> exigua	<u>Achilea</u> millefolium	<u>Eriogonum</u> compositum	Misc.	
17	396	18		22	32		17	<1	11	99
18	79	47	1					25	27	100
19	109	4	11	32	14		12		27	100
20	46	24		15	11	2	17	2	29	100
Totals	3,757	20	17	12	12	7	3	3	26	100

Table 9. Nest fates (in percent) of 3,631 Canada goose nests on individual islands and bluffs, 1953-1970, excluding 1959 (year of special desertion study).

Island No.:	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20	Bluffs	Mean
Total Nests:	319	285	241	19	1,309	15	149	104	29	116	229	30	41	61	386	79	109	46	64	3,631
<hr/>																				
<u>Nest Fate</u>																				
Successful	84	73	62	63	71	60	27	69	31	62	84	40	63	84	84	84	70	76	75	71
Deserted	8	15	9	11	15	7	14	4	17	14	14	40	12	11	11	11	26	20	14	14
Destroyed	6	8	27	16	13	33	52	11	31	22	1	20	22	3	4	1	3	2	9	12
Flooded	0	2	1	11	0	0	7	15	21	2	0	0	2	0	1	3	1	2	0	2
Incomplete	2	2	0	0	1	0	0	1	0	0	0	0	0	2	1	1	1	0	2	1
Totals	100	100	99	101	100	100	100	100	100	100	99	100	99	100	101	100	101	100	100	100

Table 10. Status of 59 Canada goose nests visited at various time intervals to study desertion and renesting on lower and upper sections of Island 6, 1958

SURVEY DATE	3/31/58			4/7/58			4/8/58			4/14/58			4/21/58			4/28/58			5/5/58		
STATUS *	A	D ₁	D ₂	A	D ₁	D ₂	A	D ₁	D ₂	A	D ₁	D ₂	A	D ₁	D ₂	A	D ₁	D ₂	A	D ₁	D ₂
<u>CATEGORY AND NUMBER OF NESTS</u>																					
<u>GROUP 1</u>																					
EXPERIMENTAL	16	0	0	5	10	1	5	10	1	5	10	1	5	10	1	4	11	1	4	11	1
CONTROL	7	0	0	7	0	0	* * *			6	1	0	5	2	0	5	2	0	4	2	1 * *
TOTALS (23)	23	0	0	12	10	1	-	-	-	11	11	1	10	12	1	9	13	1	8	13	2
<u>GROUP 2</u>																					
EXPERIMENTAL	NOT PRESENT			9	0	0	6	3	0	5	3	1	4	4	1	4	4	1	4	4	1
CONTROL				13	0	0	* * *			10	22	1	9	3	1	9	3	1	9	3	1
TOTALS (22)				22	0	0	-	-	-	15	5	2	13	7	2	13	7	2	13	7	2
<u>GROUP 3</u>																					
CONTROL (11)	NOT PRESENT			NOT PRESENT			11	0	0	5	6	0	5	6	0	5	6	0	5	6	0
<u>GROUP 4</u>																					
CONTROL (3)	NOT PRESENT			NOT PRESENT			NOT PRESENT			3	0	0	2	0	1	2	0	1	2	0	1
<u>UPPER SECTION</u>																					
(24)	24	0	0	17	6	1	* * *			12	8	4	10	10	4	9	10	4	9	11	4
(19)	NOT PRESENT			9	0	0	* * *			6	3	0	5	4	0	5	4	0	5	4	0
(6)	NOT PRESENT			NOT PRESENT			* * *			6	0	0	4	1	1	4	1	1	4	1	1
(3)	NOT PRESENT			NOT PRESENT			NOT PRESENT			NOT PRESENT			3	0	0	2	1	0	2	1	0
(2)	NOT PRESENT			NOT PRESENT			NOT PRESENT			NOT PRESENT			NOT PRESENT			NOT PRESENT			2 0 0		

* STATUS: A = ACTIVE OR SUCCESSFUL; D₁ = DESERTED; D₂ = DESTROYED

** NEST INCUBATED 32+ DAYS BEFORE BEING DESTROYED

*** NESTS NOT DISTURBED THIS SURVEY

Table 11. Fates of nests on Island 6 (surveyed weekly) compared with those on all other islands (surveyed at end of nesting season) during 1959 special desertion study.

