

Response of Brant and Other Geese to Aircraft Disturbances at Izembek Lagoon, Alaska

FINAL REPORT



U.S. Fish and wildlife Service
Alaska Fish and wildlife Research Center

RESPONSE OF BRANT AND OTHER GEESE TO
AIRCRAFT DISTURBANCE AT IZEMBEK LAGOON, ALASKA

Final Report

by

David H. Ward

Robert A. Stehn

U.S. Fish and Wildlife Service
Alaska Fish and Wildlife Research Center
1011 East Tudor Rd
Anchorage, Alaska 99503

Submitted to:

Minerals Management Service
Outer Continental Shelf Region
949 E. 36th Avenue
Anchorage, Alaska 99501

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EXECUTIVE SUMMARY

Effects of increased aircraft disturbance and other disturbances on Pacific black brant (Branta bernicla nigricans) and other geese were studied at **Izembek** Lagoon, Alaska. Each fall from September to November nearly the entire Pacific Flyway population of 130,000 brant flies to **Izembek** Lagoon and feeds on eelgrass (Zostera marina) to accumulate fat reserves for non-stop transoceanic migration to wintering areas as distant as Mexico. In 1984, helicopters based in Cold Bay frequently flew over **Izembek** Lagoon to support offshore oil exploration activities in the North Aleutian Basin. Brant, Canada geese (Branta canadensis taverneri), and emperor geese (Chen canagica) were observed to interrupt foraging behavior and take flight in response to helicopters. Disturbance caused by aircraft overflights may be harmful to brant.

Spatial distribution, foraging ecology, and normal behavior of brant were determined by extensive field observations made each fall from 1985 to 1988. Response of flocks to aircraft overflights and noise produced by aircraft were also quantified. Behavioral and physiological data were integrated into a model to explore the potential impact of disturbance on the energetic requirements of fall staging brant.

At least 10% of the total population of brant were present at **Izembek** Lagoon between 28 August and 20 November. Although 17% of the brant were counted in adjacent lagoons, these areas do not contain adequate habitat to provide alternative staging areas for most of the population. Duration of stay for individual brant averaged 54 days. Brant used the entire lagoon but were mostly (>40%) concentrated in the southern section. Distribution of brant within nearshore areas was most influenced by tide stage and date. Overflight corridors directly crossing the lagoon between Grant Point and Round Island, coincident with an extension of the present IFR (Instrument Flight Rules) corridor, would pass over fewer birds compared with most other corridors.

Eelgrass composed 99% of the diet of brant. Entire leaves were found in esophageal contents. Brant selected shorter and narrower leaves compared to the average size of eelgrass in the lagoon. Foraging areas had plants with higher levels of carbohydrates compared to similar plants from other areas. With dry weight consumption per bird estimated at 270 g per day, total forage consumed by the entire population in the fall would be 1.8% of the standing stock of eelgrass. However, the

availability and abundance of eelgrass plants of suitable size and nutritional quality were restricted by location and tide stage. Foraging conditions deteriorated as the season progressed.

Time and activity budgets of brant during undisturbed conditions provided the baseline for evaluations of added disturbance. Tide height influenced brant behavior and use of **eelgrass** beds and roosting areas at **Izembek**. When observed nearshore during low and flooding tide stages, undisturbed brant spent about 85% of their time foraging. At high tide about half the birds moved to non-vegetated roosting areas on shallow sand flats inside the barrier islands. While at roost sites brant were mostly engaged in resting (51%) and maintenance (42%) behaviors. Over 24 hours, brant spent 46% of their time in foraging, 23% in maintenance, 27% at rest, 2% in alert posture, and 1.3% in flight behaviors.

Response to disturbance usually involved alert behavior followed by flight. After landing, brant remained alert, shifted positions, and engaged in maintenance behavior before they resumed foraging. In 1,912 hr of daylight observations, rate of potential incidental disturbance events occurred at **1.07/hr**. Aircraft (**0.57/hr**) and persons on foot (**0.08/hr**) were the most frequent human-related disturbances, and bald eagles (**Haliaeetus leucocephalus**) (**0.25/hr**) the most frequent natural cause. The entire brant flock responded to 48% of all detectable events and took flight in 35%. Of all incidental disturbances, bald eagles and boats elicited the greatest magnitude of response in flocks of brant. Canada and emperor geese responded most to bald eagles and persons on foot. Incidental aircraft caused the least response in geese; however, response was highly dependent on aircraft type and proximity to the flock. Using data grouped by altitude and lateral distance to the flock, brant and emperor geese reacted similarly to different types of aircraft, and were more responsive than Canada geese. Depending on stimulus type, average duration of response for brant ranged from 1 to 4 minutes with about half that time spent in flight. An average of 89 seconds per hour, 2.5% of the total daylight time, was spent responding to incidental disturbance events of all types.

Experimental flights by aircraft along planned flightlines allowed precise determination of aircraft altitude and lateral distance to the flock. Multiple regression on the logistic transformation of the proportion of birds responding determined a best fit equation that provided three-dimensional surfaces relating brant response to aircraft altitude and lateral distance for each aircraft type. The percent response by flocks was least with the Piper Navajo twin-engine aircraft and greatest for the Bell 205 helicopter. In contrast to **fixed-wing** aircraft, the response of brant to helicopter overflights

did not diminish with increasing altitudes up to 610 m (2,000 ft) .

For various categories of aircraft altitude and lateral distance, the degree of behavioral response of brant was correlated with noise levels measured for each aircraft type. Assuming a linear relationship between percent response and maximum noise level, the threshold noise level would be 49 dB for alert response and 58 dB for flight response. These levels are considerably below any other levels reported in the literature for other species. The behavioral response of brant and measured noise level both increased as the Bell 205 helicopter flew at greater altitudes at 1.6 km lateral distance. This provided evidence that noise rather than a visual cues triggered the behavioral response.

A model was developed to evaluate the potential impact of disturbance on the energetic requirements of brant. The model accounted for the average weight gained by adult male brant during a 54-day fall staging period at **Izembek**. For each additional aircraft disturbance that occurred daily throughout this time period, the predicted total weight gain would be reduced by 7.4 g. The loss of 7.4 g of lipid was equivalent to energy expended in 53 minutes or 73 km of migratory flight. Ten daily disturbances reduced body weight by 4% from the expected departure weight at **Izembek**. With 45 to 50 daily disturbances, the model predicted that brant would not gain any weight at **Izembek**. If brant are able to compensate for the foraging time lost due to disturbance, energetic balance would likely be restored as predicted weight gain was sensitive to any increase in total forage intake. A 10% increase in average forage intake caused a 34% increase in weight gain and a 2.25 fold increase in number of disturbances tolerated.

The lack of precise data on maximum forage intake, behavioral compensation, or habituation to overflights prevented conclusive statements on specific levels of disturbance that would be detrimental to brant. Rather, the model permits wildlife managers an opportunity to understand the magnitude of disturbance effects in relation to behavioral change and expected weight gain necessary for migration.

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Many people helped us complete this study. In particular, we would like to thank biologists from the Alaska Fish and Wildlife Research Center (**AFWRC**) who made careful observations and collected data under often adverse conditions in the field. They are Cal Lensink, Andre Loranger, Paul Flint, Eric Taylor, Mark Wotawa, Lee Tibbitts, Karen **Kincheloe**, Michael North, Peggy **Books-Blenden**, Dawn Breese, and Mike Anthony. We especially thank Dirk Derksen (**AFWRC**) for his key role in all aspects of the study.

Izembek National Wildlife Refuge (**INWR**) staff made important contributions: John Sarvis and Chris Dau conducted aircraft overflights and surveys, Robin West and Mike Blenden helped with overflight logistics and communication to remote sites, Mark Chase and Frank Dunn provided day-to-day assistance, and Annette Alexander and Shirley Simpson helped with communication and procurement.

We thank MMS personnel **Cleve Cowles** and Joel Hubbard for their assistance in the field, and Jerry **Imm** and Bob Meyer for their cooperation and support throughout the study. US FWS personnel William Butler, Rodney King, Margaret Petersen, and William **Eldridge** conducted aerial surveys that are cited in the report. Paul Schemer, Mike White, Brian Hoover and staff of Construction Engineering Research Laboratory, Champaign, IL, provided technical assistance for operation of acoustical equipment and interpretation of data.

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CHAPTER 1: INTRODUCTION

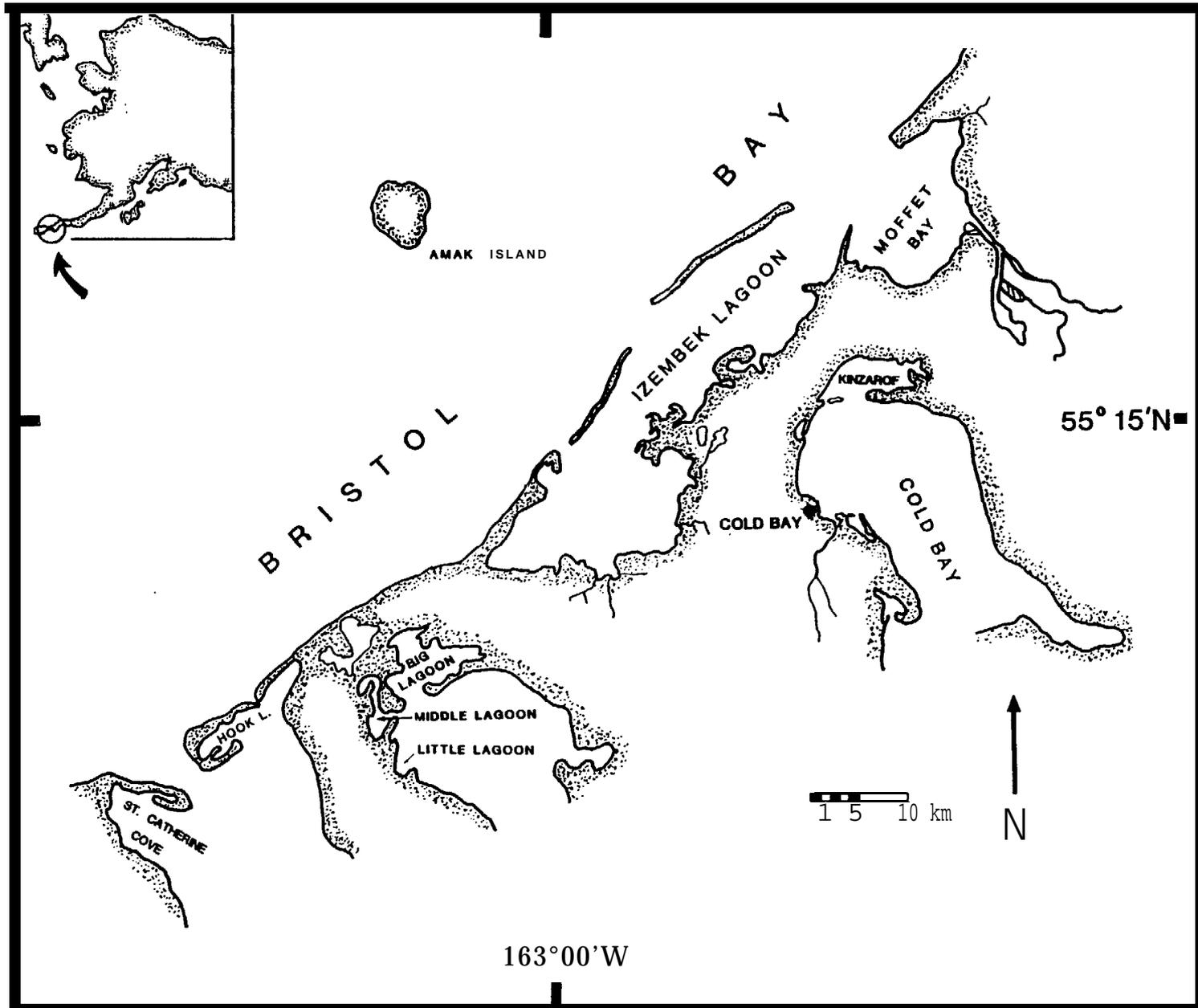
Every fall and spring, Pacific black brant (*Branta bernicla nigricans*) fly to **Izembek** Lagoon near the western end of the Alaska Peninsula (Figure 1.1) (Hansen and Nelson 1957, Bellrose 1976). **Izembek** Lagoon contains one of the largest beds of eelgrass (*Zostera marina*) in the world (**McRoy** 1970a). Brant feed almost exclusively on this intertidal seagrass prior to continuing their migration to breeding or to wintering areas (Jones in Palmer 1976). **Izembek** Lagoons critical importance to brant and other avian populations led to the establishment of **Izembek** National Wildlife Refuge (**INWR**), **Izembek** State Refuge, and designation as a wetland of international importance under the **RAMSAR** (International Union for the Conservation of Wetland Habitats) convention.

After migration from wintering areas along the Pacific coast of North America, brant acquire fat and protein reserves during spring staging at **Izembek** Lagoon. Adequate reserves are important for egg production and for energy during incubation (Barry 1962, Ankney 1984). Accumulated fat can be a major determinant of reproductive success in geese (Ryder 1970, Raveling 1979). Heavier than average brant (*B.b. bernicla*) have an increased probability of returning the following fall with young, based on a study on spring staging grounds in western Europe (**Ebbinge** et al. 1982).

During fall, brant return to **Izembek** to gain necessary fat reserves before undertaking transoceanic migration to wintering grounds. Stored lipids are the primary fuel for long distance flight in birds (King 1972) and a determinant of the distance a migrant can fly without stopping (**Blem** 1976). Most brant fly directly from **Izembek** to the west coast of Mexico (Kramer et al. 1979), a flight of at least 5,000 km (3,100 mi) that is accomplished in about 60 hours (Kramer 1976, **C.P. Dau**, **USFWS**, unpubl. ins.).

In fall of 1984 staff of **INWR** observed flocks of brant, **Taverner's** Canada geese (*Branta canadensis taverneri*), and emperor geese (*Chen canagica*) fly in response to helicopters that crossed the lagoon (J. Sarvis and **C.P. Dau**, pers. comm.). Helicopter overflights were associated with Outer Continental Shelf (**OCS**) petroleum exploration in the North Aleutian Basin. Increased levels of disturbance may be harmful to brant. Other studies have shown displacement of waterfowl from feeding areas (Owens 1977, Kramer et al. 1979, Henry 1980, **Belanger** and Bedard 1989) or reduction of foraging efficiency and feeding time (Davis and **Wiseley** 1974, Simpson et al. 1980). If brant spend less time feeding, or if caloric expenditure increases due to additional flight, rates of fat deposition and storage of critical nutrients may be reduced.

Figure 1.1. Location of Izembek Lagoon including Moffet Bay, Kinzarof Lagoon, Big, Middle and Little lagoons, Hook Lagoon, and St. Catherine Cove on the Alaska Peninsula.



Even though petroleum exploration and development activities are not occurring due to Congressional action, they may be expected to increase near **Izembek** Lagoon if Congress reverses its decision and permits exploration and development on leases from the 1988 sale. The existing 3,170 m (10,400 ft) runway at Cold Bay will likely be used in support of petroleum industry facilities. Additional aircraft traffic, particularly helicopters, is anticipated because of a U.S. Coast Guard search and rescue station which has been proposed for Cold Bay.

The location of oil industry or Coast Guard support facilities at Cold Bay would bring an increased human population and increased recreational activities such as hunting, boating, and aviation on or near the lagoon. Harassment and disturbance by hunters, boaters, and fishermen were related to displacement of wintering populations of brant that used the bays in California, Oregon, and Washington during the 1950s and 1960s (Denson and **Murrell** 1962, Einarsen 1965, Chattin 1970, Smith and Jensen 1970, Henry 1980). Appropriate management will be necessary to minimize the potential detrimental effects of development and increased human activity on the geese that use this critical staging area.

This report presents the results of research conducted at **Izembek** Lagoon from 1985 to 1988 by the Alaska Fish and Wildlife Research Center of the U.S. Fish and Wildlife Service (**USFWS**, Region 8). The study was funded by the **USFWS** (Region 8) and Minerals Management Service (**MMS**, Alaska Outer Continental Shelf Region). Additional support and essential cooperation were contributed by **Izembek** National Wildlife Refuge (**USFWS**, Region 7) and the Office of Migratory Bird Management (**USFWS**, Region 7). This research had the following objectives:

- 1) determine the effects of aircraft overflights and other human activity on the behavior, distribution, and habitat use of **brant**, Canada, and emperor geese,
- 2) examine noise levels associated with aircraft overflights and determine whether the behavioral response of geese is influenced by noise, and
- 3) evaluate the potential impact of disturbance on the energetic requirements of staging brant.

APPROACH

The approach used to study the effects of disturbance to brant and other geese at **Izembek** Lagoon was based primarily on field observations. Observations were made to understand the

behavior of brant under natural conditions at **Izembek**. Individual flock responses to specific disturbance events were quantified. These data were used in an energetic model of the relevant time and energy parameters for brant to explore the implications of different frequencies of disturbance.

Potential changes in behavioral time and energy budgets were considered to be more important than possible physiological stress associated with disturbance. The momentary alert response observed in flocks of geese may also reflect prolonged changes in heart rate (Thompson et al. 1968), hormone release, or shifts in metabolic function (**Manci** et al. 1988). Quantitative data on these physiological changes were not available, however, so behavior was used to evaluate potential impacts. Such behavioral measures have been used in similar disturbance studies (Ward and Sharp 1973, Davis and **Wiseley** 1974, Owens 1977, Simpson et al. 1980, Brackney et al. 1986, Derksen et al. 1989; see literature reviews by **Dahlgren** and **Korschgen** 1988, Herter and **Koski** 1988). Assumptions made in using behavior to evaluate disturbance at **Izembek** Lagoon included: a) that alert behavior only causes a momentary loss of feeding time and a brief increase in metabolic rate rather than prolonged physiological changes, b) that flight responses are considerably more costly than alert responses, and c) that loss of feeding time or increased energetic costs due to flight will become more important in an additive fashion as the frequency of disturbance increases.

This study was conducted during a time of relatively infrequent human disturbance. From 1985 to 1988 no helicopters were based at the Cold Bay airport in contrast to the frequent helicopter traffic present in 1984 to support offshore petroleum exploration activities. Commercial aircraft that used the **Cold** Bay airport were Boeing 727 jets, NAMC **YS-11A** and Lockheed Electra turboprops, single-engine Piper Cherokees, and twin-engine Piper Navahos. Coast Guard helicopters and cargo planes occasionally stopped at Cold Bay. Human recreational use of **Izembek** Lagoon was reduced from previous years. Sport harvest of emperor geese was closed in 1986, brant and northern pintail (**Anas acuta**) bag limits were reduced, and the number of waterfowl hunters traveling to Cold Bay declined. On occasion, one or two small boats used the lagoon.

Aircraft disturbance was experimentally introduced to address certain research objectives. Controlled overflights were made with several types of fixed- and rotary-wing aircraft. Large transport helicopters, such as the Bell 212 and 412 that typically have been used by the oil industry for transport of personnel and supplies to offshore platforms, were not used in this study because of the prohibitive cost. However, a large size Bell **205** helicopter and two types of small helicopters (Bell 206-B and Hughes 500-D) were chartered.

Emphasis of overflights was placed on determining average response levels of brant to different types of aircraft flown at varying altitudes and lateral distances to the flock. Helicopter availability and cost prevented the number of repeated overflights needed either to displace brant from specific areas of the lagoon or to habituate them over time to aircraft stimuli. Although some attempt was made to examine these questions, experimental overflights were not conducted with these goals in mind.

Work was concentrated in September and October, the fall staging period of brant. In fall, more birds are present for a longer period of time and their distribution allows better observations compared to the spring staging period. Behavioral response to aircraft disturbance at **Izembek** was assumed to be the same in spring as in fall. Qualitative observations in spring of 1986 and 1987 indicated flocks reacted similarly to aircraft as was observed of flocks in fall.

The majority of our data relied on an observational rather than an experimental approach. Statistically rigorous sampling designs were not always possible because weather conditions dictated when observations could be made. Nevertheless, in spite of sampling difficulties, patterns of brant foraging ecology and the birds' response to disturbance were determined by objective observations and large sample sizes.

The presentation of results is divided into 6 chapters.

2. ABUNDANCE, TIMING OF USE, AND DISTRIBUTION OF GEESE. Aerial survey and ground observations were used to determine the number of birds, timing of fall and spring staging, and spatial distribution of birds as functions of location, tidal stage, time, season, and year.
3. DIET AND NUTRITION. Brant and Canada goose food habits and foraging patterns are summarized. Chemical analyses of nutrients in eelgrass are presented.
4. BEHAVIOR. Patterns of undisturbed behavior are described and related to tide height, age of brant, and their location in the lagoon. An average behavioral time budget is derived.
5. BEHAVIORAL RESPONSE TO DISTURBANCE. The behavioral responses to aircraft and other potential disturbance stimuli are quantified. The probability for response is related to aircraft type, distance, altitude, and other factors.

6. ACOUSTICS OF **AIRCRAFT** OVERFLIGHTS. Acoustical measurements of noise levels are compared between aircraft types and" related to the behavioral responses observed in brant.
7. ENERGETIC COST OF DISTURBANCE. A time and energy budget model is used to predict energetic costs associated with the behavioral response to aircraft overflights. Disturbance response, pattern of undisturbed behavior, and nutritional requirements for maintenance and fat accumulation are integrated in terms of energy equivalents.

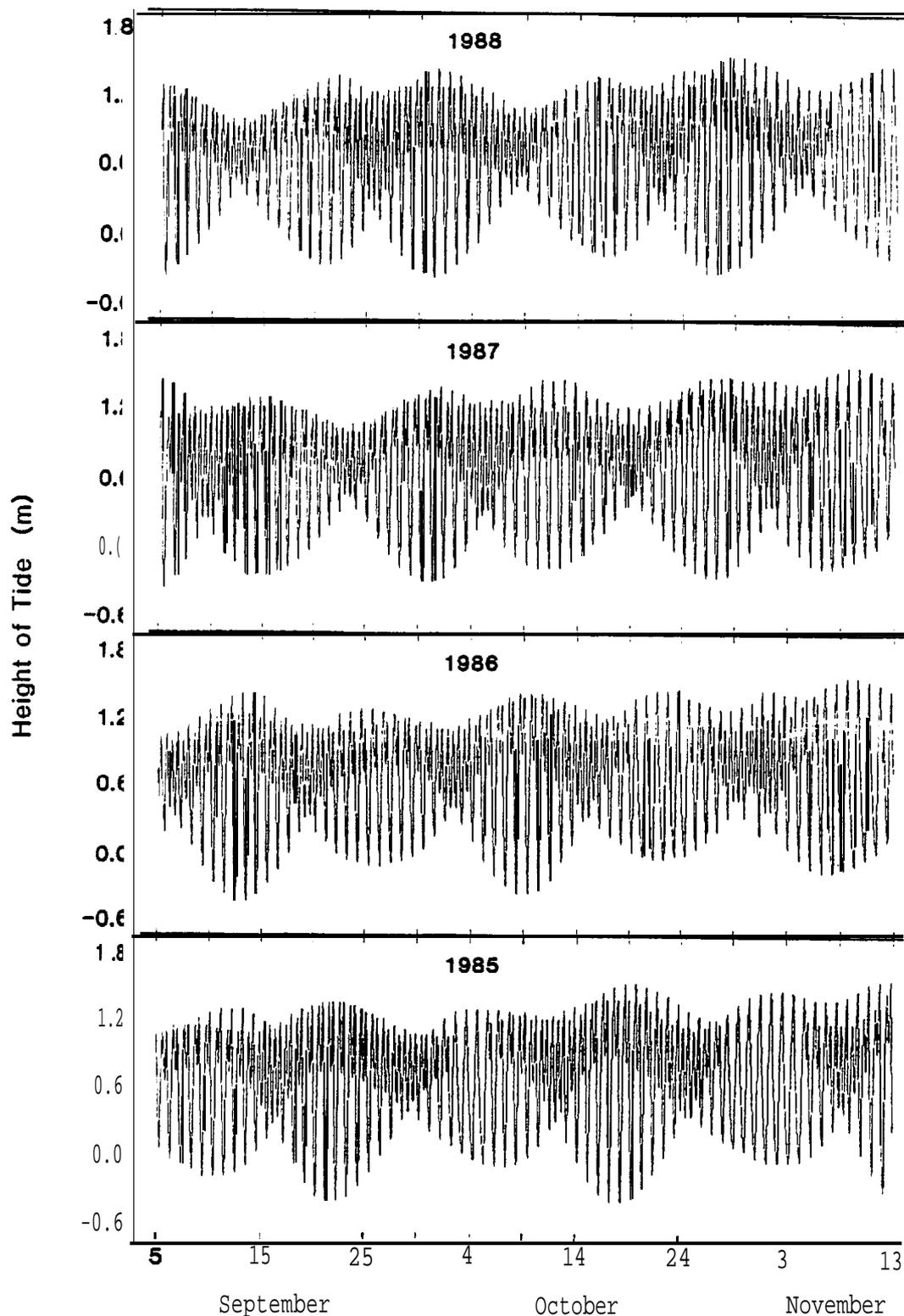
STUDY AREA

Izembek Lagoon lies on the north side of the Alaska Peninsula at 55° 15' N and 163° 00' W (Figure 1.1). The lagoon is a shallow water embayment opening to the Bering Sea at three narrow entrances between the enclosing barrier islands and spits. **Izembek** Lagoon is about 48 km (30 mi) long and 3-10 km (2-6 mi) wide. Approximately 78% of **Izembek** Lagoon is intertidal of which 68% is vegetated by eelgrass (Barsdate et al. 1974). Tides are both **semidiurnal** and mixed **semidiurnal** (Figure 1.2) with a maximum tidal range of 1.9 m (6.4 ft) and a mean range of 0.98 m (3.2 ft) [U.S. Department of Commerce (USDC) 1985, 1986, 1987, 1988]. Tide height is expressed in terms of the difference from the point of mean lower low water (MLLW= 0.0 m).

Eelgrass grows in both intertidal and subtidal areas. Intertidal areas are shallow, flat basins which protect eelgrass from the direct influence of strong tidal currents, diminish the action of wind and waves, and provide an ideal substrate for growth of eelgrass. These basins contain eelgrass with greater shoot density and shorter narrower leaf blades than eelgrass beds growing in subtidal areas (McRoy 1970a, Short 1981). At tides below 0.3 m (1.0 ft) most intertidal eelgrass beds are nearly drained or covered by shallow pools of water held back by slightly raised terraces. These beds are completely submerged when tides reach over 0.8 m (2.6 ft). At intermediate tide heights, eelgrass leaves remain within reach because the ends of the leaves **float** towards or on the water surface. Subtidal plants are often found along edges of the deeper channels in the lagoon and eelgrass can grow with leaves greater than 1.5 m in length.

