REPRODUCTION AND ECOLOGY OF CANADA GEESE ON THE HANFORD RESERVATION, 1953-1980

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ABSTRACT

Western Canada geese (Branta canadensis moffitti Aldrich) which nest on Columbia River islands within the Hanford Reservation of southcentral Washington have been studied since 1953. A description of the study area, island vegetation and results of 1953-1970 nesting studies were reported earlier. This study reanalyzes reproduction and ecology of geese nesting at Hanford during 1953-1980 with respect to changes that have occurred in the nesting habitat. Changes in composition and distribution of island vegetation are documented. Vegetation has become more heterogenous, primarily due to altered river flow patterns. Influx of cheatgrass on one island resulted from grazing pressure and soil disturbance caused by cattle. Use of and preferences for certain species of vegetation by nesting geese have changed. Physical attributes of cover species relate to observed preferences. Peak number of nesting geese was observed in the study area in 1958. An erratic decline in numbers of nests occurred after Priest Rapids Dam came into service in 1959. These decreases are due to losses of suitable nesting habitat and

increased coyote (<u>Canis latrans</u>) predation, both of which were due to altered river flow patterns. Since 1970, 95% of 1324 nests were located on 10 of 20 islands, thus being termed the favored islands. Increasing numbers of nesting geese since 1976 are due to increased use of favored islands. Opening of islands to public access in 1965 had no apparent effect on use of these islands by nesting geese. Success of goose nests was significantly dependent upon their location within the study area. Nest success fluctuated significantly through time, but was apparently unrelated to specific events. Overall success of 3544 nests was 71% during 1953-1970 and is little different from 74% success of 1254 nests observed during 1971-1980. Different personnel conducted the 1971-1980 nest surveys and the survey interval increased from weekly to biweekly after 1970, thereby preventing any conclusions about success comparisons between these periods. There was no consistent relationship between total numbers of nests and success, but success was consistently lower on islands where numbers of nests have declined sharply. Proximity of islands to human activities and success of nests correlated well. Hatched clutch size data were not comparable between weekly (1953-1970) and biweekly (1971-1980) nest survey periods. Greater proportions of completely hatched and lower proportions of incompletely hatched clutches were recorded during the biweekly survey period. Maximum laid clutch was lower during 1953-1970 than during 1971-1980 due to depressed clutch size on one island used by 37% of nesting geese during the former period. A physiological response of the geese to crowding is indicated.

Clutch size of nests on all other islands did not fluctuate through time. Clutch size was consistently lower on the island group where numbers of nests declined and success was lowest. The possibility of 2 sub-populations of geese breeding at Hanford is discussed. Changes in the reproductive performance of the Hanford goose flock relate to changes in the nesting habitat only when island security from predators is affected.

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CHAPTER 1

INTRODUCTION

Western or Great Basin Canada geese (Branta canadensis moffitti Aldrich) nest on islands and banks of the Columbia and Snake River Systems in Washington. An important population nests on the Columbia River islands which lie within the U. S. Department of Energy Hanford Reservation in southcentral Washington. It is perhaps the most continuously studied nesting Canada goose population in the United States. Nesting studies began in 1953 and have continued to the present.

The first 4 years of study (1953-1956) were summarized by Hanson and Browning (1959). Hanson and Eberhardt (1971) reported on the 18 years of goose nesting at Hanford from 1953-1970 along with the results of banding studies which began in 1950. A primary objective of those studies was to monitor the fertility of Canada geese nesting within the environs of one of the largest production nuclear reactor complexes in the U. S. (Hanson and Eberhardt 1971:5). From those 18 years of study, strong evidence was presented to refute claims of harmful effects from ionizing radiation and very substantial contributions were made to the ecological understanding of the breeding performance and nesting habits of the moffitti race. Since 1970, both nesting and banding studies have continued. Bowhay et al. (1971, in press) present a general summary of nesting trends at Hanford during the past 10 years and the results of goose banding programs in Washington through 1978.

My study was initiated to analyze the past 10 years of goose nesting at Hanford and to relate results to the entire 28-year nesting history of the Hanford population to determine whether certain changes in the nesting habitat and its management have affected goose production and habitat use and whether the changed survey methods have affected the continuity of this reproductive record.

Readers are advised to read the monograph by Hanson and Eberhardt (1971) because it is heavily referenced in this work. All nesting data have been completely reanalyzed from the original field records and small differences exist between the data presented here and that presented by Hanson and Eberhardt (1971). These differences in no way affect the conclusions made by those authors.

CHAPTER 2

METHODS

Field Study

The annual goose nest survey method utilized is described in detail by Hanson and Eberhardt (1971:12-25). A major change made in their method after 1970 was a doubling of the nest survey interval from weekly to biweekly. In addition, all nest surveys for the entire 18-year study of Hanson and Eberhardt (1971) were directed by the senior author. Since 1970, personnel in charge of the goose nest surveys at Hanford have changed 4 times. These changes in timing and personnel have affected the continuity of certain aspects of the nesting data and these effects will be discussed in later sections.

I assisted in the goose nest surveys during the 1979 nesting season and directed the surveys in 1980. After all but 4 nests had hatched in 1980, cover type vegetation of the islands and nest locations were mapped. The vegetative communities were outlined on aerial photo enlargements of the individual islands during ground surveys as done by Hanson and Eberhardt (1971:10).

Treatment of Data

Productivity

A major objective of this study was to analyze certain parameters of Canada goose reproduction on the Hanford Reservation from 1953-1980 with respect to specific events that have occurred during that time period. The parameters of goose production considered in these analyses are the number and distribution of nests in the study area, the maximum clutch size observed in nests and nest success.

Events and changes which occurred during the study period effectively divided the study period into 4 subperiods for analyses: 1953-1959, 1960-1965, 1966-1970 and 1971-1980.

The 1953-1959 subperiod is defined as a "pristine" period, in that the river was flowing in a more or less natural state and hunting was not allowed anywhere in the study area. The 1960-65 subperiod is characterized by regulated river flows due to Priest Rapids Dam, which initiated service in 1959, and continued restrictions on hunting within the study area. The 1966-1970 subperiod was the initial period in which hunting was allowed within the study area; the initial season began in October, 1965. The final subperiod, 1971-1980, is the period in which all goose reproductive data were collected during biweekly nest surveys and further increases in public access to the river and islands occurred.

A major objective of the study of Hanson and Eberhardt (1971:6) was ". . . to document the continued normal fertility of the local goose population in the presence of extensive nuclear reactor activity." Compatible with this objective, the 4 subperiods can be further catagorized by production reactor activity within the study area in terms of the number of operating reactors which released controlled amounts of radioactive contaminants into the river. During 1953-1958, the number of production reactors increased to near maximum. The number of reactors was at a maximum during 1960-1965 and began to decrease during 1966-1970. The decrease continued to the complete closure of all production reactors in the winter of 1970-1971.

The study area was divided into 3 island groups for these analyses. Islands 1-10 are the most isolated from human activities and receive the least use by the public. All reactors in the study area are situated adjacent to this island group (Figure 1).

Islands 11-17 and 18-20 form the second and third island group. Islands 12-18 were opened to hunting and other recreational uses in 1965; formerly all forms of public access and use were restricted. Island 11 is included in this group because of its close proximity to Island 12. Agricultural lands border the entire east river bank adjacent to all islands in this group.

Island 18 is included in the last group because of its close proximity to human activities on the west riverbank. Islands 19 and 20 lie within the city limits of Richaland, Washington and no public access or use restrictions (except hunting) existed on these islands until 1980. The east riverbank along this section of the study area is intensively farmed.

Islands 1, 2, 9, 11, 12, 15, 17, 18, 19 and 20 were continuously used by nesting geese during the 1953-1980 period and are henceforth referred to as favored islands.

Two portions of the nesting data have been completely eliminated from these analyses. The goose nest desertion study of Hanson and Eberhardt (1971:24-25) conducted in 1959 provided a low estimate of the goose productivity as only one nest survey

Figure 1. Map of study area (shaded portion) showing relation to hydroelectric development on the Snake and Columbia Rivers and specific island locations.

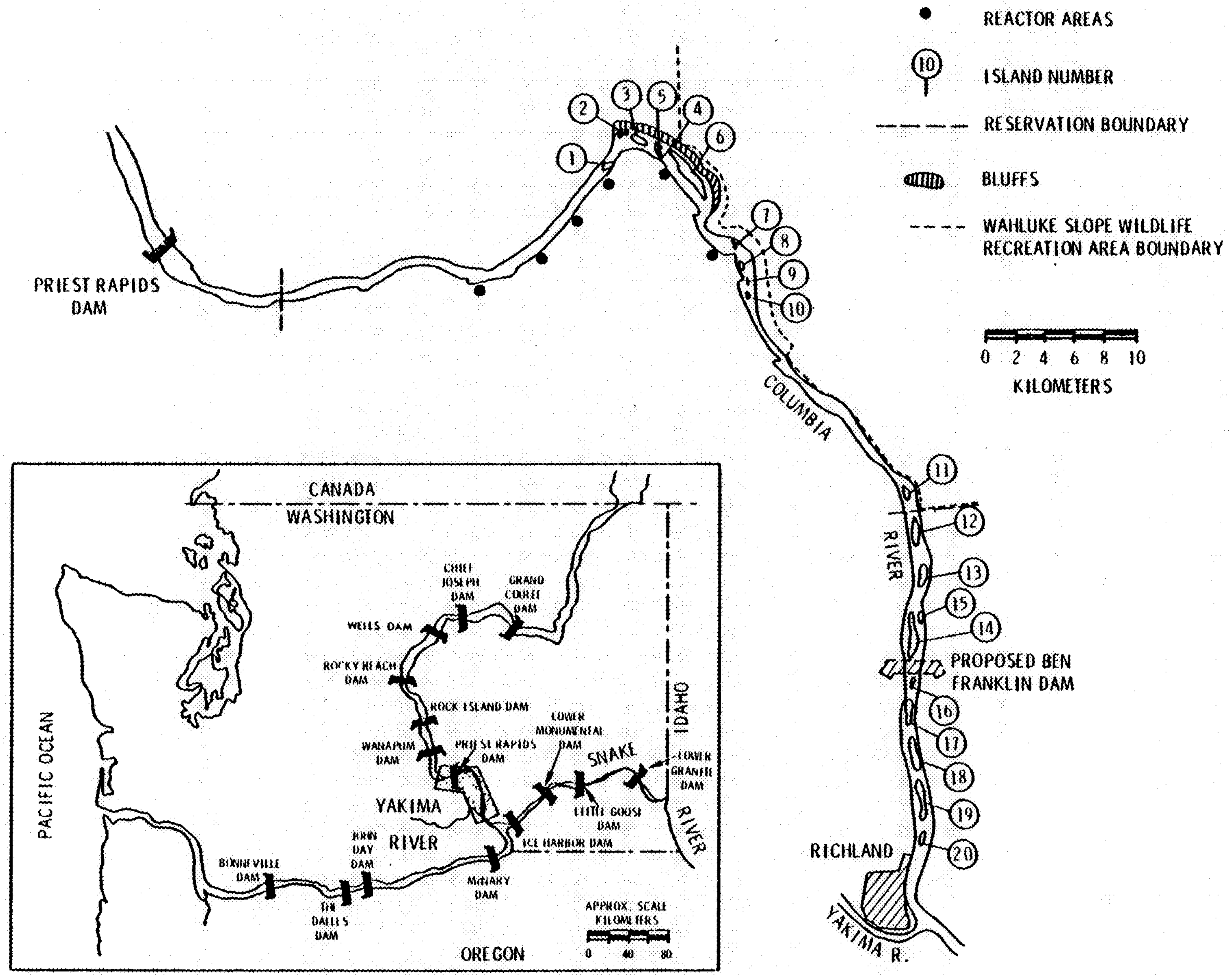

REACTOR AREAS
ISLAND NUMBER
RESERVATION BOUNDARY
BLUFFS
WAHLUKE SLOPE WILDLIFE RECREATION AREA BOUNDARY
0 2 4 6 8 10
KILOMETERS
PRIEST RAPIDS DAM
COLUMBIA
RIVER
PROPOSED BEN FRANKLIN DAM
RICHLAND
YAKIMA R.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
CANADA
WASHINGTON
IDAHO
OREGON
PACIFIC OCEAN
CHIEF JOSEPH DAM
GRAND COULEE DAM
WELLS DAM
ROCKY REACH DAM
ROCK ISLAND DAM
WANAPUM DAM
PRIEST RAPIDS DAM
LOWER MONUMENTAL DAM
SNAKE
LOWER GRANITE DAM
RIVER
YAKIMA
RIVER
LITTLE GOOSE DAM
ICE HARBOR DAM
BONNEVILLE DAM
JOHN DAY DAM
THE DALLES DAM
McNARY DAM
APPROX. SCALE KILOMETERS
0 40 80

Figure 1.

was conducted on all islands except Island 6 and the river bluffs. This represents a major discontinuity in the data and, therefore, 1959 data have been eliminated. Bluff nest data have also been eliminated because this study is concerned with island nesting phenomena.

Habitat Use

The second major objective of this study was to document any vegetative changes on the islands and to determine whether vegetative changes have affected goose nest site selection.

Two periods, 1953-1970 and 1971-1980, are compared in the analysis of cover type use in relation to availability. No division of the 1953-1970 cover data is made, since Hanson and Eberhardt (1971:10) stated that vegetative succession was not evident during their studies. Particular attention is given the use and availability of nesting cover on favored islands.

Mean clutch size, success and nesting density were determined for nests within the seven major cover types. Nest density as used here refers to effective nest density (Munro 1960).

One-way analysis of variance, t-tests, chi square tests and Spearman's rank correlation tests were applied following the methods given by Steele and Torrie (1960). Usage of the expression "significant(ly)" in the text will refer to statistical, not biological significance.

CHAPTER 3

THE STUDY AREA

The study area has been previously described in detail by Hanson and Eberhardt (1971:6-12). To avoid extensive repetition I will only present changes that have occurred or become evident in the study area since 1970. These changes are divided into 3 catagories: Management and Development, River Flow Characteristics, and Island Vegetation.

Management and Development

In reference to the gradual loss of natural Canada goose nesting habitat through continued hydroelectric development in the Pacific Northwest, Hanson and Eberhardt (1971:6) noted that the Hanford study area would ". . . soon be unique for the entire Columbia and Snake River systems." Little Goose and Lower Granite Dams on the Snake River began hydroelectric service in 1970 and 1975, respectively, and rendered the Hanford study area unique by inundating all remaining natural goose nesting islands on the Snake River in Washington (Figure 1).

The future of the islands in the Hanford study area is still uncertain. Controversy continues over proposed construction of Ben Franklin Dam (Figure 1), with subsequent inundation of all but the lower 4 islands, or excavation of a navigation channel through the Hanford Reach which would severely alter the existing river channels surrounding the islands and important riparian habitats. In January, 1980, the U. S. Army Corps of Engineers held an open discussion of these 2 "management" plans along with 2 alternatives: (1) classifying the Hanford Reach of the Columbia River as a "wild and scenic river" or (2) retaining current river management policies. A "wild and scenic river" classification would surely increase public use of the river, as provisions of this proposal include the construction of limited public access and recreational facilities. Present management policies provide the only hope for the Hanford goose population. These policies will be discussed in greater detail later in this section.

Further development within and near the study area also threatens certain goose nesting and brood rearing habitat potentials for gosling production. In a recent proposal, the Washington Department of Transportation outlined plans for a North Richland toll bridge which would span the Columbia River between Islands 18 and 19. This bridge is intended to alleviate access problems between the City of Richland in Benton County and rural Franklin County. At present, the only Benton-Franklin Columbia River bridges are between Kennewick and Pasco, Washington; about 10 miles downstream from this proposed bridge site. This bridge would certainly affect the goose nesting potential of Islands 18 and 19. Immediate development of the present agricultural Franklin County area surrounding the bridge site into a suburban area would eliminate this area as an important goose brood rearing site. Another bridge, spanning the Columbia River near the mouth of the Yakima River, is to be built as an extension of U. S.

Interstate 182. Goose nesting and brood rearing habitat potentials of the Yakima River mouth are also threatened. At present, there have been no studies initiated to determine the extent of usage of either of these areas by brood-rearing geese.

Development of irrigated farmlands within the Columbia Basin Project on the Wahluke Slope has continued. Percolation of irrigation water to subsurface clay layers has expedited sloughing of river bluffs. The rubble of the 800,000 m^3 earth sloughage reported by Hanson and Eberhardt (1971:8) appears to be enlarging and moving slowly out of its "berth" across the river channel on the north side of Island 6 (W. C. Hanson, pers. comm.). At low river flows this channel narrows to less than 100 m, possibly increasing predator access to the island. Many smaller sloughs have recently occurred in this area and one destroyed an active goose nest in 1979.

As mentioned previously, reactor activity has been nonexistent in the study area since 1971. Recent work has shown that radionuclide contamination of deserted eggs from goose nests at Hanford are of worldwide fallout origin (Rickard and Sweany 1975).

Management of the Hanford Reach of the Columbia River has changed since 1970. In December, 1977, the entire Hanford Reach was opened to public boating. Previously, no boating was allowed upstream of the Wahluke Slope Wildlife Recreation Area (Figure 1).

Island use by the public has been completely restricted on Islands 1-11 since the purchase of the Hanford site in 1943.

Access to the river has effectively opened these islands to the public, as evidenced by discarded litter and illegal digging of Indian artifacts.

Public use of Islands 12-18 is restricted to the duration of eastern Washington waterfowl hunting seasons, from about mid-October to mid-January. The U. S. Fish and Wildlife Service closed Islands 19 and 20 to all forms of public use in July, 1980 because of large losses of goose nests and eggs due to human activities on Columbia and Snake River islands in and near the cities of Richland, Pasco and Kennewick, Washington.

River Flow Characteristics

Perhaps the most quantifiable changes within the study area are the altered characteristics of the river flow rate. Hanson and Eberhardt (1971:10) presented the 1953-1967 mean daily river flows for March through July, the critical months of goose nesting and brood rearing. Mean daily river flows for 1960-1970 and 1971-1979, as measured at the U. S. Geological Survey guaging station at Priest Rapids Dam, are compared in Figure 2. The lower mid-June peak for 1968-1970 of about 9,100 cubic meters (325,000 cubic feet) per second (cms, cfs) as compared to the 1953-1967 peak (Hanson and Eberhardt 1971:9) is indicative of lower 1960-1970 mean river flows of 6,720 cms (240,000 cfs) and much higher flow rates during 1953-1959. Mean mid-June peak flows during 1971-1979 of about 5,320 cms (190,000 cfs) represent a 42% reduction from the 1970-1970 peak flows.

The mean monthly volume of water passing Priest Rapids Dam during March through July of 1960-1970 and 1971-1979 has decreased from 61% to 53% of mean annual volume, respectively. The high June river flows formerly accounted for 21% of annual volume; this has decreased to 13%. Forty-two percent of annual water volume would pass through the dam during March through July if monthly river flow was constant. Obviously, the natural cycling of the river flow has been severely dampened such that a constant flow is being approached. Despite these differences in flow pattern, mean annual river flow for the 1971-1979 period is less than 6 cms lower than the mean annual flow of 5,110 cms (182,400 cfs) during 1960-1970.

Island Vegetation

Cover type vegetation of 19 of the 20 islands was mapped in 1980 to document changes in vegetation from that reported by Hanson and Eberhardt (1971:10-11, 56-61). The individual island cover type maps appear in Appendix I (Appendix Figures 1-16) and a summary of island cover vegetation distribution appears in Table 1, in which island cover vegetation distribution documented by Hanson and Eberhardt (1971:11) is included for comparison. The 1970 island data differ slightly from that presented by Hanson and Eberhardt (1971:11) due to several typographical errors (W. C. Hanson, Pers. comm.).

Total island areas averaged 34% greater in 1980 than in 1970 due to a lower stage level of the river when aerial photographs were taken in 1979.

Hanson and Eberhardt (1971:10) reported that 67% of total island area was usable for goose nesting. In 1980, 80% of total island area was classified as usable for goose nesting. Despite

Figure 2. Mean daily flow rates of the Columbia River as measured at Priest Rapids Dam during March-July, 1960-1970 and 1971-1979.