Fate of Nests	Island 6		All Other Islands		Total	
	No.	%	No.	%	No.	%
Successful	39	41	56	58	95	49
Deserted	12	13	11	11	23	12
Destroyed	42	44	17	18	59	30
Flooded	3	3	0	0	3	2
Incomplete	0	0	13	13	13	7
Totals	96	101	97	100	193	100

Table 12. Fate of 3,824 Canada goose nests on all islands and river bluffs of the Hanford Reservation in percentage of total, 1953-1970, excluding 1959 (year of special desertion study).

YEAR	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	TOTALS
TOTAL NESTS	247	277	253	261	276	306	193*	233	240	181	178	161	131	228	192	173	171	123	3631
NEST FATE (%)																			
SUCCESSFUL	66	72	77	61	67	47	49*	76	87	83	88	87	59	79	57	69	79	77	71
DESERTED	14	13	9	13	12	27	12*	10	7	4	10	7	31	18	20	17	8	10	14
DESTROYED	13	12	13	11	20	25	30*	11	5	12	3	6	9	3	23	12	11	13	12
FLOODED	0	1	0	13	1	0	2*	2	1	1	0	0	1	0	0	2	2	0	2
INCOMPLETE	7	3	0	2	0	0	7*	0	0	0	0	0	0	0	0	0	1	0	1
TOTALS	100	101	99	100	100	99	100	99	100	100	101	100	100	100	100	100	101	100	100

* TENTATIVE VALUES FROM TABLE 10 NOT INCLUDED IN TOTALS; INCLUDED FOR COMPARISON PURPOSES

Table 13. Numbers of coyotes taken by Wildlife Services Division in Washington Counties bordering the study area during fiscal years 1950-1970 (E. A. Peacock, pers. comm. 1970)

Fiscal* Year	Percent Nests Destroyed	Number of Coyotes Taken				Totals
		Benton County	Franklin County	Grant County	Yakima County	
1950	-	289	-	71	413	773
1951	-	204	6	18	201	429
1952	-	338	48	55	59	500
1953	13	407	61	172	42	682
1954	12	378	70	117	106	671
1955	13	503	90	223	64	880
1956	11	395	21	235	68	719
1957	20	407	208	182	116	913
1958	25	460	170	61	141	832
1959	31	418	174	126	219	937
1960	11	359	210	168	241	978
1961	5	304	118	212	119	753
1962	12	81	199	208	112	600
1963	3	110	158	176	141	585

Table 13. (Continued)

Fiscal* Year	Percent Nests Destroyed	Number of Coyotes Taken				Totals
		Benton County	Franklin County	Grant County	Yakima County	
1964	6	281	173	264	139	857
1965	9	153	142	349	216	860
1966	3	113	155	284	232	784
1967	23	307	120	283	133	843
1968	12	211	46	176	116	549
1969	11	207	terminated	200	131	538
1970	13	106		115	140	361
Totals		6,031	2,169	3,695	3,149	15,044
Mean		287	120	176	150	716

* 1 July 1949-30 June 1950, etc.

Table 14. Fate of 14,796 eggs contained in 2,688 successful Canada goose nests, 1953-1970

<u>Fate of Eggs</u>	<u>Number</u>	<u>Per Cent</u>
Infertile	380	2.6
Broken, missing	300	2.0
Fertile, embryo died		
1st week development	515	3.5
2nd week development	100	0.7
3rd week development	131	0.9
4th week development	199	1.3
Dead goslings	50	0.3
Hatched	<u>13,121</u>	<u>88.7</u>
Totals	14,796	100.0

Table 15. Unusual incubation periods noted in Canada geese along the Columbia River, 1950-1970

<u>No. Nests</u>	<u>Minimum Days Incubated</u>	<u>Conclusion</u>
5	30	Deserted
1	32	Deserted
2	33	Deserted
7	35	Deserted
7	36	Deserted
3	37	Deserted
1	40	Deserted
3	42	Deserted
3	43	Deserted
2	45	Deserted
1	49	Deserted
1	50	Flooded
2	51	Deserted
1	86	Still incubating on July 1

Table 16. Various age class brood sizes of Canada goslings in the Hanford study area, 1953-1970.