Most annual growth of eelgrass occurs during late spring and early summer and is followed by senescence and sloughing of leaves in fall (McConnaughey 1977). Further information on ecology of eelgrass at **Izembek** Lagoon can be found in reports by McRoy (1966, 1970b), Barsdate et al. (1974), Dennison (1979) and Roth (1986).

Figure 1.2. Predicted heights of low and high tides at Izembek Lagoon, Alaska, from 5 September to 13 November of 1985-1988 (US Dept of Commerce 1985, 1986, 1987, 1988). Notice the changing pattern of mixed **semidiurnal** tides every two weeks from approximately equal to unequal heights. This occasionally produces only one tide change per day instead of the usual two cycles.



Topography adjacent to the lagoon varies from flat to rounded hills and ridges. Some areas have shoreline bluffs with elevations from 20 to 60 m. Dominant vegetation on shorelines and barrier islands is beach rye grass (*Elymus arenarius*). Tundra vegetation near the lagoon is variable ranging from wet grass-sedge meadows to sparsely vegetated rocky hilltops. The predominant mesic heath vegetation is mixed with many **herbaceous** species including a variety of berries that are eaten by Canada geese and sometimes by emperor geese.

Public use of the lagoon is primarily for recreation. Waterfowl hunting is most important and accounts for 25% of all use of the refuge (USFWS 1985). Although most of the annual waterfowl harvest (ea. 2,500 birds) is by local residents, the popularity of **Izembek** for hunting attracts non-resident hunters. Other activities in or near the lagoon include observation of wildlife from vehicles (22%), hiking (10%), fishing (9%), and boating (2%). The area is used primarily by residents of Cold Bay, a non-Native village of 150-175 persons situated 13 km to the southeast of the lagoon (Figure 1.1). The village of Cold Bay **is** connected to **Izembek** Lagoon by a road that provides year-round access to the lagoon by two-wheel drive vehicles. Other means of access to the lagoon include boats and wheeled aircraft that are permitted to land on flats of the barrier islands bordering the lagoon.

The climate of **Izembek** Lagoon is maritime but becomes more continental in winter when ice covers portions of the Bering Sea (McRoy 1966). Weather is characterized by high winds with a mean annual velocity of 27 **kph**. Moderate average monthly temperatures range from 4 to 13° C in summer and -2 to 2° C in winter. Low clouds, wind, and rain are typical with 83% average cloud cover for any 24-hr period in fall. Mean precipitation is 89 cm with most occurring as rain in fall. A summary of weather conditions in fall is provided in Appendix A for each field season from 1985 to 1988.

Izembek is not only important for brant but also serves as a staging area for migrating Canada geese. The primary component of the Canada goose population is a medium-sized subspecies, Taverner's goose, which breeds in western Alaska (Johnson et al. 1979). About 45,000 Taverner's Canada geese stage at **Izembek** during fall prior to migration to their wintering areas in Oregon, Washington and California (Johnson et al. 1979, King and Hodges 1979). Total population size of Taverner's Canada geese is not precisely known (**J. Bartonek pers. comm.**), but it is probably close to the estimate of 60,000 birds wintering in Oregon and Washington (**Jarvis and Comely 1988**). It has been suggested that the majority (75%) of the population uses **Izembek** Lagoon each fall (**Bellrose 1976**). Usually less than 100 cackling Canada geese (**B. c.**

minima) and occasionally Aleutian Canada geese (B. c. leucopareia) have been observed at Izembek (D.H. Ward and J. Hawkins pers. obs.) .

Emperor geese use **Izembek** Lagoon during migration in fall and spring. Recent peak counts have averaged about 6,000 birds in fall. A smaller wintering population of about 1,000 birds occurs within the lagoon and adjacent estuaries (Petersen and Gill 1982, C.P. Dau unpubl. data). The total population size of emperor geese is estimated to be 62,000 (as based on spring and fall surveys, 1984-1989) (R.J. King, USFWS, unpubl. data) .

In addition to geese, **Izembek** Lagoon is important for ducks, swans, seabirds, and shorebirds. The most common ducks are mallard (Anas platyrhynchos), American wigeon (A. Americana), green-winged teal (A. crecca), northern pintail, northern shoveler (A. clypeata), greater scaup (Aythya marila), and common goldeneye (Bucephala clangula). Pintails are most abundant, numbering over 25,000 in the fall. Large flocks of **Steller's** eider (Polystica stelleri) molt at **Izembek** in August (Petersen 1981). Returns of **Steller's** eiders banded at **Izembek** Lagoon suggest that the majority of the birds molting there breed in northern Siberia (Jones 1965). Other ducks that winter at **Izembek** include oldsquaw (Clangula hyemalis), white-winged scoter (Melanitta fusca), and black scoter (M. nigra). Tundra swans (Cygnus columbianus) nest at **Izembek** and in 1982 an overwintering population of 680 swans was counted.

Shorebirds nest adjacent to the lagoon and large numbers occur during spring and fall migration. Rock sandpiper (Calidris ptilocnemis), dunlin (C. alpina), and western sandpiper (C. mauri) are common. A complete list of birds known to use **Izembek** Lagoon and adjacent area can be found in annual reports provided by INWR. We provide a species list of all birds observed between 1986 and 1988 in Appendix B.

A variety of mammals use tundra habitats adjacent to the lagoon. Some of the more common species include caribou (Rangifer arcticus), brown bear (Ursus arctos), red fox (Vulpes fulva), porcupine (Erithizon dorsatum), arctic ground squirrel (Citellus undulates), long-tailed weasel (Mustela frenata), and tundra vole (Microtus oeconomus). Bears congregate along streams and the lagoon shoreline to eat salmon in September. The southern Alaska Peninsula population of 4,000 to 10,000 caribou uses portions of INWR as winter habitat. **Izembek** Lagoon provides feeding habitat, and the mudbars and sand spits are frequent haulout sites for sea otter (Enhydra lutris) and harbor seal (Phoca vitulina). An estimated 500 to 1,000 otters are known to use the lagoon which serves as a major nursery area for sea otter pups in the eastern Aleutians. The harbor seal population is estimated to be 2,500 to 5,000.

CHAPTER 2: ABUNDANCE, TIMING OF USE, AND DISTRIBUTION OF GEESE

The spatial and temporal patterns of habitat use by brant and other geese will determine in part the frequency of disturbance interactions if aircraft flights and other human activities increase at **Izembek** Lagoon. Data on such patterns could be used both to evaluate the likelihood for conflicts and to minimize the disturbance effects of aircraft overflights or other activities. Flight corridors could be positioned over those areas that are least used by geese, and time periods could be selected when overflights would have minimum influence. **Also**, these data could provide a basis for documenting **short-** and long-term displacement of geese away from currently used areas of the lagoon should activity increase in the future.

Counts of geese from aircraft provide information on the numbers and distribution of geese. Aerial surveys (since 1975) and shoreline observations (since 1957) of geese at **Izembek** Lagoon have been made by staff of **INWR** to monitor population change and provide age ratio data that indexes annual breeding success of brant (Jones 1964, 1970, **Voelzer** 1987). In recent years the continued slow decline in population size of brant (King and Derksen 1986, **Pamplin** 1986) has prompted more intensive efforts to monitor population trends not only in fall but also during winter and spring seasons.

We compiled all aerial survey data since 1975 to assess the abundance and distribution of geese for all seasons of use at **Izembek** Lagoon. In fall of 1987 and 1988 additional aerial surveys were flown to determine the chronology of migration and seasonal patterns of distribution at **Izembek** Lagoon. **Radio-**tagged brant in 1987 and 1988 provided information concerning the arrival, departure, and duration of stay of individual birds. Observations and counts made from shoreline points were used to examine the influence of year, tide, **season**, and time of day on the distribution and numbers of geese.

The objectives were four-fold:

- 1) define the time periods that are most important for geese,
- 2) determine if certain portions of **Izembek** Lagoon are more important than other areas,
- 3) evaluate factors that influence distribution of geese within **Izembek** Lagoon, and
- 4) compare use by geese of **Izembek** Lagoon with use of other adjacent lagoons to determine relative importance.

METHODS

Aerial surveys were flown by personnel from the Office of Migratory Bird Management and INWR to determine total number and distribution of geese between 1975 and 1988. Geese were counted during fall, winter, and spring seasons within the entire complex of **Izembek** Lagoon which included St. Catherine Cove, Hook Lagoon, **Kinzarof** Lagoon, and Little, Middle, and Big lagoons (Figure 1.1). Highest total counts during each season were used to determine population trends across years for each species. Mean numbers were calculated for brant when multiple surveys were conducted between 20 September - 24 October, 1 January - 1 March, and 21 **April** - 15 May, the periods when peak numbers of brant are present during fall, winter, and spring, respectively.

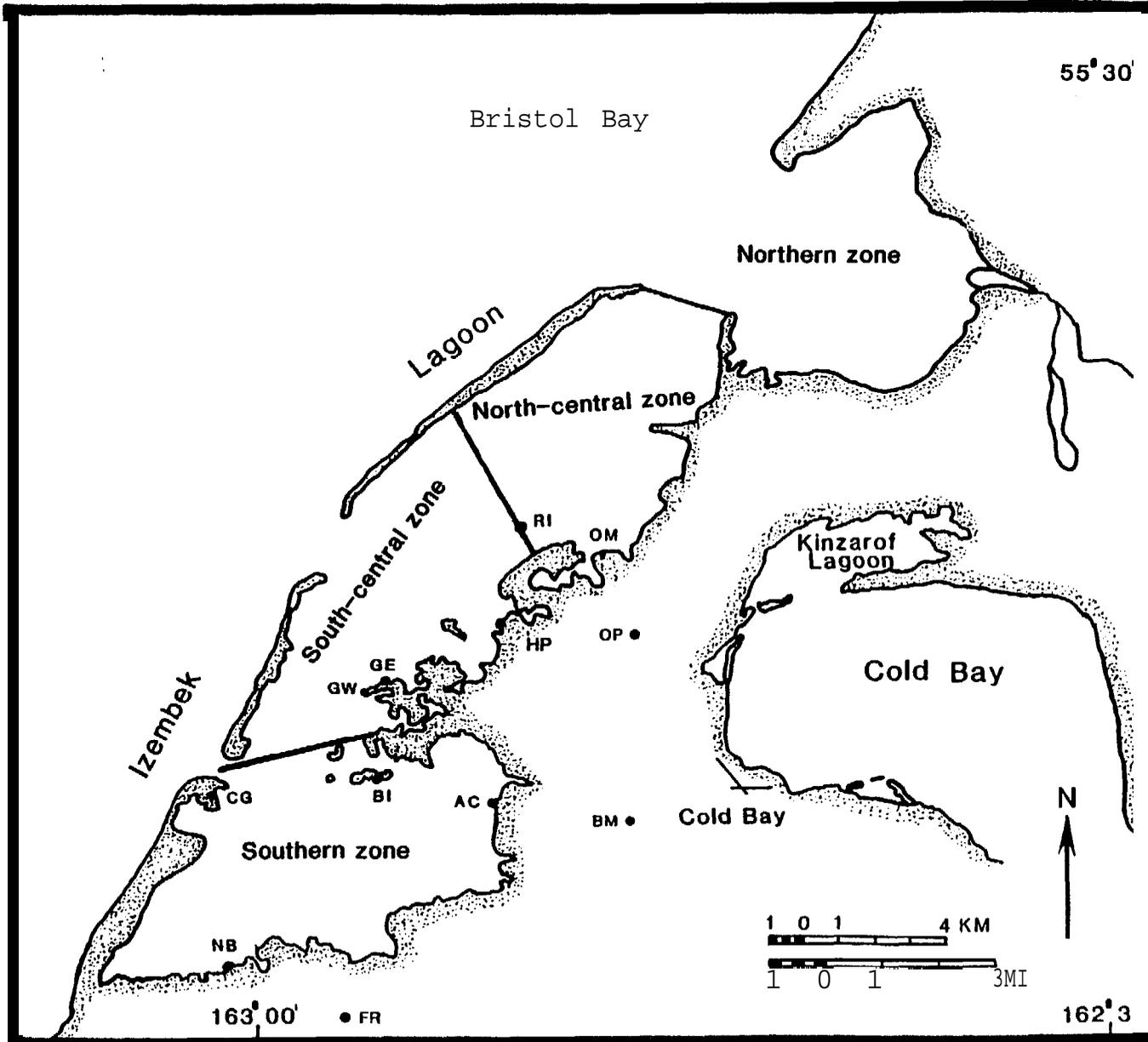
The pilot and a second experienced observer counted geese and recorded them within zones of the **Izembek** complex. Generally, surveys were flown to coincide with high tide within **Izembek** Lagoon, a period when brant are more concentrated and visible for counting (Conant et al. 1984).

Surveys were conducted from various single-engine aircraft between the altitudes of 61-91 **m** (200-300 ft) and air speeds of 155-165 **kph** (80-90 **kts**). The circuitous routes flown varied among surveys and pilots and depended on brant movements and distribution, but in all instances survey routes provided complete and systematic coverage of the area. On six surveys the regular observer or an additional observer mapped the location of all flocks. **Kruskal-Wallis** one-way analysis of variance (**SPSS** 1986) was used to test differences in the distribution of birds among zones.

Factors that influence diurnal distribution of geese were studied at specific study sites along the shoreline of **Izembek** Lagoon. Sites were selected for their abundance of geese, accessibility, and shoreline elevation to allow for maximum visibility of geese. Observation blinds were constructed and established at Applegate Cove (AC), Norma Bay (**NB**), Grant Point-West (**GW**), Grant Point-East (GE), Halfway Point (HP), Banding Island (**BI**), Round Island (RI), and Outer Marker (**OM**) (Figure 2.1).

Hourly counts were made from blinds 1-5 days per week and from sunrise to sunset for up to 12 hr per day. The field of view from a blind defined each study area. In most cases study areas were semi-circular extending to a distance of approximately 1.2 km (0.75 mi) from shore (Appendix C; Figure cl). Areas were delineated by buoys, natural landmarks, and tidal channels.

Figure 2.1. Location of observation blinds, telemetry stations, and distribution zones at Izembek Lagoon, Alaska, 1985-1987. Study areas included Norma Bay (NB), Applegate Cove (AC), Banding Island (BI), Grant Point-West (GW), Grant Point-East (GE), Halfway Point (HP), Round Island (RI), and Outer Marker (OM). Telemetry antennas included Baldy Mountain (BM), Frosty Road (FR), Cape Glazenap (CG), and Outpost #1 (OP).



Tide heights were measured at each study area by recording water levels on marked tide staffs or in the case of Grant Point by a gas-purged pressure recording tide gauge provided by NOAA (National Oceanographic and Atmospheric Administration) in 1987 and 1988. Tide flow and height were also estimated based on interpolation from the predicted tide tables at Grant Point (**USDC** 1985, 1986, 1987, 1988). Differences between actual and predicted heights at Grant Point were less than 0.2 m and the timing of predicted peak high or low water was usually within 15 minutes of observed (**D.H. Ward, unpubl.** data). To provide consistency among years, we used predicted flow and heights of tide in all analyses.

Multivariate analysis of variance (MANOVA, SPSS 1986) was used to test the influence of year, tide stage (flow and height), time of day, and date on the total number of geese present at each study area. Tide stage was categorized as low (<0.3 m), flood (0.3 to 0.9 m), high (>0.9 m), and ebb (0.9 to 0.3 m). Time of day was converted into three periods: early (<1230 h), midday (1230-1630), and evening (>1630). Date was categorized as early (<25 Sep), peak (25 Sep-8 Oct), and late (>8 Oct). Differences in the number of geese during different stages and heights of the tide were tested with one-way analysis of variance (ANOVA, SPSS 1986).

Female brant were nest trapped at the Tutakoke River colony on the Yukon-Kuskokwim Delta (**YKD**) in 1987 and 1988 and several areas in the western Canadian arctic in 1987. In 1988, nonbreeding or failed-breeders were captured at one molting area on the North Slope of Alaska near **Teshkepuk** Lake. Each bird was outfitted with a 26-33 g radio transmitter using a modified **Dwyer** harness (**Dwyer** 1972).

Tracking of radio-tagged birds at **Izembek** Lagoon occurred both from aircraft and ground locations. Radio telemetry antennas (4- or 5-element stacked, dual **Yagi**) were located at some shoreline blinds and established at additional ridge top sites on **Baldy** Mountain (**BM**), Outpost #1 (**OP**), and Frosty Road (**FR**) (Figure 2.1). Radio telemetry checks for all birds were made from **BM** and some other sites every day with a few exceptions beginning 3 September until 17 November in 1987 and 28 August to 15 November in 1988.

RESULTS

Timing and numbers

Brant

The first brant were observed at **Izembek** Lagoon during the last two weeks of August. The mean first arrival date was 21 August with a range of 5 to 30 August during our study. Most brant arrived in a three-week period from the first to the third week of September. In 1987, 62% of the fall population arrived during a 19-day period between 3 and 22 September (Figure 2.2). Arrival was about 7-10 days earlier in 1988 with 53% of the total number of brant immigrating before 12 September and 90% by 26 September (Figure 2.2). Numbers slowly continued to increase as brant from peripheral breeding areas arrived (Reed et al. 1989). Peak numbers were recorded by 9 October in 1987 and 3 October in 1988. Arrival of radio-tagged brant from the Tutakoke nesting colony on the YKD averaged 18 September in 1987 and 8 September in 1988 (Table 2.1). Arrival of YKD birds in 1988 was earlier than in 1987 (Mann-Whitney U test; $P < 0.005$).

The mean peak counts of brant ranged from a low of 115,200 in 1986 to a high of 143,100 in 1987. The peak count in 1987 was the highest since 1983 (137,200) (Figure 2.3) and was clearly related to extremely high nesting success (90%) of brant on the YKD (Yukon Delta N.W.R., **unpubl.** data) where approximately 33 to 50% of the Pacific Flyway brant nest (King and Lensink, 1971). The proportion of juveniles in the **fall** 1987 population at **Izembek** was 31% compared to 14% in 1985, 15% in 1986, and 19% in 1988 (**C.P. Dau, USFWS, unpubl.** data).

It has been speculated that the entire Pacific Flyway population of brant stages at **Izembek** each fall (**Bellrose** 1976, and others). We compared the peak fall counts of brant at **Izembek** from 1975 to 1988 to the number of brant on the Pacific coast midwinter waterfowl survey (**J.C. Bartonek, USFWS, unpubl.** data) and found that the number of brant did not differ significantly (paired t-test, $P > 0.90$) between the two counts (Figure 2.3). However, little correlation in annual variation existed between the two counts (1982-1988 data, $r = 0.02$, $P > 0.5$). Since 1982, the number of surveys conducted at **Izembek** has increased and the techniques for surveying have been improved.

Figure 2.2. Number of brant, Canada, and emperor geese counted during aerial surveys of Alaska's Izembek Lagoon and adjacent lagoons in fall of 1987 and 1988.

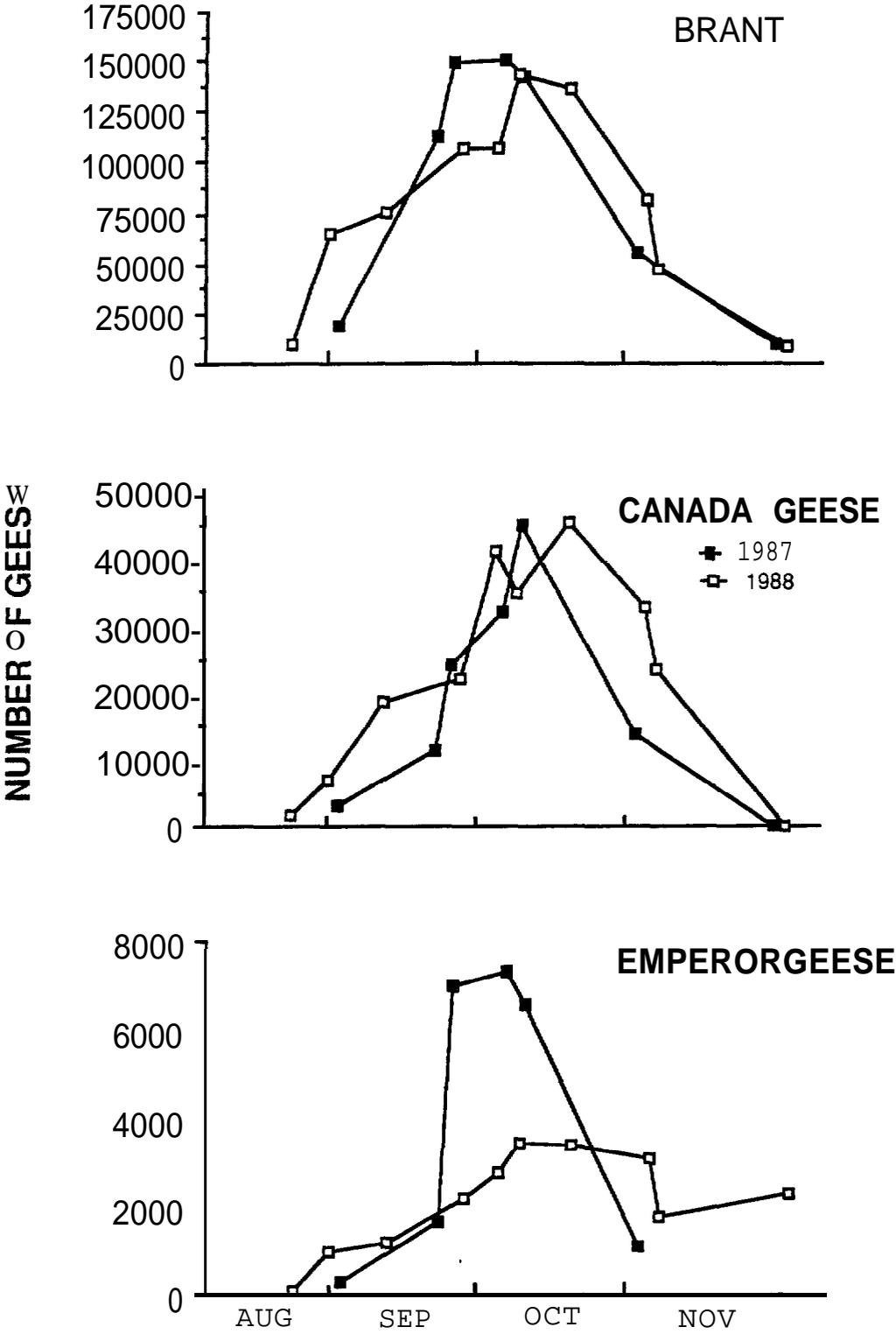
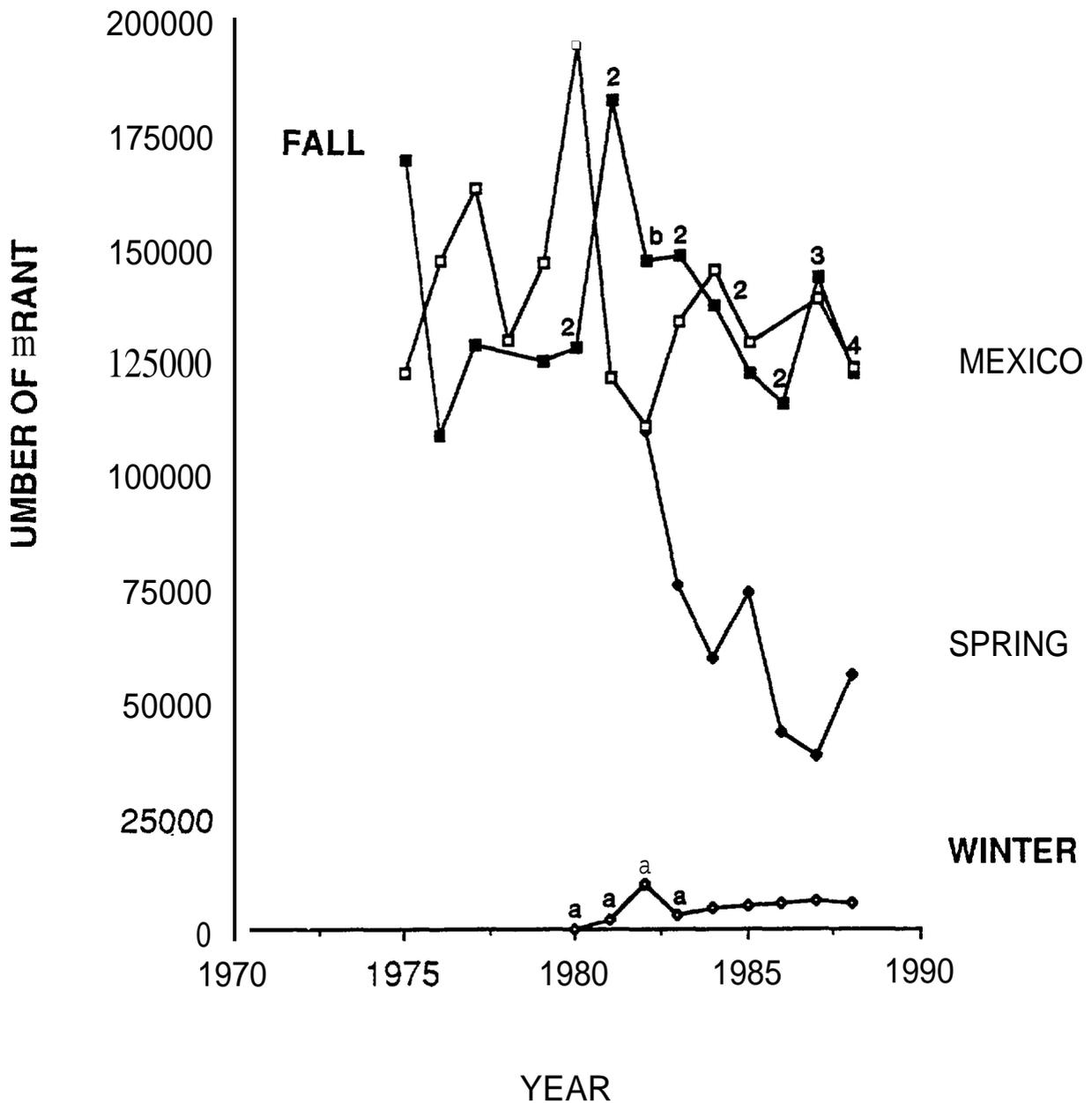


Table 2.1. Arrival and departure dates at Izembek Lagoon, Alaska, of radio-tagged brant marked on the Yukon-Kuskokwim Delta (YKD), North Slope (NS) of Alaska near Teshekpuk Lake, and on the western Canadian arctic (Canada) in 1987^a and 1988.

