HABITAT AVAILABILITY, UTILIZATION, AND NESTING SUCCESS OF DUSKY CANADA GEESE ON THE COPPER RIVER DELTA, ALASKA

by

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INTRODUCTION

A thorough understanding of the breeding biology of a species, subspecies, or population is necessary before it can be comprehensively managed. One of the primary areas of interest and concern with today's rapidly changing land use policies and ever increasing demand for natural resources is the availability of secure nesting habitat and the consequences to production from a species' selection of particular habitat types for nesting. This need for information becomes even more acute when the species or subspecies of interest is numerically small, hunted heavily, only known to nest at one location, and habitat at that location is changing.

The dusky Canada goose (*Branta canadensis occidentalis*), is such a subspecies. It is a numerically small Canada goose population with mid-winter indices ranging from approximately 8,000 birds in 1953 to 28,000 in 1960 (Pacific Flyway Council 1985). It has been hunted heavily on the wintering grounds in northwestern Oregon and southwestern Washington. Between 1953-63 nearly all (95%) of the 45% annual population mortality was the result of hunting (Chapman et al. 1969, Henny 1967). It is only know to nest on the Copper River Delta in Alaska where plant communities are in a earthquake-induced state of flux.

Habitat availability and use by nesting dusky geese have been documented quite extensively. Early qualitative descriptions (Olson 1954) were followed by more extensive and quantitative studies (Trainer 1959 and 1967, Shepherd 1965 and 1966, Bromley 1976). Unfortunately, results of these studies are only useful historically, as earthquake triggered secondary succession has dramatically changed habitat composition and structure.

Habitat changes on the nesting grounds have apparently had an impact on the dusky goose population. Through the 1960s, conditions on the wintering grounds limited the size of the population (Hansen 1962). However, as early as the 1950s biologists realized that this could change if habitat or predator foraging patterns changed on the nesting grounds (Olson 1953). Secondary succession on the Copper River Delta presented that change and led to predictions that conditions on the nesting grounds would become limiting factors for the dusky (Shepherd 1986, Bromley 1976). Bromley (1976) suggested that the population would temporarily increase for a few years after the earthquake as additional preferred grass/forb/low shrub nesting habitat developed, but ultimately, less favorable habitat such as tall shrub and forest would evolve and the population would decline. This decline would probably result from the lack of preferred nesting habitat and increased nest predation by large mammalian predators such as the brown bear (*Ursus arctos*) and coyote (*Canis latrans*) (Trainer 1967, Shepherd 1965 and 1966, Bromley 1976).

These predictions have been all too correct. During the mid-1970s, dusky production was relatively good and even with heavy annual harvest the population increased from a pre-earthquake mid-winter average of about 14,000 to a mid-winter average of around 20,000 geese. Things began to change around 1979 when production dropped off dramatically and the population started to decline (Campbell and Timm 1983, Campbell 1982 and 1984). As a result of this decline, harvest was reduced in 1983 and 1984 and, except for a very limited experimental season and harvest of less than 500 birds, was eliminated in 1985. Production remained low and the population continued to decline, suggesting that, as predicted, factors limiting the population are now at work on the nesting grounds.

OBJECTIVES

In response to apparent changes on the nesting grounds, the Alaska Department of Fish and Game initiated an investigation in 1982 to determine:

1. How habitat availability and use on the west Copper River Delta had changed since last quantified in the mid-1970s.

2. How changes in habitat availability and use, if they have occurred, have influenced dusky production.

3. Identify possible ways of increasing dusky goose nest success through habitat manipulation such as brush removal or control.

The method for accomplishing these objectives was present in the form of an ongoing monitoring program designed to follow trends in nest density and nest success. Minor changes in the methodology of this program facilitated quantification of habitat use and measurement of nest predation between 1982-86. This report presents the results of the 5-year investigation and management recommendations.

I would like to thank the numerous personnel from Regions 1 and 7 of the U. S. Fish and Wildlife Service, U. S. Forest Service, Washington Department of Game, Oregon Department of Fish and Wildlife, Alaska Department of Fish and Game, and volunteers for walking through many, many miles of marsh, often under less than ideal conditions, and dodging the occasional brown bear to collect data. I would also like to thank the U. S. Forest Service for providing support facilities and equipment. Thanks also go to Earl Becker, biometrician, ADF&G, for assisting with portions of the data analysis and Tom Rothe, Dan Rosenberg, Dan Timm, Herman Griese, Bob Bromely, John Cornely, and Keith Giezentanner for reviewing drafts of this rport.