Year	<u>Hatching</u>		<u>IA(<1)</u>		<u>IB(1-2)</u>		<u>II(2-3)</u>		<u>III(3-4)</u>		<u>IV(>4)</u>	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
1953	162	5.0	28	4.5								
1954	200	4.9	37	5.4			18	4.5				
1955	196	4.9	44	5.1			12	4.0				
1956	160	5.0			20	5.3						
1957	184	4.7			18	5.8						
1958	143	5.0			15	5.5						
1959	95	5.2	10	5.0	6	4.0						
1960	177	4.8	13	5.2	7	4.1						
1961	208	5.2	34	4.9	11	4.0	3	4.7	6	5.8		
1962	150	4.7	13	4.6	9	3.2						
1963	156	5.3	33	4.9			1	5.0				
1964	140	4.7	19	3.7	2	3.0	1	7.0				
1965	77	4.7	9	4.4	1	2.0	3	3.3				
1966	180	5.0	9	4.8								
1967	110	5.4					1	4.0	1	2.0		

Table 16. (Continued)

Year	<u>Hatching</u>		<u>IA(<1)</u>		<u>IB(1-2)</u>		<u>II(2-3)</u>		<u>III(3-4)</u>		<u>IV(>4)</u>	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
1968	119	5.4	9	3.7			4	4.2	8	3.6	3	4.7
1969	135	5.3			9	5.4						
1970	95	5.2	11	4.8					2	6.5	2	4.5
Totals	2,687	5.0	269	4.8	98	4.8	45	4.3	17	4.6	5	4.6

Table 17. Numbers of adult (>1 year old) and young Canada geese banded each year compared to the population available for binding, assuming survival to banding of all goslings.

Year	Population					Banded Sample			
	Adults			Young		Adults		Young	
	Pairs	Unemployed	Subtotal	Hatched	Total	No.	% of Total	No.	% of Total
1950	210	141	561	630*	1,191	43	7.7	129	10.8
1951	224	136	584	672*	1,256	40	7.0	83	6.6
1952	301	162	764	903*	1,667	133	17.4	152	9.1
1953	306	143	755	813	1,568	13	1.7	116	7.4
1954	299	134	732	976	1,708	25	3.4	85	5.0
1955	306	149	761	961	1,722	30	3.1	164	9.5
1956	308	134	750	802	1,552	49	6.5	107	6.9
1957	297	115	709	863	1,572	38	5.3	68	4.3
1958	289	114	692	720	1,412	45	6.5	81	5.7
1959	255	100	610	494	1,104	34	5.5	77	7.0
1960	271	85	627	844	1,471	18	2.9	43	2.9
1961	244	108	596	1,086	1,682	14	2.4	108	6.4
1962	256	114	626	702	1,328	15	2.5	71	5.3
1963	287	151	725	812	1,537	28	3.9	124	8.1
1964	202	111	515	653	1,168	45	8.8	58	5.0

Table 17. (Continued)

Year	Population				Banded Sample				
	Adults		Young		Adults		Young		
	Pairs	Unemployed	Total	Hatched	Total	No.	% of Total	No.	% of Total
1965	147	49	343	360	703	10	2.9	59	8.4
1966**	218	129	565	902	1,467	0	0	0	0
1967	214	151	579	591	1,170	15	2.6	77	6.6
1968	207	60	474	640	1,114	35	6.3	84	7.4
1969	248	55	551	717	1,268	56	10.0	133	10.5
1970	218	106	542	499	1,041	67	12.4	12.5	25.0
Mean	255	122	632	740	1,372	38	5.9	97	7.9

* Estimated production based on an average of 3.0 young per "territorial pair" for the period 1953-1970.

** Note included in totals.

Table 18. Numbers and percentages of adult and local Canada geese recovered at various ages and locations through December 1968, based upon recovery of 490 bands from a total of 2,197 birds banded, 1950-1970.

<u>Age Category</u>		<u>Recovery Location</u>		<u>Totals</u>
<u>At Banding</u>	<u>At Recovery</u>	<u>Local <50 mi</u>	<u>Distant >50 mi</u>	
Adult (>1 year)	All years	83 (17%)	59 (12%)	142 (29%)
Local	3rd year and over	72 (15%)	69 (14%)	141 (29%)
Local	2nd year	36 (7%)	73 (15%)	109 (22%)
Local	direct	77 (16%)	21 (4%)	98 (20%)
Totals		268 (55%)	222 (45%)	490 (100%)

Table 19. Recovery data for Canada geese banded as juveniles during the years 1950-1960, and for which it is assumed there will be no further recoveries.