Year Breeding location	1987		1988	
	YKD	Canada	YKD	NS
<u>Date of arrival</u>				
Mean	18 Sep	2 Oct	8 Sep	5 Sep
SD	± 7	± 4	± 10	± 3
n	14	12	23	3
First	4 Sep	22 Sep	31 Aug	2 Sep
Last	3 Oct	8 Oct	8 Oct	7 Sep
<u>Date of departure</u>				
Mean	8 Nov	18 Nov	3 Nov	6 Nov
SD	± 9	± 4	± 9	± 4
n	9	8	22	3
First	23 Oct	6 Nov	20 Oct	1 Nov
Last	17 Nov	27 Nov	19 Nov	8 Nov
<u>Duration of stay in days</u>				
Mean	52	45	56	62
SD	± 12	± 9	± 11	± 5
n	9	8	14	3
Range in Days	37-68	29-56	29-71	57-67

^aData from Reed et al. (1989) .

Figure 2.3. Annual peak counts of brant using Alaska's Izembek Lagoon and adjacent lagoons during spring (●), winter (○), and fall (■), 1975-1988. Counts from annual midwinter surveys (a) of brant on wintering grounds are also included. Mean numbers were calculated for brant at Izembek when multiple surveys were conducted between 20 September and 22 October, the time when peak numbers of brant are present during fall. No survey was conducted at Izembek in fall of 1978. Because the timing of the Mexico survey was interrupted in 1987, it was not included. Number of multiple fall surveys listed above the mean count. **a** - count made from the ground. **b** - count includes only Izembek Lagoon.



First departures of brant were observed during the third week of October with a mean first departure date of 24 October with the range. from 20 to 30 October. In 1987 small flocks of 20-200 birds were observed at dusk and heard at night during each of the last 10 days of October. Most of the brant emigrated in two large movements of approximately 93,000 on 3 November and 31,000 birds on 5 November 1987. Departures of small flocks continued over the next two weeks. Similarly, in 1988 brant emigrated in small flocks during the last half of October with the largest number of birds, about 30,000, departing 2 and 3 November. Average departure of radio-tagged brant from the YKD was 8 November in 1987 ($n=9$) and 3 November in 1988 ($n=13$) (Table 2.1). In all years of our study over 90% of the fall population had departed by 1 December (**C.P. Dau pers. comm.**) .

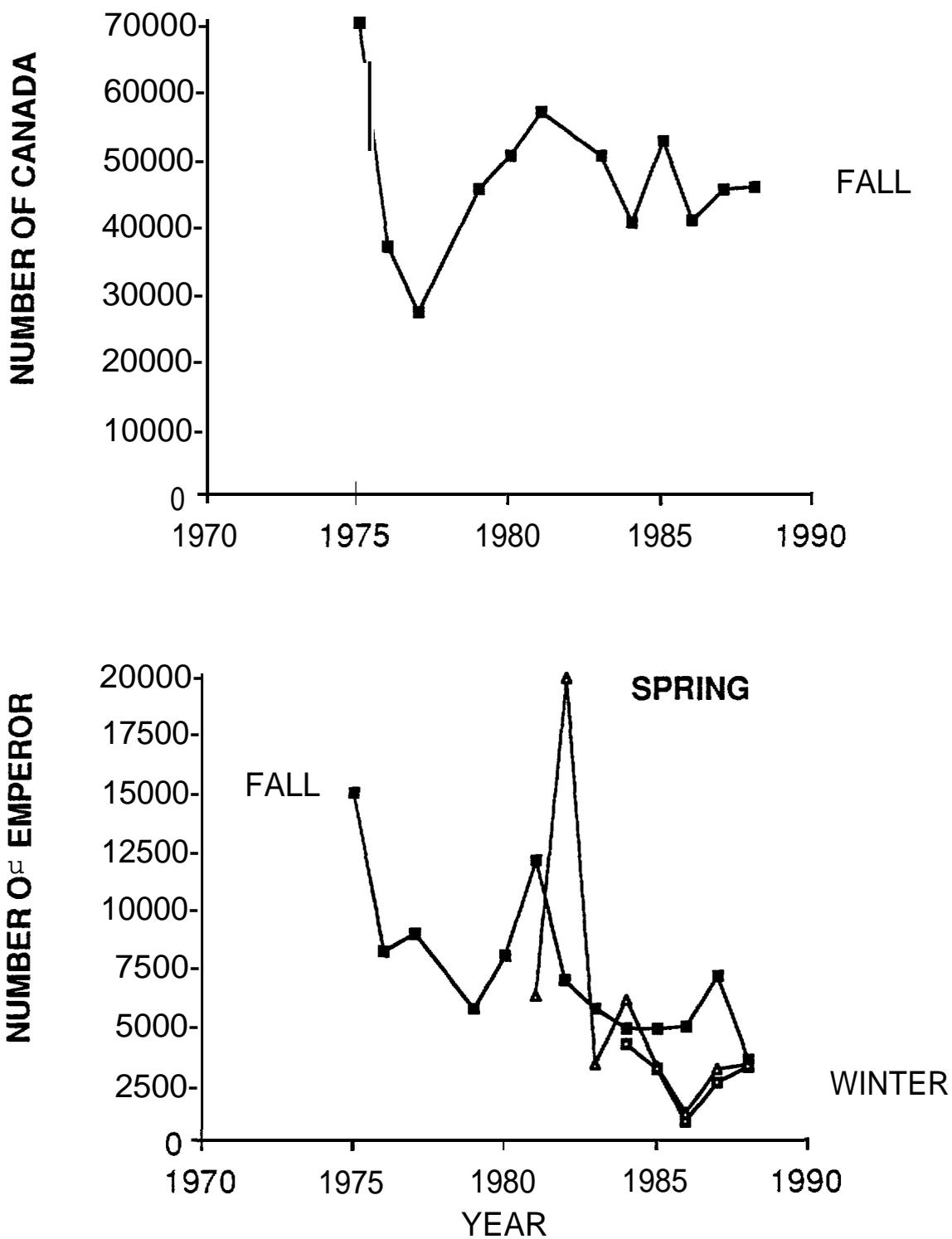
The duration of the period when at least 10% of the brant population was present at **Izembek** Lagoon was similar in both 1987 and 1988. Brant occurred approximately between 1 September and 23 November (83 days) in 1987 and between 25 August and 18 November (84 days) in 1988.

The duration of stay for individual radio-tagged birds from the YKD averaged 52 days in 1987 and 56 days in 1988 (Table 2.1). Brant from the Canadian arctic stayed slightly shorter (45 days) than YKD birds in 1987 and brant from the North Slope of Alaska stayed slightly longer (62 days) in 1988.

Since 1981 an average of 5,400 brant have overwintered at **Izembek** with counts ranging from a low of 2,100 in 1981 to 9,900 in 1982 (Figure 2.3). Prior to 1981, only about 100 brant wintered at **Izembek** (**C.P. Dau, pers. comm.**). Mild winters in the 1980s may have contributed to the increased number of winter resident brant.

The average spring arrival date for brant was 18 April (**C.P. Dau, USFWS, unpubl. data; n=8, SD=8 days**). During our observations of spring staging beginning 20 April 1987, more than 17,000 brant were already present. Small flocks of less than 300 brant each were observed arriving over Cold Bay every day from 20 April through 3 May. Arrivals continued for most days through the end of May. The number of brant present peaked at 41,100 by 29 April and levels remained between 30,000-40,000 for the next two weeks despite steady daily influxes of brant. On 18 May the population was reduced to 26,100 birds. The majority (**>90%**) of the total population had moved through the lagoon by approximately 20 June (**C.P. Dau pers. comm.**) . Small numbers of brant are sometimes observed at **Izembek** Lagoon in mid-June.

Figure 2.4. Annual peak counts of Canada geese and emperor geese at **Izembek** Lagoon, Alaska, 1975-1988.



Lower peak numbers of brant were counted during spring compared with fall (Figure 2.3) . Since 1985, the spring population of brant has ranged from a high of 74,000 in 1985 to a low of 40,500 brant in 1987. Overall number of brant in spring at **Izembek** Lagoon has markedly decreased since the first estimates in 1981. It is not known, however, to what extent this trend reflects a decrease in total population size, a decreased proportion of birds using **Izembek**, or an artifact of survey timing and the continuous turnover of brant through the area.

Canada geese

The first observation of Canada **geese** at **Izembek** averaged 23 August, only slightly later than **brant**, with a range from 21 to 30 August. Arrival date was about one week earlier in 1988 than in 1987. Numbers of Canada geese increased gradually in September and early October reaching an estimated peak by 28 October (44,800) in 1987 and 18 October (45,200) in 1988 (Figure 2.2). These dates were 3 and 1.5 weeks later than corresponding peak numbers for brant, respectively. A delayed timing of peak numbers of Canada geese was also observed in 1986.

Total numbers of Canada geese have fluctuated from a high of 70,000 in 1975 to a low of 27,900 in 1977 (Figure 2.4). Between 1985 and 1988, the number of Canada geese has averaged 45,000 birds and ranged from a high of 52,200 in 1985 to a low of 42,000 in 1986. Since 1985, the trend in the population using the **Izembek** complex appears to be stable.

Increased numbers of cackling Canada geese were observed in 1988 compared to other years. Earlier freezing of estuaries further north along the Alaska Peninsula that are traditionally used in fall was believed to have forced birds to other areas (**R.E. Gill pers. comm.**). The increased number of sightings of cacklers, however, may be due to an expansion of the search area. In 1988 we intensified observations adjacent to Moffet Bay of **Izembek** Lagoon in areas not searched in other years. Moffet Bay contained a high proportion of the Canada goose population at **Izembek** (see below: "**Distribution**" section) .

Departure of Canada geese coincided with emigration of brant. First departures of Canada geese were observed on 21 October in 1987 and on 22 October in 1988. In all years of our study, all geese had departed by the last week of November. In 1987 and 1988 timing of major movements of Canada geese were similar to brant.

The period when at least 10% of the Canada goose population was present at **Izembek** Lagoon occurred approximately

between 6 September and 23 November (78 days) in 1987 and between 28 August and 23 November (86 days) in 1988. Peak numbers of Canada geese occurred from early October to the third week of October in both years.

Canada geese are not observed at **Izembek** during winter and very rarely during spring migration.

Emperor geese

Emperor geese were the least abundant goose species during fall in all years. Unlike populations of brant and **Taverner's** Canada geese that depend almost exclusively on **Izembek** Lagoon, fall staging of emperor geese is spread among Nelson Lagoon (35-50%), Port Heiden (17-19%), Cinder River (14-24%), and Seal Islands (10-12%), all located further north on the Alaska Peninsula. **Izembek** is used by about 4% (range 3-7%) of the emperor goose population (**R. King** and **W. Eldridge, USFWS, unpubl. data**). The numbers of emperor geese using the **Izembek** complex have declined steadily since the first survey (Figure 2.4) and probably reflect the decline observed for the entire population. Within our study period the number of emperor geese fluctuated from a high of 7,300 in 1987 to a low of 4,000 in 1988.

Migrating emperor geese were first observed at **Izembek** the last week of August (mean=23 Aug, range=21-25 Aug) during our study. Immigration of emperor geese was gradual through September and peak numbers were reached on 9 October (7,300) in 1987 and on 18 October (3,400) and 29 November (4,000) in 1988 (Figure 2.2). Direct observations of arriving flocks of emperor geese were not made. Aerial counts indicated that more arrivals occurred in late October. It is expected that much of the fall population using **Izembek** has a relatively high turnover rate as the geese continue westward to scattered wintering areas on the Aleutian Islands. The period when at least 10% of the emperor goose population was present at **Izembek** Lagoon occurred approximately between 15 September and 23 November (68 days) in 1987. Because no counts were made late in fall of 1988, the period of stay was not determined, but was at least 91 days.

Aerial counts of emperor geese have been made during winter only in the last five years. These surveys indicated that an average of 1,500 birds, ranging from 800 to 3,200, were found within the **Izembek** complex.

Spring use has averaged 5,000 birds, ranging from 18,300 in 1982 to 1,100 in 1986. Since 1985 the population has averaged 2,300 birds. **Izembek** Lagoon was used by 5% (range= 2-8%) of the total emperor population observed during spring surveys between 1984 and 1987 (**R.J. King, USFWS, unpubl. data**).

Distribution of geese within Izembek Lagoon

Brant

The proportion of geese of each species observed within zones of **Izembek** Lagoon (Figure 2.1) did not differ between years (**Kruskal-Wallis** ANOVA; $P < 0.05$), therefore observations were combined across years to compare distributions of geese. Aerial survey data were also combined within each of five time periods. These were: 1) fall arrival up to 20 September, 2) peak numbers from 20 September to 24 October, 3) fall departure following 25 October, 4) winter, and 5) spring.

Izembek Lagoon, the largest of the seven lagoons surveyed (Figure 1.1), has consistently been used to the greatest extent by all species in spring and fall in all years (Table 2.2).

Table 2.2. Average percent (range) of brant (B), Canada (C), and emperor (E) geese observed in Alaska's **Izembek** Lagoon, and **adjacent^a** lagoons during aerial surveys flown between 1975 and 1988.

Season	Species	n ^b	Izembek Lagoon	Adjacent lagoons
Fall	B	12	83 (88-93)	17 (3-31)
	C	11	88 (81-97)	12 (2-19)
	E	11	67 (58-81)	33 (9-42)
Winter	B	7	42 (0-100)	58 (0-100)
	E	7	43 (1-100)	57 (0-99)
Spring	B	7	99 (98-100)	1 (0-2)
	E	7	91 (84-100)	9 (0-14)

^a Includes Hook Lagoon, St. Catherine Cove, Kinzarof Lagoon, and Big, Middle, and Little lagoons.

^b **Years** with counts.

In fall 83% of the brant, 88% of the Canada geese, and 67% of all emperor geese were counted in **Izembek** Lagoon. In spring the **Izembek** segment was used by the greatest proportion of migrant brant (99%) and emperor geese (96%). The pattern differed in winter when **only 42%** of all brant and 43% of

of geese using **Izembek** Lagoon in winter may in part be explained by the presence of ice. During most winters, ice covers the entire lagoon and forces brant to use ice-free lagoons on the southern side of the Alaska Peninsula (**C.P. Dau, pers. comm.**).

Within **Izembek** Lagoon the distribution of geese varied both among species and among seasons. Brant were found in all zones (Table 2.3) during all seasons, but the majority used either the southern or the north-central zones. Brant tended to use areas in the northern portion of the lagoon early in fall and then as more birds arrived, brant moved into the southern end where predominant (>40%) use occurred. During the period of departure, the proportion of brant using the **north-central** zone changed (increased) dramatically from the arrival period. We observed this shift about the middle of October in each year of our study. The reasons for the shift in brant distribution prior to migration are unclear but appear to be related to an increase in flock size, less frequent daytime low tides, and increased numbers of bald eagles (**Haliaeetus leucocephalus**).

During winter the distribution of **brant** was highly variable. Brant were observed primarily within the **north-central** (64%) zone. Typically, they were observed at the tip of the barrier islands at the middle and northern channel entrances between the lagoon and Bering Sea. This area often remained open during periods when the lagoon would freeze (**C.P. Dau pers. comm.**).

The pattern of use by brant in spring was similar to fall with a majority of brant observed in the southern (46%) and north-central zones (41%). One difference from fall, however, was the reduced use of foraging areas within the south-central zone (5%). In 1986 and 1987 ground observations from Grant Point indicated <1,000 birds were present on any given day in April and May.

Canada geese

The distribution of Canada geese observed by aerial survey was incomplete because at high tide, when most aerial surveys were **flown**, Canada geese were more **likely** to be using adjacent tundra habitat. Nevertheless, we feel the surveys provide a good index to their distribution.

Although Canada geese were found in all zones, the southern (54%) and northern (24%) zones received predominant use during the peak period (Table 2.3). Except for an increase of birds in the south-central zone, the pattern of use did not change during fall staging. Typically, geese were more

Table 2.3. Average percent of total geese observed within four zones of Izembek Lagoon during aerial surveys flown from 1975 to 1988. Fall was subdivided into three periods representing migration arrival before 20 September, peak numbers from 20 September to 24 October, and departure following 24 October. For Canada and emperor geese the fall peak period was from 1 October to 30 October. Winter surveys were flown between 1 December and 1 March. Spring surveys were between 2 March and 31 May.

Season	one											
	southern			South-central			North-central			Northern		
	%	Range	n	%	Range	n	%	Range	n	%	Range	n
<u>Brant</u>												
Fall												
arrival	50	(32-73)	5	23	(11-40)	5	12	(0-23)	5	16	(10-21)	5
peak	60	(48-80)	20	15	(4-29)	12	18	(8-40)	12	7	(1-16)	20
depart	41	(0-69)	8	23	(0-100)	7	34	(0-100)	7	10	(0-29)	7
winter	23	(0-100)	9	13	(0-91)	7	64	(0-100)	8	2	(0-17)	8
Spring	46	(0-96)	12	5	(0-100)	8	41	(8-100)	6	14	(0-54)	14
<u>Canada</u>												
Fall												
arrival	35	(14-54)	7	7	(0-17)	7	19	(5-43)	7	39	(26-51)	7
peak	54	(30-79)	15	9	(2-23)	11	16	(8-26)	11	24	(13-44)	15
depart	39	(15-68)	4	19	(8-40)	3	21	(16-26)	3	19	(0-45)	5
winter	0	-	9	0	-	9	0	-	9	0	-	9
Spring	0	-	14	0	-	14	0	-	14	0	-	14
<u>Emperor geese</u>												
Fall												
arrival	0	-	5	4	(0-13)	5	23	(0-36)	5	73	(60-100)	5
peak	9	(0-72)	19	27	(1-75)	15	14	(0-44)	15	51	(20-83)	18
depart	5	(0-24)	6	31	(0-46)	5	21	(0-77)	5	43	(18-66)	6
winter	54	(0-100)	7	0	(0-2)	6	23	(0-100)	7	13	(0-35)	8
Spring	21	(0-75)	11	7	(0-43)	6	11	(0-29)	5	58	(0-99)	12

concentrated during the arrival and peak periods than during the departure.

Emperor geese

Emperor geese were the least widespread of all geese (Table 2.3). They were observed in the south-central and north-central zones, but were concentrated primarily in the northern (>43%) zone (Table 2.3). Emperors occurred least often in the southern (<10%) zone and when observed were found only in a few specific areas. The pattern of use was consistent throughout the fall staging periods.

The winter distribution of emperor geese differed from fall with the largest concentration of birds using the southern (54%) and north-central (23%) zones. During spring emperor geese were again concentrated (58%) in the northern zone.

Factors affecting the distribution of geese

Brant

The distribution of geese within **Izembek** Lagoon during fall was influenced by four primary factors: 1) year, 2) stage and height of tide, 3) date, and 4) distribution of foraging and roosting habitat.

Brant were present during all days of observation and at 97% ($n=1033$) of the hourly counts at study areas (Table 2.4). **Only** at the gw study area were brant absent (**14%; $n=14$**) during any of the diurnal observations. Greatest numbers of brant occurred at NB (**mean=6,700, SD=4,100**), HP (**mean=5,200, SD=4,300**), GW (mean=4,400, **SD=8,200**), and AC (mean=4,400, SD=4,100) study areas (Table 2.4). The average number of brant at each study area for each year is listed in Appendix C in Tables C1 to **C3**.

Only the HP study area received consistent observation effort in all three years. The average number of brant increased from 1,500 in 1985, to 3,100 in 1986, and 7,700 in 1987 (Duncants multiple range test, **$P<0.05$**). Because total population size was similar in 1985 and 1986 and not much increased in 1987, other factors such as disturbance, weather, availability and quality of food, and age structure of the population must influence the use of specific areas and the distribution of brant in the lagoon.

In all years, the average number of brant counted each hour within study areas was influenced by tide stage (MANOVA, **$F=2.9, P<0.001$**) and date (**$F=2.6, P<0.02$**), but not by time of

Table 2.4. Frequency of occurrence and mean number of brant (B), Canada (C), and emperor (E) geese observed at six study locations on Izembek Lagoon, Alaska, between 1985 and 1987.

Species	Days	% days		% counts with geese	Mean geese /km ²	Geese in study area		
		with geese	Counts			mean	SD	max.
<u>Halfway Point study area- 4.2 km²</u>								
B	70	100	281	87	1200	5200	4300	20100
c	70	87	275	74	290	1200	1300	6300
E	70	79	281	55	20	100	150	630
<u>Norma Bay study area- 5.5 km²</u>								
B	40	100	225	100	1200	6700	4100	21200
c	40	93	224	86	230	1300	1300	9000
E	40	5	225	1	0.01	0.01	0.03	5
<u>Apple Cove study area- 5.4 km²</u>								
B	40	100	163	92	810	4400	4100	22500
c	40	95	151	80	220	1200	1300	6400
E	40	5	146	1	0.08	0.4	4	50
<u>Grant Point East study area - 2.3 km²</u>								
B	36	100	211	98	650	1500	1300	7800
c	36	19	211	5	4	10	50	400
E	36	25	211	10	2	4	20	200
<u>Outer Marker study area- 4.1 km²</u>								
B	20	100	84	98	680	2800	3000	12200
c	20	90	84	74	120	500	800	4000
E	20	80	84	56	20	100	100	500
<u>Grant Point West study area- 23.3 km²</u>								
B	14	86	69	87	190	4400	8200	40000
c	14	12	71	4	0	2	12	100
E	14	64	62	63	10	200	200	900
<u>combined study areas- 44.8 km²</u>								
B	54	100	1033	97	90	4000	4500	40000
c	54	75	1016	57	20	900	1200	9000
E	54	39	1004	25	10	50	120	1050

Figure 2.5. Distribution of brant flocks observed during aerial surveys at high tide on 3 and 8-9 October 1986, Izembek Lagoon, Alaska.

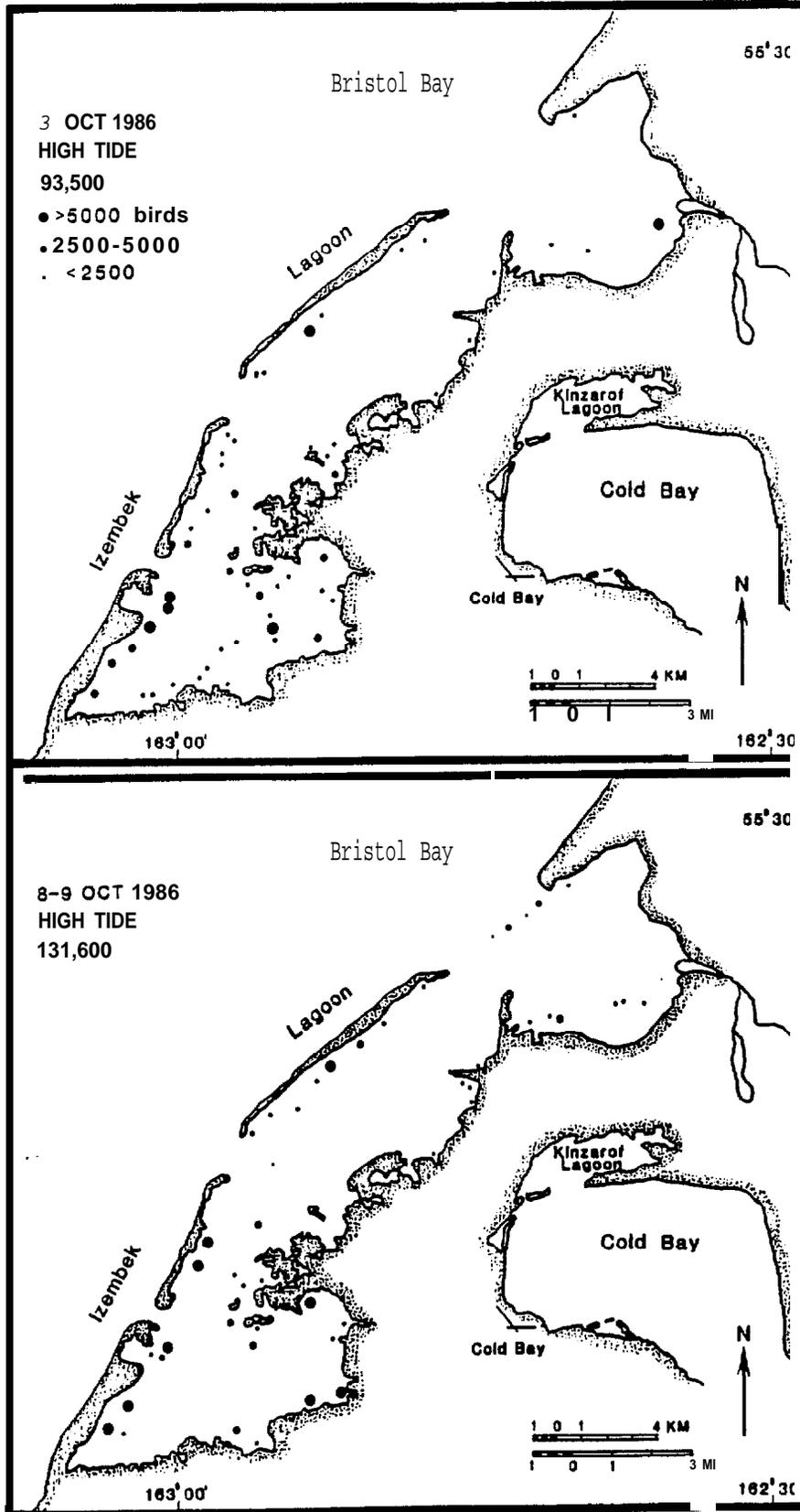


Figure 2.6. Distribution of brant flocks observed during aerial surveys at low tide on 22 September and high tide on 25 September 1987, Izembek Lagoon, Alaska.