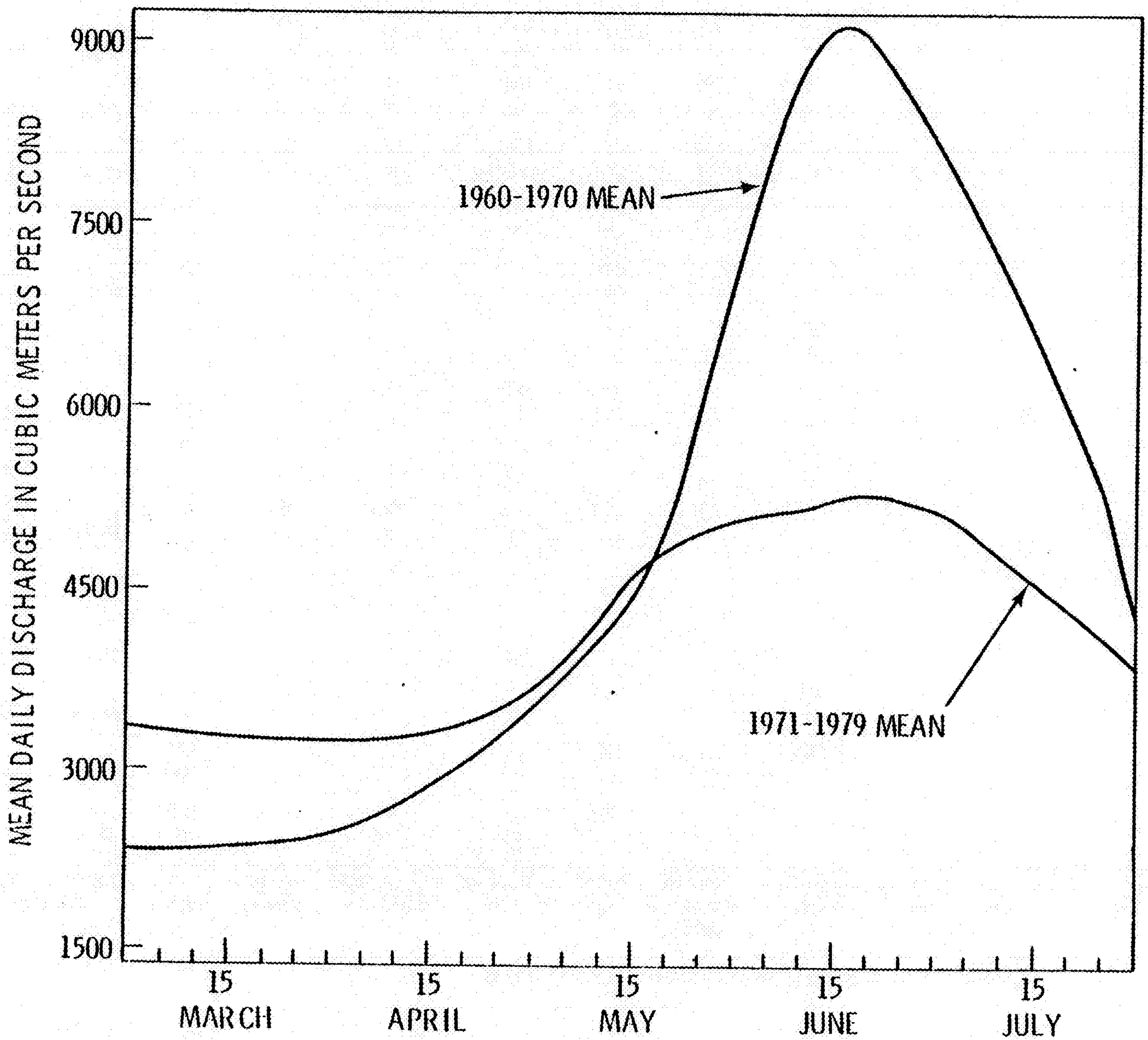

MEAN DAILY DISCHARGE IN CUBIC METERS PER SECOND
9000
7500
6000
4500
3000
1500
1960-1970 MEAN
1971-1979 MEAN
15
MARCH
15
APRIL
15
MAY
15
JUNE
15
JULY

Figure 2.

Table 1. Distribution of 10 cover type species on the Hanford Reservation study area islands, 1980 and 1970, expressed as a percent of usable island area for goose nesting.

ISLAND NO.	AREA (ha) TOTAL	AREA (ha) USEABLE	Lupinus sp.	Elymus cinereus	Agropyron dasystachyum	Artemisia absinthium	Salix exigua	Achillea millefolium lanulosa	Eriogonum compositum	Bromus tectorum[b]	Sporobolus cryptandrus[b]	Chrysopsis villosa[b]	MISCELLANEOUS[c]
			SPECIES COVER COMPOSITION AS PERCENT OF TOTAL COVER[a]										
1*	8.9	7.30	57			24							19
			(80)		(6)	(<1)	(<1)						(13)
2*	11.7	8.26	48									52	
			(95)				(5)		(<1)				
3	71.8	62.30	7			20			32	3			38
			(1)	(3)			(<1)		(60)				(36)
4	3.6	2.53				22			31				47
			(76)										(24)
5	3.8	2.78										100	
													(100)
6	152.2	121.09	4	16	20	13		1		27	5	1	14
			(5)	(51)	(34)	(<1)	(<1)	(8)					(1)
7	10.4	6.77	1			59			10			29	
			(2)						(12)				(85)
8	26.2	17.33	<1	1	2	3				31	51		11
				(1)	(41)	(29)	(4)						(25)
9*	20.3	13.79				24			68				7
			(1)				(2)		(97)				
10	16.5	1.65					40						60
			(86)				(14)						
11*	25.2	20.70	3		14	31	12	2		<1	15		23
			(11)		(59)	(7)	(8)	(2)					(12)
12*	55.8	45.97	8	3	4	29	2	10	<1	8	1	11	24
			(10)	(6)	(1)	(42)	(1)	(22)					(18)
13	83.1	66.27	1	<1	6	31	8	3	3	16	9	5	18
				(<1)		(47)	(5)	(1)					(47)
14	118.2	93.77	2	7	11	28	4	7		9	5	3	25
				(4)	(34)	(33)	(<1)	(10)					(18)

Table 1. Continued.

15*	18.4	14.35	<1 (26)		1 (20)	8	4 (2)	5 (5)	32 (46)		10	10	29 (1)
17*	40.6	37.58	3 (24)		5 (51)	31 (6)	2	8 (2)	19 (18)	10	5		16 (<1)
18*	37.2	28.82	1 (22)			19 (9)	12		27 (62)		4	7	30 (7)
19*	50.9	47.73	6 (6)	<1 (<1)	<1 (<1)	18 (39)	16 (5)	<1 (<1)	24 (14)	9	1	8	17 (36)
20*	14.1	12.77	3 (69)			5 (26)	19 (5)	(<1)	10 (<1)				63
MEAN:	ISLANDS 1-20		5 (9)	4 (14)	7 (22)	22 (17)	5 (2)	3 (5)	11 (14)	11	6	5	22 (18)
FAVORED ISLANDS(*)			6 (20)	1 (1)	2 (19)	18 (16)	7 (3)	3 (5)	15 (21)	4	3	6	19 (15)

(a) COVER TYPE DISTRIBUTION ON ISLANDS DOCUMENTED BY HANSON AND EBERHARDT (1971: 56-61) APPEARS IN PARENTHESES.
(b) THESE SPECIES NOT MAPPED BY HANSON AND EBERHARDT (1971).
(c) MISCELLANEOUS CATEGORY CONTAINS TOTAL OF MISCELLANEOUS FORBS, GRASSES AND SHRUBS (SEE APPENDIX).

the increased total island area, a possible explanation for the greater proportion of usable island area in 1980 can be gained by referring to the changed river flow rate pattern (Figure 2). Since a much greater increase in river flow and, consequently, stage level occurred during the goose nesting seasons (i.e., March through May) prior to 1971, the geese would be forced to learn where to place their nests on the islands to avoid inundation. This is supported by the low numbers of flooded nests during the 1953-1970 period. The spring freshet floodwaters formerly scoured many cobblestone and gravel island areas free of all vegetation, thus limiting usable island area by the lack of adequate nesting cover and facilitating the geese's recognition of safe nesting areas. Since 1970, river flows have increased much less during the nesting period. The now-controlled spring freshet has lost much of its scouring action and successional stages of vegetation have invaded former littoral zones. Thus, the geese do not have to nest as far above the river to avoid inundation and the expanded vegetation on the islands provides more areas for nesting.

Flood controls, maintenance of adequate pool levels for irrigation and the diurnal "power-pulsing" of the river to meet peak hydroelectric power demands by Columbia River dams ended much of the scouring action of floodwaters on the littoral zones of the islands. These may be the most important contributing factors responsible for the changes in the composition and distribution of island vegetation on the study area. The annual scouring of spring freshet floodwaters on cobblestone and gravel island areas formerly controlled successional stages of vegetation have invaded the former littoral zones, especially on the upstream portions of the islands. A definite band of vegetation now characterizes the perimeter of the islands (Figure 3), indicating that the shorelines have become more stabilized. This vegetation is usually much more lush and dense than the vegetation immediately inland. Goose nesting below this vegetation band was not observed during the 1979 and 1980 seasons, although many nests were located within and near it (see Appendix I).

Below this vegetation band, all littoral zone areas contained some type of vegetation, mostly goatweed (Grindelia columbiana) and smartweed (Polygonum sp.). In addition to the 7 most important goose nesting cover types mapped by Hanson and Eberhardt (1971:17-19), cheatgrass (Bromus tectorum), sand dropseed (Sporobolus cryptandrus) and goldaster (Chrysopsis villosa) were mapped because of their prominence on the islands.

Proportionally, lupine (Lupinus sp.), giant wildrye (Elymus cinereus), thickspike wheatgrass (Agropyron dasystachyum), common yarrow (Achillea millefolium var. lanulosa) and northern buckwheat (Eriogonum compositum) have decreased in occurrence. Willow (Salix exigua) and absinthe (Artemisia absinthium, A. lindleyana and A. ludoviciana complex) have increased in both proportional and actual areas. The mapped absinthe communities represent an intergradation of 3 species which are inseparable in the spring when only dead litter from the previous growing season remains. There is a general wet-to-dry trend with A. lindleyana and

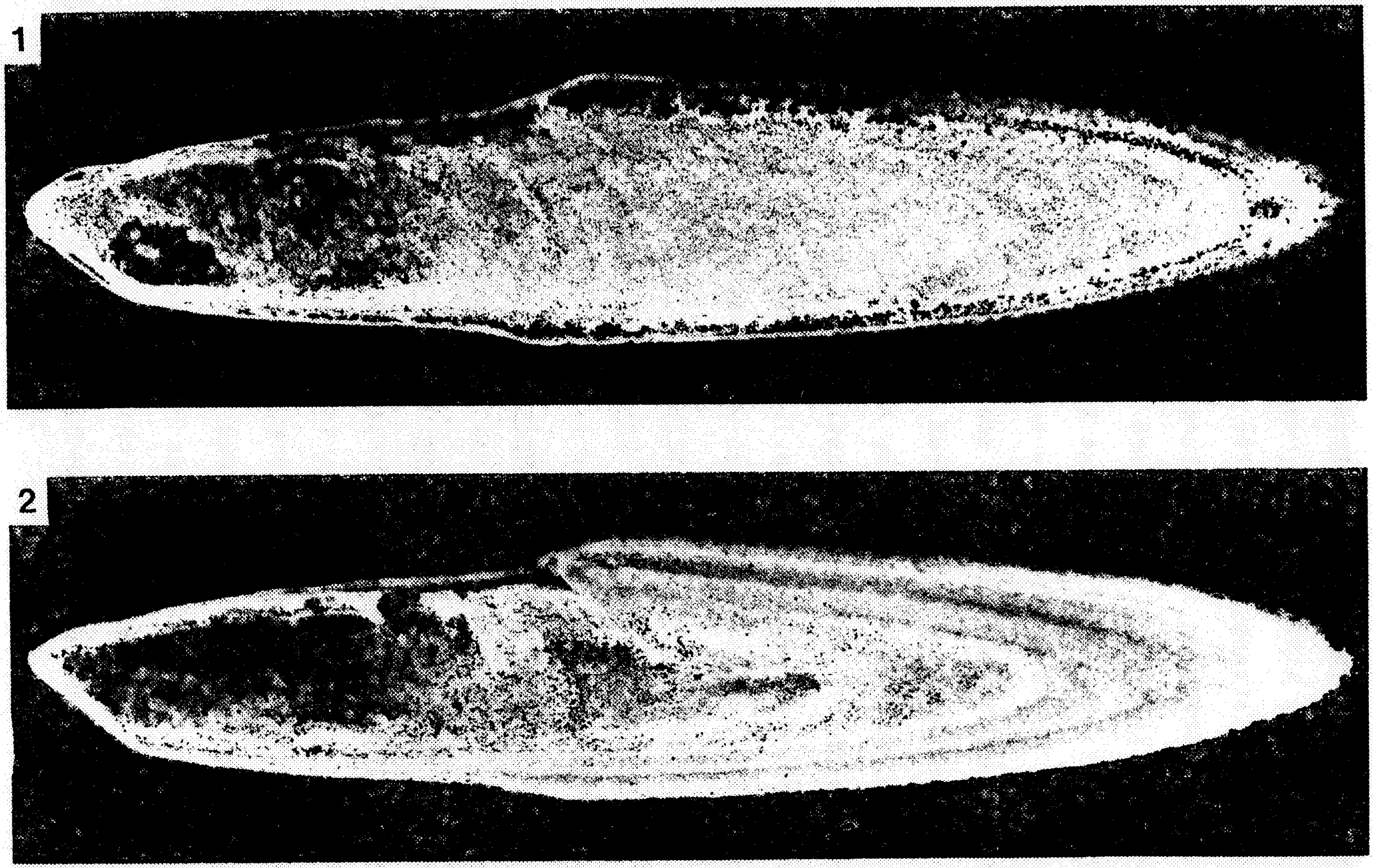


Figure 3. Aerial photographs of Island 20 taken in 1979 (1) and in 1969 (2) showing the dramatic increase in willow (Salix exigua) around the perimeter of the island. Note the disappearance of the series of shorelines in the 1979 (1) photograph.

A. ludoviciana occupying wetter areas nearer the shorelines and *A. absinthium* occurring in drier, more upland areas.

Hanson and Eberhardt (1971:56-61) showed a general trend in island vegetation from wetter to drier areas with willow along shorelines of certain islands; then lupine, absinthe and buckwheat, proceeding in that order to the driest gravel and cobblestone areas. On sandy shoreline substrates, this trend was lupine, absinthe and wheatgrass. Wildrye, wheatgrass and yarrow generally characterize upland areas with loamy substrates.

Current wet-to-dry trends in vegetation of cobblestone and gravel substrates show only slight change from the above. Dropseed has invaded several cobblestone or gravel areas classified by Hanson and Eberhardt (1971:56-61) as littoral zones and is also found in several inland areas. Goldaster is restricted to cobblestone and gravel substrates and does not appear to have colonized littoral zone areas as extensively as dropseed.

Although direct replacement of one species by another was not measured, general statements can be made about vegetative composition changes between 1970 and 1980 mappings. For instance, goldaster and absinthe now occupy many areas formerly dominated by lupine. Decreases of 35% for wildrye and 14% for wheatgrass on Island 6 are explained by their replacement with cheatgrass (Figure 4). In 1953, a pregnant cow swam to Island 6 after having been observed on the cliffs of White Bluffs (W. C. Hanson, pers. comm.). Her calf was a bull. After subsequent inbreeding, the herd increased to 14 individuals until they were removed from the island in 1970. Grazing pressure on the native wildrye and

Figure 4. The downstream portion of Island 6 showing the extensive cheatgrass (Bromus tectorum) understory and widely scattered clumps of wildrye (Elymus cinereus).

wheatgrass communities plus soil disturbance caused by the cattle provided conditions conducive for the invasion of cheatgrass in the Artemisia tridentata/Agropyron spicatum zone (Daubenmire 1970: 80). Invading cheatgrass has mostly replaced the wheatgrass understory formerly occurring in wildrye communities (W. C. Hanson, pers. comm.).

Another factor which may have contributed to the rapid influx of cheatgrass on Island 6 was an extensive fire in 1967 (Appendix Figure 5) (Hanson and Eberhardt 1971:11). Initial reduction of native perennial grass cover the year following the fire may have aided establishment of cheatgrass within the wildrye and wheatgrass communities.

Decreases in yarrow cover were also most notable on Island 6, with cheatgrass now occupying some of these areas. There have also been decreases in yarrow availability on several favored islands, especially Island 12. All remaining yarrow stands contain large amounts of Jim Hill mustard (Sisymbrium altissimum) and cheatgrass (Figure 5).

Buckwheat declined markedly on Island 3 where a large increase in absinthe was evident. Large decreases in available buckwheat cover occurred on Islands 18 and 20, apparently caused by the presence of nesting colonies of California and Ringbill gulls (Larus californicus and L. delawarensis). The area occupied by the colony is now dominated by goatweed and Russian thistle (Salsola kali).

Increases in absinthe cover were noted on all islands except Islands 8, 13, 19 and 20. On Islands 8 and 13, dropseed

Figure 5. Yarrow (Achillea millefolium var. lanulosa) community on Island 15 showing the cheatgrass (Bromus tectorum) understory.

now occupies many areas formerly dominated by absinthe. Buckwheat and miscellaneous forb communities occupy much of the former absinthe-dominated areas on Islands 19 and 20, respectively.

Willow has completely disappeared from Islands 1, 2 and 9, and has been flourishing on Islands 18-20. Hanson and Eberhardt (1971:11) also noted the expansion of willow on these islands. The upper extension of the McNary Dam impoundment ends at Island 18. The sluggish river flows and reduced seasonal fluctuations is the likely cause of the rapid influx of willow on these islands.

In general, vegetation of the nesting islands has become much more heterogenous in the past decade, as indicated by greater proportions of miscellaneous cover in 1980, even though additional cover species were mapped (Table 1).

CHAPTER 4

RESULTS AND DISCUSSION

Nesting Cover

Hanson and Eberhardt (1971:17-19) reported on the utilization of the 7 most important cover type communities by nesting Canada geese for the 1953-1970 period. Comparing the nesting use of these cover types in relation to their availability, they concluded that the nesting geese showed ". . . preference for lupine and willow rather than wheatgrass and buckwheat and an intermediate status or neutrality toward ryegrass, absinthe and yarrow." In addition, they stated that on certain islands, nesting use and availability of certain cover species were not consistent with general study area trends.

Comparisons of nesting use (Table 2) in relation to availability of cover vegetation (Table 1) were made between the 1953-1970 and 1971-1980 periods. A distinct preference for lupine cover by nesting geese is apparent for both periods. For the study area, the availability of lupine cover decreased from 9% to 5% of usable area while nesting use increased significantly from 21% to 25% of total nests. Availability of lupine declined from 20% to 6% and nesting use decreased significantly from 32% to 25% of total favored island nests.

A similar pattern of decreased usage in relation to decreased availability can be observed on all favored islands

Table 2. Utilization of the 7 most important cover type species by Canada geese nesting on favored islands during 1971-1980 and 1953-1970 (in parentheses). Utilization of each cover type species is expressed as a percentage of the total nests per island.

ISLAND	COVER TYPE SPECIES *Lupinus* sp.	*Elymus cinereus*	*Agropyron dasystachyum*	*Artemisia absinthium*	*Salix exigua*	*Achillea millefolium lanulosa*	*Eriogonum compositum*	Misc.	TOTAL NESTS
1.	44(52)**		6(8)	13(4)**	2(19)**			35(17)	210(318)
2.	79(62)**			2(1)	4(24)**	0(1)	2(5)	13(8)	165(286)
9.	3(18)*		0(2)	3(0)	0(33)	0(1)	80(40)**	19(5)	39(92)
11.	12(20)	1(0)	16(9)	20(27)	3(8)	3(1)		45(36)	74(105)
12.	6(4)	4(14)**	4(13)**	14(11)	5(6)	3(10)	4(0)	59(42)	213(225)
15.	0(39)		12(27)	5(5)		7(0)	17(3)*	60(26)	42(62)
17.	8(19)**		7(24)**	22(35)**	2(0)	6(6)	7(1)**	48(16)	211(364)
18.	22(47)**	0(1)	0(1)	12(0)	3(0)	2(0)	49(27)*	12(23)	67(74)
19.	15(4)*	11(13)	9(38)**	11(16)	19(0)	2(14)**	10(0)	24(15)	121(93)
20.	13(24)	4(0)	8(17)	6(12)	23(2)**	4(19)*	13(2)	28(24)	47(42)
Mean	25(32)**	2(3)	6(13)**	13(13)**	5(11)**	2(4)*	10(5)*	37(20)	1189(1661)
Study Area Mean	25(21)	2(18)	6(12)	12(12)	5(8)	2(3)	10(3)	36(24)	1254(3514)

* $P < 0.05$, X^2, 1 df
** $P < 0.005$, X^2, 1 df

except Islands 2, 12 and 19. On Islands 2 and 12 usage of lupine increased. The disappearance of a small willow stand on Island 2 within which clumping of goose nests was observed by Hanson and Eberhardt (1971:10) and the greatly increased availability of goldaster, which does not seem attractive to nesting geese anywhere in the study area (Figures 6 and 7), has left lupine as nearly the only suitable nesting cover on that island.

Lupine availability was unchanged on Island 19 and increased usage there likely reflects the greatly increased nesting usage of that island during the past decade.

The annual proportion of nests in lupine cover is significantly and negatively correlated with time (Table 3), indicating a strong relationship between nesting use and availability. Nest density in lupine communities increased markedly, indicating greater decreases in availability than use.

Preference for willow cover by nesting geese has changed from preferred nesting cover to a neutral status based upon decreased use compared to greater availability on the study area and favored islands. During the past decade, nesting use of willow is positively correlated with time and is most likely due to the large increases in the nesting populations on Islands 18-20 where the greatest expansion of willow communities occurred.

The selection of buckwheat cover by nesting geese increased even though nesting densities in buckwheat were lower than for most other cover types and it decreased in availability, particularly on Islands 18-20. Increases in nesting use of buckwheat during 1971-1980 do not reflect availability except on Island 2.