		<u>Recoveries During Subsequent Years</u>												
Year	No.													
Banded	Banded	n ₀	n ₁	n ₂	n ₃	n ₄	n ₅	n ₆	n ₇	n ₈	n ₉	n ₁₀	Totals	Recovery Rate
1950	129	4	13	10		2					1		30	.23
1951	83	3	6	3	4	3				1		1	21	.25
1952	152	18	5	4	4	1		1	1				34	.22
1953	116	6	5	2	3	1		4					21	.18
1954	85	2	9	4	2	2	2				1		22	.26
1955	164	16	7	2	7	6	2	1					41	.25
1956	107	4	7	6	2	3	3				1		26	.24
1957	68	2	9	3	3	1				1			19	.28
1958	81	5	5	3	2	1	1	1					18	.22
1959	77	3	7	3		1							14	.18
1960	43	5	2										7	.16
Totals		68	75	40	27	21	8	7	1	2	3	1	253	

Table 20. Recovery data for Canada Geese Banded as Juveniles During the Years 1961-1967, and for Which There May be Further Recoveries

Year Banded	No. Banded	Maximum Age at Recovery k	Total Number of Banded Geese Recovered N_k	Age at Recovery						
				1	2	3	$\times 4$	5	6	7
1961	108	7	30	14	7	3	2	1	2	1
1962	71	6	16	4	6	4	2			
1963	124	5	24	2	4	10	6	2		
1964	58	4	14	5	5	2	2			
1965	59	3	14	3	9	2				
1966	(No banding)									
1967	77	1	4	4						

Table 21. Recovery Data for Canada Geese Banded as Adults During the Years 1950-1960, and For Which it is Assumed There will be no Further Recoveries

Year	No. Banded	Recoveries During Subsequent Years										Recovery Rate
		n ₀	n ₁	n ₂	n ₃	n ₄	n ₅	n ₆	n ₇	n ₈	n ₉	
1950	43	1	2	1		1				1		.14
1951	40	2	2	2			1					.18
1952	133	14	8	7	6	1		2	1	1		.30
1953	13				1							.08
1954	25	3	2	2	1							.32
1955	30	3	2				1					.20
1956	49	1	2	3	1			1		1		.18
1957	38		2	1	2		2	1				.21
1958	45	5	2			2	2		2			.27
1959	34		1	1	1	1				1	1	.18
1960	18	2						1				.17
Totals		31	23	17	12	4	7	5	3	3	1	106

Table 22. Recovery Data for Canada Geese Banded as Adults During the Years 1961-1967, and for Which There May be Further Recoveries

Year Banded	No. Banded	Maximum Age at Recovery k	Total Number of Banded Geese Recovered N_k	1	2	3	$\times 4$	5	6	7
1961	14	7	6	3	0	2	1	0	0	0
1962	15	6	3	0	2	0	0	1	0	
1963	28	5	10	4	4	1	1	0		
1964	45	4	13	3	2	2	6			
1965	10	3	1	0	1	0				
1966	(No banding)									
1967	15	1	2	2						
Totals			35	12	9	5	8	1	0	0

Table 23. Survival Estimates for Canada Geese Banded as Juveniles as Obtained from Banding Data

Year	All recoveries			Direct recoveries deleted		
	$\hat{s}$	Variance	Chi-square value	$\hat{s}$	Variance	Chi-square value
1950	0.63	0.0030	11.2	0.49	0.0052	0.2
1951	0.73	0.0027	2.4	0.68	0.0042	0.02
1952	0.56	0.0033	2.0	0.63	0.0058	0.3
1953	0.68	0.0036	.2	0.66	0.0056	0.0
1954	0.70	0.0030	6.3	0.61	0.0049	0.5
1955	0.64	0.0021	.3	0.66	0.0032	0.6
1956	0.71	0.0024	3.3	0.65	0.0038	0.2
1957	0.67	0.0042	6.7	0.54	0.0073	0.7
1958	0.65	0.0047	.6	0.61	0.0079	0.0
1959	0.57	0.0085	4.9	0.38	0.0156	0.2
Combined data				0.601	0.00052	0.05

Table 24. Simulation of Island Goose Population--Summary of Population Structure

Pre-Nesting Populations, and Class IA Broods							
<u>Year</u>	<u>Adult Pairs</u>	<u>Age 3</u>	<u>Age 2</u>	<u>Age 1</u>	<u>Goslings</u>	<u>Brood Size</u>	<u>Surplus</u>
1950	211	0	300	400	690	4.57	0
1951	241	208	260	409	869	4.67	0
1952	260	184	231	538	956	4.62	0
1953	256	156	303	575	851	4.53	0
1954	282	204	345	495	972	4.48	0
1955	296	222	277	602	1,005	4.61	0
1956	300	188	358	607	963	4.34	0
1957	305	246	392	578	1,013	4.67	14
1958	304	261	360	619	1,015	4.51	33
1959	304	266	376	618	790	4.36	30
1960	304	276	356	467	809	4.52	37
1961	304	234	289	461	877	4.66	19
1962	304	196	281	521	941	4.66	0
1963	312	193	310	558	906	4.72	0