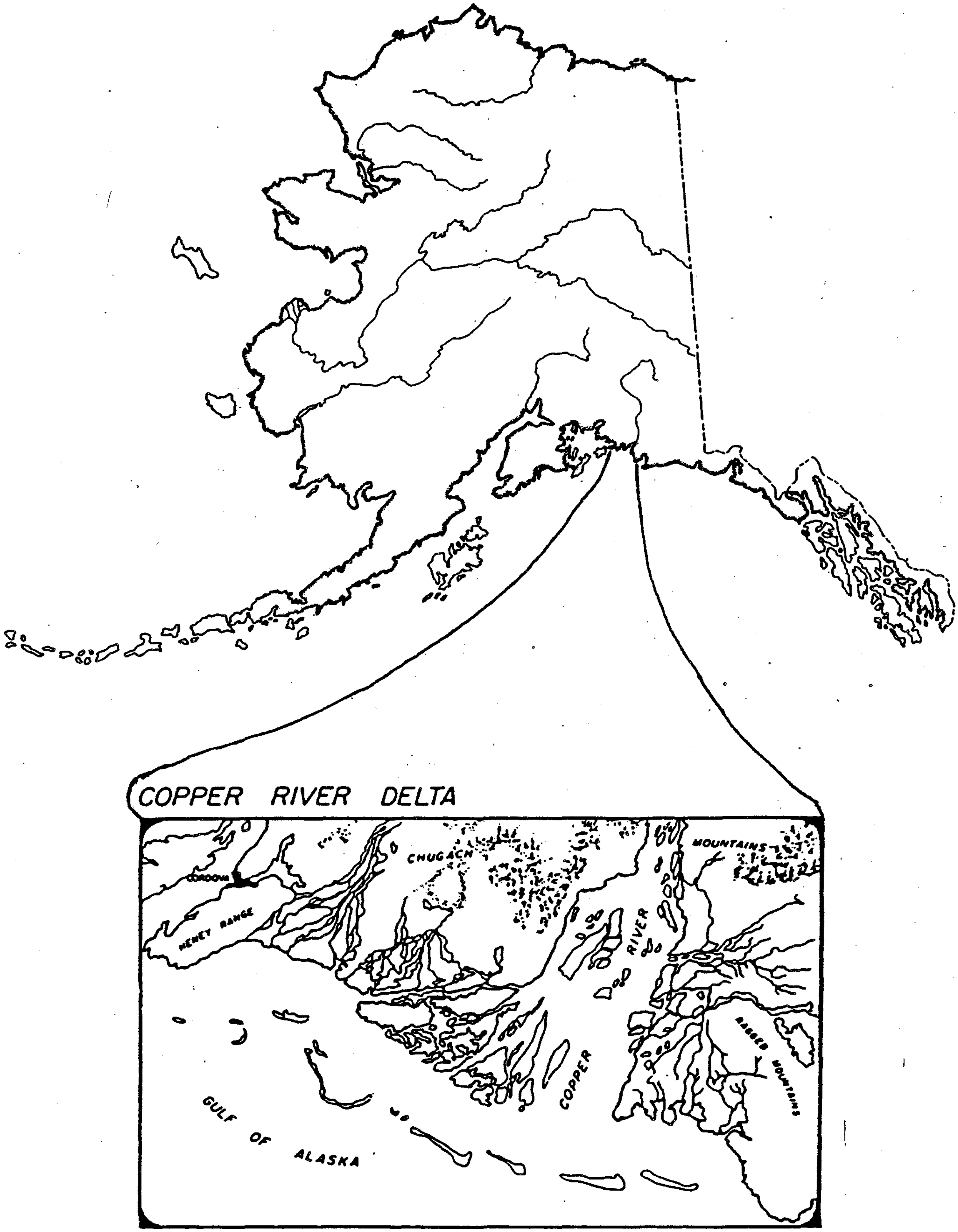
STUDY AREA

The Copper River Delta is an approximately 650-km^2 deltaic plain at the mouth of the Copper River (Figure 1). It is bounded on the west, north, and east by the Chugach and Ragged Mountain Ranges and the Gulf of Alaska on the south. The area has a typical maritime climate with cool summers, mild winters, and abundant precipitation. Annual precipitation averages 205 cm., including 318 cm of snowfall, and annual temperatures average 3.4°C, ranging from an average of -5°C in January to 12°C in July. Spring phenology, as it relates to nesting geese during the 1982-86 study period, ranged between very good for nesting in 1984 to poor for nesting in 1985 (Table 1).

The study area is located on the approximately 450-km² west Copper River Delta (Figure 2). This area is interlaced with tidal sloughs and glacial streams with numerous small, shallow, fresh water ponds between drainages. Plant communities are evolving as a result of uplifting of the area by as much as 2 m during the 1964 Good Friday earthquake (Potyondy et al. 1975). Currently, coastal communities are dominated by fresh water sedge meadows (*Carex* spp.) interspersed with dense, tall shrub (*Alnus crispa* and *Salix* spp.) stringers along drainages. Stands of tall shrub and shrub-bog (*Myrica gale*, *carex* spp. and *Menyanthes trifolicata*) increase in frequency inland from the coast with an alder-spruce (*Picea sitchensis*) Western hemlock (*Tsuga heterophylla*) community becoming dominant 7-11 km from the coast.

METHODS

Ten sample plots ranging from 0.08-0.34 km² in size have been established on the west Copper River Delta to monitor nest densities and success (Figure 2). With the exception of Egg Island to which only one exploratory visit was made in 1982, all of these plots were



Fig[redacted]. 1. Copper River Delta, Alaska.

Table 1. Spring weather indices[1/] for 1982-86 on the Copper River Delta, Alaska.

Year	Temperature deviation from normal (C°)	Contribution to weather index	Snow depth on ground(cm)	Contribution to weather index	Preciptitation deviation from normal(cm)	Contribution to weather index	Spring weather index	Subjective ranking
1982	-1.9	-9.5	5.8	-5.8	-3.5	+17.5	+2.2	Average year
1983	+4.5	+22.5	2.5	-2.5	-6.2	+31.1	+51.1	Good year
1984	+4.8	+24.0	2.5	-2.5	-17.7	+88.5	+110.0	Very good year
1985	-5.4	-27.0	71.1	-71.1	+7.1	-35.5	-133.6	Poor year
1986	-1.2	6.0	10.2	-10.2	-16.6	+83.0	+66.8	Good year

1/ Calculated according to Bromley (1976).

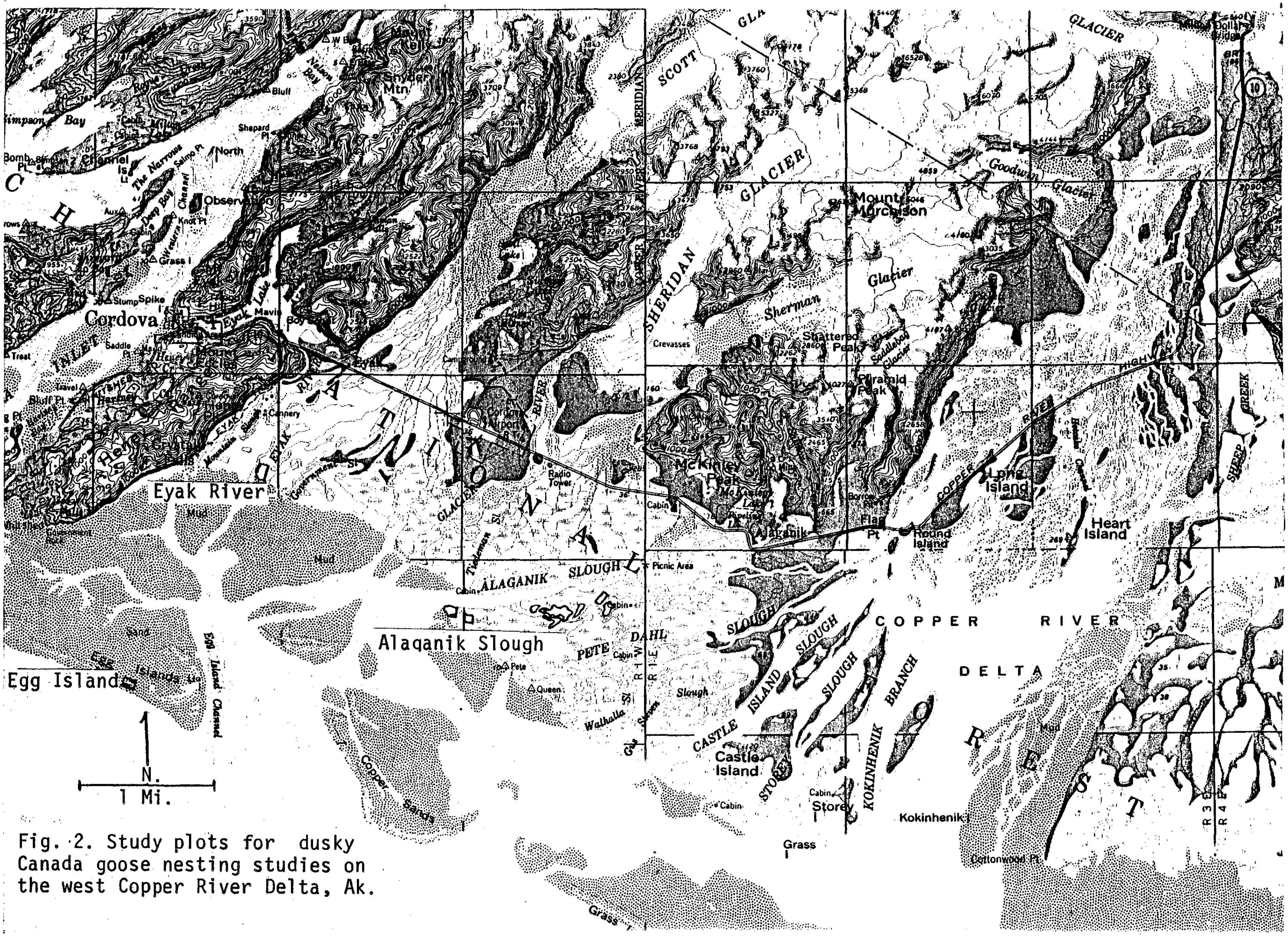


Fig. 2. Study plots for dusky Canada goose nesting studies on the west Copper River Delta, Ak.

Table 2. Characteristics of habitat types used by dusky Canada geese for nesting on the west Copper River Delta, 1982-86.