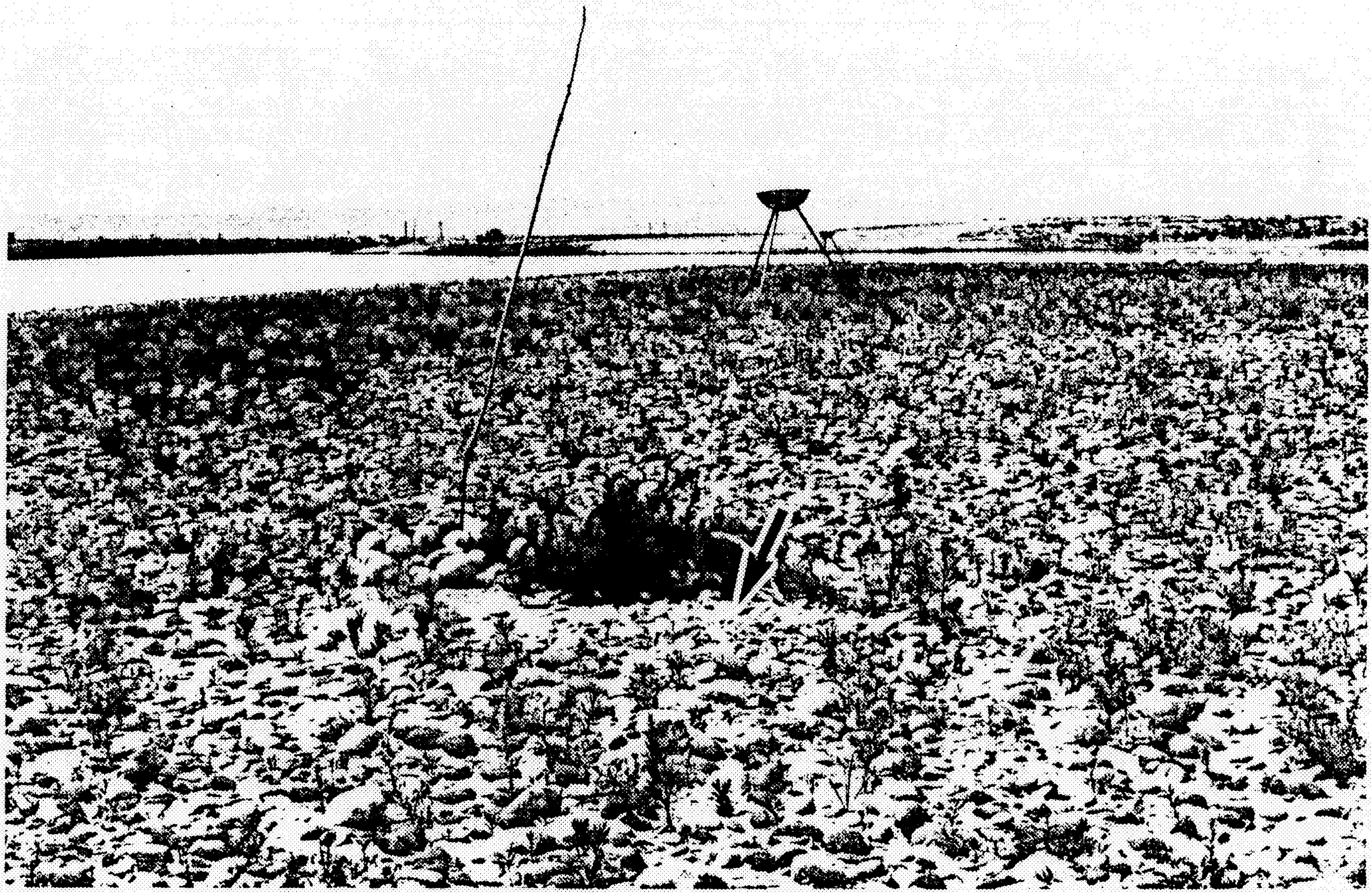


Figure 6. Successfully hatched Canada goose nest (arrow) next to the only bitterbrush (Purshia tridentata) clump on Island 2. Vegetation surrounding this nest site is goldaster (Chrysopsis villosa). Note unused fiberglass shell nesting platforms in background.

Figure 7. Nest site (arrow) on Island 5 was located in the only clump of lupine (*Lupinus* sp.) cover on the island and was used successfully by two Canada geese during 1980. Nearly all other vegetation on this island is goldaster (*Chrysopsis villosa*).

Table 3. Characteristics of utilization of the 7 most important cover type species by Canada geese nesting on favored islands: A) Annual usage during 1971-1980. B) Rank correlation between annual usage and time (in years). C) Mean annual nest density in nests/ha/year. D) Mean clutch size. E) Mean nest success. F) Number of nests represented in C-E, above.

	COVER TYPE SPECIES						
A. YEAR[a]	*Lupinus* sp.	*Elymus cinereus*	*Agropyron dasystachyum*	*Artemisia absinthium*	*Salix exigua*	*Achillea millefolium*	*Eriogonum compositum*
1971(98)	35	1	3	7	5	7	13
1972(125)	40	2	12	15	4	3	6
1973(110)	34	3	2	18	3	2	2
1974(125)	30	3	8	14	6	1	6
1975(98)	28	7	0	0	2	7	4
1976(102)	33	0	3	5	8	5	10
1977(107)	18	2	16	20	3	1	14
1978(111)	22	3	4	18	4	0	19
1979(126)	13	0	2	18	11	1	18
1980(132)	17	2	8	14	9	1	11
B. Rank correlation:	-0.93**	-0.29	+0.10	+0.16-	+0.48	-0.72*	+0.56*
C. Mean Annual Nest Density[b]:	1.8(1.1)	1.8(2.1)	1.0(0.5)	0.3(0.6)	0.3(2.7)	0.3(0.6)	0.3(0.2)
D. Mean Clutch Size[b]:	5.0(5.3)	6.1(5.7)	5.9(5.7)	5.9(5.9)	6.3(5.4)	5.8(5.6)	5.8(5.5)
E. Mean Nest Success[b]:	78(80)	77(71)	82(74)	85(79)	73(70)	88(90)	74(75)
F. Number of Nests[b]:	309(532)	22(41)	62(228)	145(220	60(174)	41(67)	118(76)

[a] Number in parentheses represents total nests for which cover types were determined on favored islands only.

[b] Number in parentheses represents that observed during 1953-1970.

* $P < 0.10$

** $P < 0.005$

Nesting use was positively correlated with time; similarly, nesting densities in buckwheat increased markedly during the past decade to 75% more than 1953-1970 densities. This indicates a slight preference for this species even though nest densities are low.

Availability and use of wheatgrass cover has declined substantially in the past decade on the study area and favored islands. Its use as nesting cover remained relatively constant during 1971-1980 while nest density nearly doubled. This increase in nest density is due to the occurence of many goose nests in wheatgrass cover which exists in communities dominated by other species. Therefore, a neutral rather than nonpreferred status as nesting cover is indicated.

The neutral status of absinthe and wildrye as goose nesting cover remains unchanged. Increases in absinthe cover have made it the most common cover type on the study area and favored islands. Changed availabilities of absinthe were not accompanied by concomitant usage on individual favored islands. Nest density in this cover type decreased by 50% due to increased availability and similar usage rates during 1953-1970 and 1971-1980. There was no relationship between use and time during the latter period.

While use and availability of wildrye decreased dramatically on the study area, no changes in use or availability occurred on the favored islands. These disproportionate changes resulted from large decreases in wildrye cover on Island 6 and near complete lack of nests on that island after 1970 due to the continued presence of coyotes (*Canis latrans*). Nests in wildrye cover during the past decade occurred primarily on Islands 12 and 19. Annual proportions of nests in wildrye on favored islands show no relationship with time, while nest density decreased slightly.

The availability and use of yarrow cover declined on the study area and favored islands. A significant negative correlation between use and time existed during 1971-1980 and nest density decreased by nearly 50%. A nonpreferred status as goose nesting cover is indicated.

The three additional cover types I mapped (cheatgrass, goldaster and dropseed) represent a combined total of 22% and 13% of usable area on the study area and favored islands, respectively. The combined use of these species as nesting cover was 7% on the study area during 1971-1980 while only 1% of total nests prior to 1971 occurred in cheatgrass and no nests were recorded in goldaster or dropseed.

Vegetation cover types as recorded and reported here were represented by the dominant species. The physical configuration or form of vegetation which provides visual screening cover has been regarded as more important to nesting geese than the species *per se* (Miller and Collins 1953:390, Naylor 1953:88, Naylor and Hunt 1954:9, Hammond and Mann 1956:347, Buss and Wing 1966:20 and others). Naylor (1953:88) was the only author to mention the phenological state of the vegetation at the onset of the goose nesting season. McCabe (1979:125) found statistically significant differences between vegetation at goose nest sites and surrounding terrain. He concluded that species composition of vegetation was not selected for but rather the physical configuration of both live and dead vegetation which provides visual screening and wind protection for the nest.

The amounts of visual screening provided by the species of cover considered here are different owing to differences in physical configuration and phenology of spring regrowth. Highly preferred lupine retains a dead shrub-like appearance over winter and completes vegetative regrowth prior to the end of the goose nesting season, thus providing screening cover the entire nesting season (Figure 8). Lupine's shrub-like form also provides excellent "breaks" in the homogenous topography of gravel and cobblestone areas.

Lower nesting densities and use of wheatgrass, absinthe, yarrow and buckwheat coincide with far lesser amounts of standing litter and later spring regrowth. Considering the availability of cheatgrass, goldaster and dropseed, the paucity of nests may be related to the very sparse cover afforded by these species (Figures 6 and 7).

Clumping of goose nests in small willow communities on Islands 1, 2 and 9 during 1954-1970 (Hanson and Eberhardt 1971:10) has not been observed in the extensive willow communities on Islands 18-20. This may be related to differences in the form of these willow communities. Willow stands on Islands 1, 2 and 9 were relatively short in stature (<1.5m) and sparse while that which now grow on Islands 18-20 is tall (2-4m) and forms a nearly impenetrable barrier along some shorelines. Extensive dense shrub growth on goose nesting islands has been noted to restrict

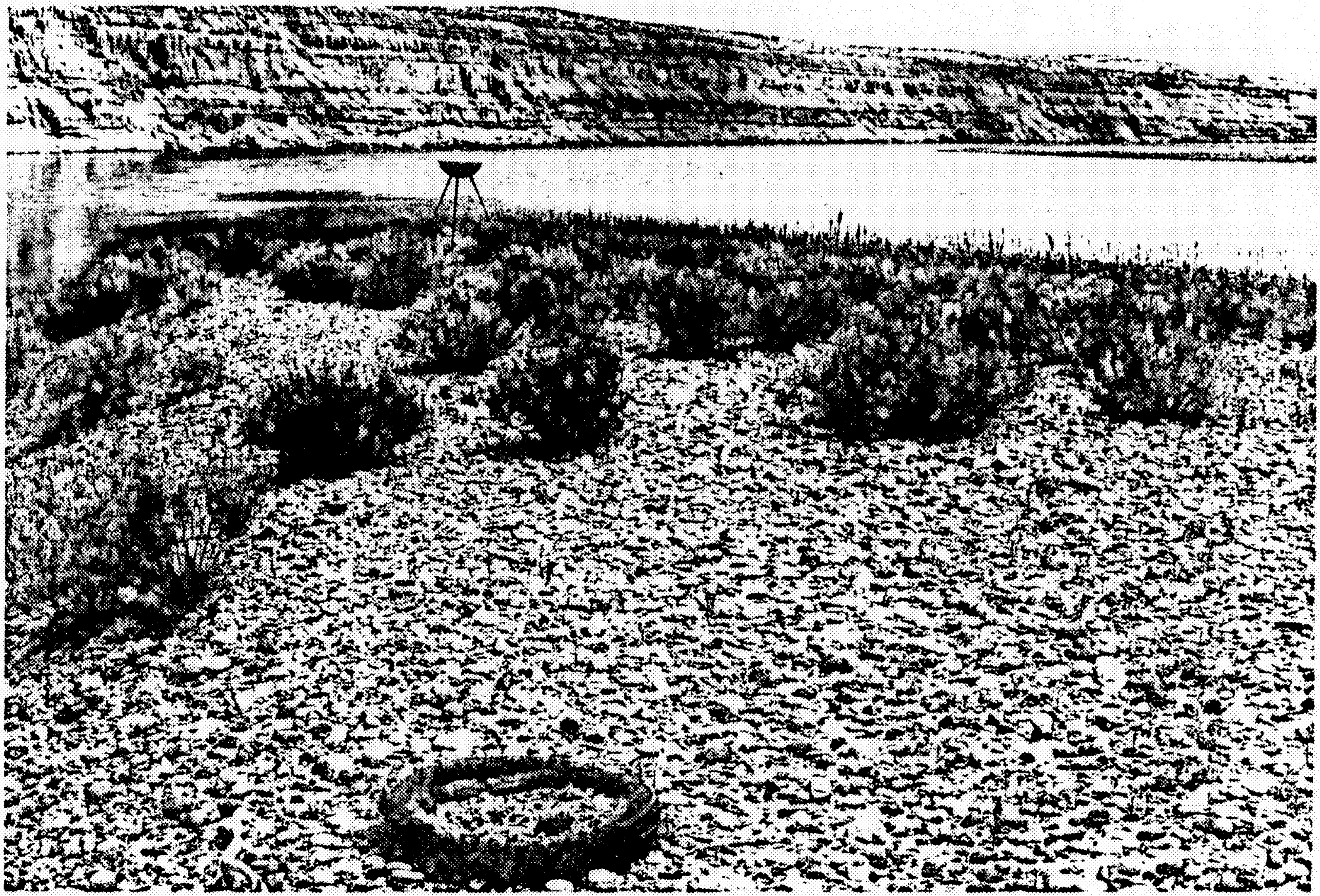


Figure 8. View of the lower end of Island 2 showing the large lupine (*Lupinus* sp.) plants. Nest site in tire in foreground was constructed by the author and used successfully by Canada geese in 1979 and 1980. Note unused fiberglass shell nesting platform in background.

western Canada goose nesting on river islands (Craighead and Craighead 1949:55, Geis 1956:415, Grieb et al. 1961:142, and Buss and Wing 1966:20). Conversely, Munro (1960:545), Vermeer (1970: 237) and Ewaschuk and Boag (1972:100) observed very high nesting densities in dense shrubby vegetation on islands located in lakes.

Hanson and Eberhardt (1971:13, 19) observed that a distinct preference of nesting geese for the wildrye cover on Island 6 was facilitated by its occurence on the sheer raised berm of that island. Clearly, this was a function of topography. Use of available wildrye on Islands 12 and 19 does not suggest such a preference. Nesting use of a 0.65 ha stand of rabbitbrush (Chrysothamnus nauseosus) on Island 1 in 1980 suggested a similar topographical effect (Figure 9). Ten geese nested in this stand, representing a nest density of 15 nests per ha. The stand is located on the most elevated portion of the island.

Lower clutch sizes of Canada goose nests in certain habitats have been attributed to less secure, inferior habitats (Sherwood 1965, 1968, and Raveling and Lumsden 1977:31). Differences in clutch size of nests in lupine, wildrye, wheatgrass and buckwheat between 1954-1970 and 1971-1980 (Table 3) reflect shifts in availability and use within the study area rather than differences in habitat quality.

The increase in mean clutch size of nests in willow cover from 5.4 to 6.3 eggs was, in part, due to increased nesting on Islands 18-20. Since mean clutch on these islands was 6.0 eggs during 1971-1980, the greater clutch size of nests in willow

Figure 9. Rabbitbrush (*Chrysothamnus nauseosus*) community on Island 1 in which 10 Canada geese nested during 1980. Note unused fiberglass shell nesting platform in background.

cover suggests that productivity of these geese may be greater due to factors such as age and experience, as suggested by Geis (1956:415).

Vegetative changes on the Hanford study area will probably continue along the lines observed during the past decade. Decreased availability of highly preferred lupine and increasing nonpreferred cheatgrass, goldaster and dropseed cover may be detrimental to the nesting population by lowering individual island nest densities. Further expansion of willow communities on Islands 15-20 is probable. Whether the development of dense willow stands encircling the islands will prove detrimental to the nesting population is not indicated by currently increasing population trends on Islands 18-20. Continued monitoring of cover type use by nesting Canada geese nesting at Hanford and periodic mapping of island vegetation is strongly recommended to ascertain further effects of vegetative changes on habitat use by nesting geese.

Attempts to increase the nesting potential of the study area during the past decade had very limited success. Fiberglass shell nesting platforms were placed on Islands 1, 2, 3, 6, 9 and 19 and along the riverbank adjacent to and downstream of Island 6. Only 10 nests have been recorded in these platforms since 1970 and 6 of these nests occurred on Island 9 platforms. No nests were observed in platforms placed on the riverbanks.

Contrasted with this disregard of platforms at Hanford is the acceptance and increasing use of platforms by nesting geese at McNary National Wildlife Refuge (H. Hill, pers. comm.).

The Nesting Population

The annually documented number of Canada goose nests in the study area during 1971-1980 is assumed to be unaffected by the change to biweekly nest surveys. Compared to the weekly survey method, if a nest had met its fate (i.e., hatched, deserted, destroyed or flooded) prior to being found, then the chances of finding that nest during beweekly surveys would be smaller. Under these circumstances, the number of nests recorded in the study area in any year, since 1970, may be biased slightly low, but this is an insignificant bias because of the intensive island searches. I assume that the 1971-1980 data concerning the number of nests are comparable and continuous with the 1953-1970 data.

Study area nests, with and without Island 6 nests, and nests on the favored islands during 1953-1980 are represented diagramatically in Figure 10. During 1971-1980, population peaks occurred in 1972, 1974 and 1980 resulting, in part, from above-average numbers of nests on certain islands. Nests on Islands 3, 6, 8 and 13 represent sporadic nesting attempts on these islands after 1970. Peaks in 1972 and 1974 were coincident with river flow patterns characteristic of the 1960-1970 period. The 1980 peak represents maximum nesting use of the favored islands for the entire study period, 1953-1980.

Distribution of nests on individual islands each year during 1953-1980 appears in Table 4. The number of nests in the study area has decreased substantially over time, especially in the past decade. The mean of 131 (S. E. = 5) nests per year since

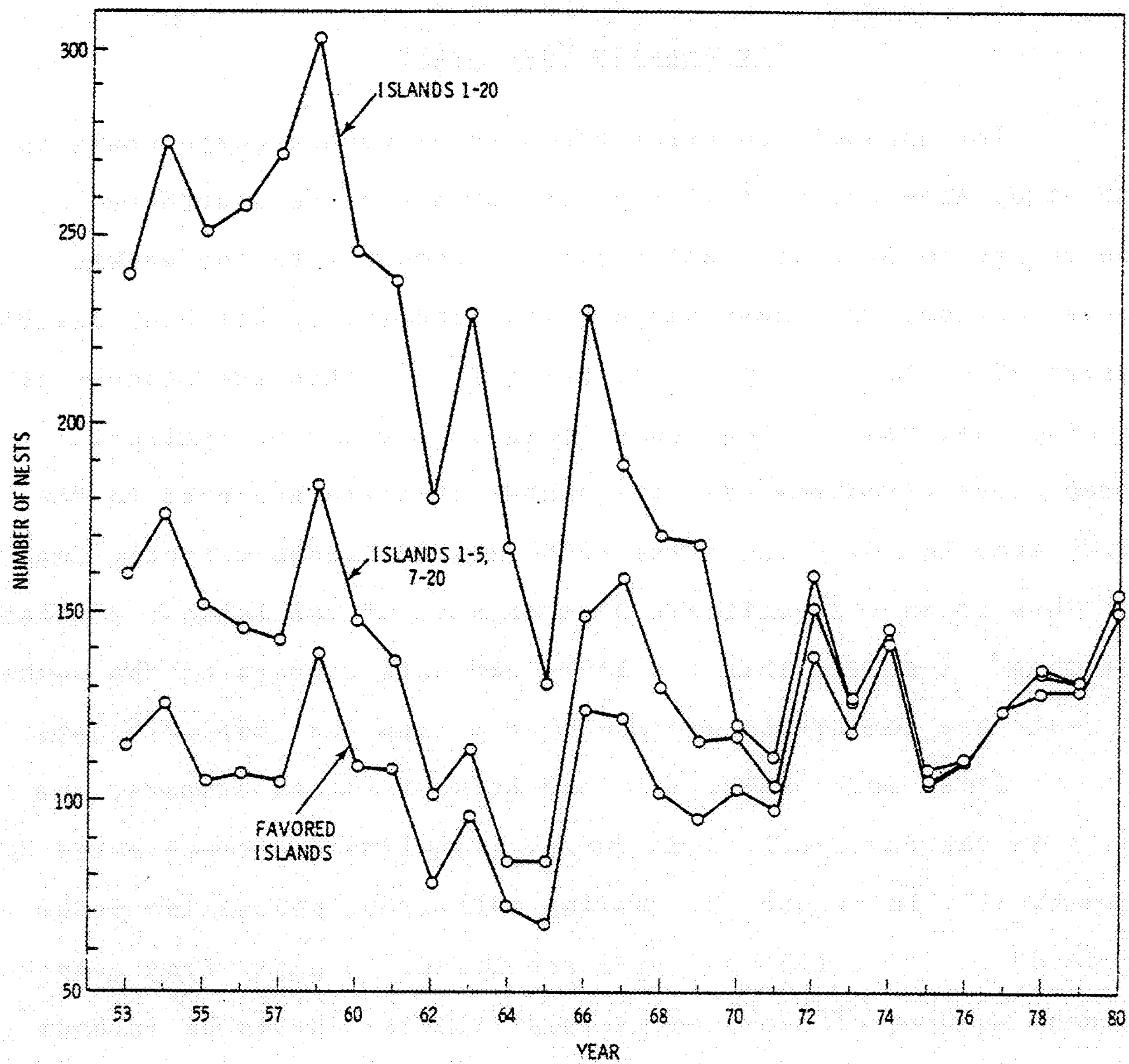


Figure 10. The number of nests on the Hanford Reservation study area, with and without Island 6 nests, and on the favored islands over the period 1953-1980.

Table 4. Distribution of 4972 Canada goose nests on the Hanford Reservation study area islands each year, 1953-1980.

	YEAR																											TOTALS FOR PERIODS	
ISLAND NO.	53	54	55	56	57	58*	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	71-80	53-80
1*	13	12	11	12	13	20	19	17	17	20	17	22	30	34	24	23	24	21	31	31	27	8	18	9	23	23	25	216	544
2*	16	19	17	21	16	22	24	25	13	12	10	10	19	17	14	15	17	16	22	20	21	18	26	20	16	7	9	175	462
3	17	21	22	17	20	21	15	15	11	16	4	11	15	19	16	8	2		1		4							5	255
4	1	2	1	1	2	3	1		1	1	1	1	1	2	1	1	1										1	1	22
5																									2	1	2	5	5
6	80	99	99	112	129	119	98	101	79	105	83	47	81	30	40	52	3	8	9	1		3			1			22	1379
7	2	2	1	1				1		2	1	1	1	2	1		1	2				1	1		2	1		7	23
8		19	10	11	13	16	22	13	10	7	5	3	6	10	3	2	4		5									5	159
9*	13	10	11	5	7	12	6	5	2	5	5	1	7	4	4	3	4	5	3	1	2	3	3	4	7	7	4	39	143
10	12	2	3	2	1	1	1	1	1			1		1	1		1												28
11*	12	9	8	6	6	10	3	4	3	6	2	6	9	9	7	10	10	9	22	2	7	3	6	11	6	3	6	75	195
12*	14	15	8	8	14	12	18	18	10	15	8	7	13	19	19	20	17	22	15	23	31	22	20	25	15	25	27	225	460
13	7	2	7	6	2	2								1	2	1			7	8								15	45
14	6	2	4	1		2			1	2	1		2	2	4	9	5	4									1	5	46
15*		7	4	5	5	5		3	2	3	5	2	4	4	3	5	5	4	4	3	5	4	4	5	4	5	6	44	106
17*	25	35	29	27	16	28	25	22	20	26	16	16	33	30	23	11	14	12	23	20	25	27	17	25	21	22	27	219	615
18*	5	5	8	7	12	8	4	5	3	4	4	2	3	1	3	3	4	5	5	4	8	5	4	9	14	9	13	76	157
19*	13	11	6	10	11	16	8	5	6	4	3	1	4	3	3	3	3		9	10	11	8	8	12	18	22	26	124	234
20*	4	3	2	6	3	6	2	3	1	1	2		2	1	2	2	5	4	4	4	5	6	4	4	5	6	7	49	94
TOTALS:																													
1-20	240	275	251	258	272	303	246	238	180	229	167	131	230	189	170	168	120	112	160	127	146	108	111	124	135	131	154	1308**	4972**
1-5,7-20	160	176	152	146	143	184	148	137	101	124	84	84	149	159	130	116	117	104	151	126	146	105	111	124	134	131	154	1296**	3593**
FAVORED ISLANDS(*)	115	126	104	107	103	139	109	107	77	96	72	67	124	122	102	95	103	98	138	118	142	104	110	124	129	129	150	1242	3010

* 1959 DATA HAS BEEN ELIMINATED, SEE TEXT.