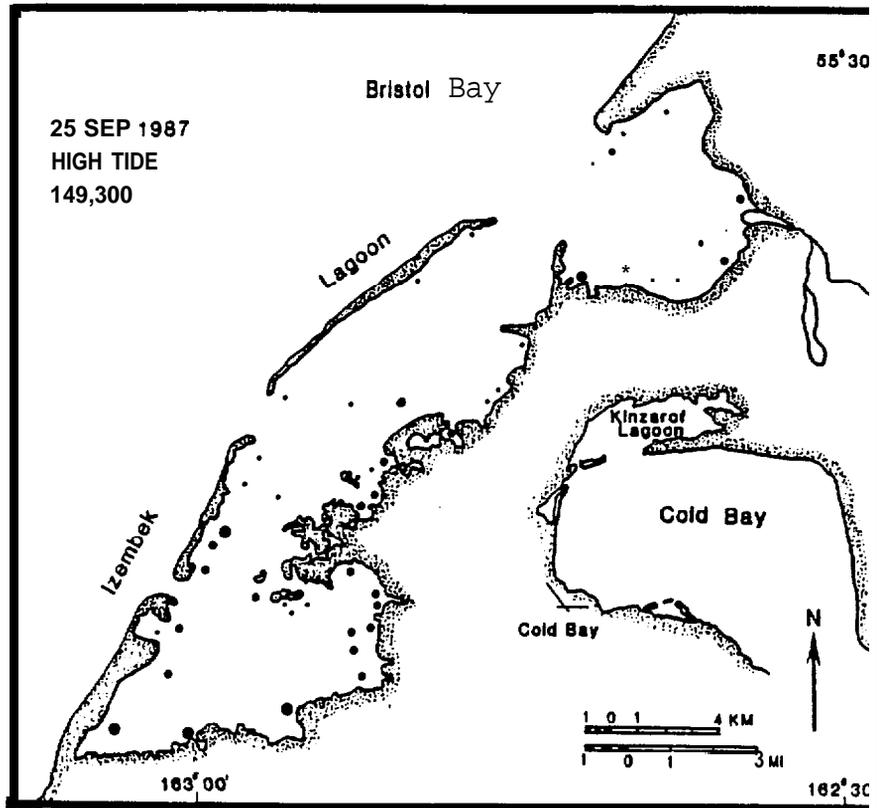
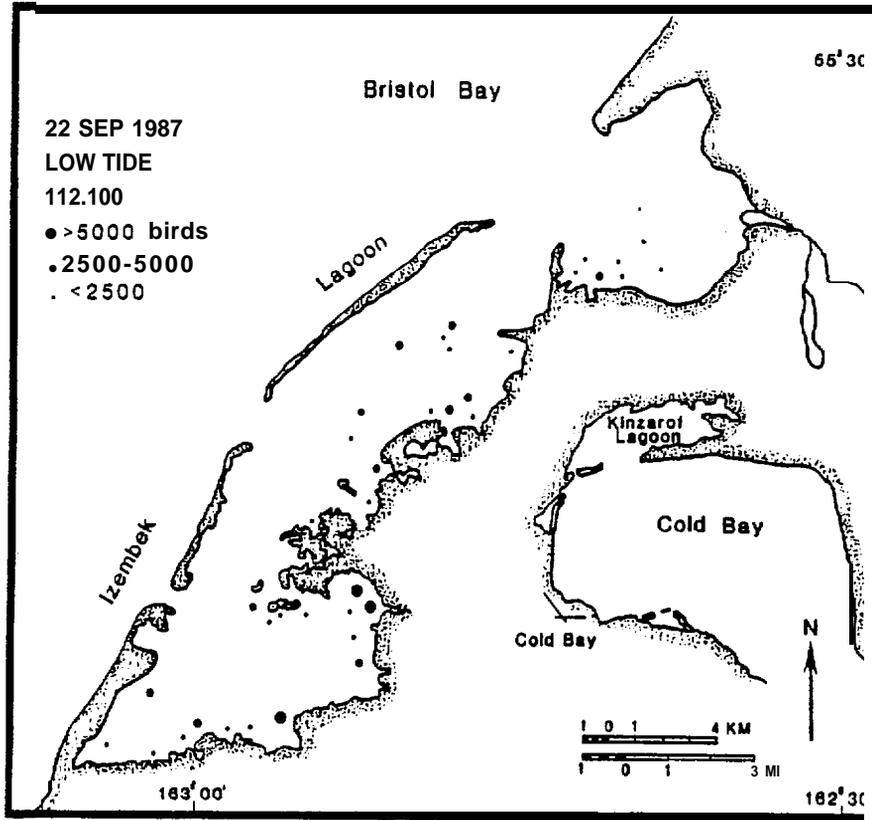


Figure 2.7. Distribution of brant flocks observed during aerial surveys at high tide on 26 September and low tide on 4 October 1988, Izembek Lagoon, Alaska.

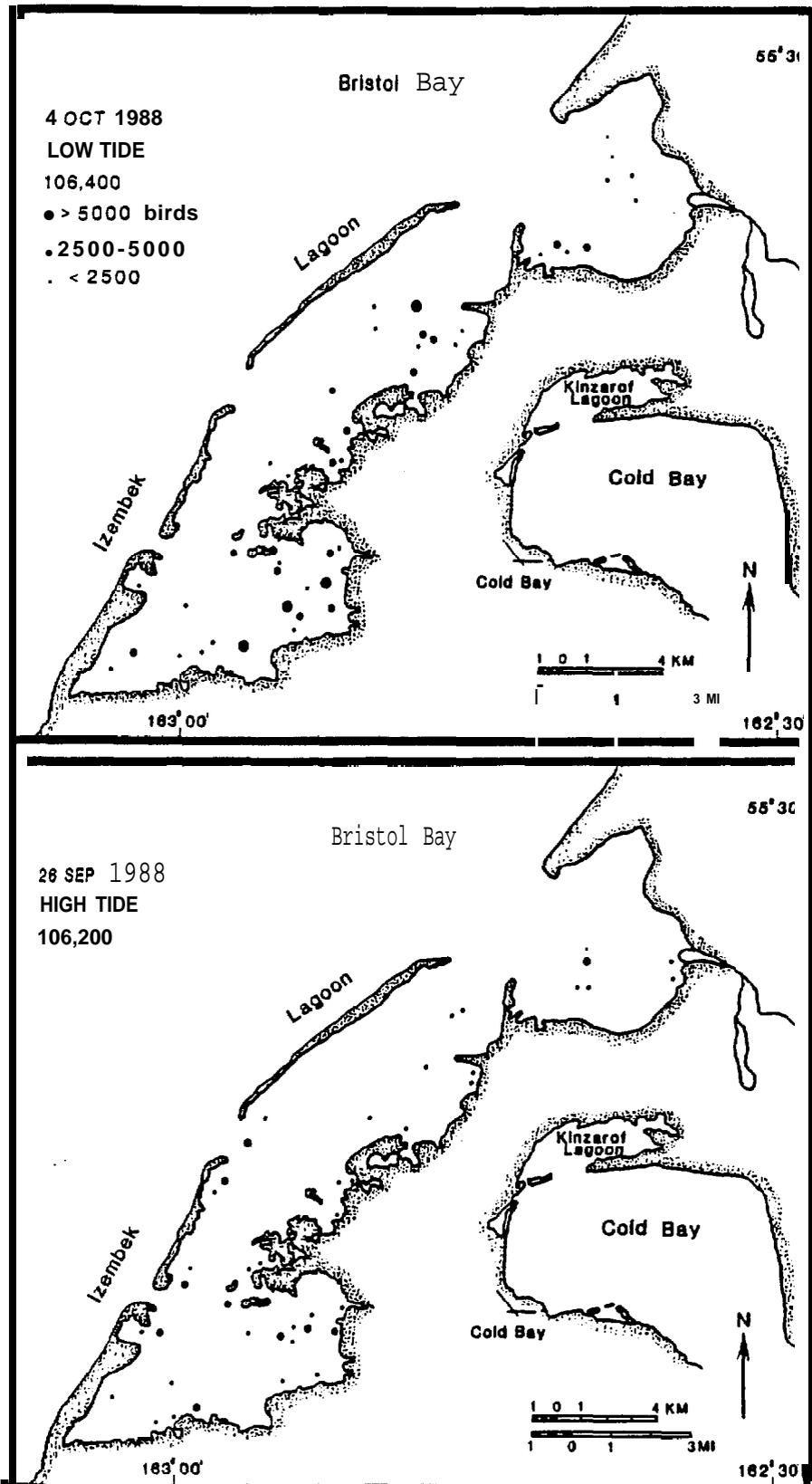
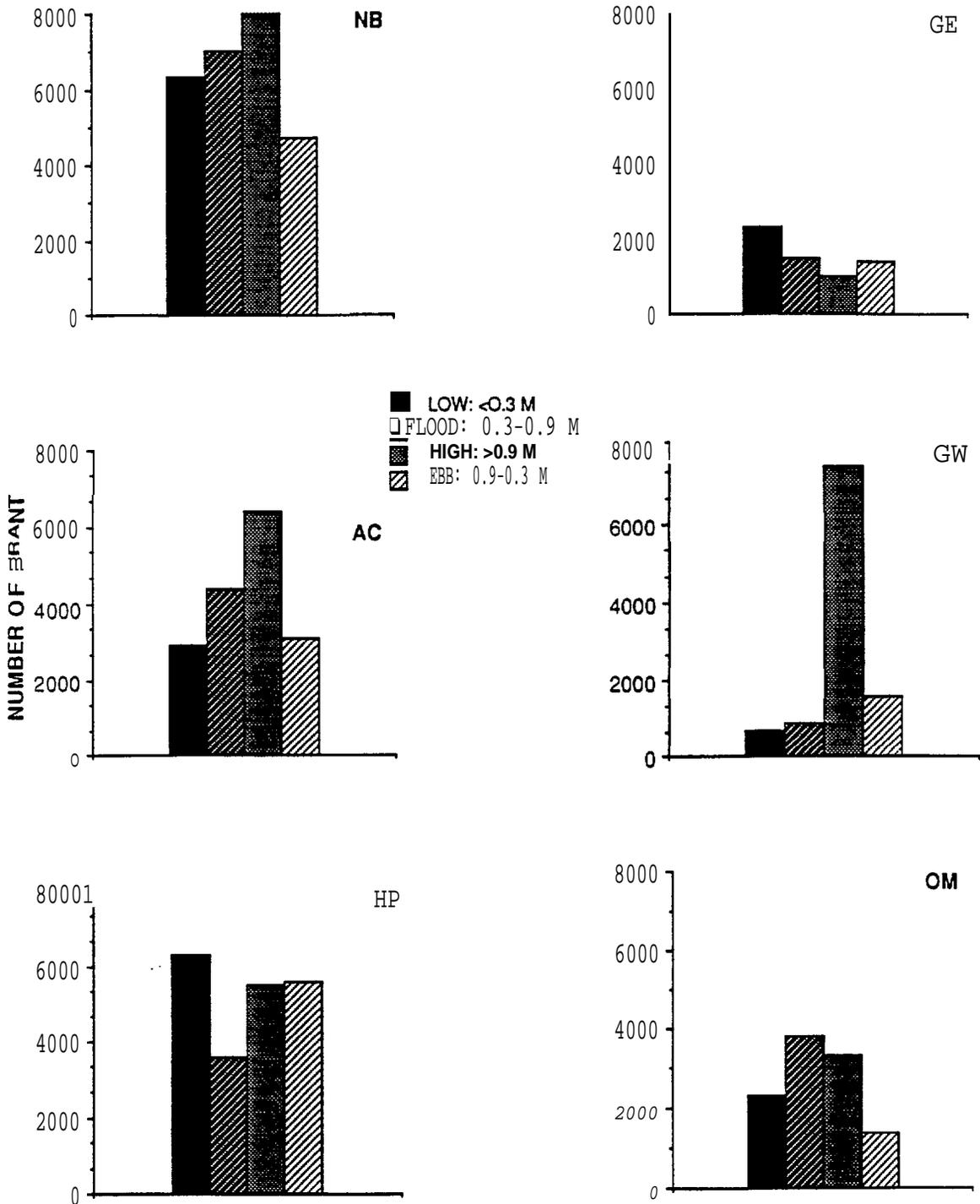


Figure 2.8. Mean numbers of brant counted at study areas during different stages of the tide at Izembek Lagoon, Alaska, between 1985 and 1987. Study areas included Norma Bay (NB), Applegate Cove. (AC), Halfway Point (HP), Grant Point-East (GE), Grant Point-West (GW), and Outer Marker (OM).



day ($F=1.3$, $P > 0.30$). The general influence of tide on the distribution of brant was evident from aerial surveys flown at low and high tides. Flocks of brant observed at low tide were widely distributed within the south and north-central zones and not concentrated in nearshore areas (Figures 2.5-2.7). At high tide, flocks were found closer to shore and along outer peninsulas and barrier islands (Figures 2.5-2.7).

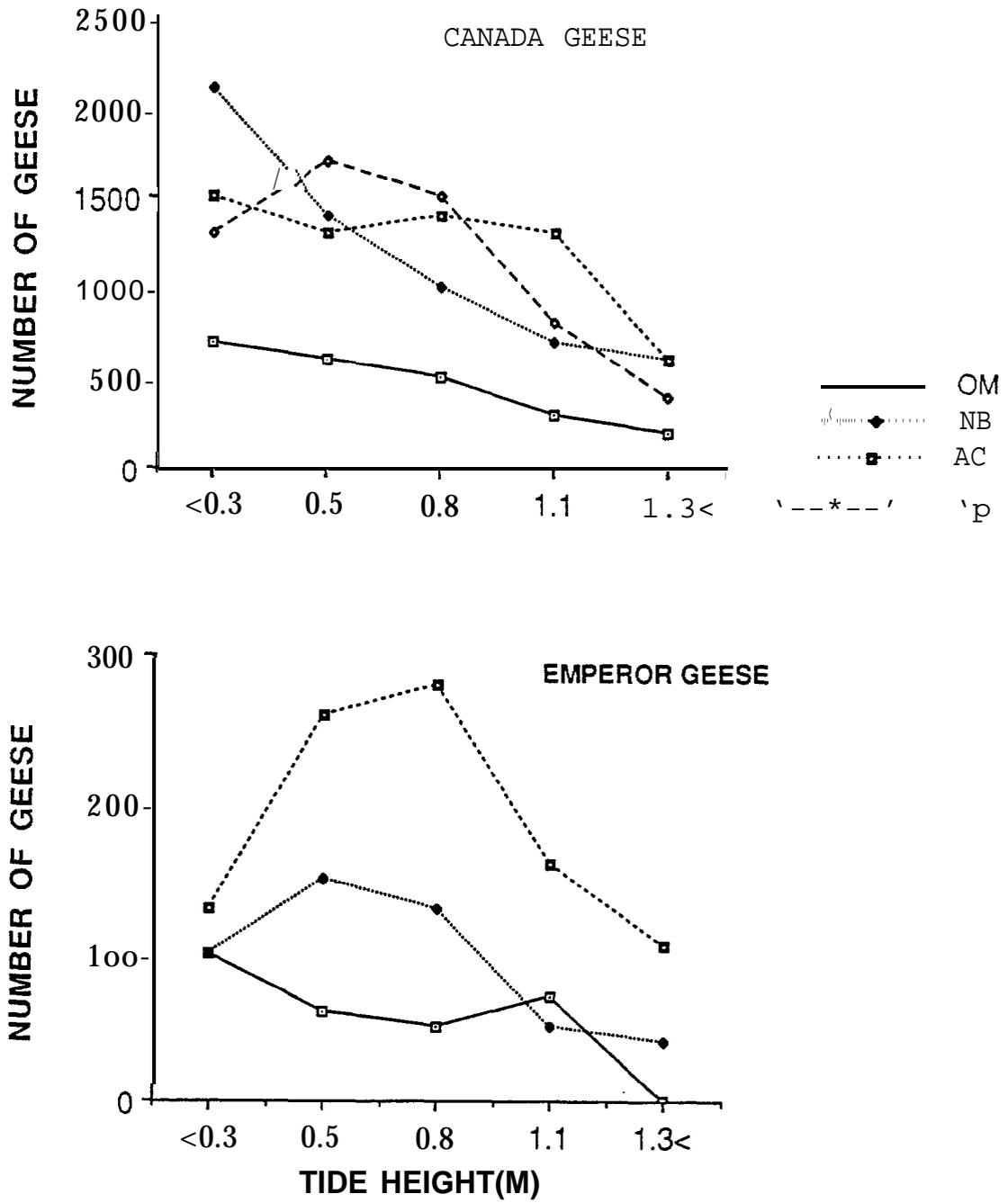
Tide did not have a uniform effect on the number of geese present in study areas (Figure 2.8). At NB, AC, and OM brant were present in large numbers during all tide stages, but greatest numbers of brant occurred during flood or high tide ($P < 0.001$). During low tide, flocks of brant could sometimes be seen foraging far offshore and then as the flooding tide submerged these beds of eelgrass, brant moved closer to the nearshore study areas. Brant would sometimes move several miles with flooding tides toward the end of a bay or cove. NB, AC, and OM study areas were located near the ends of bays furthest from the lagoon entrances. Timing of slack low and high tide at NB, AC, and OM averaged 45 min later than at GE and GW.

Brant tended to use GE and GW only at specific stages of the tide. At GE, brant occurred in greatest numbers during low tides ($P < 0.05$). As incoming tide flooded the offshore foraging areas, the number of brant decreased by 50% from 2,300 to 1,100 birds. At GW, brant were present most often during high or ebb tides ($P < 0.05$). A small number of brant (mean=700, $SD=195$, $n=6$) were observed feeding on eelgrass beds during low tide, but greatest use occurred during high tide when brant (mean=6,300, $SD=5,300$, $n=33$) were found at the periphery of the study area on the mudflat of the barrier island. Brant were observed flying to this roost site at tides >0.8 m (2.6 ft) from foraging areas in many parts of the lagoon. Use of barrier island mudflats and spits as roost sites during high tide was common throughout the lagoon.

The HP study area was exceptional in that use by brant occurred at all stages of tide. The presence of a variety of foraging sites and partial protection from the wind may have affected the pattern of brant use of this area.

The influence of date on the numbers of brant differed among study areas. Brant at AC and NB increased steadily to peak levels between 9 and 22 October (Figure 2.9). After 22 October, numbers of brant using these areas were highly variable between counts. The number of brant using GE and HP was constant through the study period. At GW, greatest numbers were observed between 25 September and 8 October after which brant decreased their use of the area except as a roosting site at the highest high tides (>1.0 m). As the use of GW decreased, a simultaneous increase at OM was observed.

Figure 2.9. Mean numbers of Canada and emperor geese present at study areas during different height of the tide at Izenbek Lagoon, Alaska, 1985-1987. Study areas are Norma Bay (NB), Applegate Cove (AC), Halfway Point (HP), and Outer Marker (OM).



Average number of brant counted at OM increased from 1,600 (**SD=1,000**) to 5,100 (**SD=2,300**) after 8 October.

Canada geese

Canada geese occurred regularly (>50% of daily observations) at four of six study areas and at 57% (**n=1,016**) of the hourly counts. Greatest numbers were found at NB (**mean=1,300, SD=1,300**), AC (**mean=1,200, SD=1,300**), and HP (**mean=1,200, SD=1,300**) (Table 2.4). The average number of Canada geese at HP at low tide (<0.2 m) was greater in 1986 (1,900) than in 1987 (900) or 1985 (400) (Duncan's multiple range test, **P<0.05**). Differences are probably related to annual fluctuations in abundance of berries. In 1986 crowberries (*Empetrum nigrum*) and lingonberries (*Vaccinium vitis-idaea*) were less abundant than in other years (D.H. Ward, pers. obs.). Canada geese were less often observed foraging on tundra habitats and apparently made greater use of nearshore eelgrass beds for food.

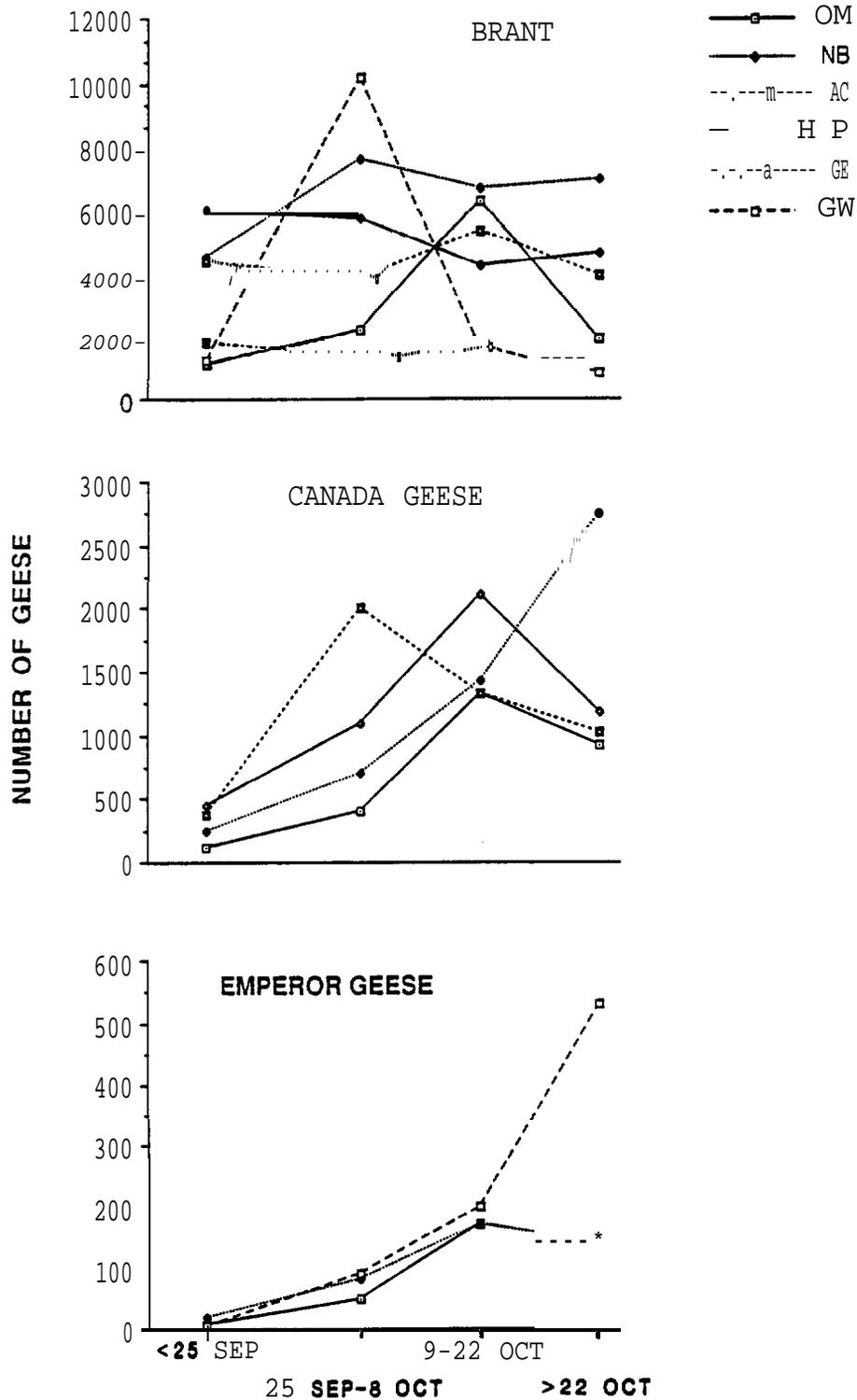
In all years, the average number of Canada geese within study areas was influenced by the stage and height of the tide (MANOVA, **F=5.5, P<0.001**) and date (**F=20.9, P<0.001**). Time of day, which was slightly more important for Canada geese than brant, had an interacting effect with tide (**F=2.0, P<0.04**). Canada geese were more abundant during low tides at all study areas where they foraged on nearshore **eelgrass** beds (**P<0.001**) (Figure 2.9). At high tides Canada geese were observed flying to upland tundra areas where they roosted or foraged on berries. Date had a consistent influence on the number of geese at each study area. The average number of Canada geese increased daily at each of the study areas until emigration was initiated the third week of October (Figure 2.10).

Emperor geese

Emperor geese were the least abundant goose at all study areas. They occurred regularly (>50% of daily observations) at only three of seven study areas, and were observed on 25% (**n=1004**) of the hourly counts. Greatest mean numbers of emperor geese were observed within **GW** (mean= 180, **SD=200**), **HP** (mean= 100, **SD=150**), and **OM** (mean= 100, **SD=100**).

The average number of emperor geese at HP during the peak was greater in 1986 (150) than in 1987 (90) or 1985 (20) (Duncan's multiple range test, **P<0.05**). Changing use of HP was probably due to annual fluctuations in populations as well as the relative abundance of alternative foods such as berries and clams. In all years, the average number of emperor geese within study areas was influenced by tide stage (MANOVA,

Figure 2.10. Mean numbers of brant, Canada and emperor geese during different time periods of the fall at **Izembek** Lagoon, Alaska, 1985-1987. Study areas are Norma Bay (**NB**), Applegate Cove (**AC**), Halfway Point (**HP**), Grant Point-East (**GE**), Grant Point-West (**GW**), and Outer Marker (**OM**) .



F=4.7, P<0.000) and date (F=12.7, P<0.000), but not by time of day (F=0.6, P>0.7). Emperor geese, like Canada geese, were more numerous in study areas during low tides (ANOVA, P<0.001) (Figure 2.9). At high tide emperors were often observed on **mudflats** of the barrier islands or occasionally observed foraging on berries in tundra habitat. Date also had a consistent influence on counts with greater numbers of emperor geese occurring after 8 October (Figure 2.10).

DISCUSSION

Brant

The entire Pacific Flyway brant population stages within the **Izembek** complex in the fall making it an ideal place to monitor its population status and emphasizing the area's critical importance to brant. No alternative fall staging area exists: although nearby lagoons are used, they do not contain adequate habitat for mass staging.

The period of use of the lagoon, as defined by the presence of at least 10% of the population, is 12 weeks in the fall. Use by individual marked birds varied from six to nine weeks and may be influenced by breeding origin, breeding status (failed or non-breeder), and physical condition. Breeding brant from the YKD and Canada have an overlapping but staggered period of stay. Failed or nonbreeders arrive earlier than breeding birds and may remain longer than the breeding populations. Jones [1964] also noted that early arriving flocks contained fewer juveniles. Age ratio counts before 15 September in 1987 and 1988 were lower than after this date (D.H. Ward, unpubl. data).

Period of use in spring is approximately five weeks. Most brant do not remain at **Izembek** over the entire period, but instead move north to breeding areas. Breeding birds arriving early on colony sites have an advantage for selecting nesting sites (McLandress and Raveling 1981). The average duration of stay for individual marked birds has not been observed in spring. The importance of spring staging at **Izembek** may also vary among breeding populations and depend on age or breeding condition.

The timing of arrival and departure of brant at **Izembek** defined three periods of fall use: the arrival period from 21 August to 21 September, the peak period from 22 September to 24 October, and the departure period beginning 25 October. up to one week variation in timing was noticed in different years. The period with peak numbers could be subdivided into two equal periods, the first half characterized by few eagle and **hunter-**

related disturbances followed by two weeks beginning 9 October with increased number of eagles and hunters. The effects of eagle disturbance were pronounced (see "Disturbance" section), and **influenced both** the distribution and flock sizes of brant.