Habitat Type	Species Composition	Structural Characteristics
Tall Shrub	Alder (Alnus) and willow (Salix)	Taller than 48"
Low Shrub	Alder and willow or sweetgale (Myrica)	Less than 48" tall
Levee	Prostrate willow, forbs, wild iris (Iris), moss (Sphagnum), scattered low shrubs, and sedge (Carex)	Very open, typically vegetation less than 12" tall with little to no overhead cover.
Meadow	Monotypic sedge meadows possibly with scattered grass and low shrubs	Open meadows, typically in pond basins between levees and ponds.
Grass/Forb Bench	Grasses, tall forbs such as Rumex, Cicuta, and Urtica with moss ground cover	Only found on Egg Island. Structurally resembled low shrub.

sampled twice each nesting season during 1982-1986. They were thoroughly searched immediately after the peak of incubation and again after the peak of hatch. Peak of incubation was determined by monitoring nests along the Copper River Highway. Peak of hatch was determined by adding the appropriate number of days to the mean age of clutches on the study plots, as determined from egg floatation data, (average 28-day incubation). During the first search, the habitat type for all nests plus the number of eggs and stage of development for active nests were recorded. Classification of habitat types was according to the categories in Table 2. Because physical configuration of habitat is a major influence on how geese select nest sites (Long 1970, Heagy and Cooke 1979, McCabe 1979), habitat classification was based primarily on physical structure. All nests were marked with wands and their location plotted on large scale (1:330-1:700) maps. Wands were placed at least 50 feet from the nest to minimize the possibility of attracting predators.

During the second visit, the fate of both previously located nests and newly discovered nests was determined. Nests in which one or more eggs had hatched were considered successful. Attended nests were considered to be incubating, and nests that were unattended with arrested development of eggs were classified as abandoned. Nest destruction was classified as avian, unknown mammal, canid, or bear, when sufficient evidence allowed, using published characteristics of predation (Darrow 1938, Sooter 1946, Rearden 1951) and techniques developed during the study. Habitat types for newly discovered nests were also recorded. Areas adjacent to the study plots were searched after the peak of hatch, and nest fate information was used as a control to determine if the presence of field crews influenced nest success on the study plots.

The availability of habitat on the sample plots was determined by analyzing aerial photography taken in June 1986. A series of 35mm slides of each study plot was taken from approximately 7,500 ft. altitude and at as vertical an angle as possible. These were projected onto mylar and the major habitat types, sloughs and ponds were transcribed without correction for the oblique angle of photography. Comparison of resulting habitat maps with 1974 aerail photography (U.S.D.A., Agricultural and Stabilization Conservation Service) of subject areas indicated that distortion from the oblique angle of the photographs was minimal. Maps were digitized and the surface area of each habitat type or physical feature was computed.

RESULTS

MAINLAND COPPER RIVER DELTA

Habitat Availability:

The basic physical features of the study area have apparently changed little in the past 12 years. In 1974, about 15% of the mainland study plots were ponds, with the remaining 85% about equally split between pond basins and levees (Potyondy 1975). In 1986, about 13% of the same areas were ponds, 44% was pond basin, and 43% was levee (Figure 3). However, habitats on these features have changed dramatically (Figure 3). While the portion of the plots covered by ponds and meadows has remained relatively constant, a significant (χ^2 = 38.71, $P<0.05$, df=4) change in plant cover on elevated areas has occurred. In 1974, the levee habitat type (prostrate willow, forbs, and moss) covered about 40% of the study area and low shrub covered about 3% of the area. By 1986, shrub habitats had increased tenfold at the expense of levee habitat which had declined by 50%. Composition of the greatly expanded shrub habitat has also changed, with over 60% of it currently composed of tall shrubs. Tall shrub habitat now typically occurs along drainages where it has displaced stands of low shrub. The dramatic development and dominance of the tall shrub community overshadows a 3½-fold increase in low shrub habitat. Low shurb habitat has apparently expanded into levee habitat, laterally into meadow habitat, and generally occurs as a transition between tall shrub and levee or meadow habitats.

Habitat Utilization:

Nesting habitat utilization by geese was determined from the distribution of 782 nests between 1982-86 (Table 3). Comparison of average habitat utilization with availability, using a chi-square goodness of fit test (Table 4), indicated that shrub habitats were preferred for nesting. Levee habitat was avoided while meadows were apparently used

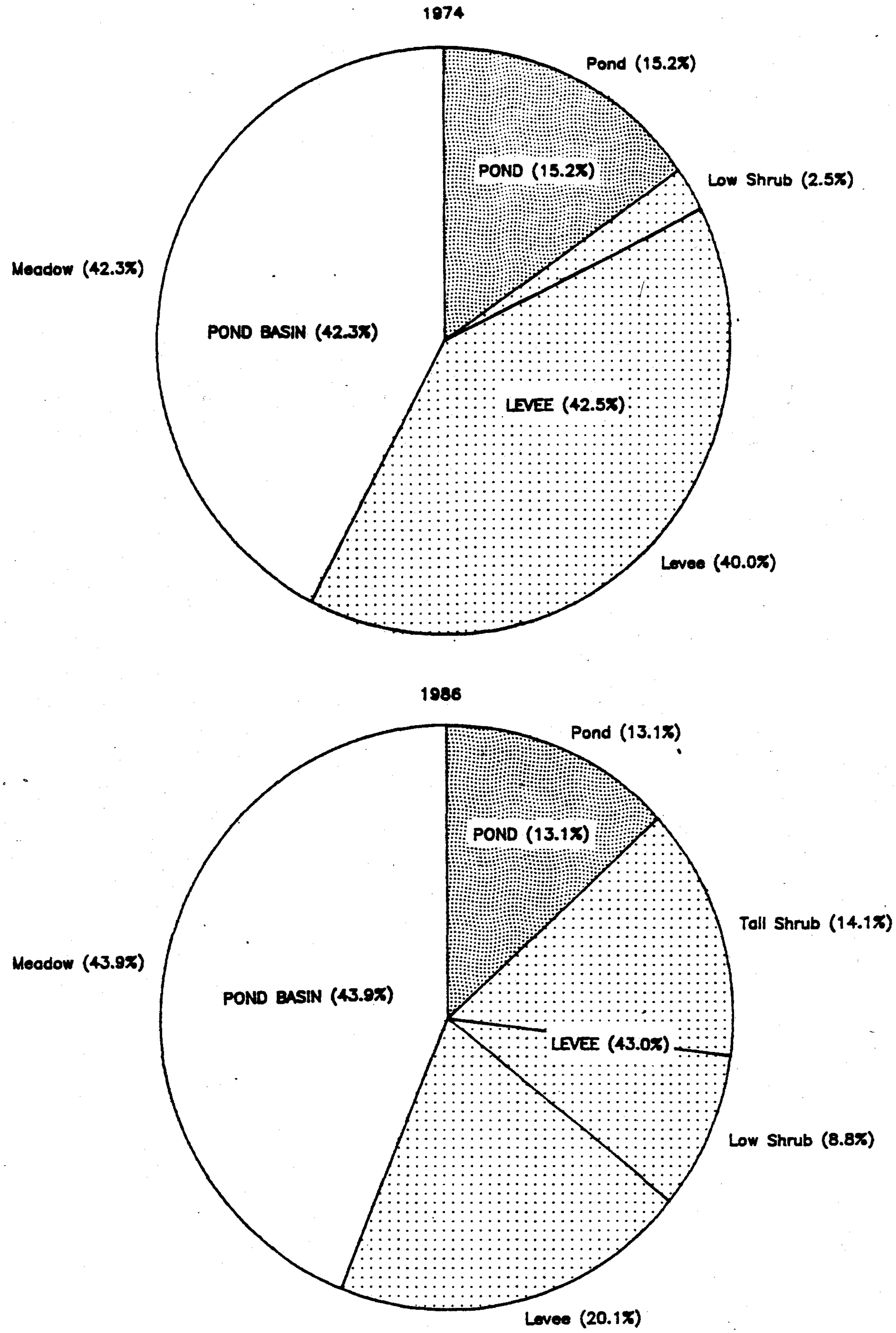


Fig. 3. Composition of basic physical features (caps.) and habitat on the mainland dusky goose nesting study plots on the Copper River Delta in 1974 and 1986.

about in proportion to their availability. However, there was a significant ($\chi^2 = 57.96$, $P<0.010$, df=12) amount of variation in the distribution of nests, by habitat types, between years.