** TOTAL INCLUDES ONE NEST ON ISLAND 16, 1978.

1970 is significantly lower than 215 (S. E. = 13) nests per year observed during 1953-1970 (t = 4.93, 25 df, $P < 0.001$). This decrease coincides with the near complete termination of nesting on Islands 3, 4, 6, 8, 10, 13 and 14. These islands supported 51% of total nests during 1953-1970 but only 4% since 1970. Island 6 along supported 37% of total nests prior to 1970 but less than 2% since then, suggesting that temporal decreases in study area nests could be explained by the pronounced loss of nesting on that island alone. Eliminating Island 6 nests from the entire data set yielded annual means of 136 (S. E. = 7) and 128 (S. E. = 5) nests per year during 1953-1970 and 1971-1980, respectively, and these means are not significantly different (t = 0.792, 24 df, $P > 0.40$). The 12% difference caused by the loss of nesting on Islands 3, 4, 8, 10, 13 and 14 after 1970 was compensated by increased nesting on Islands 1, 12 and 18-20 during 1971-1980.

Distribution of nests on the 3 island groups is presented in Figure 11. Island 6 nests are presented separately. To analyze island group data, a ratio was calculated for each year of the number of nests on Islands 1-5 and 7-10 to nests on Islands 11-17. An analysis of variance of these ratios between the 4 subperiods disclosed significant differences (F = 19.35, 3,23 df, $P < 0.005$). Although comparisons between subperiods were not an orthogonal set due to unequal sample sizes (years) within subperiods ratios differed significantly between 1953-1958 and 1960-1965 (F = 3.65, 1,23 df, $P < 0.05$), 1966-1970 and 1971-1980 (F = 9.98, 1,23 df, $P < 0.005$) and 1953-1965 and 1966-1980 (F = 34.74, 1,23 df, $P < 0.005$). Changes in the ratio were caused by a steady

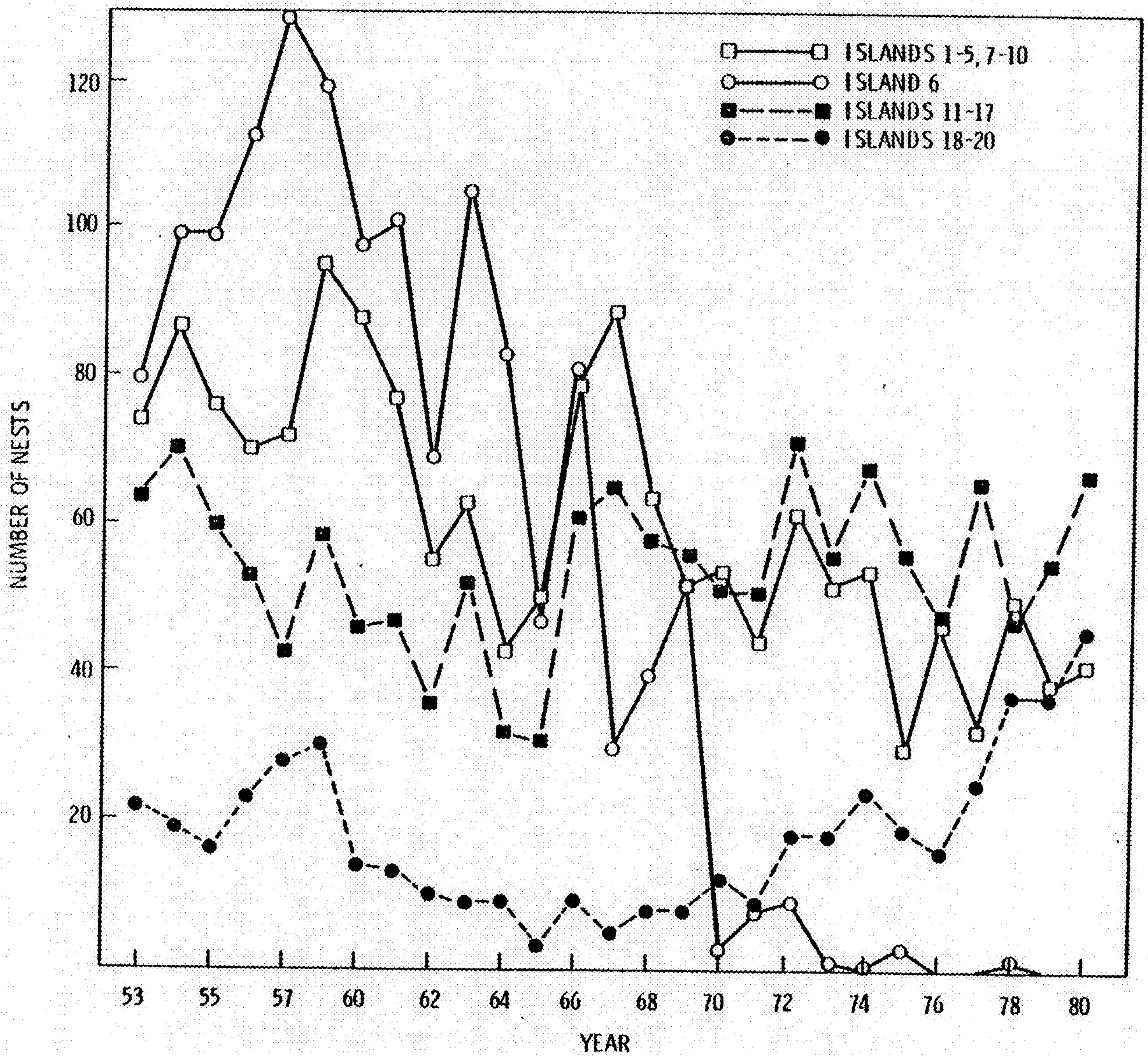


Figure 11. Number of nests on Islands 1-5 and 7-10, 11-17 and 18-20 and on Island 6 during the period 1953-1980.

increase in the ratio until 1960 and an erratic decrease thereafter. The number of nests on Islands 1-5 and 7-10 were the most variable for each subperiod owing to the decreases in nesting on islands discussed previously. This variability resulted in most of the observed changes in the ratio.

Causal factors responsible for loss of nesting on Islands 3, 4, 6, 8, 10, 13 and 14 are not known. However, reanalysis of 1971-1980 data revealed several observations of coyotes or fresh coyote sign on the initial nest surveys on Islands 3, 6, 8, 13 and 14. Numbers of geese nesting on these islands began to decrease after Priest Rapids Dam initiated service in 1959. Continued nesting on the above islands and Islands 4 and 10 ended about 1970, coicident with dramatic changes in annual river flow patterns.

The noted coyote presence indicates that the changed river flow may have facilitated access to these islands separated from the mainland by narrow channels. A relationship between island goose nest predation problems and coyote harvest data from areas adjacent to Hanford was not found by Hanson and Eberhardt (1971:28). Their analysis indicated that individual coyotes were causing the predation problems rather than the size of the coyote population. Similarly, Sherwood (1968:74) pointed out that predation problems at Seney National Wildlife Refuge were not due to too many predators, but a problem of limitations in the habitat, i.e., not enough "safe" nesting islands.

Use of Island 16 in 1977 and Island 5 during 1978-1980 also suggests that the changed river flow pattern and its effect on vegetation altered the character of these islands. Hanson and Eberhardt (1971:8) noted that these islands were not utilized by nesting geese because of their low profile and lack of nesting cover. Both islands now support adequate nesting cover and reduced fluctuations in the rivers' stage level do not inundate these islands frequently.

Numbers of nests on Islands 18-20 also began to decrease after 1959. During 1960-1970, a relatively stable mean of about 9 nests per year was found on these islands. After 1970, increasing numbers of geese nested on these islands and 46 nests found there in 1980 represent the maximum for 1953-1980. The low numbers of nests on these islands during the 1960's are possibly due to nearby construction activities on the west bank of the river adjacent to these islands during this period.

The significant difference in total nest ratios between 1953-1965 and 1966-1980 does not indicate an effect of the opening of hunting seasons on Islands 11-17, as the decline in the ratios was caused by decreased nesting on Islands 1-5 and 7-10.

Estimated harvests of western Canada geese in Washington (Bowhay et al. 1981, in press) do not appear to influence the number of geese nesting at Hanford. However, peak harvests of about 21,500 western Canada geese in 1978 and 1979 hunting seasons did coincide with increasing numbers of nests at Hanford in 1979 and 1980.

During the past decade, only 10 of the 20 islands, the favored islands, have been consistently productive. Habitat deterioration on islands has been severely detrimental to their goose nesting potential. Successful restoration of these islands to productive goose nesting islands would require special river flow modifications at Priest Rapids Dam and an effective predator control program. Hydroelectric power and irrigation requirements obviously take priority in current Priest Rapids Dam operating policy.

The Washington Department of Game has conducted an extensive predator control program at Hanford for the past 4 years, primarily to control coyote populations adjacent to the study area upstream of Island 14. Despite harvests of about 100 coyotes per year (D. Flohr, pers. comm.), observations of coyotes and coyote sign on Islands 3, 6, 8, 13 and 14 continue. I reported 3 sightings of coyotes on Island 6 during 1979-1980 and in each case, these coyotes were destroyed prior to subsequent observations. This indicates the persistent use of Island 6 by these important goose nest predators.

Nest Fates

The increased nest survey interval and changed personnel conducting the surveys in the past decade apparently affected nest fate data by obscuring evidence necessary to determine the fate of a given nest and introducing individual differences in the interpretation of that evidence. Unfortunately, biases in the 1971-1980 nest success data cannot be directly quantified and one must rely upon indirect evidence and trends to indicate diparities in nest fate data between the 1953-1970 and 1971-1980 periods. Additionally, definite conclusions about temporal changes in goose nest fates and the relationships of these changes to production are not possible.

Analyses of goose nest success during the 4 time periods (Table 5) involved testing specific hypotheses with an assumption that results of success comparisons made within either period, 1953-1970 or 1971-1980, are representative of actual fact. In each subperiod, 1953-1958, 1960-1965, 1966-1970 and 1971-1980, nest success rates were dependent on the island groups since success rates between Islands 1-10, 11-17 and 18-20 were highly significantly different for each subperiod ($P < 0.005$ for all comparisons). No consistent temporal pattern of differences in island group success rates were apparent, although nest success was usually highest on Islands 18-20 and lowest on Islands 1-10. Islands 11-17 had the highest success rate over the 1953-1970 period (Hanson and Eberhardt 1971:21).

Due to a history of predation problems during 1953-1970, nest success on Island 6 was hypothesized to have lowered significantly mean success rates of the study area and Islands 1-10. No differences in success rates between Island 6 and Islands 1-5 and 7-20 were observed ($P>0.10$) but mean success on Island 6 was significantly greater than on Islands 1-5 and 7-10 for the 1953-1958 subperiod ($P < 0.05$).

Comparisons between each pair of consecutive time periods for each island group revealed significant differences in mean success rates between all subperiods prior to 1970 for Islands 1-10 and 11-17 ($P < 0.05$ for all comparisons). Differences in

Table 5. Mean success of Canada goose nests on various island groups during each subperiod; 1953-1958, 1960-1965, 1966-1970 and 1971-1980.

Island(s)		1953-1958	1960-1965	1966-1970	1971-1980	Mean: 1953-1980
1-10	%	63	79	68	73	70
	(N)	(1091)	(822)	(540)	(449)	(2902)
1-5, 7-10	%	58	78	67	69	67
	(N)	(463)	(349)	(336)	(475)	(1623)
6	%	66	79	70	50	71
	(N)	(628)	(473)	(204)	(22)	(1327)
11-17	%	72	88	80	76	77
	(N)	(344)	(223)	(291)	(567)	(1425)
18-20	%	77	73	81	86	82
	(N)	(136)	(55)	(42)	(238)	(471)
1-20	%	66	80	72	77	73
	(N)	(1571)	(1100)	(873)	(1254)	(4798)
1-5, 7-20	%	66	81	73	78	73
	(N)	(943)	(627)	(490)	(1232)	(3525)
Favored	%	75	86	80	78	79
	(N)	(681)	(492)	(545)	(1194)	(2912)

mean success rates indicate that factors which affect goose nesting success vary in form, magnitude, and time. For example, consistent performance of geese nesting on Island 6 during 1953-1970 contrasted with the continuous record of coyotes and the low numbers of nests with low success during the past decade, supporting the predator recognition and avoidance response suggested by Hanson and Eberhardt (1971:26-27).

Differences in goose nesting success between Islands 1-10, 11-17 and 18-20 are attributed primarily to differences in predation and desertion rates. The proximity of human activities correlates well with island group success rates; geese nesting on Islands 1-10 were least successful and the most isolated, while Islands 18-20 are entirely surrounded by farmlands (east riverbank) and suburbia (west riverbank) and geese nesting there were most successful.

Hanson and Eberhardt (1971:26) reported 94% of all nests destroyed by predators on the study area occurred on Islands 1-14; the years 1955, 1957,1958 and 1970 were years of high nest predation; and that nest success was greatest during 1961-1964. Results of my analyses support these observations.

Success rates were not different between 1966-1970 and 1971-1980 for all island groups.

Geese nesting on the favored islands had consistently greater success than that for the study area during each subperiod. The temporal pattern of success rates on favored islands was similar to that on Islands 11-17, while the study area pattern emulated success on Islands 1-10. The relative proportion of nests from these island groups within these island totals affects this result, because Islands 1-10 contribute most to the study area total and Islands 11-17 contribute most to the favored island total.

Success rates between 1953-1958 and 1960-1965 were apparently unaffected by river flow controls being imposed at Priest Rapids Dam. Flooding of nests was notable only in 1956 when an early spring runoff flooded 12% of the goose nests (Hanson and Eberhardt 1971:20). Differences in other nest losses, primarily by predation, caused the observed differences in success rates.

The 1966-1970 subperiod was characterized by lowered success rates on Islands 1-10 and 11-17 but increased success on Islands 18-20. Whether the change in success between 1960-1965 and 1966-1970 represents an effect of hunting on natal grounds (i.e., Islands 12-18) is questionable because success rates on Islands 1-10 and 11-17 were lower during 1953-1958 than during 1965-1970 when hunting was first allowed. This is possibly due to the very high nesting populations observed during 1953-1958. Desertion of nests increased significantly between 1960-1965 and 1966-1970 from 10% to 15% of total nests ($X^2 = 8.905$, 1 df, $P < 0.005$) and predation rates also increased significantly from 8% to 12% ($X^2 = 9.674$, 1 df, $P < 0.005$). This indicates that desertion and predation of goose nests are related (Hanson and Eberhardt 1971:26, 47) but does not substantiate any affect of hunting on natal grounds.

Distinguishing whether a nest was destroyed or initially deserted and then destroyed is further complicated by the increased survey interval. The nest destruction rates for 1971-1980 reported here are probably biased, but the direction, magnitude and variability of this bias is unknown.

The proportion of nests deserted and destroyed on the study area decreased slightly during the past decade (Tables 6 and 7) compared to the 1953-1970 period (Hanson and Eberhardt 1971:21, 25). Nest success of 1254 nests of known fate was 74% during 1971-1980 and is slightly greater than 71% success observed during 1953-1970. Similarity of these nesting fates determined from weekly and beweekly nest surveys plus the survey method and personnel changes prevent any conclusions about this change in success rate.

Desertion of nests by geese accounted for 12% of 1308 nests during the past decade. The greatest number of deserted nests was observed in 1980 when 42 of 154 nests were deserted. Of the deserted nests, 55% were on Island 12, representing 81% of the 1980 nesting population on that island. Most of these nests were deserted over a period of 4 weeks coincident with an excellent spring run of steelhead trout (Salmo gairdneri) returning to spawn near the Washington Department of Game fish hatchery in which they had been reared. The hatchery lies adjacent to Island 12 and the riverbanks near the hatchery are fished heavily. No evidence could be found at any of the deserted nests on Island 12 which would have indicated a natural disturbance. Avian predators usually cause small nesting losses whereas mammalian disturbances usually devastate all nests on a given island over a short period of time (Hanson and Eberhardt 1971:26).

Rather, a repeated disturbance is indicated as new nests were initiated and some of these deserted prior to each of the first 3 nest surveys.

Island 12 had the highest nest desertion rate of all islands during 1971-1980. The 25% desertion rate is much higher than the 14% observed during 1953-1970. Deserted nests on Island 12 accounted for 39% of all deserted nests during 1971-1980.

During 1980, record numbers of nests and desertion of nests were observed on Islands 18 and 19 suggesting that a carrying capacity had been approached on these islands.

Nests classified as destroyed by predators accounted for 10% of total nests during 1971-1980. Islands 1, 2, 9 and 11 had the greatest incidence of predation. High predation of nests on Islands 1 and 2 are due to losses of all nests to coyotes on Island 1 in 1974 and on both islands in 1977. Nest predation normally accounted for 4%, 1% and 6% of nests on Islands 1, 2 and the study area respectively.

Hanson and Eberhardt (1971:25) observed no nest predation by California and Ring-billed gulls even when geese nested within a nesting colony of these gulls on Island 12. After 1971, this and another colony moved to Islands 18 and 20 (Appendix Figures 14 and 16). Canada geese lost more nests on these islands prior to 1971 and increased their nesting there during the past decade. The gulls' disregard of goose nests and eggs was apparent in 1980. Within the colony on Island 18, 2 deserted nests containing 5 eggs each remained fully intact for over 3 weeks after the geese

Table 6. Fates of 1308 Canada goose nests on the Hanford Reservation study area islands during 1971-1980. There were no nests on Island 10 during this period.

Island No.	Total Nests	Successful %	Successful (#)	Deserted %	Deserted (#)	Destroyed %	Destroyed (#)	Flooded %	Flooded (#)	Incomplete %	Incomplete (%)
1	216	71	(153)	5	(10)	20	(43)	4	(1)	4	(9)
2	175	75	(131)	6	(11)	12	(22)	2	(3)	4	(8)
3	5	-		-		100	(5)	-		-	
4	1	-		-		-		-		100	(1)
5	5	100	(5)	-		-		-		-	
6	22	50	(11)	4	(1)	41	(9)	-		4	(1)
7	7	57	(4)	-		14	(1)	-		28	(2)
8	5	-		-		100	(5)	-		-	
9	39	64	(25)	8	(3)	15	(6)	-		13	(5)
11	75	48	(36)	19	(14)	32	(24)	-		1	(1)
12	225	67	(150)	26	(59)	4	(10)	-		3	(6)
13	15	93	(14)	-		-		-		7	(1)
14	5	80	(4)	-		-		-		20	(1)
15	44	84	(37)	11	(5)	2	(1)	2	(1)	-	
16	1	-		100	(1)	-		-		-	
17	219	86	(188)	10	(21)	1	(2)	-		4	(8)
18	76	78	(59)	9	(7)	-		4	(3)	9	(7)
19	124	85	(106)	10	(13)	2	(3)	-		2	(2)
20	49	82	(40)	14	(7)	-		-		4	(2)
Totals:	1308	74	(963)	12	(152)	10	(131)	1	(8)	4	(54)

Table 7. Fates of 1308 Canada goose nests on the Hanford Reservation study area each year, 1971-1980.

Year	Total Nests	Successful %	Successful (#)	Deserted %	Deserted (#)	Destroyed %	Destroyed (#)	Flooded %	Flooded (#)	Incomplete %	Incomplete (#)
1971	112	83	(93)	5	(6)	-		5	(6)	6	(7)
1972	160	82	(131)	6	(9)	9	(15)	-		3	(5)
1973	127	82	(104)	12	(15)	1	(1)	-		6	(7)
1974	146	53	(77)	15	(22)	27	(40)	1	(1)	4	(6)
1975	108	78	(84)	11	(12)	7	(8)	-		4	(4)
1976	111	78	(87)	11	(12)	6	(7)	-		4	(5)
1977	124	57	(71)	8	(10)	30	(37)	-		5	(6)
1978	135	77	(104)	5	(7)	13	(17)	-		5	(7)
1979	131	79	(104)	13	(17)	3	(4)	-		4	(6)
1980	154	70	(108)	27	(42)	1	(2)	1	(1)	4	(1)
Totals:	1308	74	(963)	12	(152)	10	(131)	1	(8)	4	(54)

had deserted them. Anderson (1965) also observed no gull predation of goose nests in a similar situation in California.

Mean nest success on all nonfavored islands averaged 58%. But, much variation existed between nonfavored island nesting fates. Apparently, the loss of continued nesting on some islands is due to factors other than increased accessability by predators and subsequent destruction of nests. Presence of a predator on islands prior to the nesting season may have discouraged or disrupted nesting attempts as observed by Hanson and Eberhardt (1971: 27).

Less than 1% of nests were flooded by rising river flows during 1971-1980.