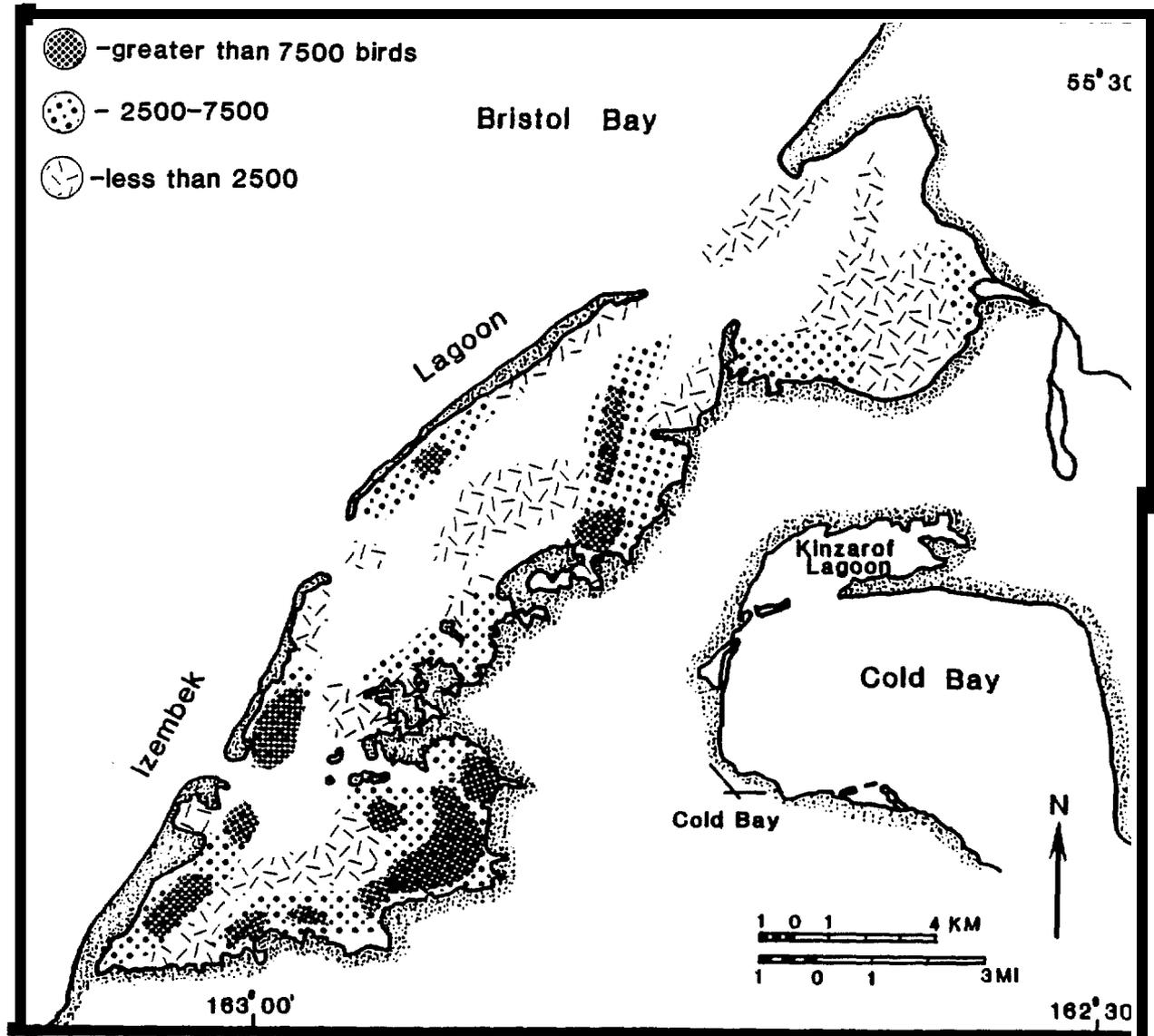
Distribution of brant within nearshore study areas of **Izembek** Lagoon is dynamic, varying between sites and years. Brant were highly influenced by the stage of tide and date, but not time of day, although time of day interacted with tide. Despite the constant shifting of birds within study areas, brant did have favored zones of use. During fall and spring more brant used the southern and north-central zones (Table 2.3). Areas that received the greatest intensity of use during fall are shown in Figure 2.11. In winter brant also have favored areas of use but their distribution is more linked to weather conditions.

Tide clearly influenced the distribution and habitat use of brant. During low tide brant generally foraged on eelgrass beds offshore (>0.8 km), usually at the ends of tidal channels or in areas inaccessible at higher tides. Nearshore (<0.8 km) foraging sites are used by the greatest number of brant during flooding and high tides. Some birds remain at these areas through the daytime high tide rather than move to more typical roosting areas on barrier islands and peninsulas. This trend intensifies as diurnal food availability and weather conditions deteriorate as fall progresses. Flocks of brant remaining through a high tide have the opportunity to feed on mats of floating **detrital** eelgrass until preferred **eelgrass** beds are again available for foraging. These same birds also reduce energetic costs associated with flight (Hart and Burger 1972) to and from roost sites. During high winds, nearshore areas bordered by shoreline bluffs may provide partial protection by reducing wind flow and energetic costs of increased thermoregulation (**Wooley** and Owen 1978).

Any overflights or planned human activities at **Izembek** prior to September 1 and after 30 November would avoid interactions with nearly all the fall population of brant (based on counts in years 1986 through 1988). During spring migration, activities on either side of April 15 to 1 June would safely avoid the period of brant use. Winter use is variable and often restricted to small portions of **Izembek** or other nearby lagoons depending on ice conditions and numbers of birds. Specific guidelines to avoid disturbance of wintering birds should be based on field observations made at the time.

If flight lines (Figure 2.12) were established over or around the lagoon while brant were present in fall, the number of birds potentially influenced within a 3.2-km-wide (2 mi) flight corridor would vary dramatically with the location of the flight line (Table 2.5). Assuming uniform density of brant

Figure 2.11. Intensity of use by brant at Izembek Lagoon, Alaska, in fall, 1985-1988. Distribution and intensity of use based on Figures 7-9.



within each of the four zones of **Izembek** Lagoon, and assuming a constant zone of influence by an aircraft (1.6 km on either side of a flight line; see "Disturbance" section), flights potentially impacting the fewest number of birds would use a path at least 1.6 km away from the shoreline of **Izembek** Lagoon (lines 1 and 14 in Figure 2.12). The greatest potential effect would occur from flights crossing or close (<1.6 km) to the shoreline of the southern zone, lines 2-4. Flight lines 5-13, which includes the existing IFR (Instrument Flight Rules) flight path, would influence fewer birds as they go over or around other zones of the lagoon. The actual density of birds encountered within these flight corridors may be higher or lower depending on tide, date of flight, and the specific location of the flight line. Although density (110 birds/km²) of brant in the northern zone is lower than any other zone, flight

Table 2.5. Average number of brant expected to be within 14 hypothetical flight Corridors^a situated over or around **Izembek** Lagoon, Alaska.

Flight line ^b	Corridor distance over water (km)		Mean density ^c of brant/km ²	Mean number of birds within the corridor
	length	width		
1	0	0	690	0
2	0	1.6	690	17,500
3	12.4	3.2	690	27,600
4	9.2	3.2	690	20,300
5	400	3.2	270	3,500
6	6.8	3.2	270	5,900
7	6.4	3.2	270	5,600
8 ^d	6.4	3.2	290	6,000
9	8.1	3.2	290	7,500
10	8.8	3.2	290	8,200
11	8.1	3.2	290	7,500
12	32.6	3.2	110	4,500
13	0	1.6	110	1,400
14	0	0	110	0

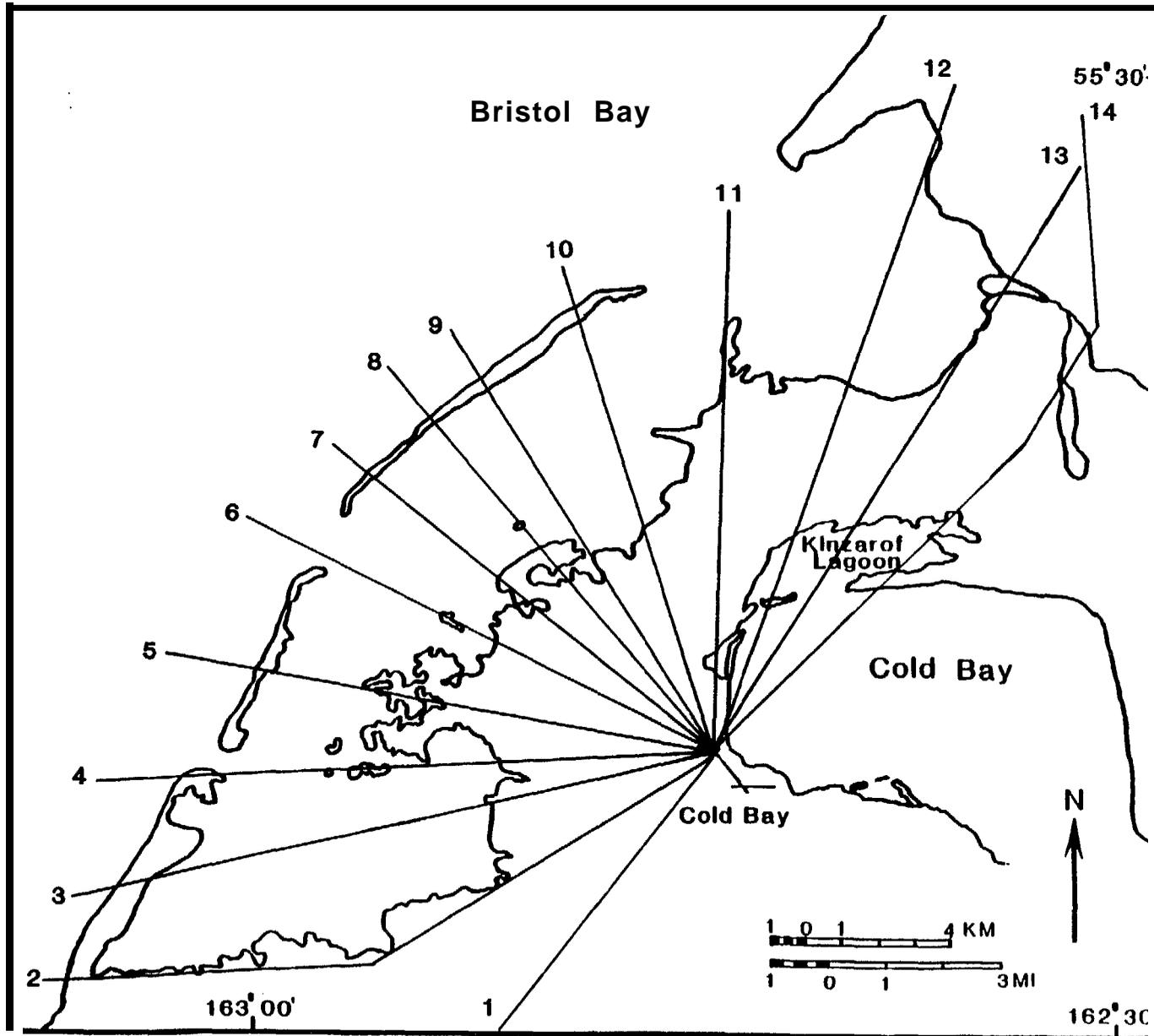
^a Assumes a distance of potential influence to be 1.6 km on either side of the aircraft.

^b Location of flight lines shown in Figure 2.12.

^c Density of brant based on the average number of birds counted during the fall peak period of use (20 September-22 October) on aerial surveys in 1985 through 1988.

^d IFR (Instrument Flight Rules) corridor.

Figure 2.12. Location of 14 hypothetical flight lines for comparing the relative numbers of birds that potentially would be disturbed by aircraft overflights of the lagoon.



lines here are likely to influence a small (20,000) **subpopulation** of brant (**B.b. horta**) that nest in the Canadian high arctic and tend to use only this portion of the lagoon (Reed et al. 1989).

Canada geese

The large number (approximately 75% of the total population) of Taverner's Canada geese using **Izembek** Lagoon in fall stresses the importance of the lagoon to this subspecies. Other populations of Canada geese make less use of **Izembek**, but the lagoon may serve as an alternative staging area for cackling Canada geese, especially during years when unfavorable weather conditions exist to the north and east.

Canada geese only used **Izembek** Lagoon in fall. Although the timing of peak numbers of Canada geese was slightly later (1.5-3 weeks) than for brant, the period of use by Canada geese, when at least 10% of the population was present at **Izembek** Lagoon, was similar to brant (11-12 weeks) .

The distribution of Canada geese within **Izembek** Lagoon was similar to that of brant except for the greater and lesser use of northern and south-central zones, respectively. Numbers of Canada geese also varied with stage and height of tides, date, year, and relative abundance of alternative tundra foods. Generally, Canada geese used tundra habitats immediately adjacent (<1.6 km) to the lagoon but occasionally geese were observed foraging >3.0 km away. Jones (**USFWS, unpubl. ms**) also reported Canada geese at similar distances from the lagoon. When Canada geese were found on the lagoon they used nearshore **eelgrass** beds and were rarely observed >0.8 km from shore even during the lowest tides. Flocks of Canada geese often foraged near brant and on occasion Canada geese and brant formed mixed species flocks.

Use of marine and terrestrial habitats was common for migrating Canada geese (Weller 1975). Burger et al. (1983) found that the number of Canada geese on a bay along the south coast of Long Island, **N.Y.** was not influenced by tides. There, geese preferred terrestrial habitats and fresh water ponds. At **Izembek**, Canada geese used both tundra and marine habitats. **Although we** did not study use of all habitats, our observations indicated that the lagoon not only provided an abundant source of food but also served as a diurnal roost site. Greatest use of eelgrass beds occurred during low tides and increased later in the fall as alternate foods on tundra habitats became less available. Fresh water ponds with emergent vegetation and estuarine or fresh water marshes with grasses and sedges-- habitats that provide foods commonly eaten by Canada geese (Weller 1975)-- are a minor portion of **Izembek's** total area (**USFWS** 1985). We suggest that **Izembek** Lagoon is important to

Canada geese because it provides both a stable food source and a relatively safe habitat for roosting.

Emperor geese

Izembek Lagoon was used in fall and spring by a small proportion (approx 5%) of the emperor goose population. Few remain at **Izembek** during winter. The duration of stay of >10% of the peak population in fall appeared to be similar to brant and Canada geese but in some years may extend through November. In spring the duration of stay has not been determined but is believed to be less than fall (**C.P.** Dau pers. **comm.**).

Emperor geese preferred specific locations within **Izembek** Lagoon that differed from areas used by brant and Canada geese. During high tides emperors used roost sites on the barrier islands or peninsulas. Greatest concentrations of emperor geese occurred in the northern zone. Use of nearshore foraging areas was influenced by similar factors (year, stage of tide, date) as brant and Canada geese.

CHAPTER 3: DIET AND NUTRITION

During fall staging geese increase their intake of **high** energy foods to accumulate body fat (Wypekma and Ankney 1979, **Brackney** et al. 1986) in preparation for an energetically costly migration. Fat is the primary fuel for migration flights and the amount of stored lipids greatly influences the theoretical maximum flight range of a bird (**Wypekma** and Ankney 1979, Vangilder et al. 1986). Birds with insufficient energy reserves for migration are likely to stop more often on their migration route (King and Farner 1963, Barry 1967) and may suffer increased mortality (**Cooch** 1958).

Food plant availability, abundance, and quality can affect selection by geese which in turn influences their body weight and lipid gain (Sedinger and Raveling 1984, Coleman and Boag 1987). Weight gain in lesser snow geese (**Chen caerulescens caerulescens**) during staging at James Bay, Canada, prior to fall migration (**Wypekma** and Ankney 1979) was attributed to their selection of plants high in carbohydrates (Prevett et al. 1979). Coleman and Boag (1987) showed that weight gain in Canada geese foraging on tundra in southern Yukon Territory, Canada resulted from selection of plants higher in digestibility and soluble carbohydrates. Canada geese in Minnesota maximized their energy intake and body weight by foraging on younger more proteinaceous grass prior to nesting (McLandress and Raveling 1981). Geese tend to select plants or forage in areas where plants contain higher levels of nutrients. Sedinger and Raveling (1984) found that plants selected by foraging cackling Canada geese were higher in protein and carbohydrates than hand-clipped samples of the same plants. Geese may also choose more nutritious parts of plants. Snow geese selected below-ground stem bases richer in carbohydrates compared to leaves (**Brackney** et al. 1986).

Brant are herbivorous like most geese (Owen 1980). Eelgrass is the main food item consumed throughout the year, except in northern breeding and molting areas (Einarsen 1965, Kramer 1976, Henry 1980). Studies have indicated that brant are not as dependent on eelgrass as was once thought (Cottam et al. 1944), and that other marine plants and some terrestrial grasses are important in their diet (**Penkala** 1976, Owen 1980, Kirby and Obrecht 1982). Still, along most of the fall and winter range of Pacific Flyway **brant**, eelgrass is the predominant food in their diet. During winter, brant were observed foraging only on eelgrass at San Quintin Bay, Mexico (Kramer 1976). In Oregon and California eelgrass comprised over 75% of the diet of **brant** (Cottam et al. 1944). Eelgrass

is believed to be their only food at **Izembek** Lagoon (Jones in Palmer 1976), however detailed studies of diet have not been conducted.

Our objectives were to assess the diet of brant staging at **Izembek** Lagoon, to analyze the nutritional quality of brant foods, to determine selection patterns for both plants and plant parts, and to determine the distribution and abundance of eelgrass.

METHODS

Diet of brant was determined from gut contents of birds collected at **Izembek** Lagoon from early September to late October of 1985-1987. Specimens also provided data on weight, nutrition, and body composition. Some birds shot by hunters were used for food habits and weight data. When possible birds were collected from actively feeding flocks. Foods of Canada geese were determined only from birds shot by hunters between 1985-1988. The upper digestive tract (esophagus, proventriculus, and gizzard) was removed from each bird and frozen for later processing. In the laboratory, food items from the esophagus and **proventriculus**, hereafter referred to as esophageal contents, were combined and sorted by plant species and by leaves, shoots (sheaths), and rhizomes. Whole eelgrass plants containing unbroken outer leaves attached to sheaths were measured for leaf length and leaf width. Samples were dried at 25° C to constant weight and each type of food item was weighed to the nearest **0.001 g**. Geese with less than 0.01 g of total dried material were excluded from the analysis. Contributions of foods to the diet are reported as a percentage of aggregate (combined) dry weight and percent occurrence across individuals (Prevett et al. 1979).

Eelgrass for chemical analyses was collected in fall of 1985 and 1986. Samples consisted of green leaves, leaf sheaths, and rhizomes of rooted plants taken from **eelgrass** beds exposed at low tide. Bimonthly collections were made at the same location from 19 September to 20 October in 1985. Additional samples of above ground portions (leaves plus sheath) of plants were collected in 1986 along five transects in brant foraging areas. **Eelgrass** samples were taken at 200 m **intervals** for measurements of leaf length and width, and for nutrient analysis. From each collection site, the longest leaves of 20 representative plants were measured to determine the average leaf length and width for that site.

Samples saved for nutrient analysis were washed of epiphytes and sediment, and all dead material was removed. Plants were frozen within **24 hr**. Later the samples were **oven-**

dried at 60° C to a constant weight and ground in a Wiley mill to pass through a 20-mesh screen. Samples were analyzed for nitrogen, total nonstructural carbohydrates (**TNC**), neutral detergent fiber (**NDF**), acid detergent fiber (**ADF**), nitrogen contained in the NDF, crude fat, ash, and minerals by the Palmer Agricultural Experiment Station, University of Alaska. Nitrogen, phosphorus, and nitrogen in NDF were determined using a block digester (Isacc and Johnson 1976) and measured on a **Technicon** Autoanalyzer II System (Anon. 1976). The cations calcium, potassium, and magnesium were examined by atomic absorption spectrophotometry. Analysis of TNC followed procedures by Smith (1969) and was measured **colormetrically** on the Autoanalyzer II. ADF and NDF were determined by Van Soest method (Goering and Van Soest 1970) and crude fat by ether extraction using a Randall Extractor (Randall 1974). Total ash was examined by combustion for 4 hr at 500° C. Analysis of variance (ANOVA, SPSS 1986) was used to determine differences between nutrient content of plant parts.

Habitat

The coverage and distribution of **eelgrass** within Izembek Lagoon was estimated from LANDSAT scene 30145-21103 taken at low tide of approximately -0.15 m (-0.5 **ft**) on 28 July, 1978. Registration of the scene was accomplished by geometrically correcting to a Universal Transverse Mercator (**UTM**) projection and matching selected control points from the LANDSAT scene to a **1:250,000** scale U.S. Defense Mapping Agency topographic map. The control points were used to define a second-order, **least-squares** polynomial transformation, relating UTM northing and casting to the line and sample of the scene. The mean residual errors associated with the second order transformation indicated a registration accuracy of + or - 1.5 pixels (75 m²). Digital processing and analysis were conducted at USGS/EROS in Anchorage using Interactive Digital Image Manipulation System software (ESL Incorporated 1981).

To guide interpretation of the LANDSAT spectral data, field data were collected from 14-20 October, 1986. A variety of sites were selected that represented the major habitat types (**eelgrass**, water, mud) found in the lagoon. Within areas containing **eelgrass**, sites were selected that contained the different morphological types (long, wide-leaved plants versus short, narrow-leaved plants) to determine if these distinctions would be apparent in the LANDSAT image. Observations made at each site included percentage of total surface area covered with plants, leaf length and width, water depth, drainage characteristics, grass zonation, and proximity to major land or **mudflat** areas.

Training sites containing representative spectral

variability of the data were derived from the scene using the clustering function ISOCLS (ESL Incorporated 1981). The cluster function produced discrete clusters of **pixels** based on the brightness value of each pixel in each of four spectral bands. The clustered pixels were further separated from overlapping clusters (i.e. those with redundant statistics) using the function DIVERGE (ESL Incorporated 1981). A final statistical file was produced by a maximum likelihood algorithm (**CLASSFY**, ESL Incorporated 1981) to provide an independent estimate of the spectral properties of the scene. Each pixel was then assigned to a specific spectral cluster which produced a preliminary classification where each pixel was assigned to a habitat class.

Accuracies of preliminary classifications were reviewed with data collected from the field. Areas incorrectly classified (i.e. areas outside the lagoon classified as eelgrass) were removed. Once the spectral analysis was finalized, it was applied to the entire LANDSAT scene.

RESULTS

Diet of brant

Of the 63 brant collected, 39 contained adequate (>0.009 g dry weight) foods for analysis. The sample of brant was composed of 9 adult males (23%), 10 hatching-year males (26%), 8 adult females (21%), and 12 hatching-year females (31%). The higher proportion of juvenile brant in the sample compared with the proportions in the population [14% in 1985, 15% in 1986, 31% in 1987 (**C.P. Dau, USFWS, unpubl. data**)] was due to greater susceptibility of juveniles to hunting (**Einarsen 1965, Penkala 1976**) and their higher use of nearshore areas (**D.H. Ward, unpubl. data**). Although **sample** sizes were small, no aspect of food item size, frequency, or nutrient quality differed by age or sex.

The diet of brant was composed almost entirely (99%) of eelgrass. Leaves and sheaths of eelgrass were the principal parts of plants consumed, accounting for 98% of the aggregate percent of all foods (Table 3.1). The rhizomes (1% of the diet) found in brant were almost always attached to the above ground plant. The remaining 1% of the brant diet contained grit, sand granules, and a small (<2.0 mm) **epiphytic** bivalve (**Turitionia minuta**) that is common on eelgrass leaves.

The contribution of animal foods in the diet of brant could be greater than what we report if soft-bodied invertebrates were under represented because of postmortem digestion and **autolysis** (Swanson and Bartonek 1970). However,

we did examine esophageal contents of 10 brant whose upper digestive tracts were removed immediately and preserved in a 10% **formalin** solution to stop post-mortem digestion of food. The esophageal contents still contained only eelgrass with very few **epiphytic** invertebrates. Only *Turitionia minuta* (n=5) and an **amphipod** (*Caprella alaskana*) (n=1) , were found despite often observing these animals on leaves of plants in the same bed where brant had been foraging. The ingestion of animal foods probably occurs incidentally to foraging on **eelgrass** and is not a significant part of the diet of brant at **Izembek** in fall.

Table 3.1. Aggregate percent and percent of occurrence of eelgrass plant parts in the diet of 39 brant (B) and 17 Canada (C) geese at **Izembek** Lagoon, Alaska.

Plant part	Species	Aggregate percent	Percent occurrence
Leaves	B	84	100
	C	71	100
Sheaths	B	14	56
	c	17	77
Rhizomes	B	1	2
	c	12	39
Grit	B	< 1	< 1
	c		

Diet of Canada geese

Seventeen of the 39 Canada geese collected contained adequate foods for analysis. Eelgrass was the predominant (99%) food item in their diet (Table 3.1). As in brant, leaves of eelgrass were the principal part of the plant consumed and accounted for 71% of the aggregate percent of all **eelgrass** consumed. Unlike that of brant, the diet of Canada geese contained a higher aggregate percent of rhizomes (12% vs. 1%) and the rhizome pieces were not attached to above ground plants as they would be if they were taken incidentally while consuming whole plants. All Canada geese that consumed rhizomes were collected in October.

The contribution of berries and other terrestrial plants to the diet of these staging Canada geese was not investigated in our study. Canada geese were often observed foraging in upland tundra habitat primarily on **lingonberries** and crowberries during periods of high tide. These **plants** presumably form an important component of their total diet. The hunter-killed geese we examined represented birds moving from lagoon feeding areas to tundra roosting and feeding sites.