A logistic regression model (Agresti 1984), fit to the data using stepwise regression and incorporating spring weather and the effect of habitat on nest distribution, ($G^2 = 6.99$, $P>0.25$, df=6) best explained the annual variation. This model, which categorizes nest distribution data according to poor, average, good, and very good springs (weather indices from Table 1), indicates that the annual variation on nest distribution was primarily the result of weather influenced changes in the utilization of levee and low shrub habitat. During late springs, levee habitat was used more frequently than shrub habitats, primarily low shrub. However, in years of early spring phenology, the relative frequency of nests occurring in shrub habitats was higher. This difference undoubtedly reflects the relative availability among habitats when nesting sites are being selected in early May.

Geese typically select sites that are, or will become, snow-free first (McInnes 1972). Shrub habitats act as snow traps, and during years with late springs, are still drifted in when geese arrive. Levees, on the other hand, are generally the first areas to become snow- and ice-free and, in "late" years, are more frequently selected by geese as nest sites. The expected relative odds of the use of general habitat types as the spring weather index increases one category (poor

Table 3. Distribution of dusky Canada goose nests by habitat type on the mainland west Copper River Delta, Alaska, 1982-86.

Habitat Type	1982		1983		1984		1985		1986		5yr $\bar{x}$	
	nests	%	nests	%	nests	%	nests	%	nests	%	nests	%
Tall shrub	25	15.6	20	13.9	32	22.5	28	18.5	52	28.1	157	20.0
Low shrub	38	23.8	42	29.2	39	27.5	26	17.2	59	31.9	204	26.0
Levee	32	20.0	12	8.3	10	7.0	39	25.8	14	7.6	107	13.6
Meadow	65	40.6	70	48.6	61	43.0	58	38.4	60	32.4	314	40.0
Total	160		144		142		151		185		782	

Table 4. Availability of four general habitat types, average nest distribution by habitat type, and nesting preference/avoidance test for dusky Canada geese on west Copper River Delta, Alaska, 1982-86.

Habitat type	% of area	Number of nests (o_i)	Expected number of nests* (e_i)	Cell contribution [$\pm(o_i-e_i)^2/e_i$]	Habitat type Selection
Tall shrub	14.1	157	110.3	+19.8	preferred
Low shrub	8.8	204	68.8	+265.7	preferred
Levee	20.1	107	157.2	-16.0	selected against
Meadow	43.9	314	343.3	-2.5	no preference

* Expected number of nests=percentage composition of habitat types x total nests.

Table 5. Expected odds (p:q) of habitat type utilization by dusky Canada geese as the spring weather index increases* one category (poor, average, good, and very good from Table 1) on the west Copper River Delta, Alaska.

Habitat type(p)	Odds of utilization (q) Low shrub	Levee	Meadow
Tall shrub	0.94:1	1.88:1	1.08:1
Low shrub		2.01:1	1.16:1
Levee			0.58:1

* odds of utilization as the spring weather index declines 1 category (very good to good, etc.) are e_p^x.

to good, etc.) are presented in Table 5. Odds of habitat utilization as weather becomes poorer for nesting, i.e. "later" springs, are e^x of the "p" values in Table 5.

Nest Fate:

The fate of 726 nests was documented between 1982-86. Of these, 696 were either successful or destroyed. While nest success and destruction averaged about 43% and 57%, respectively (Table 6), these parameters varied considerably between years; nest success ranged from 7% (1985) to 88% (1984) and nest destruction ranged from 12% (1984) to 93% (1985).

An ordinal loglinear logit model (Agresti 1984) indicated that nests had about even odds of succeeding or failing (0.972:1.0) during the study and that the primary influence on these odds was weather (G^2=8.84, P›0.75, df=12, 12). The expected odds of nest success on the west Delta indicate that "late" springs have nearly twice as much negative influence on nest success as "early" springs have positive influence (Table 7).

Though the magnitude of nest predation varied from year to year in association with spring phenology, the composition of that destruction did not. Based on information from 349 nests for which the predator could confidently be identified (Table 8), brown bears were consistently (no significant variation between years, X^2=6.91, P›0.10, df=4)

Table 6. Distribution of successful and destroyed dusky Canada goose nests, by habitat type, on the west Copper River Delta mainland study plots, 1982-86.

Habitat type	1982					1983					1984				
		Success nests		Destroyed nests			Success nests		Destroyed nests			Success nests		Destroyed nests	
	N	No.	%	No.	%	N	No.	%	No.	%	N	No.	%	No.	%
Tall shrub	21	13	61.9	8	38.1	18	10	55.6	8	44.4	30	27	90.0	3	10.0
Low shrub	35	18	51.4	17	48.6	38	23	60.5	15	39.5	35	32	91.4	3	9.3
Levee	31	14	45.2	17	54.8	11	7	63.1	4	36.4	10	9	90.0	1	10.0
Meadow	61	34	55.7	27	44.3	62	34	54.8	28	45.2	57	48	84.2	9	15.8
Total	148	79	53.4	69	46.6	129	74	57.4	55	42.6	132	116	87.9	16	12.1

Table 6. (continued)

Habitat type	1985					1986					1982-86 $\bar{x}$				
		Success nests		Destroyed nests			Success nests		Destroyed nests			Success nests		Destroyed nests	
	N	No.	%	No.	%	N	No.	%	No.	%	N	No.	%	No.	%
Tall shrub	27	3	11.1	24	88.9	45	7	15.5	38	84.4	141	60	42.5	81	57.4
Low shrub	39	0	0.0	39	100.0	53	7	13.2	46	86.8	200	80	40.0	120	60.0
Levee	25	2	8.0	23	92.0	12	1	8.3	11	91.7	89	33	37.1	56	62.9
Meadow	44	4	9.1	40	90.1	42	9	21.4	33	78.6	266	129	48.5	137	51.5
Total	135	9	6.7	126	93.3	152	24	15.8	128	84.2	696	302	43.3	394	56.7

Table 7. Expected odds of dusky Canada goose nest success and failure based on spring weather on the west Copper River Delta, Alaska.

Spring weather*	Expected Odds	
	Success vs. failure	Failure vs. success
Poor	.073:1	13.70:1
Average	1.145:1	0.873:1
Good	1.489:1	0.672:1
Very good	7.173:1	0.139:1

* Based on spring weather indices in Table 1.

Table 8. Nest fate and types of nest destruction for dusky Canada goose nests of known fate on the west Copper River Delta mainland study plots, 1982-86.