Several aspects of aberrant nesting behavior were observed during 1979 and 1980. Two probable cases of dump nesting were observed in 1979. These nests were discovered on Islands 19 and 20 and contained 5 and 6 cold, down covered eggs, respectively. During the following survey interval, 5 additional eggs had been deposited in each nest but neither nest was incubated.

The single nest on Island 5 in 1980 (Figure 7) was successfully used by 2 nesting geese. These nests hatched all 7 and 3 of 4 eggs on 16 April and 21 May, respectively.

Similarly, on Island 12 a nest containing 6 incubated eggs was found on 3 April 1980. The nest was deserted prior to the 16 April survey but contained 9 eggs. On 29 April, a goose flushed from the nest which then contained 11 eggs. Four of the 11 eggs had hatched by the 14 May survey. Whether the same or different geese laid eggs in this nest is not known. Reoccupation of a nest site in the same season was previously observed at Hanford by Hanson and Eberhardt (1971:30).

Clutch Size

Maximum laid clutch size is a measure of potential production whereas the hatched clutch size of successful nests is a measure of actual production and more useful for management purposes since it reflects the number of goslings produced. In this study, hatched clutch data were not comparable between weekly (1953-1970) and biweekly (1971-1980) collected data (Figure 12). Mean differences between maximum laid and hatched clutch size of successful nests are 0.67 (S. E. = 0.004) and 0.38 (S. E. = 0.02) eggs for 1953-1970 and 1971-1980, respectively, and are significantly different ($t = 5.02$, 26 df, $P < 0.005$). To determine how this change occurred in the 1-9-egg clutches, recorded hatch success distributions of these clutches was compared between the 1953-1970 and 1971-1980 data (Figure 13). Significantly greater proportions of completely hatched 4-8-egg clutches and in completely hatched 3-8-egg clutches were recorded with beweekly surveys. These results can be explained, in part, by the increased nest survey interval. The chances that unhatched eggs will be scavenged during the interim between surveys are logically greater with biweekly than weekly surveys.

Differences in hatching success of 1-9-egg clutches between 1953-1970 and 1971-1980 suggest a 7% overestimation of production per nest in the latter period because of disappearance of stolen, broken or destroyed eggs during the longer survey interval.

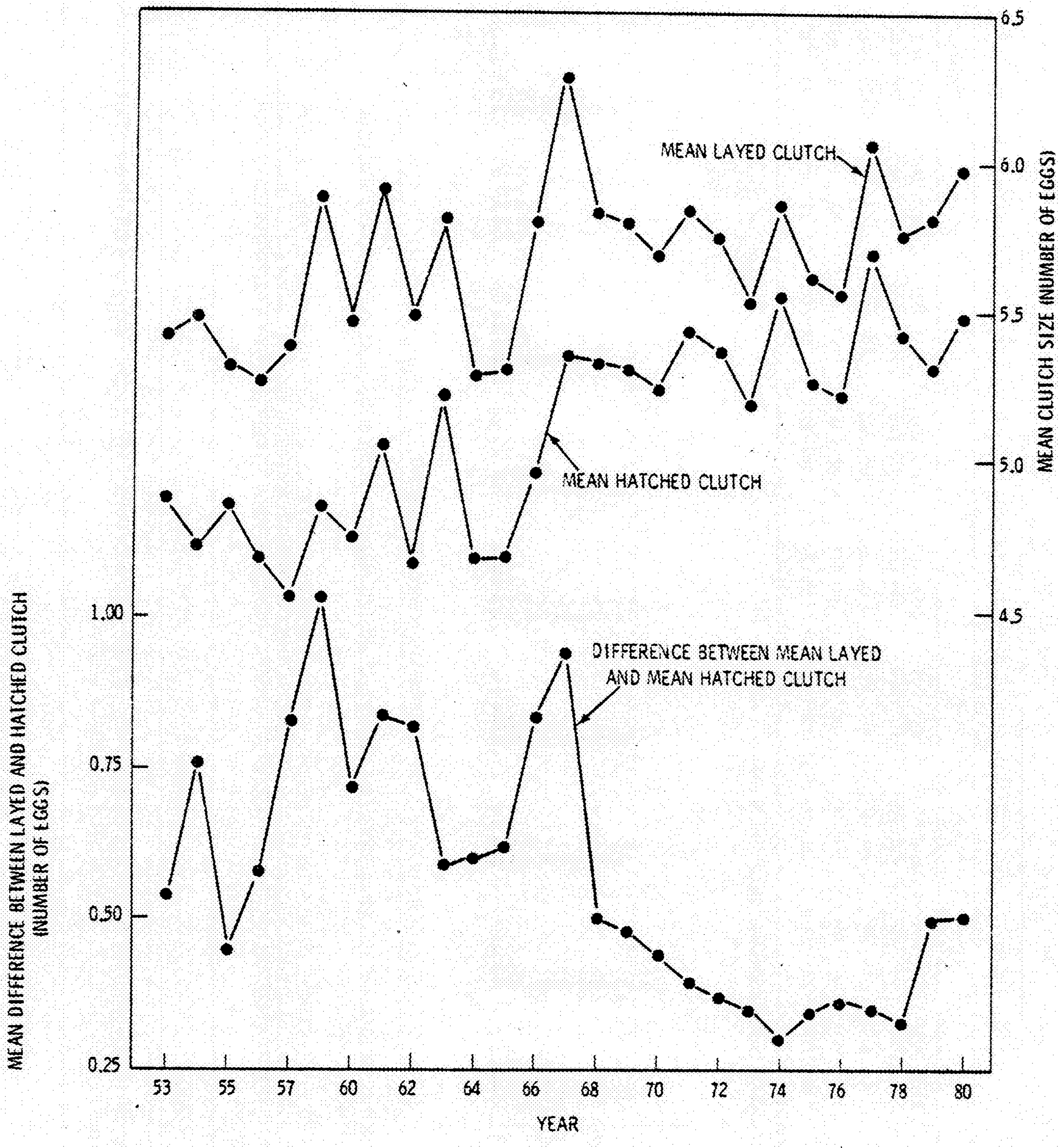
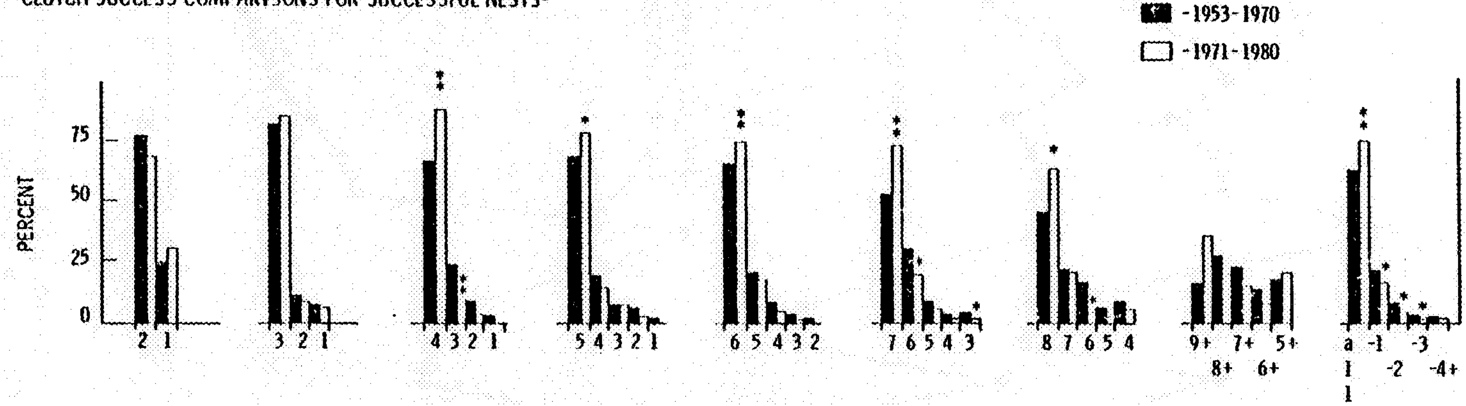


Figure 12. Maximum layed and hatched clutch size and the difference between these parameters each year during 1953-1980.

	CLUTCH SIZE 1		2		3		4		5		6		7		8		9		TOTALS	
	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980	1953-1970	1971-1980
TOTAL NESTS	53	12	97	42	197	60	466	129	1035	317	1118	396	486	228	114	67	60	22	3626	1273
SUCCESSFUL NESTS	1	2	29	20	96	32	305	87	703	237	890	319	392	188	90	62	47	14	2553	961
PERCENT SUCCESS[a]	2	**17	30	**48	49	53	65	67	68	**75	80	81	81	82	79	**92	78	64	70	**76

CLUTCH SUCCESS COMPARISONS FOR SUCCESSFUL NESTS[b]



[a] PROBABILITIES ARE FROM X^2 TESTS OF INDEPENDENCE BETWEEN SUCCESS AND TIME PERIODS WITH ONE DEGREE OF FREEDOM EACH AND 9 DEGREES OF FREEDOM FOR THE TOTAL

[b] CLUTCHES OF 2-9+ EGGS ANALYZED ONLY. THE PROPORTIONAL DISTRIBUTION OF SUCCESS CLASSES; i.e., ALL EGGS HATCHED, ALL MINUS ONE, ETC., WAS COMPARED BETWEEN 1953-1970 AND 1971-1980. DEGREES OF FREEDOM ASSOCIATED WITH EACH CLUTCH SIZE IS THE NUMBER OF SUCCESS CLASSES THE TOTAL HAS 34 DEGREES OF FREEDOM. FOR 6-9+ EGG CLUTCHES, NESTS IN WHICH 4 OR MORE EGGS DID NOT HATCH WERE COMBINED DUE TO SMALL SAMPLE SIZE.

* P <0.05

** P <0.005

Figure 13. Hatch success and clutch success distributions of 1-9+ egg clutches for each period, 1953-1970 and 1971-1980.

MacInnes and Misra (1972:420) noted increased partial losses of clutches due to predation when human activities increased (i.e., nesting surveys), just opposite the situation at Hanford. As human activity decreased, partial losses of clutches increased. This is possibly due to the different set of possible nest and egg predators in the McConnel River, Northwest Territories study area of the above mentioned authors.

Maximum laid clutch size data are assumed to be comparable between weekly and biweekly survey periods. The data analyzed appear in Appendix II and mean clutch sizes are presented in Table 8. Significant differences in clutch size distributions between island groups were consistent for all subperiods, even when Island 6 clutch size data were eliminated.

In all comparisons between clutch size distributions, the differences in distributions are related primarily to differences in the relative proportions of 4-7-egg clutches. Mean clutch size was lowest on Islands 1-10, which had the greatest proportions of 2-5-egg clutches. Nests on Islands 18-20 had the greatest mean clutch size and proportion of 7-egg clutches. Munro (1960-545) attributed differences in clutch size distributions between 2 more widely separated populations of island nesting geese to genetic factors. The large differences in mean clutch size and distributions between Islands 1-10 and Islands 11-17 and 18-20 suggest this possibility. For this to come about, the 14 km gap between Islands 10 and 11 must serve as an effective barrier to interchange between the 2 subpopulations. Many observations of homing female Canada geese to former nesting sites and/or

Table 8. Mean clutch size of Canada goose nests on various island groups during each subperiod; 1953-1958, 1960-1965, 1966-1970 and 1971-1980. Clutch size distributions appear in Appendix II.

Island(s)		SUBPERIOD 1953-1958	1960-1965	1966-1970	1971-1980	Mean
1-10	$\bar{x}$	5.0	5.3	5.3	5.0	5.2
	(n)	(1086)	(886)	(543)	(455)	(2970)
1-5, 7-10	$\bar{x}$	5.2	5.3	5.4	5.0	5.2
	(n)	(457)	(375)	(337)	(434)	(1603)
6	$\bar{x}$	4.8	5.3	5.3	5.4	5.1
	(n)	(629)	(511)	(206)	(21)	(1367)
11-17	$\bar{x}$	5.8	5.6	5.9	5.8	5.8
	(n)	(338)	(244)	(291)	(570)	(1443)
18-20	$\bar{x}$	6.0	5.8	6.0	6.0	6.0
	(n)	(138)	(58)	(42)	(248)	(486)
1-20	$\bar{x}$	5.2	5.4	5.5	5.6	5.4
	(n)	(1562)	(1188)	(876)	(1273)	(4899)
1-5, 7-20	$\bar{x}$	5.6	5.5	5.6	5.6	5.5
	(n)	(933)	(677)	(670)	(1252)	(3532)
Favored	$\bar{x}$	5.7	5.6	5.7	5.6	5.6
	(n)	(683)	(528)	(540)	(1209)	(2966)

natal grounds have been reported (Hanson and Browning 1959, Martin 1964, Hanson 1965, Brakhage 1965, Sherwood 1965 and 1968, Surrendi 1970, Hanson and Eberhardt 1971 and Raveling and Lumsden 1977). Initiation of a banding and individual brood marking program carried out over several generations of geese at Hanford could provide interesting and valuable information about subpopulational divisions of breeding goose populations due to imprinting of natal grounds on goslings.

Clutch size distributions for each island group were compared between the 1953-1958 and 1960-1965 periods (prior to any hunting on the study area), 1966-1970 and 1971-1980 periods (after hunting was allowed on the study area) and 1953-1966 and 1966-1980 periods. Clutch size distributions were not different in any subperiod comparisons for Islands 11-17 and 18-20. Clutch size distributions on Islands 1-10 differed significantly in all comparisons ($P < 0.005$) but no significant differences were found after Island 6 clutch size data were eliminated. Similar results were obtained in study area comparisons. Clutch size distributions were different on Island 6 due to consistently high 4- and 5-egg and low 7-egg clutch proportions. Mean clutch size of Island 6 nests was consistently lower than on Islands 1-5 and 7-10 during 1953-1970 and the study area during 1953-1980.

The difference in clutch size mean and distribution between Island 6 and Islands 1-5 and 7-10 and lack of similar differences in success rates suggests a response by the geese nesting on Island 6 to crowding, even though mean nest density on that island was only 0.7 nests/ha/year (Hanson and Eberhardt 1971:18). Effective nest density (Munro 1960) was most likely much greater. Smaller clutch size and greater nest success prevailed during 1953-1958 on Island 6 when maximum numbers of geese nested there. That nest success and clutch size increased during the following 2 subperiods, 1960-1965 and 1966-1970, provides further evidence for this response to crowding. This occurred at nesting densities much lower than that reported to cause lowered nest success in other Canada goose populations (Naylor 1953, Collias and Jahn 1959, Munro 1960:548, Wiegand et al. 1968: 902 and Ewaschuk and Boag 1972:1105). To my knowledge, there are no reported studies dealing with the affects of nest densities on the clutch size of Canada geese.

On the favored islands, clutch size distributions were significantly different between the 1953-1958 and 1960-1965 periods only ($P < 0.005$). This does not appear to relate to numbers of nesting geese or success. Other than Island 6, there has been few changes in clutch size distributions over time and changes observed do not show consistent patterns.

Results of these analyses compared with previous analyses of the nesting population and nest fates, indicate that the variability in these parameters is not closely linked. In addition, there does not appear to be any relationship between the variability of these parameters and the relative degree of production nuclear reactor activity within the study area.

CHAPTER 5

SUMMARY

Nesting studies of western Canada geese nesting on Columbia River islands within the Hanford Reservation during 1953-1980 were analyzed to determine effects of certain events and changes in the study area upon goose reproductive performance. Cover type use in relation to availability during 1953-1970 and 1971-1980 periods were contrasted. Number and distribution of nests in the study area, nest success and clutch size were analyzed with respect to the influence of Priest Rapids Dam, which began hydroelectric service in 1959, hunting on certain study area islands since 1965 and changed nest survey method and personnel after 1970.

Dramatically altered spring river flow patterns that now typify the Hanford Reach of the Columbia River caused significant changes in the composition and distribution of island vegetation. Successional vegetative stages have invaded habitats formerly scoured by spring floodwaters.

Changed availabilities of cover over the past decade effected shifts in nesting use and preferences by nesting geese for certain cover types. Vegetative changes have not effected individual island populations indicating the adaptive nature of the _moffitti_ race. Observed preferences of nesting geese for certain cover types indicated that physical characteristics of the vegetation were important for screening purposes.

Decreasing numbers of nests at Hanford were observed immediately after Priest Rapids Dam initiated service and induced river flow changes. Abandonment of certain islands that are separated from the mainland by narrow channels and observations of coyotes or coyote sign during nest surveys coincided with dramatically altered river flows. This strongly indicates a direct effect of the dam on island security from predators.

Nest success and clutch size fluctuated independently during the study period. Biweekly survey data was not considered sufficiently comparable with weekly survey data to merit conclusions about nesting success between these periods. Significant overestimations of the mean number of goslings produced per nest resulted from the change to biweekly surveys.

Success rates and clutch size were dependent upon study area location, both being lowest on islands where numbers of nests decreased markedly. These islands are most isolated from human activities. A density-dependent physiological effect on clutch size was indicated on one island. Existence of 2 subpopulations of geese nesting at Hanford is indicated by a significant difference in clutch size between 2 sections of the study area.

LITERATURE CITED

Anderson, W. 1965. Waterfowl production in the vicinity of gull colonies. Calif. Fish Game 51(1):5-15.

Bowhay, E. L., I. J. Ball and C. F. Tocum. 1981. Ecology and management of the western Canada goose in Washington. Wash. Dept. Game Publ., in press.

Brakhage, G. K. 1965. Biology and behavior of tub-nesting Canada geese. J. Wildl. Manage. 29(4):751-771.

Buss, I. O. and L. D. Wing. 1966. Pre-impoundment observations of wintering mallards and nesting Canada geese in the Snake River, southeast Washington. Res. Stud. Wash. St. Univ. 34(1):51-64.

Collias, N. E. and L. R. Jahn. 1959. Social behavior and breeding success in Canada geese (_Branta canadensis_) confined under semi-natural conditions. Auk 76(4):478-509.

Cooper, J. A. 1978. The history and breeding biology of the Canada geese of Marshy Point, Manitoba. Wildl. Monogr. 61:1-87.

Craighead, F. C. and J. J. Craighead. 1949. Nesting Canada geese on the upper Snake River. J. Wildl. Manage. 13(1): 51-64.

Daubenmire, R. 1970. Steppe vegetation of Washington. Wash. Agric. Exp. Stat. Tech. Bull. 62. 131pp.

Ewaschuk, W. and D. A. Boag. 1972. Factors affecting hatching success of densely nesting Canada geese. J. Wildl. Manage. 36(4):1097-1106.

Geis, M. B. 1956. Productivity of Canada geese in the Flathead Valley. J. Wildl. Manage. 20(4):409-419.

Grieb, J. R., M. G. Sheldon and D. J. Neff. 1961. The nesting Canada geese of Moffat County, Colorado. Proc. Ann. Conf. West. Assoc. Game. Fish Comm. 41:136-146.

Hammond, M. C. and G. E. Mann. 1956. Waterfowl nesting islands. J. Wildl. Manage. 20(4):345-352.

Hanson, H. C. 1965. The giant Canada goose. S. Ill. Univ. Press, Carbondale, Ill. 226 pp.

Hanson, W. C. and R. L. Browning. 1959. Nesting studies of Canada geese on the Hanford Reservation, 1953-1956. J. Wildl. Manage. 23(2):129-137.

_________ and L. L. Eberhardt. 1971. A Columbia River Canada goose population, 1950-1970. Wildl. Monogr. 28:1-61.

MacInnes, C. D. and R. K. Misra. 1972. Predation on Canada goose nests at the McConnel River, Northwest Territories. J. Wildl. Manage. 36(2):414-422.

Martin, F. W. 1964. Behavior and survival of Canada geese in Utah. Utah Dept. Fish Game; Infor. Bull. Nos. 64-67. 89 pp.

McCabe, T. R. 1979. Productivity and nesting habitat of Great Basin Canada geese, Umatilla, Washington. Pp. 117-129. In Jarvis, R. L. and J. C. Bartonek (Eds.). Management and biology of Pacific flyway geese. Ore. St. Univ. Book Stores, Corvallis, Ore.

Miller, A. W. and B. D. Collins. 1953. A nesting study of Canada geese on the Tule Lake and Lower Klamath National Wildlife Refuges, Siskiyou County, California. Calif. Fish Game 39(3):385-396.

Munro, D. A. 1960. Factors affecting the reproduction of Canada geese (Branta canadensis). Pp. 542-556. In Proc. XII Intern. Ornithol. Congr. Helsinki, 1958.

Naylor, A. E. 1953. Production of Canada geese at Honeylake Refuge, Lassen County, California. Calif. Fish Game 39(1): 83-94.

_________ and E. G. Hunt. 1954. A nesting study and population survey of Canada geese on the Susan River, Lassen County, California. Calif. Fish Game 40(1):5-16.

Raveling, D. G. and H. G. Lumsden. 1977. Nesting ecology of Canada geese in the Hudson Bay lowlands of Ontario: evolution and population regulation. Ont. Minis. of Nat. Res. Rep. No 98:1-77.

Rickard, W. H. and H. A. Sweany. 1975. Radionuclides in Canada goose eggs. Pp. 623-627. In Drucker, H. and R. E. Wildung (Chmn.). Biological implications of metals in the environment. Proc. 15th Ann. Life Sci. Symp., Richland, Wash.

Sherwood, G. A. 1965. Canada geese of the Seney National Wildlife Refuge. Completion report for Wildl. Manage. Stud. Nos. 1 and 2. Seney National Wildlife Refuge. U. S. Bur. Sport Fish and Wildl., Div. Wildlife Refuges. Minneapolis, Minn. 222 pp.

_________. 1968. Factors limiting production and expansion of local populations of Canada geese. Pp. 73-85. In Hine, R. L. and C. Schoenfeld (Eds.). Canada goose management. Dembar, Madison, Wis.

Steele, R. D. G. and J. H. Torrie. 1960. Principles and procedures of statistics: with special reference to the biological sciences. McGraw-Hill Book Co., New York. 481 pp.