Table 24. (Continued)

Pre-Nesting Populations, and Class IA Broods							
<u>Year</u>	<u>Adult Pairs</u>	<u>Age 3</u>	<u>Age 2</u>	<u>Age 1</u>	<u>Goslings</u>	<u>Brood Size</u>	<u>Surplus</u>
1964	310	202	349	541	897	4.60	0
1965	280	238	343	539	613	4.26	53
1966	255	250	342	379	696	4.64	66
1967	252	213	215	423	667	4.63	18
1968	237	135	247	390	634	4.63	0
1969	252	166	239	378	599	4.31	0
1970	256	154	210	348	592	4.26	2

Table 25. Simulated population by island, showing carrying capacity and simulated number of territorial pairs for each island

	ISLAND POPULATIONS (TERRITORIAL PAIRS)																		
ISLAND NO.	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20	
CARRYING CAPACITY	<u>19</u>	<u>18</u>	<u>23</u>	<u>5</u>	<u>113</u>	<u>2</u>	<u>13</u>	<u>9</u>	<u>2</u>	<u>10</u>	<u>17</u>	<u>8</u>	<u>2</u>	<u>5</u>	<u>28</u>	<u>10</u>	<u>19</u>	<u>5</u>	
YEAR																			
1950	11	14	23	0	54	4	6	8	2	10	12	6	5	5	17	10	19	5	
1951	15	12	23	3	77	3	9	10	1	5	16	5	4	5	24	7	15	7	
1952	17	13	23	5	89	2	8	8	2	9	16	8	2	5	20	11	15	7	
1953	18	12	21	4	95	0	7	10	2	12	13	7	2	3	21	11	11	7	
1954	16	16	22	5	104	2	11	6	1	11	13	7	2	5	27	12	17	5	
1955	19	19	26	4	110	2	11	14	0	9	16	8	2	7	24	9	12	4	
1956	19	19	25	3	106	3	14	11	2	9	18	9	2	5	28	10	14	3	
1957	19	19	22	1	114	2	13	11	2	11	17	9	1	5	30	10	13	6	
1958	20	16	22	6	117	1	12	9	1	9	18	7	2	4	29	11	15	5	
1959	13	28	29	4	107	3	10	7	1	11	18	6	2	4	31	9	16	5	
1960	18	18	20	4	115	2	13	12	2	12	17	11	2	3	26	7	17	5	
1961	19	17	23	5	115	2	13	9	2	11	18	7	1	6	27	9	15	5	
1962	37	15	20	4	100	1	13	10	1	8	15	7	1	5	34	10	19	4	
1963	29	14	28	5	119	1	13	8	1	8	17	7	0	6	28	10	13	5	
1964	32	20	24	4	113	1	13	9	2	9	13	5	2	6	24	12	16	5	
1965	30	17	23	4	78	4	15	10	1	10	15	10	2	5	30	10	12	4	
1966	32	19	19	7	53	2	13	13	2	10	15	8	1	6	28	9	14	4	
1967	33	19	23	5	45	2	13	8	2	14	18	6	3	3	30	9	12	7	
1968	30	17	20	5	47	1	11	10	1	10	16	7	1	5	28	10	12	6	
1969	31	14	29	3	47	2	14	11	7	5	16	9	0	3	30	11	12	8	
1970	30	13	23	2	53	1	13	10	3	14	15	7	2	4	34	10	15	7	

Table 26. Simulated Population with First-Year Survival Reduced to 0.50--Summary of Population Structure