Year	Nests of know fate	% destroyed	N	Brown bear (%)	Canid (%)	Unknown Mammal (%)	Avian (%)
1982	151	46.4	55	36.4	14.5	1.8	47.3
1983	134	40.3	41	61.0	17.1	12.2	9.8
1984	136	11.8	15	46.7	26.7	13.3	13.3
1985	140	90.0	126	49.2	27.0	12.7	11.1
1986	169	75.7	112	55.4	13.4	23.2	8.0
$\bar{x}$	730	54.0	349	50.4	19.5	14.3	15.8

responsible for about half of the nest destruction. This means that regardless of whether 4 or 40 nests were destroyed in any year (weather dependent), half (2 or 20) were destroyed by bears; proportion of nest destruction attributed to bears was independent of spring phenology (r_s=0.10, $P>0.05$, df=4). The proportion of total nest losses resulting from predation by canids, primarily coyotes (fox and wolves were rare on the Delta), averaged about 20%, but differed significantly (X^2=9.03., $P>0.05$, df=4) from year to year independent of spring phenology (r_s=-0.30, $P>0.05$, df=4). Avian predators were responsible for an average of only 16% of the total nest destruction each year. Like canid predation, avian predation differed significantly (X^2=66.87, $P<0.0001$, df=4) from year to year and was independent of weather (r_s=-0.20, $P>0.05$, df=4).

Similar to what others have found (Bromley 1976, Gotmark et al. 1984) nest visits by field crews had little influence on nest fates. With the exception of 1983 when nest success was significantly greater on the study plots, nest fates on the plots did not differ significantly from the controls during the four years (1983-86) when control information was gathered (Table 9).

<u>Habitat Use by Predators</u>:

No association between habitat type and level of nest destruction was observed. The magnitude of nest destruction did not differ significantly (χ^2=11.72, $P>0.75$, df=19) among habitat types in any single year.

Table 9. Comparison of the fate of all dusky Canada goose nests on the Copper River Delta mainland study and control plots, 1983-86.

	Study plots (o_i)					Control plots (e_i)						
Year	N	% Successful (o_1)	% Destroyed (o_2)	% Abandoned (o_3)	% Other*	N	% Successful (e_1)	% Destroyed (e_2)	% Abandoned (e_3)	% Other*	χ^2 (1-3)	P
1983	146	51.4	37.0	3.4	8.2	24	41.7	50.0	0.0	0.0	9.26	<0.05
1984	143	81.1	11.2	2.8	4.9	21	76.2	9.5	4.8	9.5	1.42	>0.05
1985	151	6.0	83.4	3.3	7.3	92	4.3	80.4	1.1	14.1	5.26	>0.05
1986	185	13.0	69.2	9.2	8.6	31	12.9	64.5	12.9	9.7	1.41	>0.05

* Not used to calculate χ^2 due to small sample sizes and large number of possible fates such as incubating, unknown, flooded, etc.

Table 10. Number of dusky goose nests destroyed by brown bears in each habitat type (o_i) compared to the expected number of nests destroyed by bears (e_i) based on availability of nests and predation rates on the west Copper River Delta mainland study plots, 1982-86.

Habitat type	1982 (average spring)		1983 (early spring)		1984 (very early spring)		1985 (very late spring)		1986 (early spring)	
	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)
Tall shrub	2*	3.1	6*	3.5	1	1.6	10	11.5	21*	17.4
Low shrub	6*	4.8	9*	7.3	2	1.9	14*	10.7	21*	19.8
Levee	3	4.0	1	2.0	0	0.5	14	16.0	7*	4.7
Meadow	9	8.1	9	12.2	4*	3.0	24	23.8	13	20.1

* Number of nests destroyed considerably exceeded expectations indicating a possible preference for foraging in this habitat type.

Table 11. Number of dusky goose nests destroyed by canids in each habitat type (o_i) compared to the expected number of nests destroyed by canids (e_i) based on availability of nests and predation rates on the west Copper River Delta mainland study plots, 1982-86.

Habitat type	1982 (average spring)		1983 (early spring)		1984 (very early spring)		1985 (very late spring)		1986 (early spring)	
	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)
Tall shrub	0	1.3	0	1.0	1	1.0	10*	6.3	4	4.2
Low shrub	0	1.9	2	2.0	1	1.1	11*	5.9	5	4.8
Levee	6*	1.6	1*	0.6	0	0.3	3	8.8	1	1.1
Meadow	2	3.3	4*	3.4	2	1.7	10	13.0	5	4.9

* Number of nests destroyed considerably exceeded expectations indicating a possible preference for foraging in this habitat type.

Table 12. Number of dusky goose nests destroyed by avian predators in each habitat type (o_i) compared to the expected number of nests destroyed by birds (e_i) based on availability and predation rates on the west Copper River Delta mainland study plots, 1982-86.

Habitat type	1982 (average spring)		1983 (early spring)		1984 (very early spring) [1]		1985 (very late spring)		1986 (early spring)	
	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)	Observed (o_i)	Expected (e_i)
Tall shrub	5*	4.1	1*	0.6	---	---	2	2.6	3*	2.5
Low shrub	8*	6.2	1	1.2	---	---	7*	2.4	4*	2.9
Levee	4	5.2	0	0.3	---	---	2	3.6	1	0.7
Meadow	9	10.6	2	1.9	---	---	3*	5.4	1	2.9

[1] Insufficient data (N=2).

* Number of nests destroyed considerabily exceeded expectations indicating a possible preference for foraging in this habitat type.

Comparison of the distribution of nest destruction by habitat type with the expected distribution (number of nests available x predation rates) (Table 10-12) using a chi-square goodness of fit test indicated that none of the predators had a strong preference for specific habitats. There was no significant difference (bear, $X^2=11.54$, $P>0.05$, df=19; canid, $X^2=28.67$, $P>0.05$, df=19; avian $X^2=13.23$, $P>0.05$, df=15) between the number of nests destroyed and expected number of nests destroyed in each habitat type. Brown bears did demonstrate a slight preference for foraging where a majority of the nests were, but, this preference was not of significant magnitude. They took a few more nests than expected in shrub habitats in years with "average" and "early" springs (Table 10). Coyotes typically took fewer nests than expected in those habitats, where bears took more nests than expected (Table 11) and the distribution of avian predation suggested a slight preference for shrub habitats (Table 12).

EGG ISLAND

Similar to the mainland study plots, the basic geological features on Egg Island have remainded constant since 1974 (Fig. 4). About 40% of the Egg Island plot was tidal flats and 60% elevated dunes in 1974 compared to 38% lowland (tidal or supratidal) and 61% dunes and uplands in 1986.