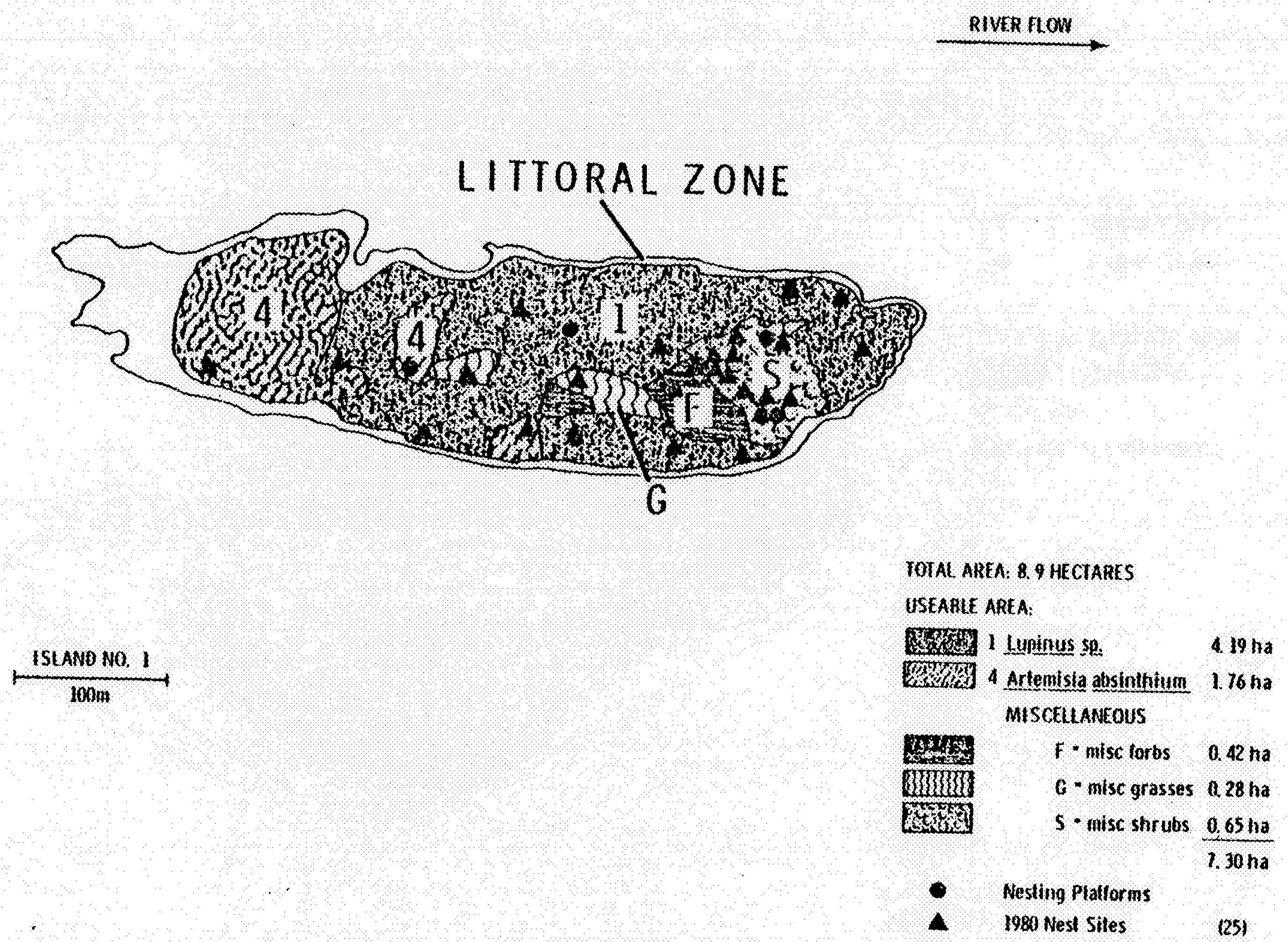
Surrendi, D. C. 1970. The mortality, behavior and homing of transplanted juvenile Canada geese. J. Wildl. Manage. 34(4):719-733.

Vermeer, K. 1970. A study of Canada geese, Branta canadensis, nesting on islands in southeastern Alberta. Can. J. Zool. 48(2):235-246.

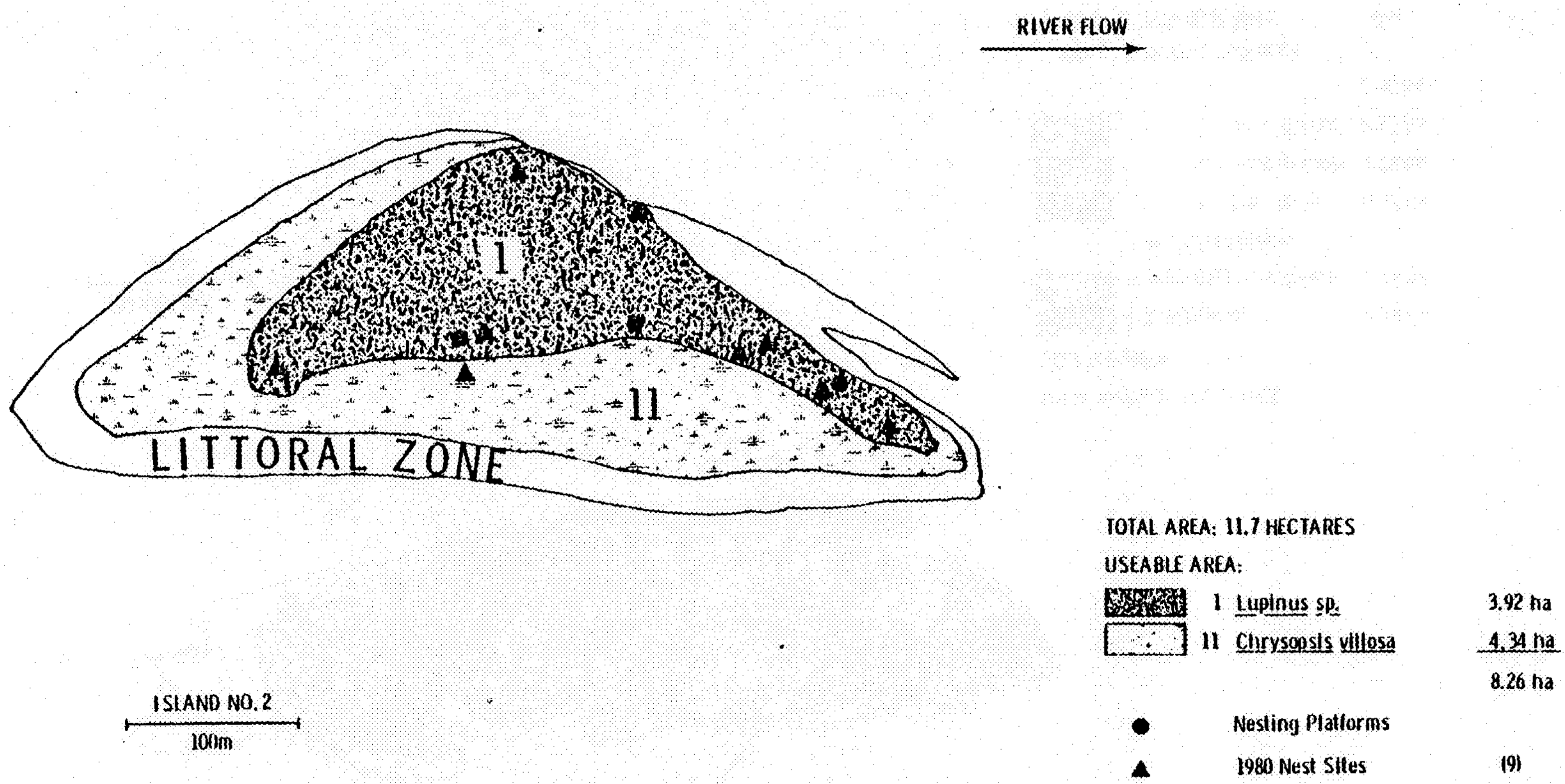
Wiegand, J. P, M. J. Pollock and G. E. Petrides. 1968. Some aspects of reproduction of captive Canada geese. J. Wildl. Manage. 32(4):894-905.

APPENDIX I

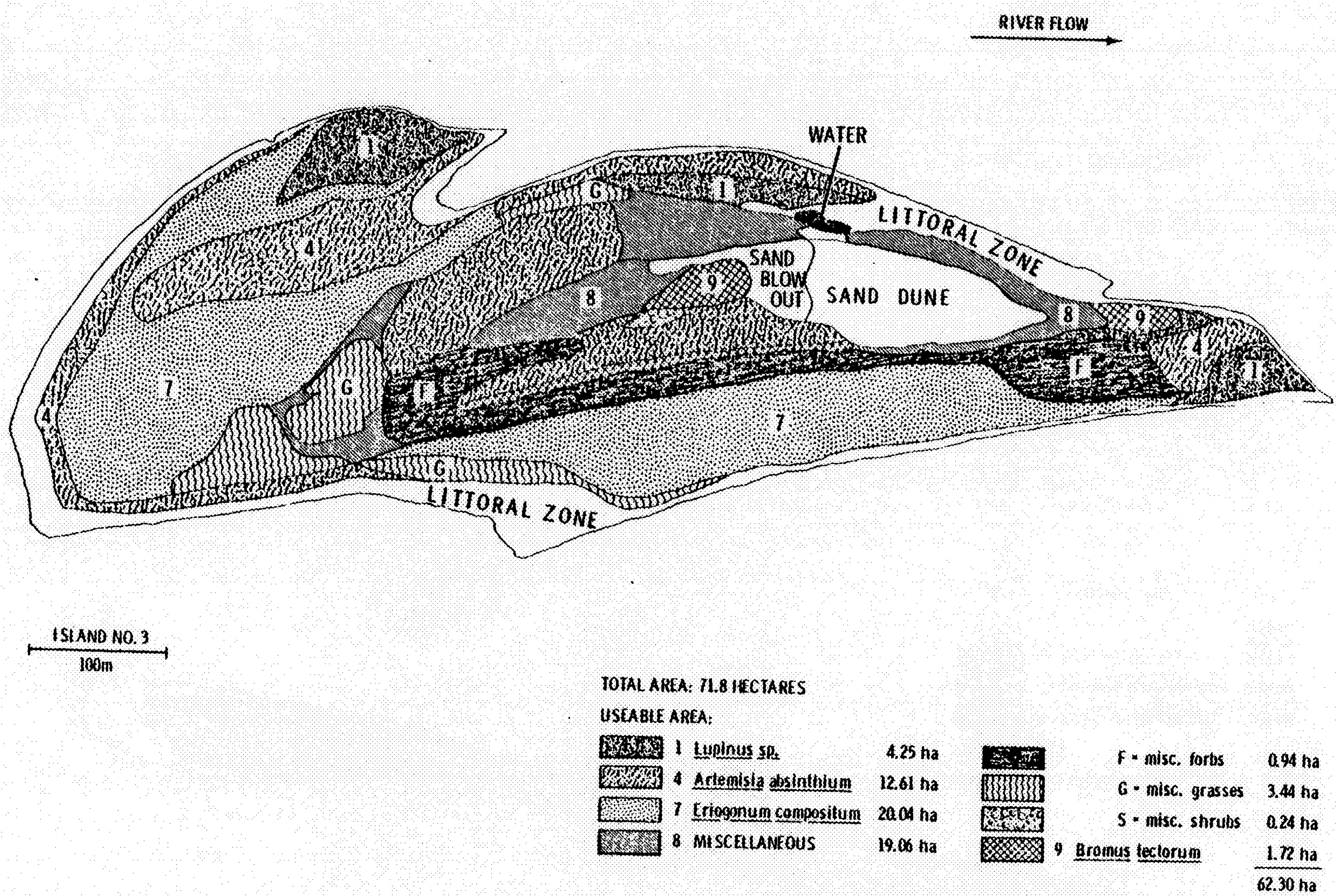
COMPOSITION AND DISTRIBUTION OF VEGETATIVE COVER AND LOCATION OF CANADA GOOSE NESTS ON COLUMBIA RIVER ISLANDS WITHIN THE HANFORD RESERVATION, 1980



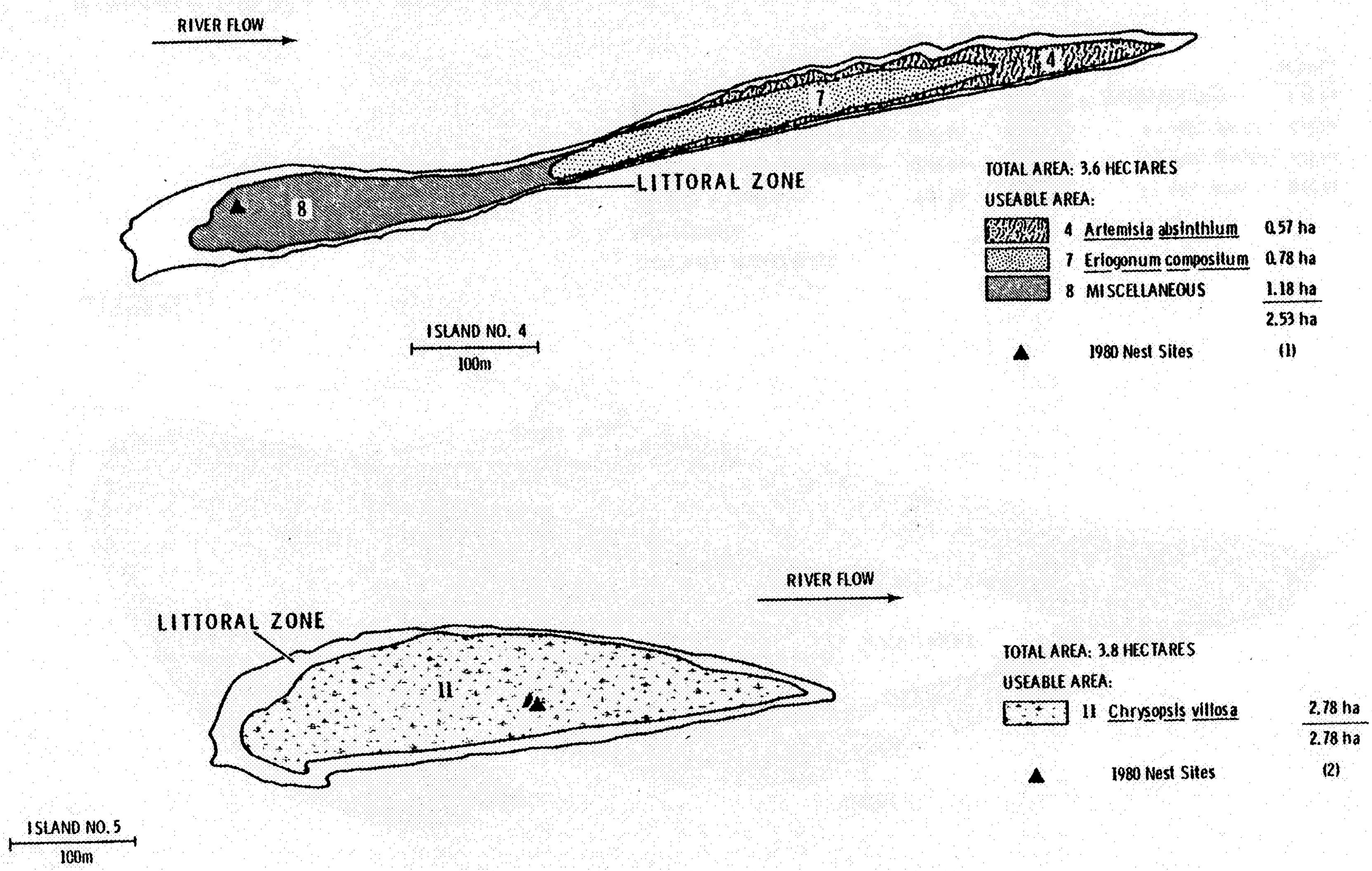
Appendix Figure 1. Distribution and composition of vegetative cover and location of Canada goose nests on Island 1, 1980.



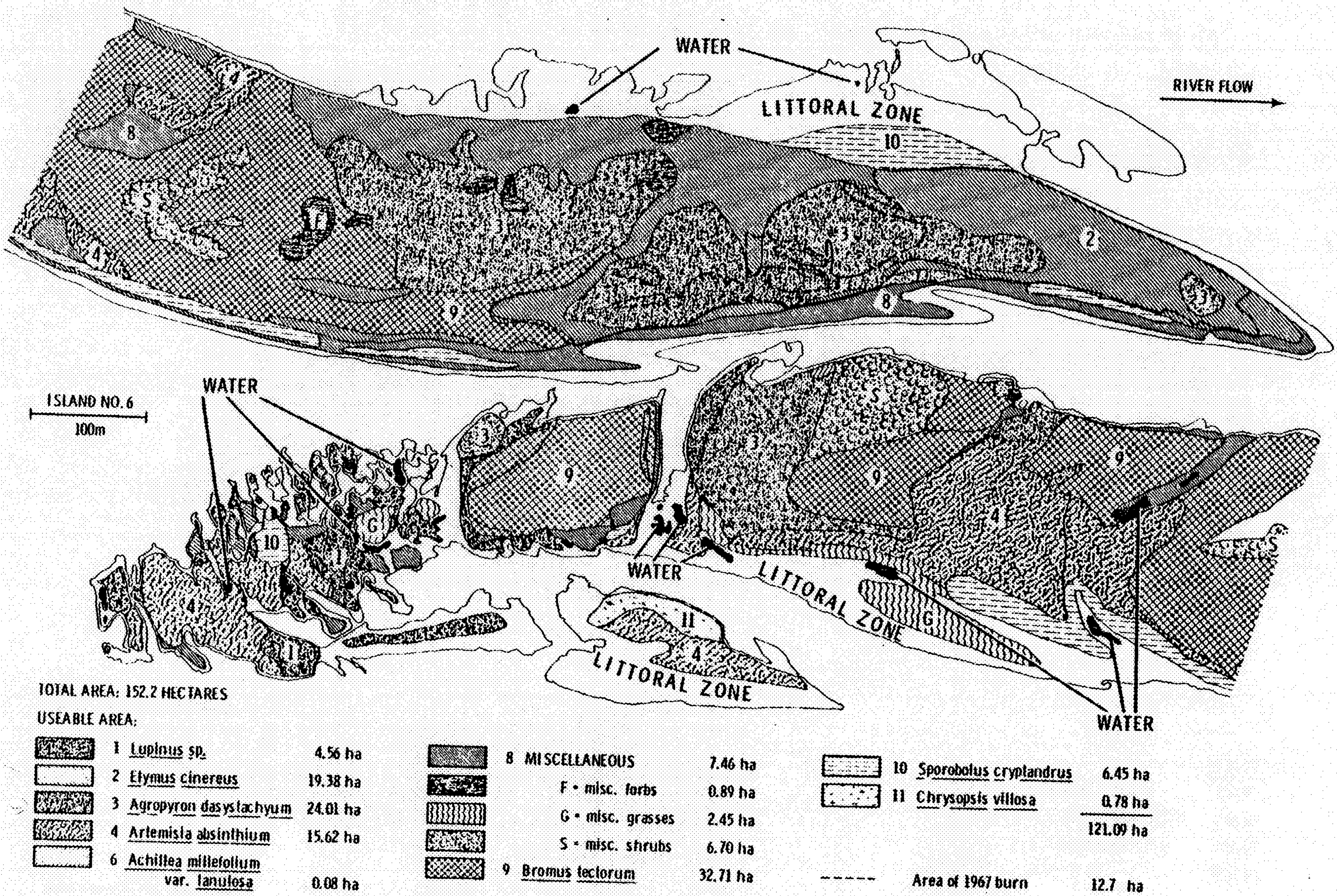
Appendix Figure 2. Distribution and composition of vegetative cover and location of Canada goose nests on Island 2, 1980.



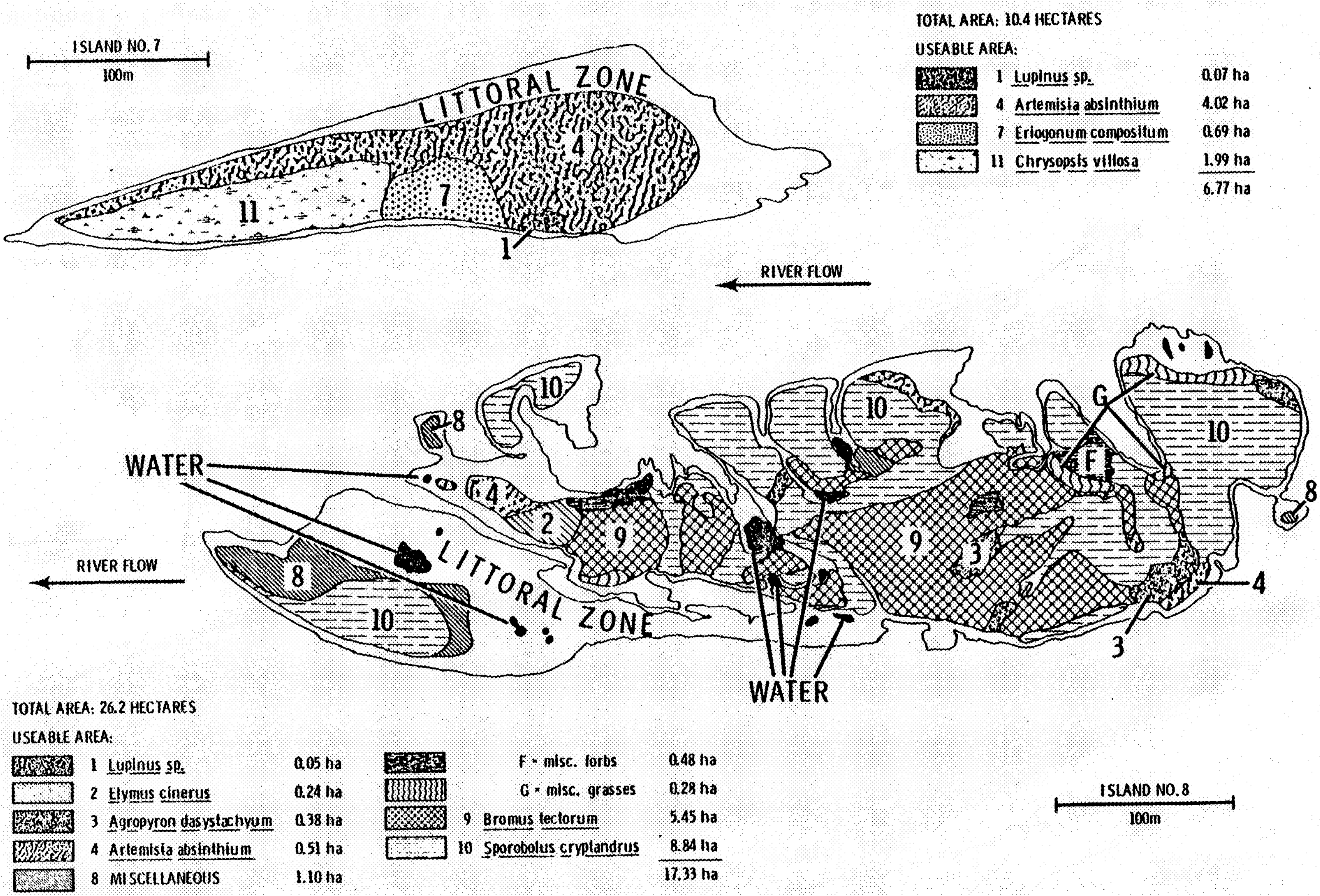
Appendix Figure 3. Distribution and composition of vegetative cover on Island 3, 1980.