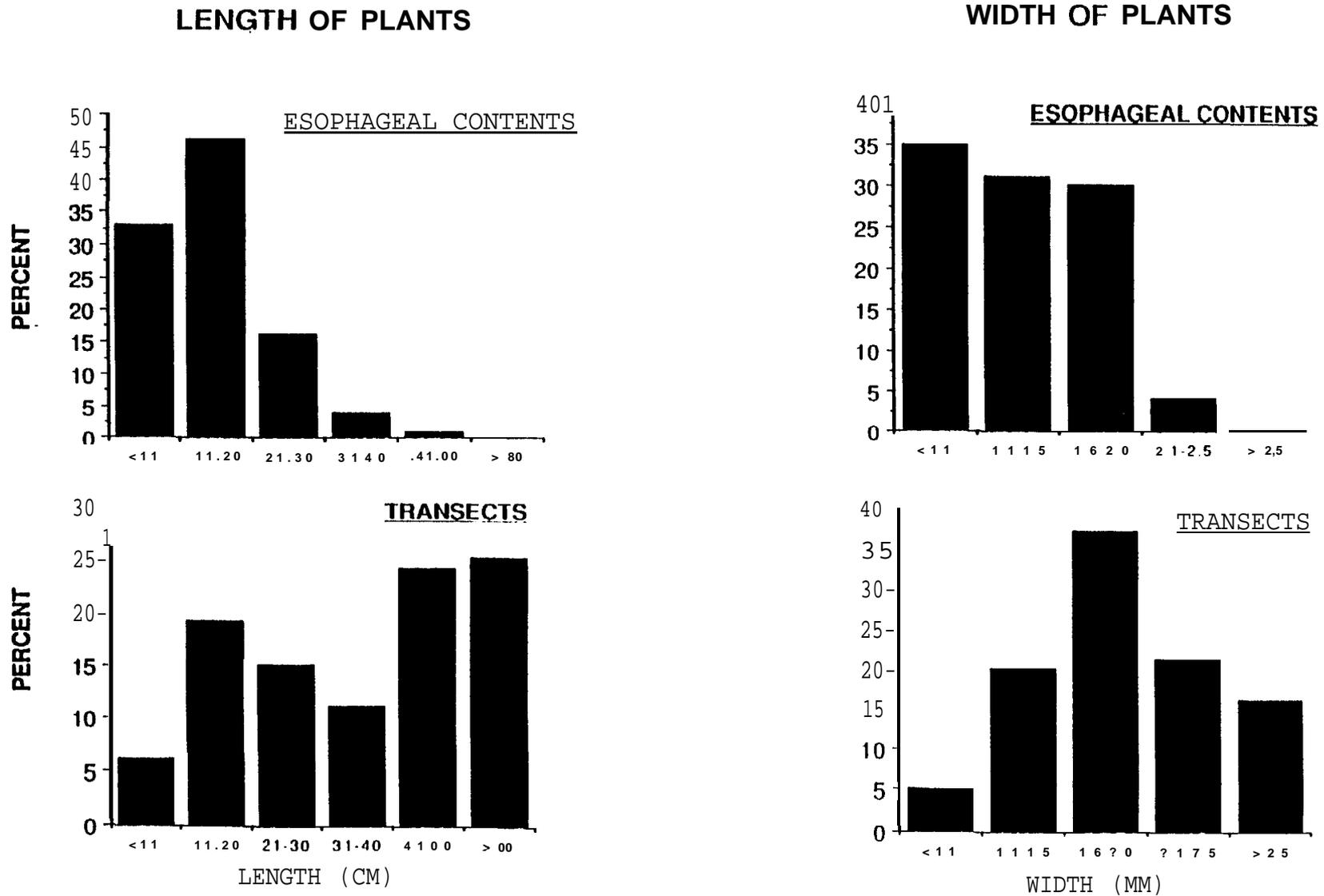
Type of eelgrass consumed

Whole plants were found in the esophageal contents of 82% of the brant and all of the Canada geese. The longest outer leaf of these whole plants indicated that leaf lengths were relatively short and widths were narrow (Figure 3.1). Few whole plants found in the esophageal contents were greater than 30 cm (<3%) long and 2.1 mm (<5%) wide, and none were longer than 80 cm or wider than 2.5 mm. All of the larger plants were in the esophageal contents of only 2 of 39 birds. The distributions of plant lengths and widths in brant diet differed from size distributions of plants found along systematic transects of eelgrass beds (Figure 3.1). The majority of plants on transects were longer than 30 cm and wider than 1.8 mm.

Nutrient content of eelgrass

Concentrations of nutrients did not vary between years or between bimonthly sampling periods in 1985, therefore data were combined to compare nutrient concentrations among parts of plants. Nutrient content did vary among plant parts (Table 3.2). Nitrogen, which reflects protein content, was higher (1.8% of dry weight) in above ground plant parts (leaves and shoots) compared with the rhizome. Crude fat concentration was low in all parts of eelgrass although fat was slightly higher in rhizomes (1.1% of dry weight) than in leaves (0.9% of dry

Figure 3.1. Length and width of plants found in the diet of brant and Canada geese and collected along 5 transects placed across eelgrass beds at Izembek Lagoon, Alaska.



weight) . Above ground portions of plants contained less cell wall (41.7 vs. 52.8% of dry weight) and ash (14.6 vs. 30.0% of dry weight) than rhizomes. Carbohydrate levels (**TNC**) varied widely among samples of above ground portions of plants ranging from 5.2 to 26.5% of dry weight. TNC was higher in leaves (19.5% of dry weight) than in rhizomes (14.6% of dry weight) but this difference was not found to be significant ($P>0.1$).

Table 3.2. **Mean nutrient** content (% dry weight) of **eelgrass** plant parts. Values with a different letter across each row are significantly different from one another (**ANOVA, $P<0.05$**).

	<u>Above ground</u>			<u>Leaf</u>			<u>sheath</u>			<u>Rhizome</u>		
	mean	SE	n	mean	SE	n	mean	SE	n	mean	SE	n
Nitrogen	2.0 ^a	0.1	35	1.8 ^a	0.1	3	1.8 ^a	0.1	8	1.0 ^b	0.7	9
Nitrogen in NDF	2.4 ^a	0.1	9	3.4 ^a	0.2	8				0.9 ^b	0.1	9
TNC	15.2	1.1	35	19.5	1.9	3				14.6	2.3	4
Fat	0.9	0.1	9	0.5	0.2	3				1.1	0.1	8
Ash	14.6 ^a	1.6	34	14.8 ^a	1.3	8				25.4 ^b	1.9	9
NDF	41.7 ^a	0.8	14							52.8 ^b	1.8	9
ADF	27.0	0.7	14									
Phosphorus	0.4	0.1	22									
Calcium	0.7	0.6	22									
Potassium	1.7	0.3	22									
Magnesium	0.6	0.2	22									

TNC- total nonstructural carbohydrates

NDF- neutral detergent fiber

ADF- acid detergent fiber

Collections of eelgrass taken from sites where **brant** foraged showed plants from these foraging locations had a higher ($P<0.004$) concentration of TNC (**mean=19.9%**) than plants collected at other locations systematically placed along the transect (mean=12.5%).

Levels of TNC and nitrogen in above ground portions of plants varied with leaf length. Concentrations of TNC in short plants (<40 cm) were 30% higher than levels in the longer plants (>80 cm) (Table 3.3). These shorter plants also provided most of the diet of **brant**. In contrast, levels of nitrogen were greater in longer plants than in the shorter leaved eelgrass. Levels of ash and NDF did not differ with plant length. This suggests that **brant** selected plants higher in carbohydrates rather than plants higher in protein.

Table 3.3. Nitrogen and total nonstructural carbohydrates (TNC) expressed as percent of dry weight found in stems and leaves of eelgrass plants of different length at **Izembek** Lagoon, Alaska. Values with different letter within a column are significantly different from one another (ANOVA, $P<0.05$).

Plant length (cm)	n	<u>Nitrogen</u>		<u>TNC</u>	
		mean	SE	mean	SE
> 80	13	2.2 ^a	0.1	12.0 ^a	0.8
40 - 80	12	2.0	0.1	15.5	1.7
< 40	12	1.7 ^b	0.1	18.9 ^b	1.7

Distribution and abundance of eelgrass

Although detailed verification of major habitat classes (mud, eelgrass, water) of the 1978 LANDSAT image has not been undertaken, field observations indicate the classified image is an accurate representation of the lagoon. The lack of suitable color or color infrared aerial photography, which has been used to corroborate patterns in seagrass communities (**Orth** and Moore 1983), prevented comparison of LANDSAT data with photographic images. Inaccurate U.S. Geological Survey topographic maps also prevented precise geographic registration of the LANDSAT data. Consequently, it was not possible to ground truth the

data and verify the coverage of the major classes. Instead, the relative accuracy of the classes was determined from numerous field observations conducted over the four year study.

The location of tide channels and eelgrass beds on the 1978 LANDSAT scene was remarkably stable over time when compared with an older (1959) composite of aerial photographs and a more recent (1987) mosaic of black and white aerial photos. Most of the differences were found in size and shape of non-vegetated sand bars and spits near the entrances to the lagoon.

LANDSAT data indicated the total area of the lagoon was 34,302 ha. The lagoon was composed of 45.7% eelgrass, 36.5% **mudflat**, and 17.8% water (Figure 3.2). Most of the eelgrass occurred in the south (40.6%) and north-central (28.3%) zones. These zones also contained the greatest number of geese (see previous chapter).

Total area of the lagoon and proportion of eelgrass coverage from the 1978 LANDSAT scene were comparable to estimates made by **C.P. McRoy** (**unpubl.** data) of a 1959 black and white photograph: 34,302 vs. 33,688 ha and 46 vs. 53%, respectively.

The estimated standing stock of eelgrass leaves of 650 g/m² dry weight (**McRoy** 1966) was used to estimate the total **eelgrass** stock of **Izembek** Lagoon at 101,894,091 metric tons. If brant consume an average 270 g dry weight of eelgrass per day (Drent et al. 1981), the fall population of brant would consume 1.8 billion g dry weight of eelgrass, or 1.8% of the standing stock of leaves. This assumes that an individual brant remains at **Izembek** Lagoon for 54 days (average stay of radio-tagged brant 1987-1988) and an average fall population of 125,700 birds (average peak fall count from 1985 to 1988).

DISCUSSION

Brant feed almost exclusively on eelgrass while staging at **Izembek** Lagoon in fall. Although only a few factors that may control food selection were studied, our data indicates that certain parts and types of eelgrass were chosen. Brant and Canada geese preferred the above ground (leaves and sheaths) portion of eelgrass. Rhizomes were not important in the diet of brant and only slightly more important in Canada geese. Short plants dominated the diets despite their less frequent occurrence in the lagoon compared with longer, wider-leaved plants. Short (1981) described two morphological types of eelgrass at **Izembek** Lagoon. Plants growing closer to shore in tidepools occurred in dense stands and had generally shorter

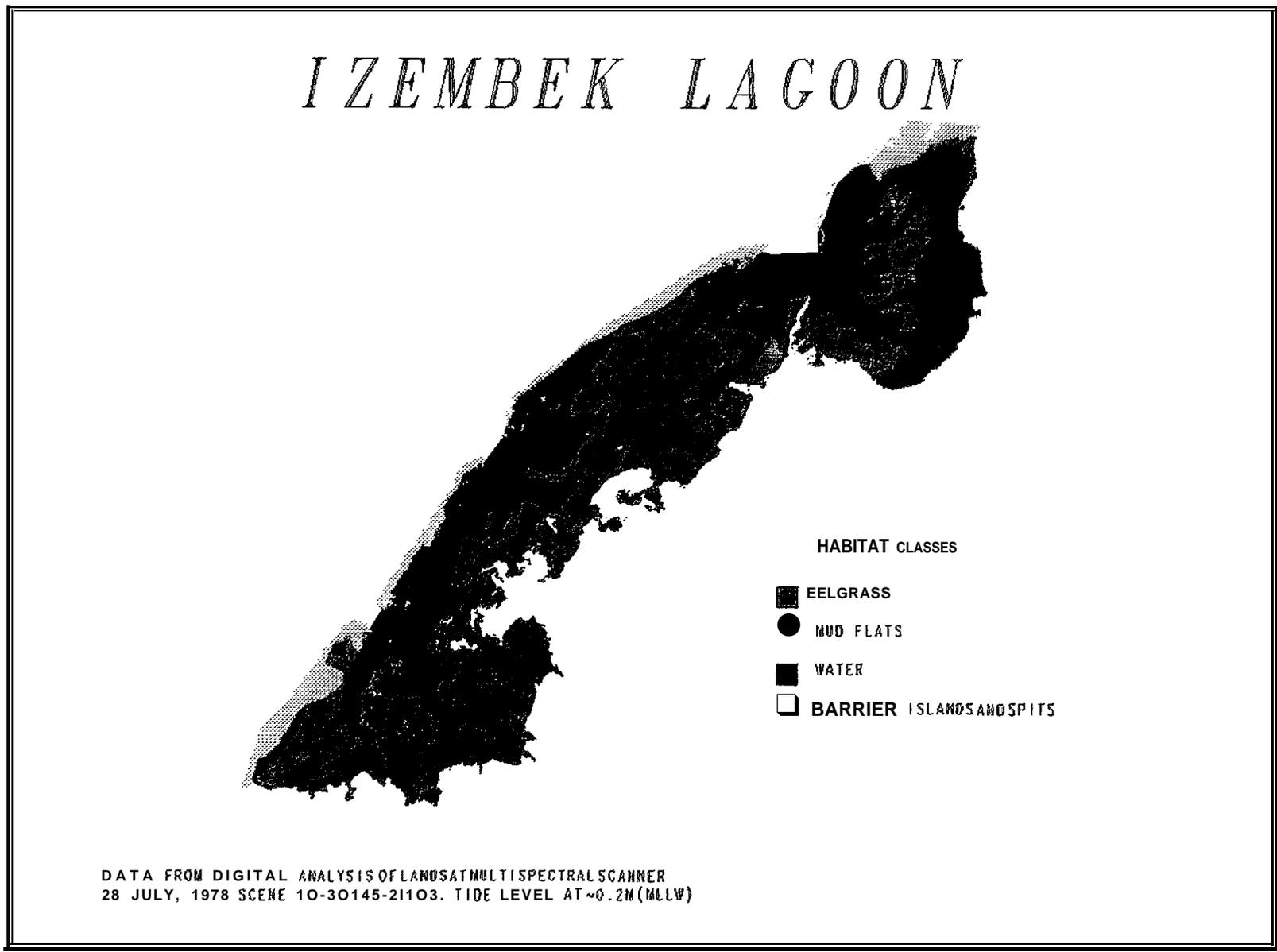


Figure 3.2. Distribution of major habitat classes of IZEMBEK LAGOON, Alaska as determined from a 1978 LANDSAT image.

and narrower leaves. Plants farther from shore and in deeper water or along tidal channels were longer, wider, and occurred in sparser stands. Shorter and narrower plants grow in areas which are higher in elevation (Short 1981) and thus they are more often available for foraging than longer plants.

Geese have simple gastrointestinal tracts that **limit** their ability to digest plant fiber (Demment and Van Soest 1983). Due to this constraint, instead of holding the food for more complete extraction of nutrients, geese maximize their ingestion and turnover rate of food (Owen 1972, 1975) and utilize only the rapidly extracted portions of plant nutrients. The short, narrow-leaved eelgrass plants may be more easily gathered and ingested by brant compared with longer broader plants. Digestion may also be facilitated due to a larger surface to volume ratio of small plants.

The predominance of shorter and narrower plants in the diet of brant could be a result of only collecting brant from nearshore feeding areas where these plants occur. We attempted to collect birds from offshore eelgrass beds but those birds were too wary to be approached by boat. We did collect birds moving to and from foraging sites but the majority of these birds (54%; n=24) lacked esophageal contents. Those birds with food, however, contained only short and narrow plants. It is possible that long, wide-leaved plants may be more likely broken in the esophagus or **proventriculus** of the geese. However, we observed no esophageal contents containing wide leaf fragments which would suggest breakage of long-leaved plants, and of the two birds which contained long, wide-leaved plants most (60%) of these plants were whole. Although more extensive unbiased sampling of esophageal contents of brant are needed, the available data indicate brant predominantly eat eelgrass plants with short and narrow leaves.

Results of eelgrass nutrient analyses from our study were comparable to levels reported by Roth (1986) and Morehouse (1974) also made in fall at **Izembek** Lagoon. Roth (1986) found higher levels of nitrogen and carbon in leaves than in rhizomes of eelgrass in early fall. Nitrogen concentrations were greatest in leaves of eelgrass in mid-November and again in March and April when levels increased from 2-3% to 4-6% ash free dry weight. Short, narrow-leaved plants contained significantly higher levels of carbon than long, wide-leaved plants. Differences in levels of nitrogen between plant types were due to age of plants: younger plants have higher levels of nitrogen (Thayer et al. 1976, Roth 1986). It is likely that differences between short and long plants were also related to age. Perhaps beds of short plants contained a greater number of younger plants. Morehouse (1974) reported similar levels of nitrogen (1.7-2.3% of dry weight) for whole plants. Lipid levels also were low (<1.5% of dry weight). One exception

between Morehouse (1974) and this study was the two-fold difference in levels of soluble carbohydrates (34-35% of dry weight vs. 5-26% this study). Morehouse (1974) collected whole (above and below ground) plants, especially those with **"attached organisms-t"**. The added nutrient content of **epiphytes** (plant and animal) along with the spatial and temporal variation in TNC may account for the higher levels.

Brant preference for the above ground portion of eelgrass may be associated with lower ash, lower cell wall content, higher protein, or higher carbohydrate content compared with rhizomes. Lower cell wall and ash content allows greater mechanical breakdown of the **plant** and facilitates digestion and assimilation of nitrogen and carbohydrates (**Buchsbaum et al. 1986**). Rhizomes may become increasingly important in late fall as growth of **eelgrass** declines and carbohydrates are translocated from shoots to rhizome in preparation for winter storage (**McRoy 1970b**). The occurrence of rhizomes in the diet of Canada geese in October may be due to this seasonal increase in carbohydrates in rhizomes.

Brant selected short, narrow-leaved plants that contained higher levels of **TNC** than longer plants (Table 3.3). Brant are relatively efficient at utilizing soluble carbohydrates (**Buchsbaum et al. 1986**, Sedinger et al. 1989) and thus they benefit from the higher energy content of shorter leaves even if protein content is slightly reduced (Table 3.3). Higher concentrations of carbohydrates will help meet energetic costs and allow for deposition of lipids needed for migration.

Although brant staging at **Izembek** Lagoon have an abundant total supply of **eelgrass**, its availability and quality is highly variable. The amount, location, and access to shorter, narrow-leaved plants are all much more restricted than the total quantity and **distribution of eelgrass**. Net energy intake depends on both quality and quantity of food. A reduction in caloric content of foods may dramatically influence the time needed to gain and replenish fat reserves. Fredrickson and **Drobney** (1979) hypothesized that with a 19% (390 **kcal/day**) reduction in daily caloric intake, a mallard would have to double its time feeding to replenish fat reserves. Brant selected specific foraging locations within larger **eelgrass** beds where plants contained higher carbohydrate levels. Selection of individual leaves within a certain size range or of higher nutrient quality may also occur. These preferences, along with the high variability in nutrient content and availability of **eelgrass** underscores the complexity of foraging adaptations and the probable need for brant to have unrestricted access to large areas of the lagoon in order to meet their foraging requirements. This need for brant to be free-ranging has also been indicated by Drent et al. (1981).

Body weight of brant collected from early September to late October indicated that males gained 13% and females gained 11% of their weight at **Izembek** Lagoon (**D.V. Derksen, USFWS, unpubl.** data) . Geese in better condition may be capable of migrating sooner and thereby avoid harsher weather conditions compared with those in poor condition. Large **endogenous** fat reserves can increase the distance birds can migrate (**Blem 1976**) and influence post-migration over-winter survival (**Haramis et al. 1986**).

CHAPTER 4: BEHAVIOR

The time budget and energetic of staging brant are important components in evaluating the impact of increased aircraft disturbance at **Izembek** Lagoon. Behavioral adjustments and flexibility in meeting energy demands determine whether brant can obtain adequate food and gain enough weight before migration in spite of disturbance. In order to evaluate possible effects, the extent and duration of behavioral response caused by natural disturbance and by increasing levels of aircraft disturbance were compared with undisturbed behavior. The proportion of time brant spend in foraging, resting, flight, and other behaviors during natural conditions provides the baseline against which added disturbance is to be evaluated.

Fall staging is a critical period for brant. The fat stored in body tissues at **Izembek** before fall migration provides the energy for their non-stop flight to wintering grounds. Species that forage on aquatic vegetation, which is generally high in water and fiber content, spend a high proportion of their time feeding (**Paulus** 1988). Also, geese grazing on low quality forage require considerable time for feeding. Barnacle geese (***Branta leucopsis***) required over 80% of daylight hours for feeding on grass (**Ebbinge** et al. 1975). Brant spent 78% of their time feeding on eelgrass in wintering habitat at San Quintin in Baja California (**Kramer** 1976). The amount of time required to obtain adequate forage could be an important consideration for brant staging at **Izembek** particularly if the interruption of feeding behavior caused by disturbance is of long duration or if disturbance events are frequent.

Foraging conditions change at **Izembek** from optimal in early September to poor in November. Decreasing air and water temperatures, shorter daylight periods, and less frequent low tide periods during daylight hours (Figure 4.1), all combine either to decrease the opportunity for feeding or to increase rate of energy expenditure during foraging. By October when salmon runs are exhausted, bald eagles congregate at the lagoon and cause frequent disturbance to brant flocks. Brant seem to reduce foraging time on preferred **eelgrass** beds located near shore. The combination of these late season factors limits the opportunity for brant to acquire additional energy reserves simply by extending their stay at **Izembek**. As a result, adequate accumulation of weight depends on sufficient time for foraging on **eelgrass** throughout the fall staging period at **Izembek**.

Casual observation of brant flocks suggests that disturbance may not greatly affect their foraging behavior. When flocks **of birds** are disturbed they often circle in flight and return within minutes to resume prior behavior. Even if flocks are displaced, they can move and forage elsewhere in the lagoon. If more energy is needed because of increased flight, brant could perhaps spend greater time foraging or increase rate of food intake in order to compensate. Food itself is probably not limiting because there is a tremendous biomass of eelgrass present (see previous chapter) , although forage quality, duration of food availability, and limitations on rate of intake and assimilation may be important.

Determining realistic 24-hr time budgets for behavior of both adult and hatching year brant were the objectives. Identification of factors that account for differences in behavior observed at different times and locations was important because brant frequently moved to different areas of the lagoon.

METHODS

The sampling procedures necessary to objectively estimate the behavioral time budget of brant at **Izembek** presented a series of problems. Procedures successful for some purposes or under some observation conditions became limited and impossible to use for other situations. Sampling foraging behavior required quite different observation techniques compared with determining the percent of time brant spent in flight. Age specific sampling was possible for those flocks located within 300 m (0.2 mi) of shoreline blinds but not possible for those flocks on large central **eelgrass** beds or barrier island **mudflats** more distant from shore. A series of sampling procedures and some assumptions were used to build a reasonable time budget. Different sampling procedures were cross-checked whenever possible to verify results and to examine biases.

Four levels of observation intensity and sampling methods were used:

- 1) Continuous behavioral observations made on individuals within a flock estimated the average flock behavior. This provided detailed data on the duration and sequence of behaviors and permitted separation of the behavior of adult and hatching year birds.
- 2) Instantaneous scan sampling allowed classification of the behavior of **many** individuals within a flock. Scans were less time **consuming** and could be completed on flocks at greater distances. This reduced dependence on shoreline blinds and specific study locations.

- 3) Special techniques estimated time spent in flight based on either a) frequency and duration of flight behavior, b) instantaneous scans to determine the average proportion of birds in flight, or c) minimum time required to account for movements of radio-tagged individuals sampled at 20 minute intervals. The data obtained from instantaneous scans were most numerous and representative, therefore only these results are presented.
- 4) Frequency of locations on individual brant in foraging versus roosting habitat areas were determined by radio telemetry. This provided a method to determine the relative importance of foraging and roosting behaviors that were not limited by shoreline observations.

Continuous behavioral data recording and analysis

Most observations were made from plywood blinds located on shoreline bluffs (Figure 2.1). Solidly constructed enclosed blinds with **moveable** plexiglass windows were necessary for telescope **observations** under the often windy and rainy conditions. The 10 to 40 m observation height above the water also improved the ability to accurately age individuals and to follow individuals during continuous behavior sampling.

A limitation of observations from blinds was that essentially all the continuous behavior data collected were from flocks foraging nearshore. No random selection of flocks or flock locations could be made. Flocks that were close enough to be observed were sampled when conditions permitted data to be collected.

A small portion of some of the study areas included an island beach or a **mudflat** that brant would occasionally use as a resting or gritting area. Brant flocks that used these small areas were included when they could be observed, but the proportion of birds engaged in resting or maintenance activity was under sampled. When tidal flooding made beds of eelgrass unavailable at a study area, most birds either moved to other foraging areas or roosted on the shallow-gradient mud (sand) flats inside the barrier islands.

Continuous behavioral observations on individual brant were recorded on a handheld computer (Hewlett-Packard 71B) . It was programmed to record the sequence and duration to the nearest 0.4 second of each of 10 behaviors recorded by key strokes. This computer program also guided the sampling protocol.

A bird was selected from within a flock and then, the fifth bird to the right of that bird was selected for

observation. Age was determined by plumage characteristics (Harris and Shepherd 1965). Entry of the **brant's** current behavior started the computer timing a 60-second sampling period. While keeping constant watch on that same bird, an observer keyed in any change in behavior as soon as it was seen. At the end of 60 sec or whenever the brant was lost from view, the individual sampling period was ended. The scope field of view was moved, another bird selected, the fifth bird to the right aged, and then it was observed for 60 sec. If possible, behavior of 30 individuals in each flock was sampled.

Data analysis of the continuous behavior recorded on the computer followed the suggested methods of Bradley (1985) that included examination and correction for bias caused by differential probability for the detection or loss of specific behavior patterns. A considerable portion of our data set, 16.5% of all events, consisted of first or last observed behaviors because each brant was observed for only 60 sec or less. This short sampling time was necessary because constant foraging movements of individuals within the flock resulted in the selected individual being hidden from view behind other birds even before the end of the brief sampling period. Examination of detectability bias is also particularly important to verify interpretation of the data collected by instantaneous scan sampling of flocks (see below).

The unbiased proportion of time spent in each behavior was obtained by a two-step calculation. First, a transition matrix was established to summarize the observed probability by which each behavior was followed by another behavior (Bradley 1985). The stable proportions across any row, obtained by multiplying the transition matrix by itself 64 times and dividing each term by the sum across a row, gave the expected stable frequency distribution for all behavior events. Next, an estimate of the proportion of time engaged in each behavior was obtained by multiplying expected frequency distribution by the average duration of each type of behavioral event (Bradley 1985).

In our data, the recorded duration of the first and last behavioral events for each individual were shortened (right censored) by the sampling procedure. Therefore, the average duration of all events in the sample was an underestimate because of this censoring. Average duration of all mid-events, excluding the first and last events, was also an underestimate because the probability was greater that longer behavior events would be those censored by the end of the sampling period. Product limit estimation techniques (SAS procedure LIFETEST) for censored data were used to obtain less biased estimates of average behavioral event durations.

Continuous behavioral data from **all** adult and hatching

year brant observed by three of the principal observers were examined in detail to investigate detection and loss bias in the behavioral sampling procedure. With the intention to keep analysis as simple as possible, and to provide independent sets of data to verify that sources of bias were consistent, the data from three observers and two age classes of brant were kept separate. The number of individuals sampled ranged from 55 to 413, and the number of behavioral events varied from 1,009 to 5,439 in the six different sets.