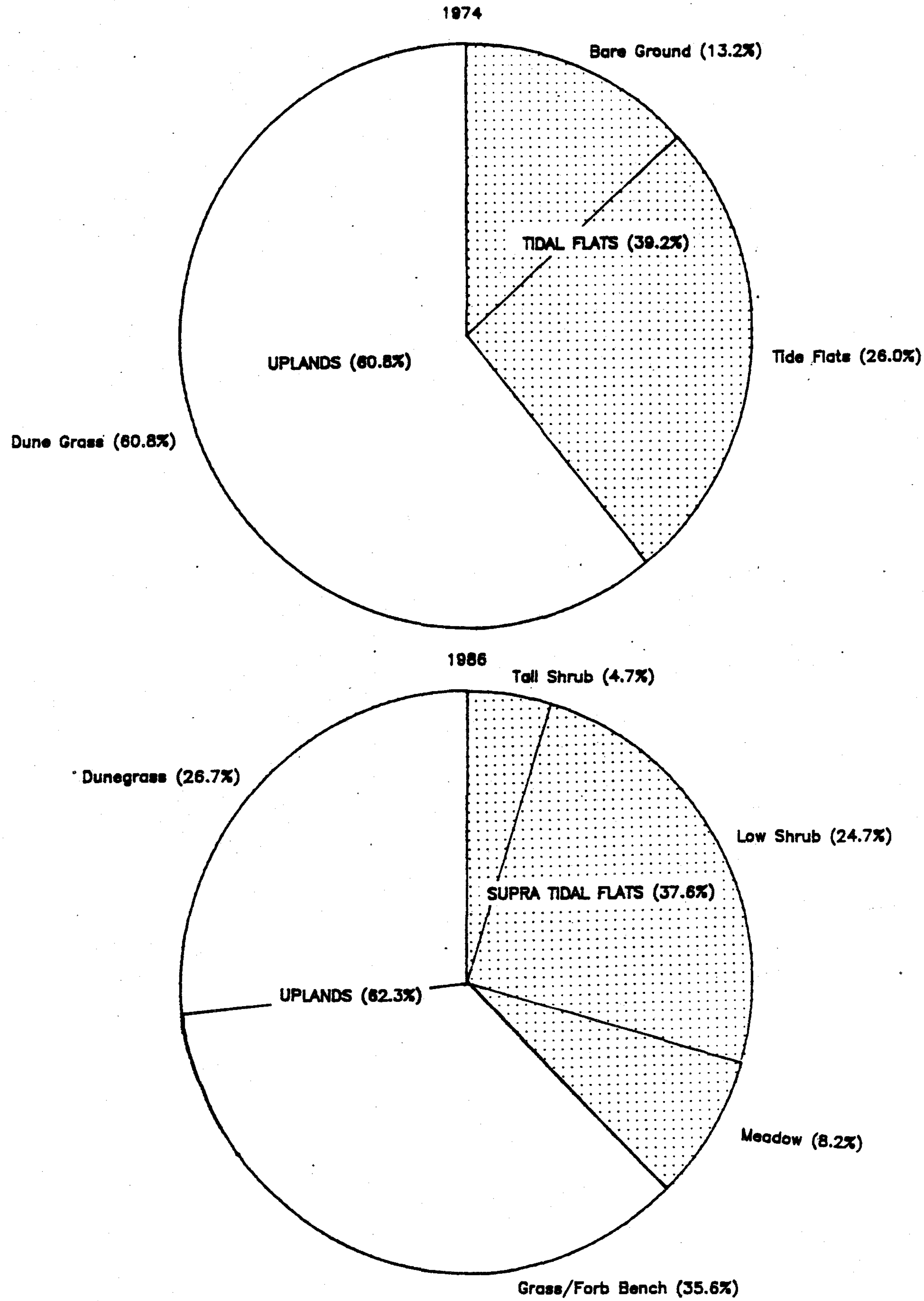


Fig. 4. Composition of basic physical features (caps.) and habitat on the Egg Island dusky goose nesting study plots on the Copper River Delta in 1974 and 1986.

Habitat composition has changed dramatically on Egg Island since 1974 (Figure 4). Habitat diversity has increased and low shrub, primarily *Myrica*, has become abundant. Areas that were bare ground and tide flats in 1974 now support low shrub and sedge/ *Equisitum* meadows, and a grass/forb/moss covered bench has developed between the dunes and old tide flats along the north side of the island. A stringer of tall shrub occurs on portions of the old tide flats at the toe of this bench.

Eighty-five goose nests were sampled on Egg Island between 1982-86, 15 on an exploratory visit to the island in 1982 and 70 from a study plot established in 1983. The majority (84%) of these nests were located in either low shrub or grass/forb habitats (Table 13) and, unlike the mainland, this distribution did not vary significantly (X^2=15.94, $P>0.10$, df=12) from year to year. Analysis of habitat availability and use indicated that geese preferred the low shrub habitat type for nesting, used tall shrub, grass/forb, and meadows in about the same proportion as they were available, and selected against dune grass (Table 14).

Although sample size was small, the fate of 70 nests (Table 15) on the Egg Island study plot suggests that nest success has been more consistent (32%-56%) than on the mainland (6%-81%). There have been significant (X^2=7.96, $P<0.05$, df=3) differences in nest success between years, but two-thirds of the significant X^2 value was the result of higher nest success in 1983. Nest success was independent of weather (r_s=0.40, $P>0.04$, df=3).

Table 13. Distribution of dusky Canada goose nests by habitat type on Egg Island, Copper River Delta, Alaska, 1982-86.

Habitat type	1982		1983[a/]		1984		1985		1986		5 yr. $\bar{x}$	
	Nests	%	Nests	%	Nests	%	Nests	%	Nests	%	Nests	%
Tall shrub	2	13.3	2	12.5	1	4.5	2	12.5	0	0	7	8.1
Low shrub[b/]	9	60.0	9	56.3	8	36.4	5	31.3	5	31.3	36	42.4
Grass/forb bench	4	26.7	5	31.3	10	45.5	9	56.3	8	50.0	36	42.4
Meadow	0	0	0	0	3	13.6	0	0	3	18.8	6	7.1
Total	15		16		22		16		16		85	

a/ Permanent study plot established

b/ Predominately sweetgale (Myrica gale)

Table 14. Availability and utilization analysis of dusky Canada goose nest site selection of five general habitat types on Egg Island, Copper River Delta, Alaska, 1982-86.

Habitat type	% of area	Number of nests (o_i)	Expected number of nests* (e_i)	Cell contribution $[\pm(o_i-e_i)^2/e_i]$	Habitat type selection
Tall shrub	4.7	7	4.0	+2.3	no preference
Low shrub	24.7	36	21.0	+10.7	preferred
Grass/forb bench	35.6	36	30.3	+1.1	no preference
Meadow	8.2	6	7.0	-0.1	no preference
Dunegrass	26.7	0	22.7	-22.7	selected against

* Expected number of nests = proportionate area of each habitat x total number of nests.

While data were insufficient for a detailed analysis of the causes of nest destruction on Egg Island, some general trends are discernible. Nest destruction in the preferred low shrub habitat was relatively high (Table 15) and primarily the result of avian predators (72%) and coyotes (18%). Nest predation in the frequently used, but less preferred grass/forb habitat was lower (25%) and also primarily the result of coyotes (50%) and avian predators (38%). Overall, avian predators were the major cause of nest failure followed by coyotes (Table 16), although predation by coyotes was apparently on the rise over the 1983-86 period. The annual composition of nest predation was independent of spring phenology (avian r_s=0.20, canid r_s=0.00, unknown r_s=0.20, $P>0.05$, df=3).

DISCUSSION

Habitat Changes:

Judging from comparison of the results of this investigation with those of earlier studies (Trainer 1959, Shepherd 1965 and 1966, Crow 1972, Potyondy et al. 1974, Bromley 1976), habitat structure on the Copper River Delta has changed significantly since 1964. On the mainland, it has changed from predominantly tidal influenced meadows and mixed forb/low shrub on elevated areas (Trainer 1959) to mixed freshwater marshes and shrub communities. Shrub cover has increased tenfold with tall shrub cover increasing from nonexistent prior to

Table 15. Dusky Canada goose nest distribution and fate by habitat type on Egg Island, Copper River Delta, Alaska, 1983-86.