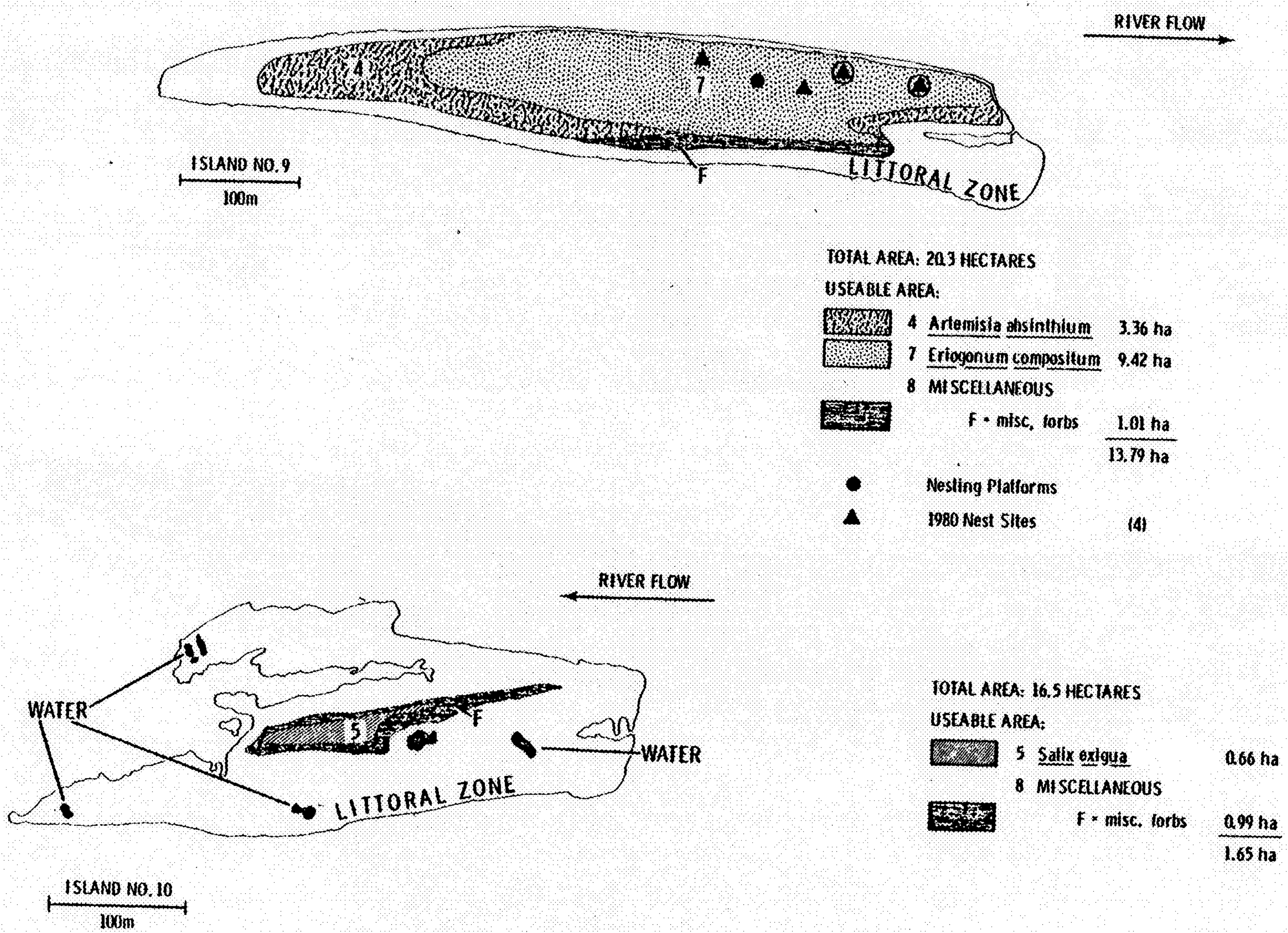
Appendix Figure 4. Distribution and Composition of vegetative cover and location of Canada goose nests on Islands 4 and 5, 1980.



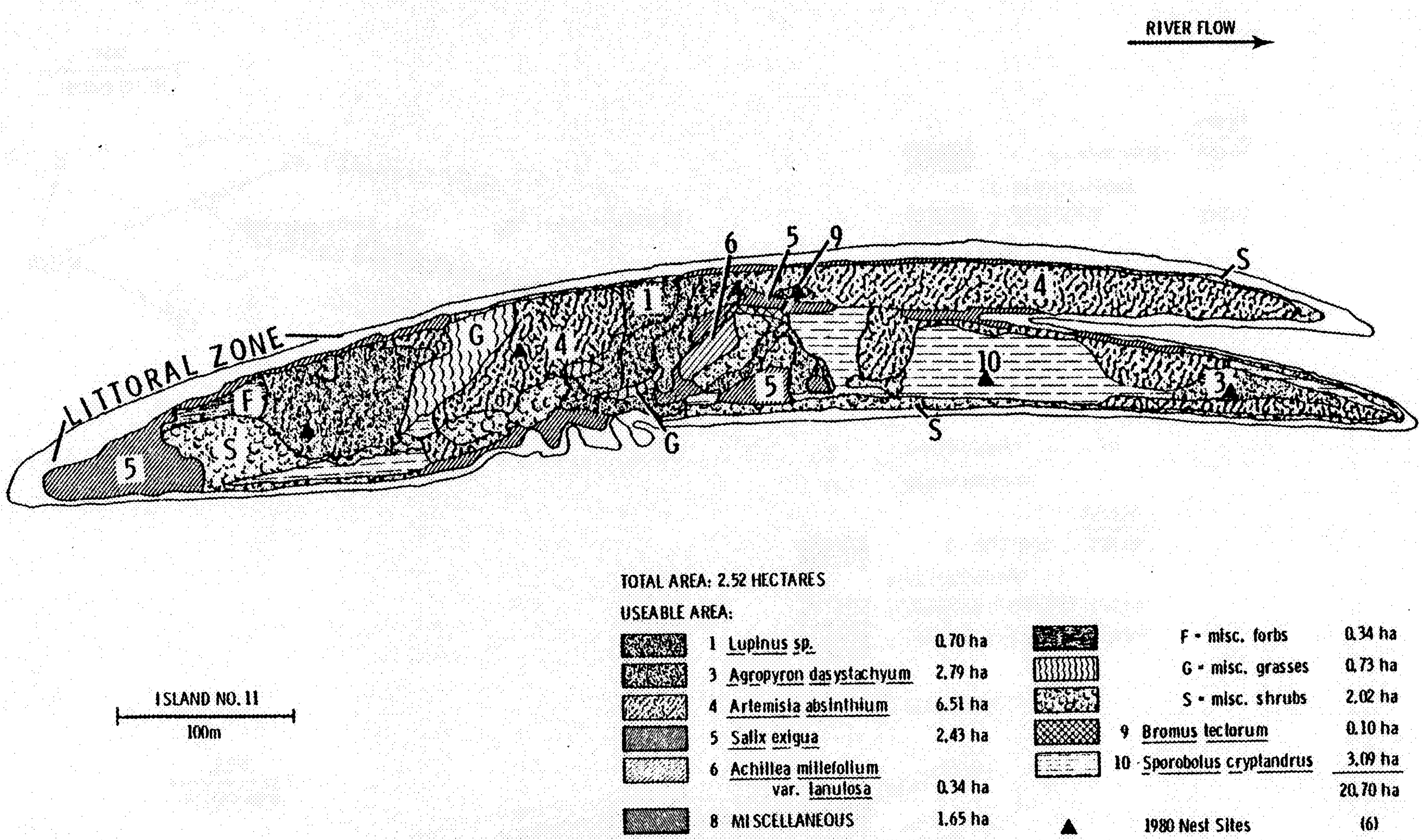
Appendix Figure 5. Distribution and composition of vegetative cover, 1980 and area burned in 1967 on Island 6.



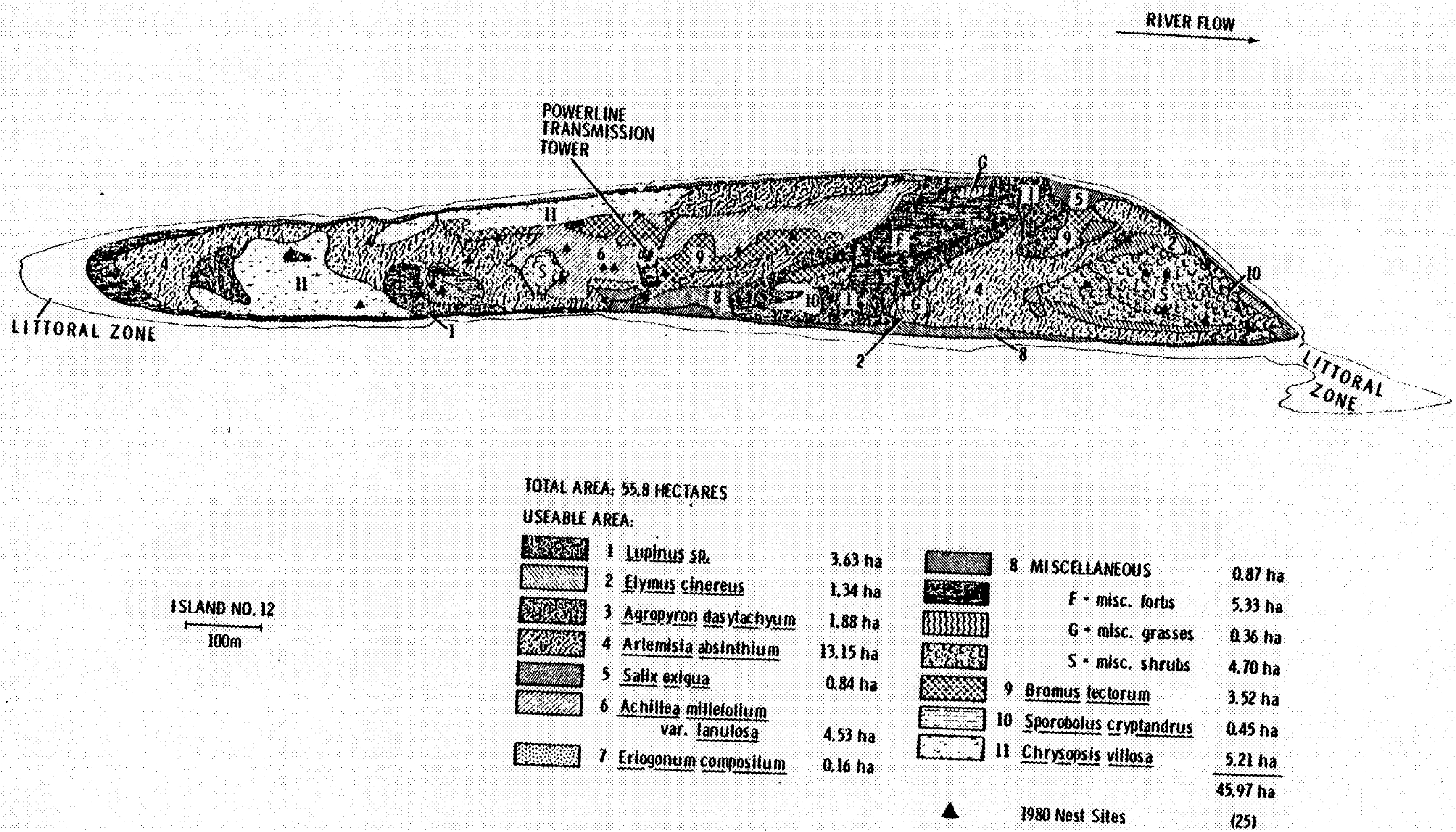
Appendix Figure 6. Distribution and composition of vegetative cover on Islands 7 and 8, 1980.



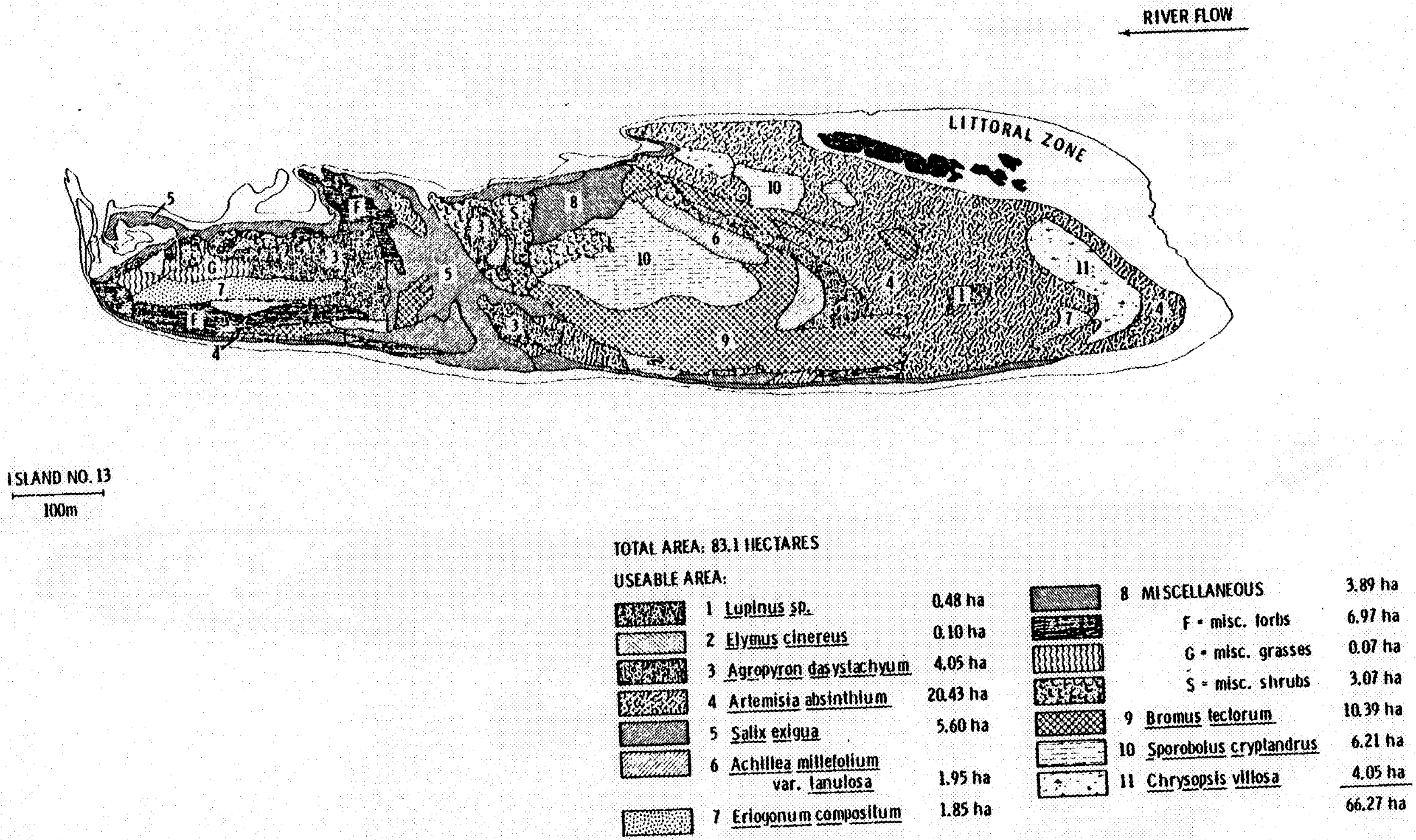
Appendix Figure 7. Distribution and composition of vegetative cover on Islands 9 and 10, and location of Canada goose nests on Island 9, 1980.



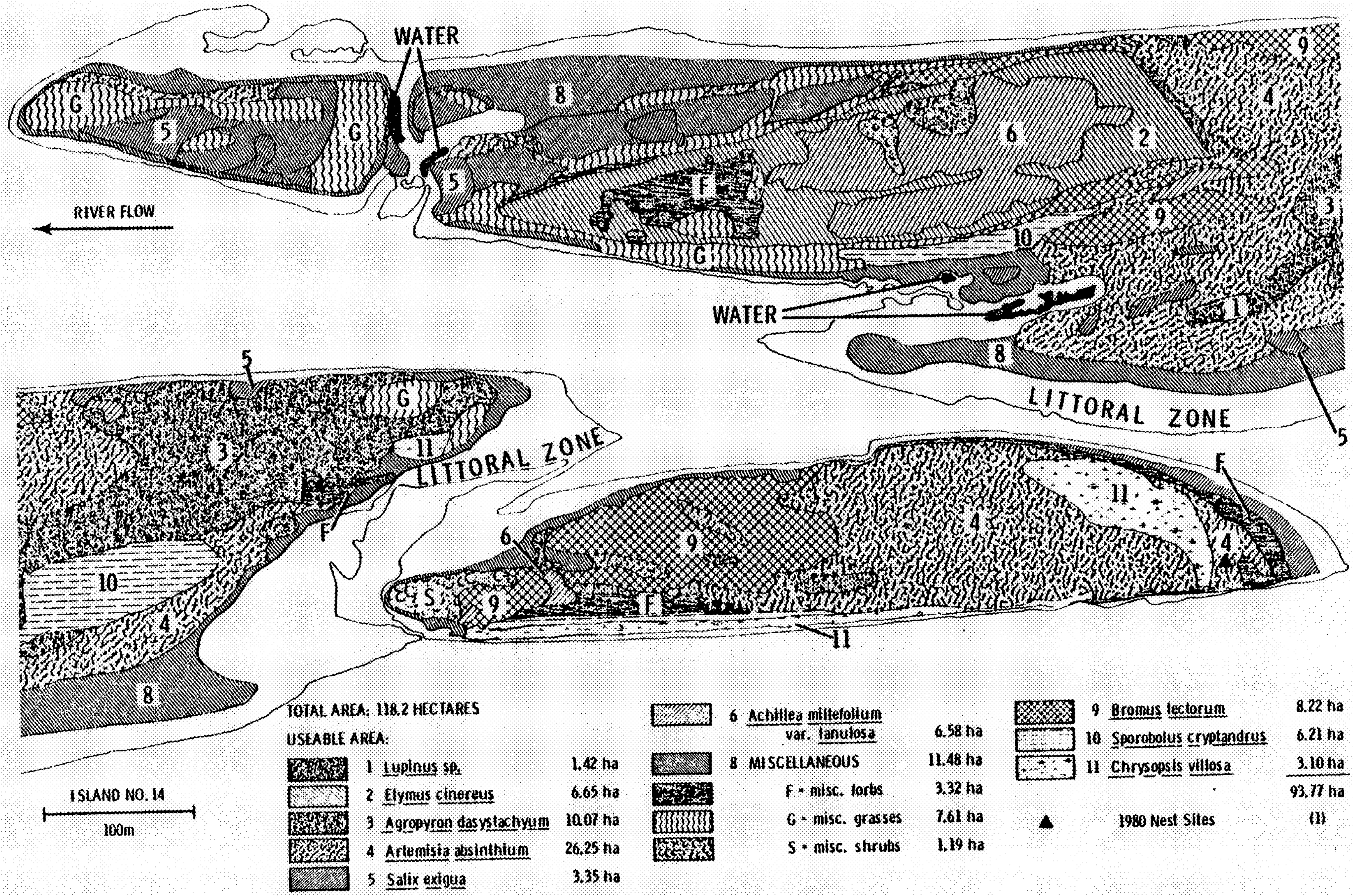
Appendix Figure 8. Distribution and composition of vegetative cover and location of Canada goose nests on Island 11, 1980.