The expected proportion of time for each behavior was calculated based on the long term transition matrices and product limit estimates of event durations calculated separately for each data set. Frequency distribution of first and last observed behaviors was tested against expected proportions using a G-test with Williams^c correction (Sokal and Rohlf 1981) with any cells having expected frequency <4 being combined. In order to test if differences were consistent, deviations between observed and expected proportions of each behavior were averaged across the six data sets and tested to determine if the average differed significantly from zero (t-test, n=6).

Flock scan behavioral sampling

Instantaneous scan sampling of individuals in flocks permitted behavioral data to be collected at greater distance and under more diverse weather and light conditions because individual birds did not have to be carefully followed for 60 seconds. In 1986 and 1987, scan samples of flock behavior were conducted systematically during every hour of observation at the blinds. The relationship of flock behavior to variables such as time of day, tide height, and date is best represented in these data. Some bias associated with nearshore foraging locations was still present but this problem was reduced because flock behavior could be scan sampled at distances up to about 1,000 m (0.6 mi).

Behavior data were not collected on days with frequent aircraft overflight disturbance. Disturbance caused by eagles or hunters was also under represented because flocks were usually displaced away from study areas by these events and the scan sampling procedure was usually initiated by selection of a stable, undisturbed flock. The sampled behavior reflects undisturbed and presumably normal conditions for brant at **Izembek.**

Flock scan data collection was also aided by the handheld computer. A program was written to tally counts of each of the 10 behavior types and to produce a metronome beep to ensure systematic random sampling of behavior. Proceeding

systematically across a scope field of view from right to left or from back to front, an observer watched each individual (usually a 2-see interval was sufficient) and the ongoing behavior at the beep was tallied by keystroke. Data collection without the computer and timer was also possible as individual behaviors could be identified and counted in any systematic manner. Selection of 200 to 500 birds from all portions of a flock was an important consideration because brant near the periphery are more likely to be young in family groups and perhaps would exhibit slightly different behavior.

The proportion of individuals engaged in each behavior was taken as the estimate of time spent by the flock in that behavior. Average proportions of each behavioral type were calculated giving each flock equal weight regardless of flock size or sample size. Data were not transformed. Analysis of variance (SAS procedure **GLM**) was used to determine significance of tide stage, flock size, date categories, time of day, year, study area, and observer.

Time in flight behavioral sampling

Three sampling procedures were used to determine average time in flight. In the first method, flocks were selected, counted, and watched continuously for **10-min** intervals. The number of birds that initiated any flight behavior was recorded and a sample of flight duration times was measured. The probability of flight for a single brant within a given time period multiplied by the duration of flight was used to estimate the proportion of time in flight.

A second method was based on sampling an entire section of the lagoon rather than a discrete flock. Following an initial count of all the birds present in the selected area, the majority of which were flocks on the water, repeated scans and rapid counts were made of only those brant in the air. These were made by slowly sweeping the field of view of binoculars from one edge of the selected area to the other. Usually 20 scans were systematically made at 30- or 45-see intervals. The average number of birds in the air at any instant divided by the total number of birds present in the area estimated the proportion of time spent in flight. Each set of repeated scans over an area represented a cluster sample. The estimation of variance of proportions in cluster sampling was determined using a ratio estimator (**Cochran 1963:64**).

A third sampling method relied on sequential locations of individual radio-tagged brant as determined by triangulation from fixed antennas. The minimum time to account for straight line flights between each change of position gives a minimum

estimate of flight time per 20-min interval. This method was the only suitable procedure to estimate flight time at night.

Preliminary analysis and comparison of all three data sets indicated that the second method seemed reliable and yielded the most data. Therefore, analysis of the repeated instantaneous scans for proportion of birds in flight is presented here.

Foraging versus roosting behavior

Most roosting areas could not be observed except by aerial survey. The large expanse of shallow water and sand (**mudflats**) on the inside of the barrier islands provided roosting habitat used by thousands of brant. Roosting occurred mainly at high tides with roosting duration dependent on weather, time of day, and tidal height. The shallow water diminished wave heights, allowing birds to stand rather than swim and making grit easy to obtain. Brant may also favor these locations because little disturbance occurs on these sand flats. The lack of nearby bluffs or vegetation assures high visibility of eagles and foxes. On a few occasions we were successful in approaching to within about 400 m of these flocks. After sitting and waiting for at least **15-min**, we sampled behavior by flock scans.

The time spent at roosts and the number of brant using roosts were important to determine. Roosting time could not be adequately estimated with data from shoreline blinds. At the one large roosting area on **Operl** Island which could be regularly observed from Grant Point, only approximate counts of birds present could be made because of the 2,200 m (1.5 mi) observation distance. Therefore, the proportion of time that brant used the non-feeding roosting areas was indicated indirectly based on frequency of use by radio-tagged birds.

The lagoon was divided into two broad habitat zones, vegetated versus non-vegetated, based on aerial photography and LANDSAT imagery. Foraging behavior, except for scattered feeding on detached floating **eelgrass** leaves, was restricted to **eelgrass** beds. Resting and maintenance behaviors predominate in the non-vegetated sand flat roosting areas. Resting and maintenance behaviors also occurred in flocks using portions of the vegetated zone such as small sand bars and shorelines of islands. Also many brant rest and preen while floating in large dispersed rafts in deep water over grass beds. These cases were appropriately sampled by and included in the continuous and scan sampling of behavior conducted from shoreline blinds.

Radio-tagged brant were tracked using 4- or 5-element twin yagi antennas located on ridges or shoreline bluffs (Figure 2.1). The 340 m elevation of **Baldy** Mountain, which was 5 km (3 mi) from the edge of the lagoon, enabled radios to be detected up to 28 km (17 **mi**). Antennas on shoreline bluffs typically could detect birds at distances up to 11 km (7 mi). Null border azimuths on radio signals were taken synchronously (within a few minutes) at two to four antenna locations at 20-min intervals. Locations were based on azimuth intersections or maximum likelihood triangulation calculations (White 1985). The azimuth data were analyzed, brant locations determined, and points plotted on a map of the lagoon using TrueBasic computer programs. Locations were categorized as a) associated with **eelgrass** beds, b) non-vegetated **mudflats**, or c) undetermined for borderline locations or obvious errors.

RESULTS

Behavior patterns

The behavioral patterns observed were categorized into 10 separate types, five associated with foraging, plus alert, maintenance, rest, **agonistic**, and flight behaviors.

Foraging behavior predominated. Brant ate the above ground portion of rooted eelgrass plants or **detrital** flow of eelgrass leaves in the tidal currents of the lagoon. Occasionally standing and walking brant would graze on exposed beds of eelgrass at which time some grubbing and breaking of rootstock occurred, but this was exceptional. Nearly all foraging occurred in shallow water while brant swam over grass beds and reached to the water surface for floating leaves or below the surface to grab leaves. This posture was **called head down feeding** and ranged from the bird's bill being inclined downward often almost touching the water surface to the bird plunging the entire head and neck beneath the water surface. Head down involved active movements to obtain eelgrass.

Occasionally when the incoming tide flooded part of a grass bed, in order to reach deeper for leaves, brant would show a **tip up** posture. Brant were not observed to dive completely below the surface to obtain food. However, they would dive when pressed to escape an eagle or gyrfalcon (**Falco rusticolus**).

Alternating with head down feeding was **head up** feeding posture. This behavior commonly appeared to involve searching for suitable grass leaves as well as swallowing them. On rare occasions when light was sufficient and the bird was relatively close, the observer could see that this same head up posture

involved the actual intake of grass leaves. A long blade of grass hanging from the bill was pulled into the mouth, probably by repeated tongue movements. Esophageal contents showed many entire leaf blades folded in a zigzag pattern (see Einarsen 1965:47).

Head up posture graded into swim behavior when the head up swimming was prolonged and the speed and direction of travel was constant. Similarly, in situations where the water was not deep enough for swimming, head up graded into walk behavior. Swimming was necessary to counteract tide currents or wind and to stay over a particular grass bed or to move with incoming or receding tides to maintain an appropriate water depth for feeding. Movement during head up and head down was not categorized as swim behavior.

For data analysis, head up, swim, and walk were grouped together as an inactive or pause part of foraging behavior. Head down and tip up were grouped as the intake or **active** portion of foraging. Both head down and head up behaviors were part of feeding. Although brant constantly alternated between head down and head up, the relative durations of the two phases of foraging behavior appeared to be a good indication of rate of intake of eelgrass leaves.

Spacing within a foraging flock was maintained both by individual distance and enforced guarding of families by adults. A short burst of rapid swimming with head and neck extended far forward, probably accompanied by vocalization, was used to repel offending or intruding birds. This agonistic behavior, both the aggressive attacks and the simple retreats, was not elaborate and never prolonged.

Reaction to disturbance and watching for predators were typically associated with an exaggerated alert posture with head held high and neck straightened. Specific vocalizations, or the lack of the constant chattering heard during foraging, usually accompanied the alert posture. Vocal communication may be elaborate and very important for **brant**, a gregarious species found in flocks or colonies throughout the year. The distance at which our observations were made, as well as high ambient noise levels caused by wind and waves, prevented data collection on vocalization behavior of brant.

Preening, wing stretching, bathing, and a variety of comfort movements were grouped as maintenance behavior. Resting and sleeping either with the head tucked or held without movement in a low position, whether the bird was standing, sitting, swimming, or floating, were grouped as rest behavior.

Although continual readjustment and some local movement

occurred by swimming, flight was used for nearly all movements around the lagoon. Brant are efficient and strong flyers and make frequent flights under any wind conditions. Short flights to adjust feeding location within the same flock were the most frequent movements and occurred several times per hour. Flights of 200 to 2,000 m between flocks were observed several times within each tide period. Flights between foraging areas or between roosting and foraging areas at distances up to 10 km also occurred several times a day.

Detection and loss bias in sampling

The presence of bias in sampling behavior was investigated using six subsets of the continuous data. Detection bias is present when frequency of the first observed behaviors from each individual brant do not correspond to the proportion of total time engaged in those behaviors. First observed behaviors were not representative (G-tests, $P < 0.01$) in three of the six data sets (Table 4.1). The largest differences were due to under representation of head up foraging behavior and this pattern was consistent over the 6 data sets (Table 4.1). Head up foraging occurred as the first behavior 10% less frequently than expected ($t = -4.7$, $P < 0.01$). All observers tended to start their timed observations on an individual with a more defined category of behavior, such as head down feeding. Also flight behavior was seldom the first observed behavior ($t = -4.0$, $P < 0.05$), a bias that was partially caused because flocks in flight were never chosen to be sampled. All sampling began with relatively stationary flocks located fairly close to blinds. All other first observed behaviors, besides head up and flight, were not significantly different in frequency than expected (Table 4.1).

Loss bias occurs if certain behavior patterns are more likely to be the last one observed for each individual. Of the six data sets, four had different frequency distributions for the last behavior observed compared to expected proportions (G-tests, $P < 0.01$). Rest and maintenance behaviors were over represented as last behaviors (Table 4.1) because of the frequent censoring of these long duration events by the end of the sampling period. The only significant bias ($t = 3.3$, $P < 0.05$) found across all data sets was that flight behavior was last observed "with 1.3% frequency compared to an expected frequency of 0.5%. Extended observation of brant in flight was usually not possible because the individual bird, and often the flock, was lost from view.

Detection and loss bias were unimportant for most types of behavior. Although some differences in proportions occurred for feeding, head up, rest, and flight behaviors (see below; **Table 4.4**), these deviations had either a small effect on bias

or they were not consistent across all data sets. Because head up behavior was frequent and of short duration, even with some bias in detection, the total time spent in head up behavior was still accurately measured. The longer duration of flight and rest behaviors caused more of a problem.

For both flight and rest, the product limit method could not produce good estimates of average event duration because the number of censored cases greatly exceeded the number of uncensored cases, and all of the longer duration events were censored. Therefore, because average duration of flight and rest were underestimated, the expected proportions for these behaviors were known to be under assessed, and consequently expectation for other behaviors were slightly overestimated. The transition matrix and event duration approach (Bradley 1985) can not be completely reliable if average event duration is not accurate. However, for the flocks observed, rest and flight behaviors were infrequent and therefore these had a small influence on total time and proportions of behavior.

Behavioral time budget

The observed total time that brant were engaged in each behavior provides an unbiased estimate of proportions even if event durations are censored by a short sampling period, provided that detection and loss bias are not important. The frequency of behavior events and the average duration of events were estimated only to examine whether significant detection or loss bias exists (see above). The observed proportions of time for each behavioral pattern (Table 4.2) were tabulated from the complete continuous observation data set for all adult and hatching year brant. These proportions were almost identical to expected proportions derived from the stable frequency of the transition matrix multiplied by the average duration of all events.

The relative proportions of intake foraging and pause foraging was strongly related to tide stage (Table 4.3) and to date, but **not** influenced by time of day (SAS procedure GILL, main effects). The same relationships held for both adult and hatching year birds. Intake foraging was observed 15% more of the time at low and flood tide stages compared with high and ebb stages (Table 4.3). Total foraging time (intake plus intervening head up, swim, and walk behaviors) did not change with tide or time of day. However for both adult and hatching year birds, total proportion of time foraging was 10% higher (91 and 93%, respectively) between 9 and 22 October just before departure (see "**Diet and Nutrition**" section) compared with 79-83% for the other dates examined. Age class influenced the proportion of four behaviors (SAS procedure GLM). Intake foraging accounted for 8% more time and pause foraging was 6% less in hatching year compared to adult brant.

Table 4.2. Frequency of occurrence and proportion of time engaged in various behaviors by adult and hatching year brant as recorded by continuous sampling of nearshore foraging f leeks (n=199) at Izembek Lagoon, Alaska.

	Behavior									
	Feed	TipUp	HedUp	Swim	Walk	Maint	Rest	Alert	Aggr	Fly
Adult :	1,706 individuals, 21,022 behavioral events, 98,530 sec									
obs prop time	.516	.010	.208	.105	.006	.070	.059	.015	.003	.008
num. events	9409	426	8358	1442	140	654	211	243	102	37
avg. duration	5.4	2.4	2.5	7.2	4.3	10.5	27.5	5.9	3.2	21.5
transit. matx	.439	.021	.419	.063	.006	.028	.006	.011	.005	.002
exp prop time	.528	.011	.229	.100	.006	.064	.034	.015	.004	.009
Hatching year:	840 individuals, 9,388 behavioral events, 49,182 sec									
obs prop time	.557	.014	.189	.090	.004	.068	.064	.005	.001	.008
num. events	4288	225	3693	664	45	300	94	48	10	21
avg. duration	6.4	3.0	2.5	6.7	4.6	11.2	33.4	5.4	3.1	19.4
transit. matx	.444	.025	.418	.067	.005	.029	.004	.005	.001	.002
exp prop time	.570	.015	.212	.090	.004	.065	.029	.005	.001	.009

Comparison of flock scan and continuous sampling

Flock scan sampling was compared to continuous behavior sampling by two methods. First, for 33 flocks, both sampling methods were used in sequence. Average paired differences did not differ from zero for any of the behaviors (t-tests, $P > 0.05$). Slopes did not significantly differ from 1.0 and the intercepts did not differ from 0.0 (t-tests, $P > 0.05$) in linear regressions used to predict scan data based on continuous data. An exception was head-up foraging which regression indicated as significantly less frequent by scan sampling methods. The direction of this bias was the same as seen earlier when head up foraging was under represented as the first observed behavior compared with expected proportions. However, the results of this particular regression were greatly influenced

Table 4.3. Average proportion of time for various behaviors summarized by tide stage. Behavior was sampled by continuous 1 minute observations of individuals in foraging flocks in September and October, 1985-88 at IZembek Lagoon. The flock was the sampling unit. Unweighed averages were calculated using all flocks that had more than two adults, or two hatching year, or more than 2 individuals of either age. Intake included head-down and tip-up foraging. Pause included head-up, swim, and walk foraging behaviors.

Tide stage (In)	n	Behavior						
		Intake	Pause	Maint	Rest	Alert	Aggres	
<u>Adult</u>								
low <0.3	17	0.60	0.27	0.10	0.016	0.007	0.003	
flood 0.3-0.9	39	0.59	0.24	0.12	0.006	0.015	0.004	
high >0.9	78	0.45	0.40	0.04	0.088	0.013	0.002	
ebb 0.3-0.9	33	0.43	0.38	0.07	0.073	0.027	0.005	
<u>Hatching Year</u>								
low <0.3	14	0.68	0.20	0.11	0.000	0.007	0.000	
flood 0.3-0.9	28	0.68	0.20	0.09	0.006	0.017	0.000	
high >0.9	58	0.53	0.31	0.04	0.109	0.004	0.001	
ebb 0.9-0.3	28	0.50	0.34	0.06	0.070	0.001	0.001	
<u>Ages combined</u>								
low <0.3	21	0.60	0.23	0.14	0.021	0.009	0.002	
flood 0.3-0.9	45	0.59	0.25	0.11	0.009	0.019	0.002	
high X3.9	84	0.46	0.37	0.05	0.100	0.013	0.002	
ebb 0.9-0.3	37	0.45	0.39	0.06	0.061	0.014	0.005	

by two data points and the rest of the data points indicated good agreement.

The high degree of scatter observed in all regression relationships indicated that behavior of a flock can shift rapidly in the time between two sequentially taken samples or during the 30-min continuous sampling period. Also the variation in behavior among 30 individuals of a flock makes the estimate of average flock behavior rather imprecise because of sampling error resulting from the selection of only 30 individuals. Although flock scan and continuous behavior did not usually differ, this test based on paired data for 33 flocks was not particularly convincing.

A second comparison between the two sampling methods was made by examining average proportions for the various behaviors using all the data collected by each method. The continuous data were reanalyzed ignoring age classes (Table 4.3). Data sets were divided by the four tide stages. The average proportion for intake foraging, pause foraging, maintenance, rest, alert, and agonistic behaviors were compared and indicated remarkable agreement between flock scan and continuous sampling at all tide stages except high (Table 4.4). From these 24 comparisons of means, the only two that were significantly different (t-test, $P < 0.05$) were intake and pause foraging at high tide. The continuous data at high tide showed 18% greater intake and 6% less pause foraging behavior compared to scan samples.

Rather than a bias caused by the method used for behavior sampling, which was somehow only important at high tide, the difference was more likely due to bias in the selection of flocks being observed. With continuous sampling methods observed flocks had to be closer to blinds and viewed under better weather and light conditions than with scan sampling. Those flocks that do not fly to roosts but instead continue to feed at high tide must forage nearshore, and these were more easily observed from blinds. In contrast, flock scans were able to sample flocks at greater distances from shore and included flocks roosting or feeding at low rates in open water locations.

Because detection and loss bias were usually not important and because of the agreement between continuous and flock scan sampling, flock scan methods were accepted to accurately identify behavior events and to provide unbiased estimates of proportions of time spent in each behavior. Because sample sizes of individuals per flock and the number of flocks observed were both larger for flock scan data, and because scan samples were less restricted to nearshore locations, flock scan data (Table 4.4) provided better estimates of behavior time budget. It was, however, limited by the lack of age specific data.

Table 4.4. Average proportion of time **engaged in** various behaviors as **determined** by flock scan sampling of brant flocks in **September and October, 1985-88**, at **Izembek Lagoon, Alaska**.

Tide stage (m)	n	Behavior						
		Intake	Pause	Maint	Rest	Alert	Aggres	
<u>Nearshore foraging flocks</u>								
low <0.3	74	0.59	0.26	0.10	0.02	0.025	0.007	
flood 0.3-0.9	125	0.58	0.28	0.10	0.02	0.012	0.005	
high >0.9	188	0.28	0.43	0.07	0.20	0.013	0.005	
ebb 0.9-0.3	98	0.38	0.33	0*1.2	0.16	0.011	0.005	
<u>Barrier island roosting flocks</u>								
high >0.9	3	0.003	0.04	0.42	0.51	0.029	0.004	

Factors influencing behavior

Tide stage influenced the mean proportions of intake foraging, pause foraging, maintenance, and rest behavioral events tallied during flock scan observations (SAS procedure **GLM**). At high tide, the decrease (-32%) in intake behavior from 59% to 27% was balanced by changes in pause foraging (+17%), rest behavior (+18%), and maintenance (-3%) behaviors (Table 4.4).

Alert and **agonistic** behaviors were not influenced by tide stage. Date, time of day, and year were not significant factors (SAS procedure **GLM**) for any behavior.

Study areas showed similar patterns of intake foraging and larger flocks, particularly those over 1,500 birds, showed higher intake foraging at all tide stages. Study area and flock **size** factors, nested within tide stage, were significant (SAS procedure **GLM**) for intake foraging behavior, but not significant for other behaviors.

Time in flight

Repeated instantaneous scans of sections of the lagoon were conducted at intervals of 30 or 45 sec to determine the

average number of brant in the air. The proportion of birds in flight at any instant out of the total number present estimates the average proportion of time an individual spends in flight if large enough samples can be obtained to integrate over time, individuals, and conditions. A total of 6,651 scans were obtained during 300 sets of samples. Samples with fewer than 150 brant at either the beginning or end were excluded (n=30, **avg=8.9%** flight) as these small samples have greater bias involved in calculating ratios. Also excluded were periods having aircraft or human related disturbance (n=8, **avg=4.3%** flight). In contrast, those periods having natural disturbance from eagles or unknown causes were included (n=22, **avg=5.9%** flight) in the overall sample.

The total sample recorded 268,110 brant in flight. An average of 40.3 brant were counted in flight and an average of 2,279.4 total birds were present. The time spent in flight was 1.77% (n=300, **SE=0.44%**). Brant passing through sections of the lagoon in flight but that never landed in the area accounted for an additional 0.11% (**SE=0.26%**) in flight. However, because these birds were not part of the sampled population, they were excluded. If all sampling periods with known or suspected disturbance events were excluded, the estimated percent of time in flight was 1.26% (n=278, **SE=0.34%**).

Some flight occurs at night. Radio-tagged brant shifted locations and occasional flocks were heard calling while flying at night. Clear weather and moonlight may increase flight but insufficient data were collected to document this. An arbitrary assumption of the percent of time spent in flight at night was made at 0.9%, half of the daylight estimate.

Behavior and frequency of use of roosting areas

The behavior of brant at high tide using the shallow water sand flats inside **Operl** Island was sampled on three occasions. Behavior observed by flock scans averaged 51% resting and 42% maintenance behaviors (Table 4.4). In contrast, nearshore flocks were rarely observed to show as much as 50% rest and maintenance behaviors. Brant using the roosting area inside the barrier islands consistently displayed rest and maintenance behaviors. The lack of **eelgrass** precludes intensive feeding, therefore presence of brant at these roosting sites was clearly related to rest and maintenance behaviors.

The proportion of radio telemetry locations of brant in roosting (non-vegetated) areas versus **eelgrass** foraging areas was an indirect measure of behavior that was not biased by the shoreline locations of observation blinds. Brant were

classified as located either in foraging or roosting areas. The frequency of these locations were grouped by categories of tide height at Grant Point and daylight versus night periods. During daytime low tide and flooding tides nearly all brant (98 and 92%, respectively) were in foraging areas (Table 4.5). At high and ebb tide 47% of the birds moved to roosting areas (Table 4.5). At night the pattern was similar but the number of locations in foraging areas was reduced. During flood tides at night, 64% were in foraging areas [tides below 0.3 m (1.0 ft) did not occur on the night sampled]. At high and ebb tides at night most brant (60-64%) moved to roosting areas (Table 4.5).

Table 4.5. Number of locations of radio-tagged brant determined to be either on foraging areas associated with eelgrass beds or on roosting areas on non-vegetated mudflats. All determinations based on triangulations of 2 to 4 azimuths taken systematically at 20-minute intervals from shoreline or ridgetop antennas. Locations are grouped by four tidal stages and day or nighttime periods.

Tide stage (m)	Eelgrass	Mudflat	Undet.	Total
Daylight period (0830 - 2030)				
low <0.3	128 98%	3 2%	7	138
flood 0.3-0.9	280 92%	23 8%	53	356
high >0.9	316 53%	280 47%	124	720
ebb 0.9-0.3	96 54%	81 46%	23	200
Night period (2030 - 0830)				
low <0.3	0	0	0	0
flood 0.3-0.9	43 64%	24 36%	2	69
high >0.9	22 36%	39 64%	1	62
ebb 0.9-0.3	68 40%	105 60%	0	173

Construction of 24 hour behavioral time budget

Data collected on behavior of brant was dominated by nearshore foraging flocks. Behavior varied with age of the individual and tide stage. Adjustment to obtain a 24-hr behavioral time budget incorporated three additional factors: percent of time in flight, relative number of birds using roosting versus foraging habitats at each tide stage, and the relative duration of each of the daylight and night tide stage periods (Figure 4.1).

Flock scan data (Table 4.4) provided the best estimates of average time engaged in each behavior type. In foraging areas behavior varied with each tide period. Based on the average difference between behavior of adult and hatching year brant (Table 4.3), the behavior of hatching year birds showed 8% more intake, 6% less pause, 1% less rest, and 1% less maintenance compared to adults. Differences were similar at all tide stages, therefore they were added to all the **flock scan** behavior rates to obtain behavior estimates for hatching year birds.

The flock scan data closely reflects behavior of adults as approximately 80% of the population was adult birds in most years. Nevertheless, for the two dominant behavior types, before the adjustment of flock scan data for hatching year brant, the flock scan data was adjusted by **-1% (20% of 8%)** for intake and **+1% (20% of 6%)** for pause to correct for the influence of the 20% hatching year birds observed in the flock scan data. Resting and maintenance behavior **observed** at roosting sites (Table 4.4) was assumed to be independent of tide stage and age of the bird. Following these adjustments for age, a time in flight of 1.8% during daylight and 0.9% during night was also added to the behavior flock scan data, and consequently all other behavior proportions were adjusted by multiplying by (1-0.018) or (1-0.009).

The number of radio-tagged brant locations in each habitat type (Table 4.5) determined a weighting factor proportional to the total number of brant using each habitat at each tide stage. Behavior proportions for each habitat were weighted to combine brant in the two habitats at each tide stage period for both **adult** and hatching year birds (Table 4.6). Nocturnal behavior was assumed to be equivalent to behavior observed during the day for each habitat type. Thus, the reduced feeding at night reflects the increased use of roosting habitat rather than a decreased rate of feeding in foraging habitat. No data exist to show that brant located on **eelgrass** beds at night are not foraging.

Figure 4.1. Frequency distribution of the proportion of each 24-hour period at low, flood, high and ebb tide stages that occurred during daylight or dark-periods at Grant Point, Izembek Lagoon, Alaska.