Pre-Nesting Populations, and Class IA Broods							
<u>Year</u>	<u>Adult Pairs</u>	<u>Age 3</u>	<u>Age 2</u>	<u>Age 1</u>	<u>Goslings</u>	<u>Brood Size</u>	<u>Surplus</u>
1950	211	0	300	440	664	4.34	0
1951	251	202	267	336	853	4.35	0
1952	271	176	209	423	898	4.54	0
1953	260	155	261	457	856	4.60	0
1954	280	180	290	434	929	4.47	0
1955	300	200	252	467	968	4.34	0
1956	285	159	274	478	937	4.42	0
1957	295	176	292	444	978	4.59	0
1958	304	198	266	495	1,075	4.57	7
1959	304	188	300	528	873	4.55	1
1960	305	208	335	440	835	4.49	0
1961	299	209	265	433	782	4.34	0
1962	295	180	268	407	812	4.46	0
1963	301	200	243	386	887	4.69	0
1964	292	164	224	435	815	4.34	0
1965	274	155	258	404	617	4.28	4

Table 26. (Continued)

Pre-Nesting Populations, and Class IA Broods							
<u>Year</u>	<u>Adult Pairs</u>	<u>Age 3</u>	<u>Age 2</u>	<u>Age 1</u>	<u>Goslings</u>	<u>Brood Size</u>	<u>Surplus</u>
1966	252	170	229	309	690	4.79	12
1967	239	147	195	334	668	4.51	0
1968	223	132	208	340	572	4.43	0
1969	234	137	201	273	660	4.52	0
1970	228	132	162	324	566	4.42	0

Table 27. Second Simulation with First-Year Survival Reduced to 0.50
(Parameters Identical to Those of Table 27)

Pre-Nesting Populations, and Class IA Broods							
<u>Year</u>	<u>Adult Pairs</u>	<u>Age 3</u>	<u>Age 2</u>	<u>Age 1</u>	<u>Goslings</u>	<u>Brood Size</u>	<u>Surplus</u>
1950	211	0	300	440	764	4.63	0
1951	254	197	253	371	835	4.54	0
1952	253	158	222	491	831	4.40	0
1953	244	145	258	407	814	4.71	0
1954	261	183	246	420	907	4.68	0
1955	267	165	252	424	896	4.35	0
1956	270	184	253	443	922	4.54	0
1957	272	170	249	475	927	4.57	0
1958	272	167	293	473	854	4.42	0
1959	286	195	283	410	802	4.36	0
1960	303	210	262	409	902	4.58	0
1961	282	179	250	439	745	4.66	0
1962	271	176	265	351	688	4.25	0
1963	281	179	223	355	825	4.61	0

Table 27. (Continued)

Pre-Nesting Population, and Class IA Broods							
<u>Year</u>	<u>Adult Pairs</u>	<u>Age 3</u>	<u>Age 2</u>	<u>Age 1</u>	<u>Goslings</u>	<u>Brood Size</u>	<u>Surplus</u>
1964	276	158	238	432	819	4.43	0
1965	265	168	251	385	730	4.93	11
1966	254	181	232	369	715	4.67	38
1967	246	155	225	360	580	4.50	0
1968	243	157	221	284	642	4.55	0
1969	235	156	158	317	586	4.69	0
1970	204	108	168	284	533	4.52	0

Table 28. Individual Island Populations for Table 28

Island No.	Island Populations (Territorial Pairs)								
	1	2	3	4	6	7	8	9	10
Carrying Capacity	19	18	23	5	113	2	13	9	2
<u>Year</u>									
1950	11	14	23	0	53	4	6	8	2
1951	16	19	18	3	84	3	10	7	2
1952	15	14	17	5	87	2	11	6	2
1953	15	17	16	5	88	1	9	6	2
1954	15	15	20	5	90	2	12	5	2
1955	14	17	17	5	96	2	12	8	1
1956	21	16	21	2	101	2	11	6	1
1957	18	12	19	6	97	2	10	9	2
1958	16	18	24	5	99	2	12	8	2
1959	23	18	21	5	92	3	13	7	2
1960	21	17	21	5	109	3	10	9	2
1961	18	16	21	4	109	2	10	8	2
1962	20	19	18	4	100	2	14	7	2
1963	28	16	23	5	96	1	11	7	4
1964	31	16	23	3	95	1	8	6	2
1965	28	20	22	9	62	2	13	6	2
1966	29	18	23	7	52	2	11	12	2
1967	28	19	18	6	53	3	17	9	2
1968	31	15	20	6	49	2	13	7	2
1969	27	18	25	5	45	2	15	6	2
1970	22	16	19	4	37	2	10	5	2

Table 28 (Continued)