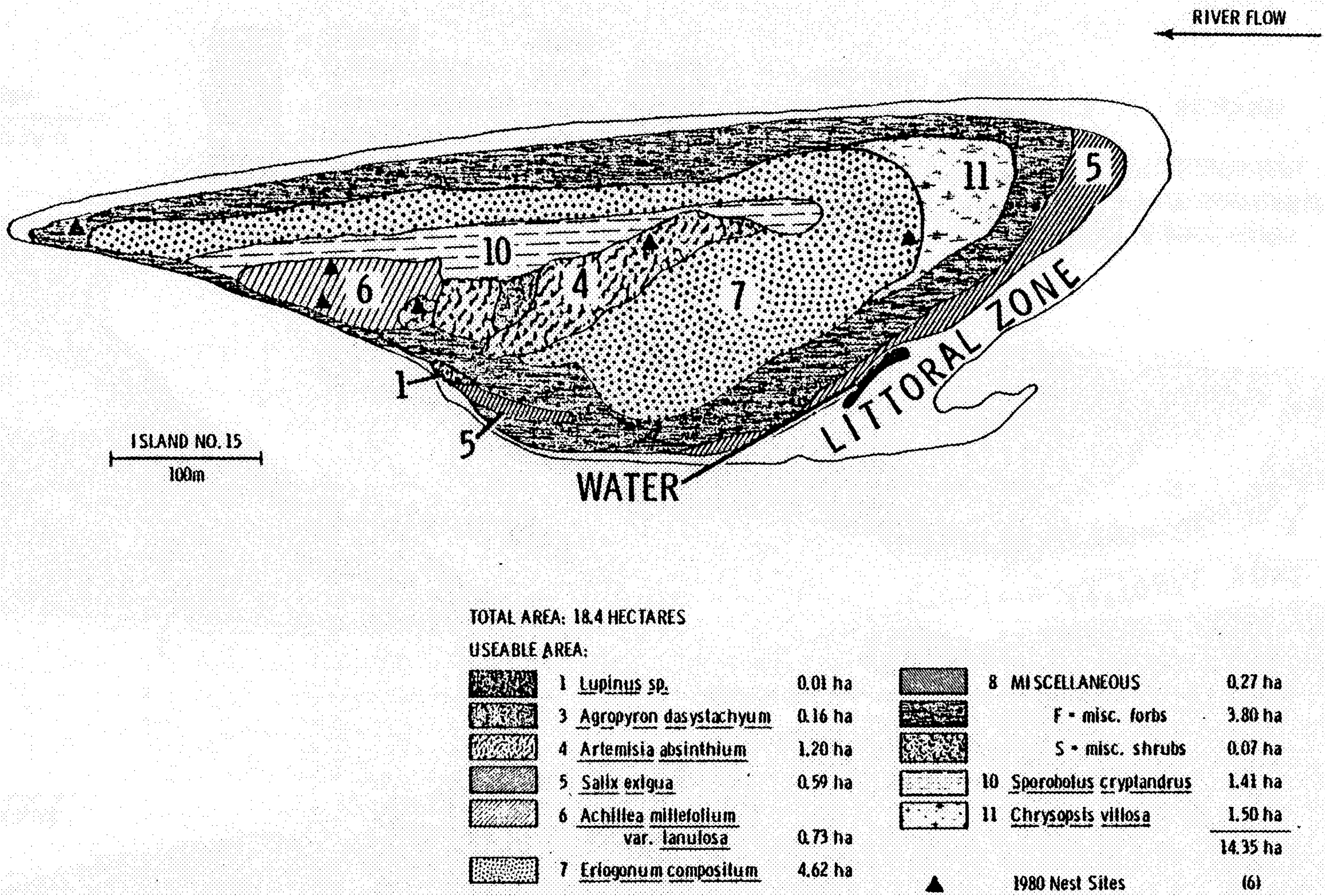
Appendix Figure 9. Distribution and composition of vegetative cover and location of Canada goose nests on Island 12, 1980.



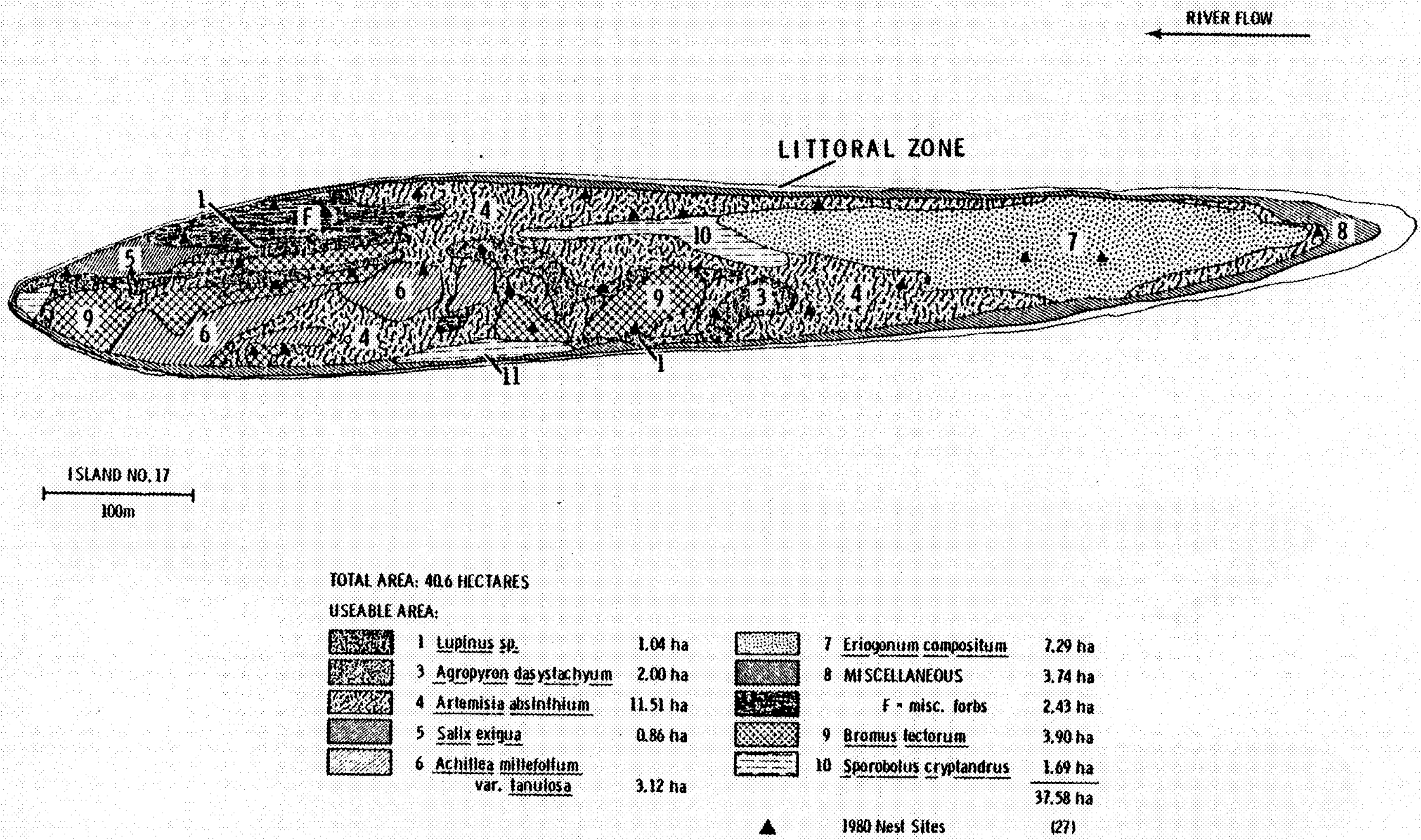
Appendix Figure 10. Distribution and composition of vegetative cover on Island 13, 1980.



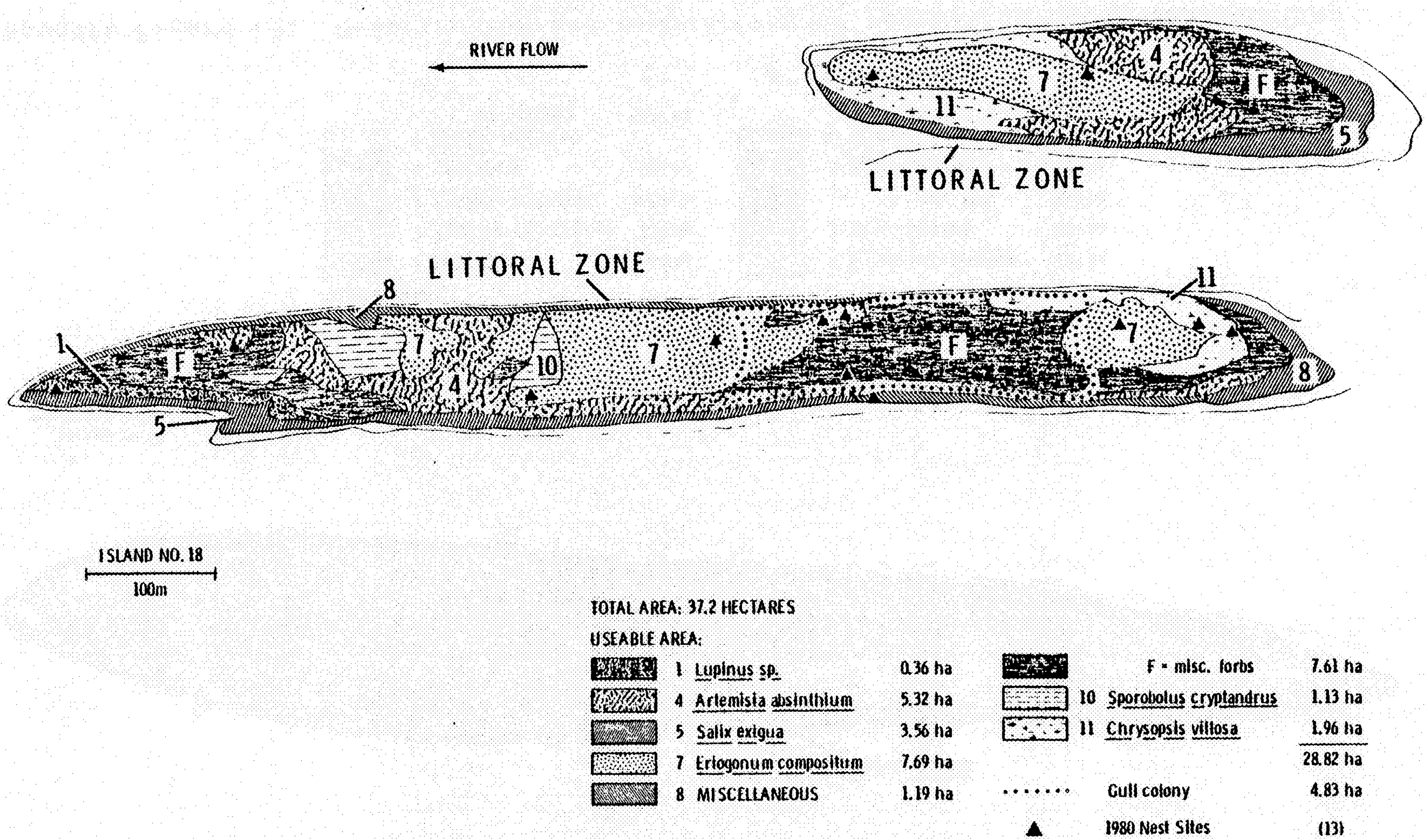
Appendix Figure 11. Distribution and composition of vegetative cover and location of a Canada goose nest on Island 14, 1980.



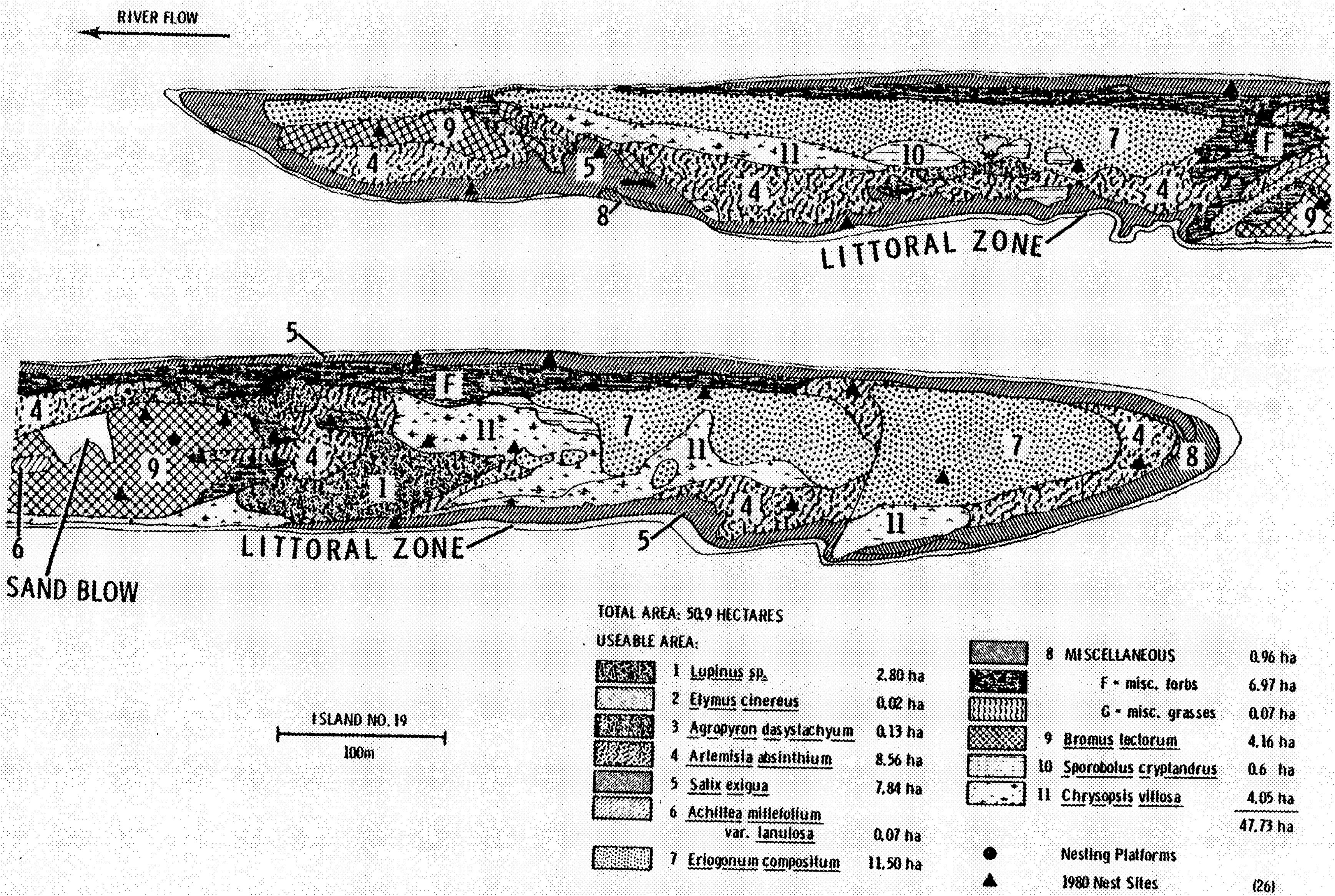
Appendix Figure 12. Distribution and composition of vegetative cover and location of Canada goose nests on Island 15, 1980.



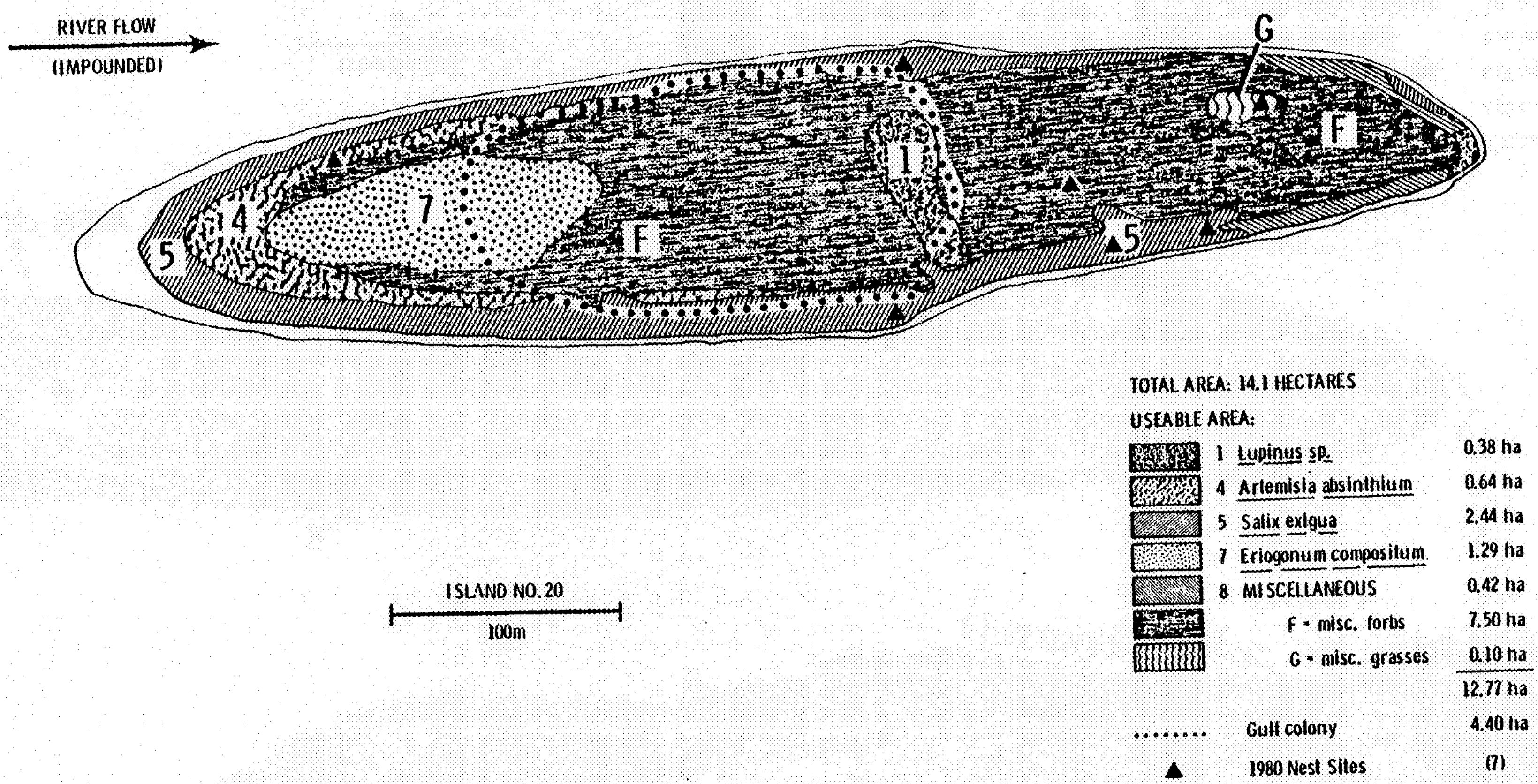
Appendix Figure 13. Distribution and composition of vegetative cover and location of Canada goose nests on Island 17, 1980.



Appendix Figure 14. Distribution and composition of vegetative cover and location of Canada goose nests on Island 18, 1980. The 2 portions of this island are joined by littoral zone.



Appendix Figure 15. Distribution and composition of vegetative cover and location of Canada goose nests on Island 19, 1980.



Appendix Figure 16. Distribution and composition of vegetative cover and location of Canada goose nests on Island 20, 1980.

APPENDIX II

CLUTCH SIZE DISTRIBUTIONS OF CANADA GOOSE NESTS ON THE HANFORD RESERVATION, 1953-1980

Appendix Table 1. Clutch size distributions[a/] of Canada goose nests on island groups and study area totals during; A. 1953-1958, B. 1960-1965, C. 1966-1970, D. 1971-1980 and E. 1953-1980.

A. 1953-1958

Island(s)	CLUTCH SIZE DISTRIBUTION 1	2	3	4	5	6	7	8	9+	Total Nests
1-10	1	4	9	17	33	26	7	2	1	1086
1-5, 7-10	1	4	7	13	31	28	11	4	2	457
6	1	4	10	20	35	24	4	1	0	629
11-17	2	2	2	8	21	37	21	5	2	338
18-20	1	3	2	7	22	28	20	4	4	138
1-20	1	3	7	14	30	28	12	3	1	1562
1-5, 7-20	1	3	5	10	26	31	17	4	2	933
Favored	2	3	3	10	24	30	20	5	3	683

B. 1960-1965

Island(s)	CLUTCH SIZE DISTRIBUTION 1	2	3	4	5	6	7	8	9+	Total Nests
1-10	1	2	4	14	32	33	10	2	1	886
1-5, 7-10	1	4	5	13	31	32	10	3	2	375
6	1	1	3	15	32	34	10	1	1	511
11-17	2	1	5	9	27	34	14	5	2	244
18-20	0	0	3	5	26	36	28	2	0	58
1-20	1	2	4	13	31	34	12	3	1	1188
1-5, 7-20	1	2	4	11	30	33	13	4	2	677
Favored	1	2	4	10	30	32	13	4	2	528

C. 1966-1970

Island(s)	CLUTCH SIZE DISTRIBUTION 1	2	3	4	5	6	7	8	9+	Total Nests
1-10	3	3	7	12	27	30	12	3	3	543
1-5, 7-10	2	3	8	14	28	27	10	3	5	337
6	4	4	6	9	24	34	16	3	0	206
11-17	2	1	2	9	19	34	25	6	1	291
18-20	0	2	2	10	12	36	31	7	0	42
1-20	2	3	5	11	23	32	17	4	2	876
1-5, 7-20	2	2	5	12	23	31	18	5	3	670
Favored	2	3	4	11	22	31	19	5	3	546

Appendix Table 1. Continued.

D. 1971-1980 Island(s)	CLUTCH SIZE DISTRIBUTION									
	1	2	3	4	5	6	7	8	9+	Total Nests
1-10	1	6	8	15	33	25	8	3	2	455
1-5, 7-10	1	6	8	15	33	24	8	3	2	434
6	0	5	0	19	14	52	10	0	0	21
11-17	1	2	4	7	20	35	22	6	2	570
18-20	1	1	2	7	21	33	27	7	2	248
1-20	1	3	5	10	25	31	18	5	2	1273
1-5, 7-20	1	3	5	10	25	31	18	5	2	1252
Favored	1	3	5	10	25	31	18	6	2	1209

E. 1953-1980 Island(s)	CLUTCH SIZE DISTRIBUTION									
	1	2	3	4	5	6	7	8	9+	Total Nests
1-10	1	4	7	15	32	28	9	2	2	2970
1-5, 7-10	1	4	7	14	31	27	10	3	2	1603
6	1	3	7	16	32	30	8	1	1	1367
11-17	1	2	3	8	21	35	21	6	2	1443
18-20	1	1	2	7	21	32	28	6	2	486
1-20	1	3	5	12	28	21	14	4	2	4899
1-5, 7-20	1	3	5	10	26	31	17	4	2	3532
Favored	1	3	4	10	25	31	18	5	2	2966

[a]/Clutch size distributions are expressed as a percent of total nests.