Habitat type	1983					1984					1985				
		Success nests		Destroyed nests			Success nests		Destroyed nests			Success nests		Destroyed nests	
	N	#	%	#	%	N	#	%	#	%	N	#	%	#	%
Tall shrub	2	0	0	1	50.0	1	0	0	0	0	2	0	0	1	50.0
Low shrub	9	5	55.6	0	0	8	2	25.0	5	62.5	5	1	20.0	4	80.0
Grass/forb	5	4	80.0	0	0	10	4	40.0	3	30.0	9	5	55.6	2	22.2
Meadow	0	0	0	0	0	3	1	33.3	1	33.3	0	0	0	0	0
Total	16	9	56.3	1	6.3	22	7	31.8	9	40.9	16	6	37.5	7	43.8

a/ Majority of nest still incubating when sampled in June to determine nest fate.

b/ Incubating nests pipping or near hatching as determined by floatation were considered successful.

Table 15. (continued)

Habitat Type	1986[a/] N	Success nests #	Success nests %	Destroyed nests #	Destroyed nests %	1983-86 $\bar{x}$ N	Success nests #	Success nests %	Destroyed nests #	Destroyed nests %
Tall shrub	0	0	0	0	0	5	0	0	2	40.0
Low shrub	5	2[b/]	40.0	2	40.0	27	10	37.0	11	40.7
Grass/forb	8	5[b/]	62.5	3	37.5	32	18	50.0	8	25.0
Meadow	3	0	0	3	100.0	6	1	16.7	4	66.7
Total	16	7	43.8	8	50.0	70	29	41.4	25	35.7

a/ Majority of nest still incubating when sampled in June to determine nest fate

b/ Incubating nests pipping or near hatching as determined by floatation were considered successful.

Table 16. Types and extent of dusky Canada goose nest destruction on Egg Island, Copper River Delta, Alaska, 1983-86

Year	N	% destroyed	Types and extent of destruction: Avian (%)	Canid (%)	Unknown (%)
1983	16	6.3	0	0	100.0
1984	22	40.9	77.8	11.1	11.1
1985	16	43.8	85.7	14.3	0
1986	16	50.0	0	62.5	37.5
$\bar{x}$	70	35.7	52.0	28.0	20.0

1964 to over 14% in 1986. Shrub communities have now displaced the mixed forb/low shrub communities and are the dominant habitat type on elevated areas.

Egg Island probably emulates, to some extent, habitat on the mainland prior to the earthquake. Grass/forb and low shrub habitats are predominant with tidal flooding playing an important role in determining the availability of the low shrub/horsetail habitat to nesting geese and suppressing tall shrub development. Based on observations of standing, brackish water, all but the most elevated portions of the low shrub/horsetail habitat are inundated by spring storm tides. The grass/forb habitat covers more elevated terrain and is more secure from flooding. The vertical structure of this habitat, which is dominated by Rumex, Cicuta, and Urtica, probably resembles that of the sweet-gale dominated low shrub habitat that existed on elevated portions of the mainland prior to the earthquake.

Habitat Selection by Geese:

As might be expected, changes in habitat structure on the Delta since 1974 have affected the distribution of nests among habitats. Prior to the earthquake geese preferred to nest on elevated areas in mixed forb and low shrub stands (Trainer 1959). Where mixed forb habitats still occur, such as Egg Island, this preference continues to exists. However, on the mainland where mixed forb habitat has disappeared, geese prefer the shrub habitats on elevated terrain for nesting.

Whether this apparent change in preference is real and the geese now prefer shrub cover for nesting, as is the case in some other Canada geese (Ewaschuk and Boag 1972), or reflects their traditional preference for elevated nesting sites regardless of the cover type, as suggested by Bromley (1976) is not known. The latter is certainly a possibility because virtually all nest failure was the result of nest destruction and it was proportionately equal in all habitat types. There seems to be little selective advantage in developing a preference or avoidance for certain habitat types.

Nest and Predation:

Dusky production has declined in conjunction with changes in habitat on the Delta. Because of the availability of apparently preferred nesting habitat (shrub habitat), which is more abundant now than in the mid 1970s when the population exceeded 25,000, something besides habitat availability is causing poor production and limiting the size of the population. Nest predation appears to be that limiting factor. Predators have been responsible for the destruction of over 55% of the nests during the past five years and nest success has averaged only 40%, considerably below the 70+% nest success typical of healthy, self-sustaining Canada goose populations (Trainer 1959; Hanson and Eberhardt 1971; MacInnes 1972, MacInnes and Misra 1972; Bromley 1976; Cooper 1978; Krohn and Bizeau 1980; Ball et al. 1981).

Brown bears are the major predator on dusky goose nests, followed by coyotes and avian predators, primarily Parasitic Jaegers (*Stercorarius parasiticus*) and Glaucous-winged gulls (*Larus glaucescens*). All of these predators were present on the nesting grounds prior to 1964, however, their numbers apparently increased dramatically after the earthquake. Early reports (Olson 1954, Trainer 1959) suggest that both brown bears and coyotes were uncommon on the coastal nesting grounds in the 1950s. By the 1980s, brown bear density on the nesting grounds had increased to an estimated 1 bear/3-4.6 mi^2 (Campbell and Griese 1987). Based on harvest records and observations, coyote numbers on the nesting grounds have also increased considerably since the earthquake (Shepherd 1966, Campbell and Griese 1987). Glaucous-winged gulls and parasitic jaegers, both of which were the primary predators on goose nests prior to the earthquake (Trainer 1959) have increased in number since 1964 also. Patten (19__) estimated that the glaucous-wing gull colony on the barrier islands of the Delta was growing at the rate of 3% annually in 19__.

Factors Affecting Brown Bear Predation on Nests

The primary influence on dusky nesting success appears to be environmental. As is the case with other populations of geese nesting in northern latitudes (McEwen 1958, Barry 1962 and 1967, Upenski 1965, Ryder 1970, MacInnes et al. 1974) spring weather affects nest success on the Delta with nest success typically being higher during springs with mild weather and early "break-up." However, at the current high level of nest predation, this influcence is apparently on how the major nest predator, the brown bear, uses the Delta in May and June rather than on the nesting biology of the geese. Weather had no discernible influence on nest success on portions of the nesting grounds such as Egg Island where bears are absent.

While the exact mechanism(s) by which spring phenology influences the timing and magnitude of nest predation by brown bears are not known, they undoubtedly involve factors that influence how the wide ranging, opportunistic omnivore uses the coastal delta in the spring. The arrival of female bears with offspring and immature animals, both of which are primary nest predators (Campbell 1986 and 1987b), on the nesting grounds appears to be closely associated with leaf emergence and may reflect the availability of preferred plant food items. Wielgus (1986) found that spring movements by female bears were closely tied to the availability of plant food items, and Quimby and Snarski (1974) and Atwell et al. (1980) demonstrated that the availability of lush sedge/forb meadows, one of the predominant habitat types on the Delta, affected seasonal home range use. In addition to the availability of preferred dietary items, it is possible that female bears with offspring and immature animals move onto to the coastal delta in the spring for security. Because adult male and estrus female bears are not as common on the nesting grounds (Campbell 1986 and 1987b), the security of family groups and immature animals may be greater there. Security from conspecifics is known to have an influence on seasonal home ranges and habitat use of brown bears in other areas (Pearson 1975, Gebhard 1982, Nagy et al. 1983, Knight et al. 1986).