Island No.	11	12	13	14	15	17	18	19	20
Carrying Capacity	10	17	8	2	5	28	10	15	5
<u>Year</u>									
1950	10	12	6	5	5	18	10	19	5
1951	9	18	6	4	5	20	9	16	5
1952	7	17	7	2	5	25	11	15	5
1953	8	15	7	2	4	24	8	12	5
1954	10	19	6	1	6	24	10	17	2
1955	9	16	6	3	4	28	10	14	5
1956	8	15	7	2	3	26	9	14	5
1957	9	14	13	2	3	26	8	17	5
1958	9	12	9	2	5	25	6	14	4
1959	10	15	7	2	4	34	11	15	4
1960	14	13	9	2	6	30	11	16	5
1961	8	11	8	2	5	25	8	14	6
1962	8	12	7	3	7	24	7	12	5
1963	8	21	5	2	6	26	7	11	4
1964	10	15	7	2	5	24	8	13	7
1965	10	17	5	2	4	29	11	17	6
1966	9	15	6	2	6	29	9	17	5
1967	7	13	6	2	5	27	8	17	6
1968	8	18	7	3	5	27	11	13	6
1969	8	17	7	2	5	22	12	13	4
1970	9	13	6	3	4	22	10	15	5

Table 29. Variability of Island Populations (Territorial Pairs, 1950-1964),
Showing Comparisons Between Actual and Simulated Data

Island No.		Mean	Median	Range	Variance
		Population Size	Population Size		
1	Actual	17.3	17.0	17	24.4
	Simulated	18.8	18.0	20	29.0
2	Actual	15.7	16.0	12	11.4
	Simulated	16.3	16.0	7	3.8
3	Actual	20.5	22.0	25	44.0
	Simulated	20.1	21.0	8	6.4
4	Actual	5.4	5.0	10	9.3
	Simulated	4.1	5.0	6	2.4
6	Actual	101.1	104.0	78	423.6
	Simulated	93.1	96.0	56	175.0
7	Actual	1.6	2.0	4	1.8
	Simulated	2.1	2.0	3	0.7

Table 30. "Nearest neighbor" goose nesting distances (in meters) on Hanford Reservation Islands during 1968 & 1969

Table 30. "Nearest neighbor" goose nesting distances (in meters) on Hanford Reservation Islands during 1968 & 1969

Island No.	1968			1969		
	<u>N</u>	<u>$\bar{x} \pm$ S.E.</u>	<u>Range</u>	<u>N</u>	<u>$\bar{x} \pm$ S.E.</u>	<u>Range</u>
1	28	25 $\pm$ 9.5	6-75	21	25 $\pm$ 9.9	10-69
2	12	42 $\pm$ 21	29-108	9	67 $\pm$ 12	19-119
3	16	124 $\pm$ 85	24-450	8	162 $\pm$ 161	33-517
6	38	106 $\pm$ 12	10-333	52	97 $\pm$ 10	24-422
8	3	183 $\pm$ 33	150-250	2	530	-
9	0	-	-	3	247 $\pm$ 33	220-300
11	7	102 $\pm$ 19	39-157	10	97 $\pm$ 26	47-299
12	22	73 $\pm$ 10	35-238	18	103 $\pm$ 22	37-375
14	5	236 $\pm$ 279	71-450	9	130 $\pm$ 193	34-600
15	3	148 $\pm$ 9.0	130-157	5	72 $\pm$ 15	36-96
17	25	78 $\pm$ 11	39-242	10	118 $\pm$ 17	48-187
18	3	410 $\pm$ 25	385-461	2	400	-
19	2	225 $\pm$ 112	113-450	4	134 $\pm$ 18	103-168
20	2	64	-	2	74	-
Bluffs	5	254 $\pm$ 100	10-450	3	300 $\pm$ 224	400-500
Mean		91			109	

Table 31. Comparison of percent of infertile eggs in Canada goose population samples at various locations and times.

Location	Year	No. of Eggs in Sample	Percent Infertile	Authority
Utah	1937	410	6	Williams and Marshall (1937:82)
Illinois	1945-46	729	1.7-4.6	Kossack (1950:645)
Idaho	1949-51		7	Steel <u>et al.</u> (1957:41)
British Columbia	1949-53	1,907	1.8	Munro (1960:551)
California	1951	350	2.0	Naylor (1953:91)
California	1952	432	1-2	Naylor and Hunt (1954:13)
California	1952	810	1.9	Miller and Collins (1953:393)
California	1957	1,147	1.0	Rienecker and Anderson (1960:486)
Washington	1953-70	14,796	2.6	This study

Figure 1. Map of study area (shaded portion) and hydroelectric dams on the Columbia and Snake Rivers.

Figure 2. Islands 2 and 3 from atop the western end of the White Bluffs shown in the background.

Figure 3. Discharge of the Columbia River at Priest Rapids during the goose nesting and brood rearing period. Based on USGS published averages.

Figure 4. Upstream end of Island 17, showing lupine and absinth in the nesting cover on cobblestone substrate.

Figure 5. Goose nest in buckwheat on Island 9 during April, when cover is at a minimum. Greater utilization of such cover by nesting geese could probably be achieved by placing driftwood or other objects on such islands.

Figure 6. Margin of Island 6, showing ryegrass clumps and wheatgrass stand heavily used by nesting geese. Note the raised berm in the background, a favored nesting site.

Figure 7. Yarrow and absinthe dominated nesting cover on downstream end of Island 17.

Figure 8. Willow and lupine community on lower end of Island 2 which was heavily utilized by nesting geese each year.

Figure 9. Breeding ground population of Canada geese at Hanford, 1950-1970.

Figure 10. Initiation of nesting of 2,688 goose nests in relation to average daily temperature on the Hanford Reservation, 1953-1970.

Figure 11. Frequency distribution of clutch sizes of 2,688 hatched goose nests on the Hanford Reservation, 1953-1970.

Figure 12. Annual variation of average clutch size and number of goose nests on the Hanford Reservation, 1953-1970.

Figure 13. Fate of 3,824 Canada goose nests on the Hanford Reservation, 1953-1970.

Figure 14. Hatching progression of 2,688 Canada goose nests on the Hanford Reservation, 1953-1970.

Figure 15. Local (<50-mi or 80-km radius) band recoveries of 2,197 geese banded on the Hanford Reservation, 1950-1967.

Figure 16. Distant band recoveries of 2,197 geese banded on the Hanford Reservation, 1950-1967. Breeding ground (circled) shown in detail in Figure 15.

APPENDIX

Maps showing cover type for each island.

TOTAL AREA: 2.67 HECTARES

USEABLE AREA:

8 MISCELLANEOUS: 0.70 ha

ISLAND NO. 5

100 m

RIVER FLOW

ISLAND NO. 4

TOTAL AREA: 2.67 HECTARES

USEABLE AREA:

1	<u>Lupinus sp.</u>	1.0 ha
8	MISCELLANEOUS	0.3 ha
		<u>1.3 ha</u>

100 m
ISLAND NO. 7

TOTAL AREA: 6.8 HECTARES

USEABLE AREA:

1	<i>Lupinus</i> sp.	0.04 ha
7	<i>Eriogonum compositum</i>	0.20 ha
8	MISCELLANEOUS	1.40 ha
		1.64 ha

100 m
ISLAND NO. 8

TOTAL AREA: 56.7 HECTARES

USEABLE AREA:

2	<i>Elymus cinereus</i>	0.49 ha
3	<i>Agropyron dasystachyum</i>	15.35 ha
4	<i>Artemisia absinthium</i>	10.81 ha
5	<i>Salix exigua</i>	1.62 ha
8	MISCELLANEOUS	9.36 ha
		37.63 ha

TOTAL AREA: 4.05 HECTARES

USEABLE AREA:

1	<i>Lupinus</i> sp.	1.21 ha
5	<i>Salix exigua</i>	0.20 ha
		1.41 ha

ISLAND NO. 10

ISLAND NO. 9

TOTAL AREA: 11.3 HECTARES

USEABLE AREA:

5	<i>Salix exigua</i>	0.12 ha
7	<i>Eriogonum compositum</i>	6.35 ha
		6.47 ha

RIVER FLOW

TOTAL AREA: 17.9 HECTARES

USEABLE AREA:

1	Lupinus sp.	2.67 ha
3	Agropyron dasystachyum	2.10 ha
5	Salix exigua	0.20 ha
6	Achillea millefolium lanulosa	0.53 ha
7	Eriogonum compositum	4.78 ha
8	MISCELLANEOUS	0.08 ha
		10.36 ha

TOTAL AREA: 33.9 HECTARES

USEABLE AREA:

1	Lupinus sp.	4.98 ha
3	Agropyron dasystachyum	10.68 ha
4	Artemisia abinthium	1.17 ha
6	Achillea millefolium lanulosa	0.49 ha
7	Eriogonum compositum	3.72 ha
8	MISCELLANEOUS	0.08 ha
		21.12 ha

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