Unfortunately, the possible factors affecting the timing of brown bear movement onto the nesting grounds do not explain why the magnitude of nest destruction varies annually according to spring phenology. Because bears are opportunistic predators and take nests in all habitat types at about the same rate as they are available, annual variation cannot be attributed to weather influenced changes in habitat preference by foraging bears. It is possible that annual variations in predation rates reflect the level of cover development at the nest. During "late" springs, nests frequently have little or no cover and are quite conspicuous. This may make nests easier to visually locate plus, due to their conspicuousness, geese on nests may be uneasy and flush more readily, attracting foraging bears to nests.

Regardless of the mechanisms that determine timing and magnitude of nest predation by bears, recognition of the relationship between spring phenology and the magnitude of nest destruction by brown bears, independent of habitat, is important. This relationship must be considered during the development of any population or habitat management schemes designed to improve goose production.

Factors Affecting Coyote Predation on Nests

The level and distribution of nest predation by coyotes is independent of spring phenology and habitat, but likely reflects the influence of the prey base variety and availability on coyote foraging strategies. A relationship between the availability of buffer prey species such as lemmings or microtines and nest predation is known to exist in other waterfowl nesting areas (Angstadt 1961, MacInnes 1962, Barry 1967, Eisenhauer and Kirkpatrick 1977, Summers and Underhill 1987) and apparently occurs on the Delta. A strong, negative correlation (R=-0.89) between the number of microtines captured per unit of trap effort on assessment traplines on the Delta and coyote predation on geese as measured through systematic carcasses and kill site counts on the study plots exists (Table 17). This suggests that, during years when alternative prey is available, coyotes opportunistically take geese and nests as they are encountered. However, during years when alternative prey is limited, nesting geese may become the primary food source and are not only actively hunted, but preferred over eggs. Evidence of this was found in 1986, a year when alternative prey was scarce. In several cases, geese were killed at nest sites by coyotes, but eggs were left undamaged.

The availability of buffer prey species probably also explains the increase and wane in coyote predation on Egg Island during 1982-86. Even though the availability of alternative prey species was not quantified, microtine sign and observations indicated a relatively

Table 17. Alternative prey species abundance, as determined from assessment traplines, goose carcass counts, and nest destruction by canids on the mainland goose nesting study plots, Copper River Delta, 1983-87.

Year	Assessment line trap hours	Microtines captured	Capture Index (captures/hrs.)	Goose carcasses	Nest destruction by canids (%)
1983	2,304	31	0.01346	3[1]	17.1
1984	1,849	25	0.01352	4	26.7
1985	3,000	4	0.00133	17	27.0
1986	3,125	2	0.00064	34	13.4
1987	1,621	26	0.01604	15	11.8

[1] Incomplete count, based on incomplete field notes.

high and steady microtine population on the island between 1982-86. It is likely that, as microtine populations declined on the mainland, coyotes foraged more widely and were attracted to Egg Island by the stable prey base. The consequent build-up of coyote numbers on Egg Island resulted in an increase in predation on nests and geese. This condition continued until 1987 when microtine populations rebounded on the mainland and predation by coyotes on Egg Island dropped off (ADF&G unpubl. data).

Factors Affecting Avian Predation on Nests

The post-earthquake increase in avian nest predators would suggest that avian predation would be high, but this does not seem to be the case. The apparent low predation by relatively abundant parasitic jaegers and glaucous-winged gulls, both of which are known serious predators on goose nests (Angstadt 1961, MacInnes 1962, Barry 1965 and 1967, Mickelson 1975), may be due to either changes in their foraging habits on the Delta or to heavy predation by mammals masking avian predation. The latter is likely since avian predators typically raid nests while the goose is absent and destroy one egg at a time. The subtle evidence of such predation are lost when the eggs and nest bowl are destroyed by large mammalian predators. The potential impact of avian predators on goose nests is demonstrated on Egg Island where, in the absence of extensive nest predation by brown bears, they are the major nest predator.

Based on the work of others (Hanson and Browing 1959), the distribution of nest predation by avian predators could be related to habitat on the Delta. Bromley (1976) speculated that avian predators would be more active in habitats preferred by nesting geese, i.e. shrub habitats plus grass/forb habitat on Egg Island, due to the greater density and subsequent availability of nests. Though not strong, such a relationship apparently existed on the mainland Delta. A slightly higher rate of destruction was observed in shrub habitats, but may have resulted from the masking effect of mammalian predation skewing these data. On Egg Island, where nest destruction and supposed masking of avian predation by large mammals was less severe, avian predators preferred to forage in low shrub habitat where nests were abundant.

Because of its effects on the energetics of nesting geese, spring phenology would also be expected to influence the magnitude of nest predation by avian predators. "Late" springs place nesting geese under additional energy demands (Bromley 1984) which require more frequent or longer absences from nests to feed. These extended or frequent absences make the nest more vulnerable to avian predators. However, little evidence of a relationship between the magnitude of nest destruction by avian predators and spring phenology is demonstrated. Again, the apparent lack of a relationship may be due to the masking effect of heavy predation by large mammals, but, on Egg Island where nest destruction by large mammals and, presumably, the masking effect was low there was also no relationship between the magnitude degree of nest predation and spring phenology.

RECOMMENDATIONS

One of the primary objectives of this investigation was to identify possible habitat management actions based on habitat availability and use of preferred habitats by nesting geese and predators. Brush removal and control has been identified as a possible means of habitat enhancement (Campbell and Griese 1987). However, based on the results of this investigation, it may not be effective to improve goose production. The objectives of habitat enhancement through brush removal and control would be to either increase the availability of preferred nesting habitat for the dusky goose or to reduce the attractiveness of existing habitat to nest predators. The first objective is not applicable since geese currently prefer shrub habitats, including tall shrub, for nesting even though other types are readily available. The second is not valid because there is apparently little direct relationship between nest site selection and rates of nest destruction by either of the large mammalian predators. Brown bear opportunistically take nests as they are encountered with no preference for habitat types and coyotes appear to be more dependent upon prey availability than habitats available for foraging.

This is not to say that shrub cover in general does not influence nest predation, it is very likely that the extensiveness of shrubs across the delta attracts and provides cover for bears and coyotes, but that it would not be effective to do small scale enhancement for nest sites or practical to do enough enhancement to remove the basic cover function attracting predators. Both mammalian predators have relatively large seasonal home ranges. Female brown bears with offspring and immature bears, range over an average 46.6±26.3 mi^2 area in the spring (Campbell et al. 1987) while coyotes probably range over several square miles. In a review of home-range sizes for coyotes, Laundre and Keller (1984) present spring home ranges for coyotes that range from 10.2 km^2 for a female with pups to 48 km^2 for a male assisting with the rearing of pups. To effectively influence seasonal foraging patterns of these predators, large portions of the delta would have to be cleared of brush.

Other types of habitat enhancement that are currently being considered or tested include artificial nesting islands and artificial nesting habitat development on the the mudflats exposed by the 1964 earthquake. Islands are a created habitat type that does not occur naturally and it is yet to be determined how dusky geese will adapt to them or how effectively they will repel predators. It may be that islands will not affect foraging patterns of the predators, or, since both brown bears and avian predators respond to visual cues in their environment, they may attract predators. Because of the dusky's preference for low shrub habitat for nesting, emphasis should be placed on developing such habitat. To minimize the "visual obviousness" of nesting habitat to predators, efforts should be placed on developing scattered stands of low shrubs rather than the more visible stringers of low shrub or stands of tall shrub. It is important that managers be aware that all three major nest predators are currently active on the mudflats. Given their mobility, large home ranges of the two mammalian predators, and the opportunistic foraging pattern of the major predator, it is difficult to assess whether nest destruction will be significantly lower on the newly developed habitat without some predator population management or predator behavior modification.

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