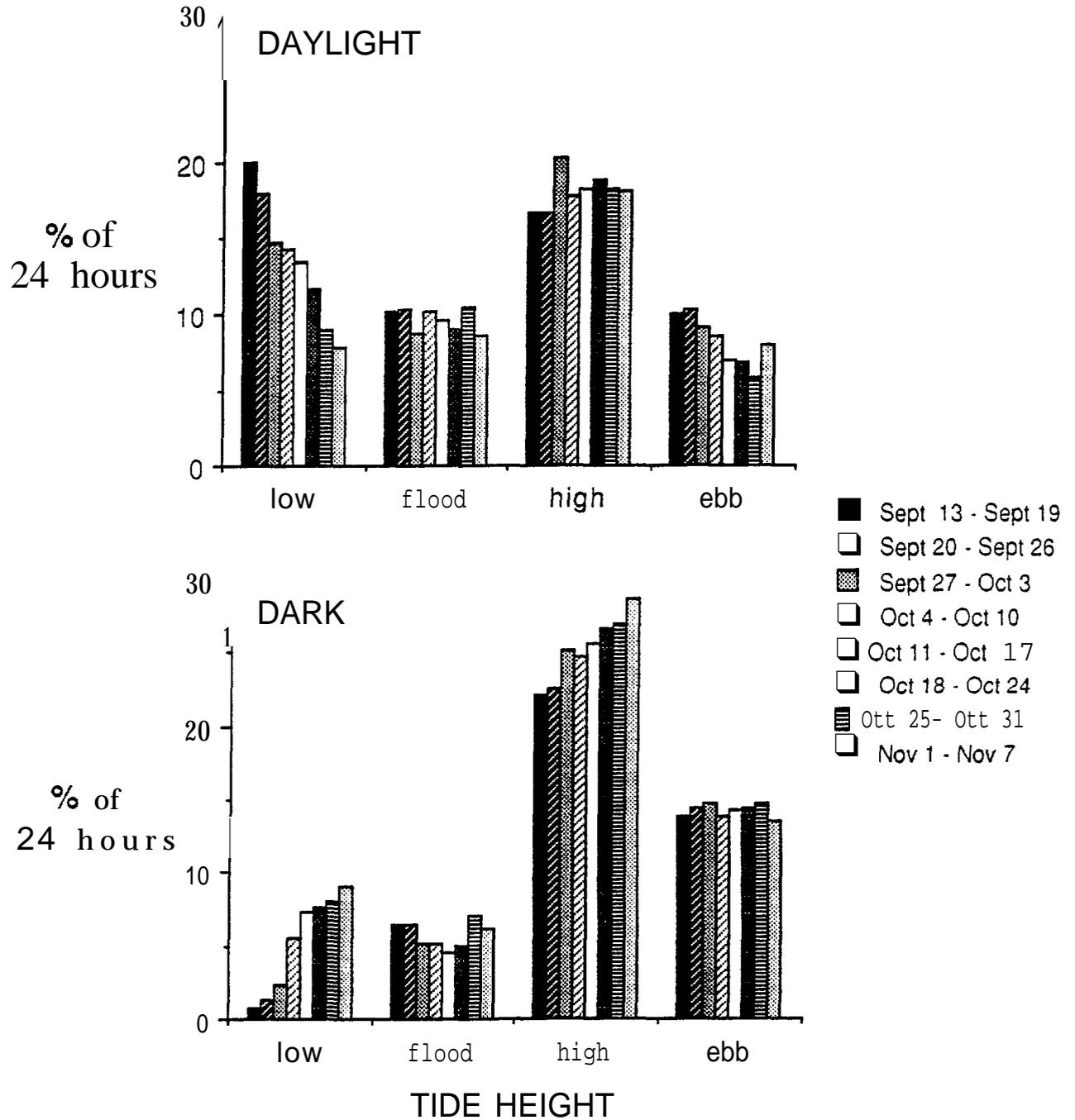


Table 4.6. Construction of 24-hour behavioral time budgets for adult and hatching year brant staging in September and October at Izembek Lagoon, Alaska. The proportion of time spent in each behavior was determined by flock scans at various tides (Table 4.4) and weighted by the proportion of locations of radio-tagged brant within each habitat (Table 4.5) for both daylight and night periods.

Tide stage	Behavior							Tide stage per 24 hrs
	Intake	Pause	Maint	Rest	Alert	Aggres	Fly	
ADULT:								
<u>Daylight</u>								
low	0.555	0.261	0.105	0.029	0.025	0.007	0.018	0.138
flood	0.515	0.265	0.123	0.058	0.013	0.005	0.018	0.096
high	0.142	0.248	0.230	0.340	0.020	0.004	0.018	0.181
ebb	0.198	0.198	0.253	0.315	0.019	0.004	0.018	0.081
<u>Night</u>								
low	0.339	0.186	0.213	0.195	0.026	0.006	0.009	0.051
flood	0.363	0.198	0.213	0.195	0.018	0.005	0.009	0.057
high	0.098	0.182	0.291	0.395	0.023	0.004	0.009	0.252
ebb	0.148	0.159	0.297	0.367	0.022	0.004	0.009	0.143
<u>24-hr behavior weighted by habitat and tide stage</u>								
	0.254	0.212	0.228	0.270	0.021	0.005	0.013	
HATCHING YEAR								
<u>Daylight</u>								
low	0.635	0.203	0.095	0.020	0.025	0.007	0.018	0.138
flood	0.588	0.211	0.114	0.049	0.013	0.005	0.018	0.096
high	0.184	0.216	0.225	0.334	0.020	0.004	0.018	0.181
ebb	0.240	0.167	0.248	0.310	0.019	0.004	0.018	0.081
<u>Night</u>								
low	0.420	0.147	0.207	0.188	0.026	0.006	0.009	0.051
flood	0.413	0.160	0.207	0.188	0.018	0.005	0.009	0.057
high	0.127	0.161	0.288	0.391	0.023	0.004	0.009	0.252
ebb	0.180	0.135	0.293	0.363	0.022	0.004	0.009	0.143
<u>24-hr behavior weighted by habitat and tide stage</u>								
	0.300	0.178	0.222	0.264	0.021	0.005	0.013	

Final adjustments were made by weighting these behavior rates determined for each tide stage by the overall proportion of time at each tide. Tide tables for Grant Point and sunrise tables (**USDC** 1985, 1986, 1987, 1988) were used to generate the average time at each tide stage during daylight and night periods (Figure 4.1). Tabled data were used from four years, 1985-1988, and from 13 September to 5 November each year. This 54 day period represented the average arrival and departure dates of radio-tagged **brant** from the Yukon-Kuskokwim Delta in 1987 and **1988**. Daylight was defined as extending from 30 min before sunrise to 30 min after sunset. Tide height was interpolated between tabled high at low tide height values for any time using a sine wave function over 180 degrees, thus assigning a smooth **sigmoid** shape for change in tide height. The tabulation of a systematic sample every 20 min (**n=16,128**) determined the overall frequency and proportional duration of each tide period (Table 4.6). The average 24-hr behavior was then calculated for adult and hatching year brant by appropriately weighting and combining each tide stage period (Table 4.6).

DISCUSSION

The numerous steps and factors incorporated into the derived 24-hr behavior emphasize the need to carefully consider sampling design and potential biases in behavioral and energy budget studies on waterfowl (**Baldassarre et al. 1988**, **Jorde and Owen 1988**). The tide-dominated patterns and the constant movement of brant among eelgrass beds and roosting areas throughout the lagoon complicated data collection at **I zembek**.

Radio telemetry was used to determine time spent in each habitat and these proportions were then used to weight the behavioral observation data. Similar techniques have been used in determining time budgets of wintering black ducks (**Anas rubripes**) (**Morton et al. 1989**).

Rapid scan sampling for behavior of flocks proved to be essentially unbiased and was a more efficient and less restrictive method than recording continuous behavior. Repeated **scan** samples to quantify flight behavior was an important and particularly useful sampling method.

When actively foraging on eelgrass at low tide, adult brant spent 60% and hatching year birds spent 68% of their time actively feeding head down plus an additional 27% and 20%, respectively, handling food items, searching for suitable plants, and constantly swimming to maintain position over the grass beds. Combined, these intake and pause phases of

foraging behavior represented 83 to 88% of total time observed during low and flooding tides (Tables 4.3, 4.4). The high rate of feeding during flooding tide was related to the continued availability of eelgrass beds covered by shallow water as brant shifted their foraging locations from central beds near lagoon entrances to nearshore beds at the periphery.

In areas farthest from the lagoon entrances, the timing of tidal cycles is also delayed by slightly over an hour compared with Grant Point. By constant movement brant can forage at low tide conditions throughout the period of low and flooding tide. Because assimilation rate of natural forage by brant is quite low (**Buchsbaum** et al. 1986), they must consume large amounts of food in order to gain weight (Owen 1972, 1975) and a large fraction of the total time is needed for brant to **meet** their nutritional requirements.

This intensity of foraging is greater than reported for other species of geese at fall staging areas. Lesser snow geese staging at the end of August on the northern coastal plain of Alaska were observed grubbing and searching for food for an average of 59-47% of the time for adults and 76-67% for juveniles (**Brackney** et al. 1986). These averages were derived during 4-hr time periods throughout the day with the midday periods having the lower rates. Snow geese observed October to December in Nebraska showed 22% feeding for adults and 39% feeding times for juveniles (Frederick and **Klaas** 1982). Observations of cackling Canada geese on the Alaska Peninsula in October indicated that adults spent 53% and juveniles spent 83% of the time feeding (Sedinger and **Bollinger** 1987).

A similar behavioral time budget was observed in winter at San Quintin, Mexico (Kramer 1976), where brant feed on eelgrass. Behavioral observations indicated that brant foraged 90% during ebbing tides, 80% at low tide, and 70% just before and after high tides. This study did not include estimates of flight time or roosting time on the ocean immediately adjacent to the estuary. Other behaviors observed such as maintenance (10%), rest (8%), swim (3%), alert (0.8%), and aggression (0.1%) were similar to those made by brant at **Izembek**. The same foraging postures were observed at **Izembek** as reported by Kramer (1976). Tip-up, grazing, and detrital feeding were more frequent for brant at San Quintin compared with birds at **Izembek**. This would support the contention (Kramer 1976) that disturbance from hunting and boats caused limitation and disruption of optimal feeding behavior.

The ability of brant to compensate for lost feeding time caused by disturbance is limited because the observed intensity of foraging behavior during low and flooding tide stages is already high. For instance, if during all low and flooding tides during daylight brant increased their foraging behavior

to 100% (instead of 83-88%) of the time, and if no birds (instead of 2-8%) used roosting habitat, brant would only increase the proportion of 24 hr spent at intake foraging to 0.290 for adults and to 0.337 for juveniles. These increases are only 14% and 12% above current levels for adult and hatching year brant. As an upper limit of compensation, brant could forage continuously day and night. This change would increase intake foraging to 0.508 of the total time (100% increase) for adults and 0.587 (96% increase) for hatching year birds.

The ability to further increase foraging above this already somewhat improbable 100% increase depends on a series of increasingly questionable assumptions concerning rate of food intake, food availability, food quality, assimilation rate, equal foraging efficiency at night, and no requirement for maintenance or rest behaviors. An upper limit for intake feeding would be double the current rate.

This exploratory analysis of reducing some observed behaviors (Table 4.4) and habitat use (Table 4.5) proportions and maximally increasing foraging behavior to compare with Table 4.6 results was based on maintaining the observed ratio of intake (head down) versus pause (head up plus swim) foraging at each tide stage. Total foraging time was increased but this ratio that presumably reflects actual intake rates was the same. This assumption was reasonable because limits must exist in the rate that brant can find and ingest **eelgrass** with increasing water depth.

Sometimes at high tide flocks were observed in an unusual pattern characterized by widely scattered, evenly spaced individuals. These flocks were apparently feeding on floating **detrital eelgrass** fragments. This flock pattern was usually of short duration (less than an hour) as brant continually departed such flocks to join flocks at roosting areas. One interpretation is that this indicated it was energetically more costly to continue foraging at low intake rates than to stop foraging and move to shallow (non-vegetated) roosting habitat. The assumption that brant could successively forage all the time in order to compensate for lost time and energy during disturbance responses is unrealistic.

CHAPTER 5: BEHAVIORAL RESPONSE TO DISTURBANCE

The relative intensity of various man-caused disturbance stimuli and the influence of disturbance on the birds' time budget were indicated by the behavioral responses of geese. This section compares observed responses among various types of disturbance stimuli.

Flock behavior was a useful quantitative measure of disturbance because it was observed from a distance and unbiased by factors that might be caused by manipulation or restraint of animals. The percentage of flocks responding and/or the duration of their response may provide good measures of stimulus intensity. Comparison of responses can determine types of aircraft that provoke the least response from geese. Factors associated with the aircraft (engine type, size, distance from the flock, flight speed, altitude) or correlated with the stimulus situation (tide stage, date, species, location) provide information useful to minimize impacts and establish guidelines for regulations.

Disturbance to avian species, particularly waterfowl, by aircraft and other human activities has been frequently observed and studied (**Dahlgren and Korschgen** 1988, Herter and **Koski** 1988). Much of the information is presented without sufficient quantitative detail for comparisons between studies, however, it seems that response to disturbance is unique for each species, time, and location. Results from other studies may not apply for brant at **Izembek**.

Brant have been observed to respond to aircraft at most stages of their annual cycle including molting (Simpson et al. 1980, Derksen et al. 1982, 1988, 1989), migration (**Jones and Jones** 1966, Jones 1973) and wintering (Kramer et al. 1979, Owens 1977, Henry 1980). During nesting, brant are more tolerant of aircraft or at least they show a reduced tendency for flight response (**D.H. Ward** pers. obs.) perhaps because they are attentive to incubation and defense of nest territories. Most observations of disturbance have been made on brant during winter. "Owens (1977) found that aircraft disturbance caused twice as many wintering European brant geese to fly when compared with human disturbance. At San Quintin, Mexico, brant took flight while low-flying aircraft passed over the lagoon (Kramer et al. 1979). Henry (1980) observed flocks of brant disturbed by aircraft flights over Humboldt Bay, California.

Brant respond to many types of aircraft but appear to be most alarmed by helicopters (**Gollop** et al. 1974, Derksen et al.

1979, Murphy et al. 1989). Aircraft were the most frequent cause of disturbance to molting brant on the North Slope of Alaska (Simpson et al. 1980) and helicopters tended to disrupt flocks of brant longer than fixed-wing aircraft. However, on the North Slope of Alaska and Yukon Territories, Davis and **Wiseley** (1974) observed that flocks of lesser snow geese were prone to flush equally in response to experimental overflights by small fixed-wing (Cessna 185) and rotary-wing (**Bell** 206-B) aircraft.

The duration and frequency of response affects energetic balance through loss of feeding time and increased energetic expenditure due to alert and **flight** behaviors. Disturbance by aircraft can reduce brant foraging efficiency by causing interruptions in feeding bouts and displacement from preferred habitats. Aircraft overflights prevented flightless brant from feeding 2.4% of the time (Simpson et al. 1980). Davis and **Wiseley** (1974) estimated that experimental overflights by fixed-wing aircraft at a rate of **0.5/hr** would cause staging lesser snow geese to decrease feeding time by 8.6% which could result in a 20% reduction in energy reserves.

Specific objectives of our research on goose response to disturbance at **Izembek** were four-pronged:

- 1) determine frequency and distribution of disturbance events and human activities,
- 2) compare the responses of brant, Canada and emperor geese to disturbance,
- 3) quantify factors such as aircraft type, lateral distance, and altitude that determine both the magnitude of response and the distance at which flocks show response,
- 4) determine the relative importance of other factors (e.g. tide stage, time of day, flock size, social facilitation) that influence the magnitude of the disturbance response.

METHODS

Two categories of stimuli were used to investigate the response of geese to disturbance at **Izembek** Lagoon. These were termed incidental and experimental disturbances defined by whether the stimuli occurred independent of our project or were specifically introduced as part of this study. Incidental disturbance stimuli were caused either by human activities or by other animals such as eagles or falcons. Sources of incidental human-related disturbance included hunters, boats, commercial aircraft, U.S. Coast Guard helicopters, and **USFWS**

survey aircraft conducting aerial counts. Experimental disturbances were initiated by aircraft chartered to fly along planned routes. This procedure allowed greater precision in measuring the distance and altitude to the aircraft at the time of a flock's response.

The behavioral response of geese was measured in the same way regardless of the type of stimulus. The intensity of the response was quantified using a system adapted from work on snow geese by Davis and **Wiseley** (1974). In increasing order of energy expenditure these behavioral responses could be **observed:**

- 1) No Change - ongoing behavior continued.
- 2) Alert - head raised, neck straightened.
- 3) Mass - swimming into tight group without flying.
- 4) Flight - subdivided into three categories:

rise flights of short duration within the foraging area originally occupied by the flock;

circle flights up to a few minutes duration with birds returning to the same foraging area; and

depart flights when birds moved to a new location outside the study area.

The percent of birds in the flock exhibiting each level of behavioral response was estimated for a potential disturbance stimulus.

Flocks were the sampling unit. A flock was a spatially distinct group usually including several hundred to a few thousand individuals. In some cases flock members were dispersed or spread across an eelgrass bed for over 1 km, therefore an arbitrary subdivision of the flock was selected for observation before experimental or incidental disturbance events.

Response of a flock could be influenced by the behavior of other nearby flocks. Such social facilitation was indicated in observations of adjacent flocks taking flight before the stimulus reached the flock under observation.

Incidental disturbance

All potential disturbance factors including aircraft, avian and mammalian predators, people, boats, and gunshots were

monitored at each study area in fall of 1985-1987. For each disturbance event the following information was recorded: 1) cause of disturbance, 2) distance from flock to stimulus when the flock first reacted, or if there was no reaction, then the distance at closest approach, 3) altitude of aircraft, 4) tide height, 5) time of day, 6) wind direction in relation to the approach of the stimulus toward the flock, 7) species, 8) flock size, 9) dominant behavior of the flock prior to disturbance, 10) distance of the flock from shore, 11) direction of stimulus approach either towards or mostly lateral to the flock, 12) percent of the flock exhibiting each behavioral response, 13) duration of flight response if it occurs, and 14) total duration of the response. Flight duration was defined as the time required from flight initiation until **50%** of the flock returned to the water, and total duration of the response was the time required for 90% of the birds to return to their **pre-disturbance** behavior.

Observations were recorded on cassette tape which enabled behavioral response and duration to be determined for several flocks during a single disturbance event. VHF radios were sometimes used to monitor aircraft communications. Knowledge of approaching aircraft and information on altitude, direction of travel, and weather conditions were gathered from conversations between pilots and Cold Bay flight service personnel. Aircraft altitude and distance between the aircraft and the flock were estimated for the non-experimental aircraft. Although cloud ceilings, maps, landmarks, and experience of the **observer** helped, the altitude and distance estimates for non-experimental aircraft were not precise.

Disturbance stimuli were not equally detectable. For distant flocks, the cause of natural disturbances (e.g. eagles, falcons) sometimes was not identified until after a flock responded and the area was carefully searched with binoculars. In some instances no stimulus was detected. These disturbances were classified as an unknown stimulus type. We suspect these represented unobserved eagles or instances when a few individual birds became agitated and the flock responded to social cues despite the lack of an external stimulus. In contrast to the vagaries of natural disturbances, aircraft were heard and visible to observers at considerable distances and their detection was not conditional on brant response.

Experimental disturbance

Aircraft altitude, lateral distance, and actual distance from the aircraft to flocks of geese were measured with greater precision during controlled experimental overflights than during incidental flights. Experimental flights were conducted on 57 days in September and October during the four years of

this study, 1985-1988 (Table 5.1). Five categories of aircraft were used for experimental overflights: single-engine airplanes (Arctic Tern, Piper 150 Super Cub on floats, Cessna 180, Cessna 206 on amphibious floats), twin-engine airplanes (Piper Navajo twin, Grumman Goose, DeHavilland Twin Otter), multi-engine (Lockheed C-130 Hercules), small helicopters (Bell 206-B Jet Ranger, Hughes 500-D), and large helicopters (Bell 205, Sikorsky **HH-3F**). Each flight followed established routes and altitudes. Air speed was maintained at normal cruising speed in level flight and differed among aircraft types.

Table 5.1. Number of days of experimental aircraft overflights at **Izembek** Lagoon, Alaska, 1985-1988, the number of flocks observed, and the number of flocks with suitable data and sample sizes for response surface analysis.

Aircraft type	Year				Total days	Total flocks	Flocks used in analysis
	85	86	87	88			
Piper 150	5	6	1	2	14	242	237
Cessna 180	2				2	45	
Cessna 206	2	2	2	2	8	100	100
Grumman Goose		1			1	25	
Twin Otter		5			5	21	
C-130 cargo		1	2	2	5	74	69
Navajo twin		2		2	4	169	145
Bell 206-B	3	4	1		8	417	387
Hughes 500-D				3	3	70	70
Aerosp. Puma				1	1	4	
Sikorsky HH-3F		1			1	45	
Bell 205			5		5	419	419
Totals:	12	22	11	12	57	1,631	1,427

Flightlines (Figures 5.1-5.7) were arranged to begin and end at visible landmarks on lagoon or lake shorelines, pass over or near each study area, and maintain at least a 15- to 20-min interval between repeated passes. In a few cases, unscheduled aircraft radioed their flight line to an observation blind prior to approach, and these flights were used as experimental flights with accurate distance data. Appendix D (Tables **D1-D4**) is a summary of samples obtained for various aircraft, altitudes, species, and number of flocks observed during experimental aircraft overflights for each year.

Data collection procedures were developed for experimental overflights to improve the accurately estimated distance and timing of response by geese. Maps of each study site were drawn from aerial photographs and included start and end points of experimental **flightlines**. Prior to an overflight, the observer at each study site sketched locations of flocks on the map. During each passby, an observer in the aircraft announced the exact time when the aircraft was over the start and end points of the flight line. On the ground, observers in the blind simultaneously recorded these transmissions on continuously running tape and added their observations of the flock reactions.

With straight and level overflights at constant speed, this method enabled later interpolation and mapping of aircraft position at the point along the flight line that corresponded to the time of flock response. Actual distance (aircraft to flock) as well as the lateral distance (perpendicular distance from the flock to the aircraft flight line) were measured to the nearest 160 m (0.1 mi) from study area maps. The distance did not include altitude of the aircraft; two-dimensional calculations rather than three-dimensional slant distances were sufficiently accurate.

Data analysis

Mathematical functions were derived to express the response of brant to disturbance stimuli. Two approaches were used to find equations that best fit the data and revealed consistent patterns across the various aircraft types. Response was measured by (1) the proportion of birds in each flock that showed a response, or by (2) the proportion of flocks that exceeded a particular response level. Both data sets yielded similar values because the behavioral response observed in flocks most often involved 100% or 0% of the individuals (Figure 5.8). Averages were not weighted by flock size.

Figure 5.1. Number, position, and orientation of flight paths made by Cessna 180, 185, and 206 aircraft during experimental-overflights at Izembek Lagoon, Alaska, between 3 and 18 October, 1985.

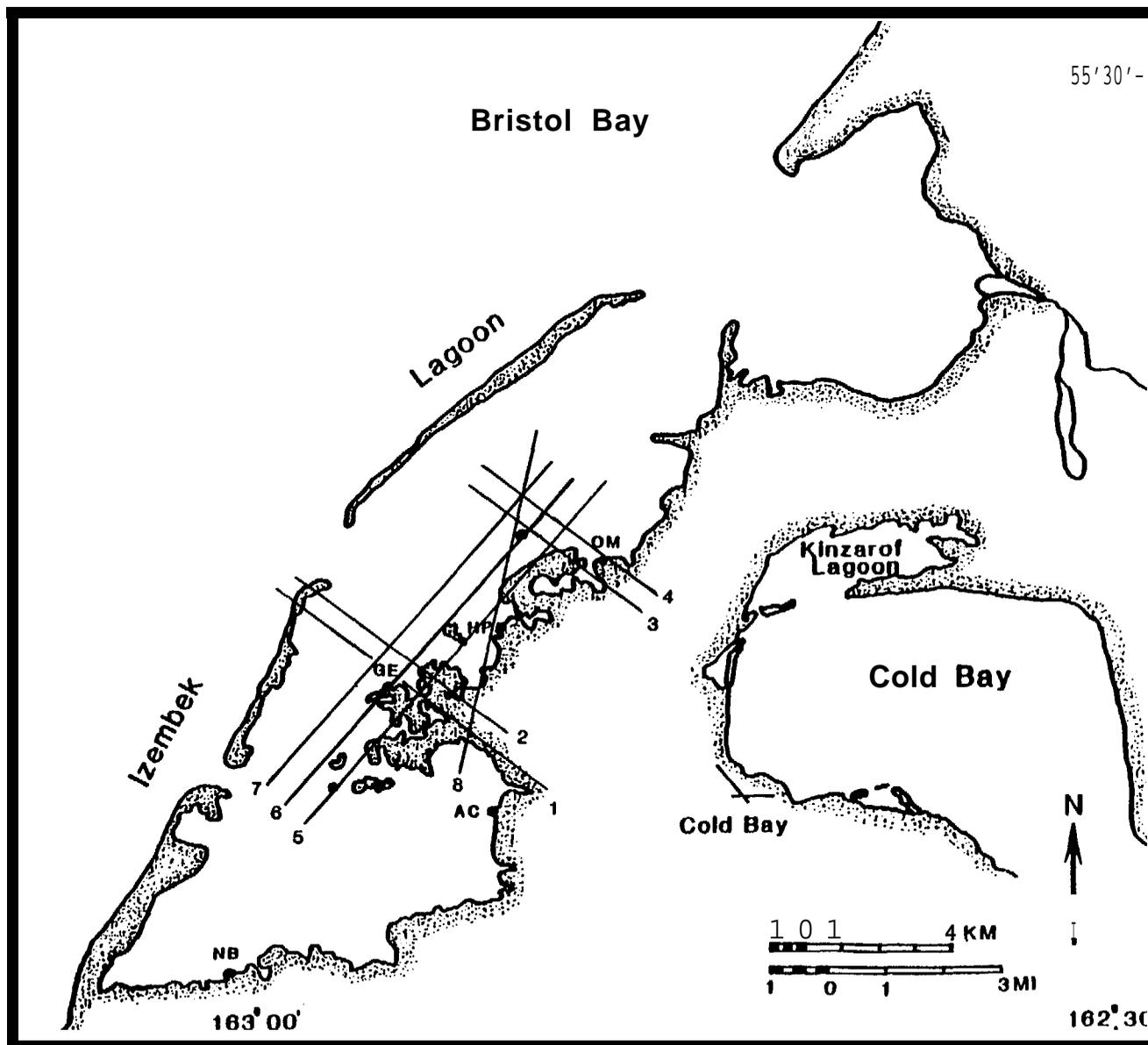


Figure 5.2. Number, position, and orientation of flight paths made by a Bell 206-B Jet Ranger helicopter during experimental overflights at Izembek Lagoon, Alaska, between 30 September and 3 October, 1985.

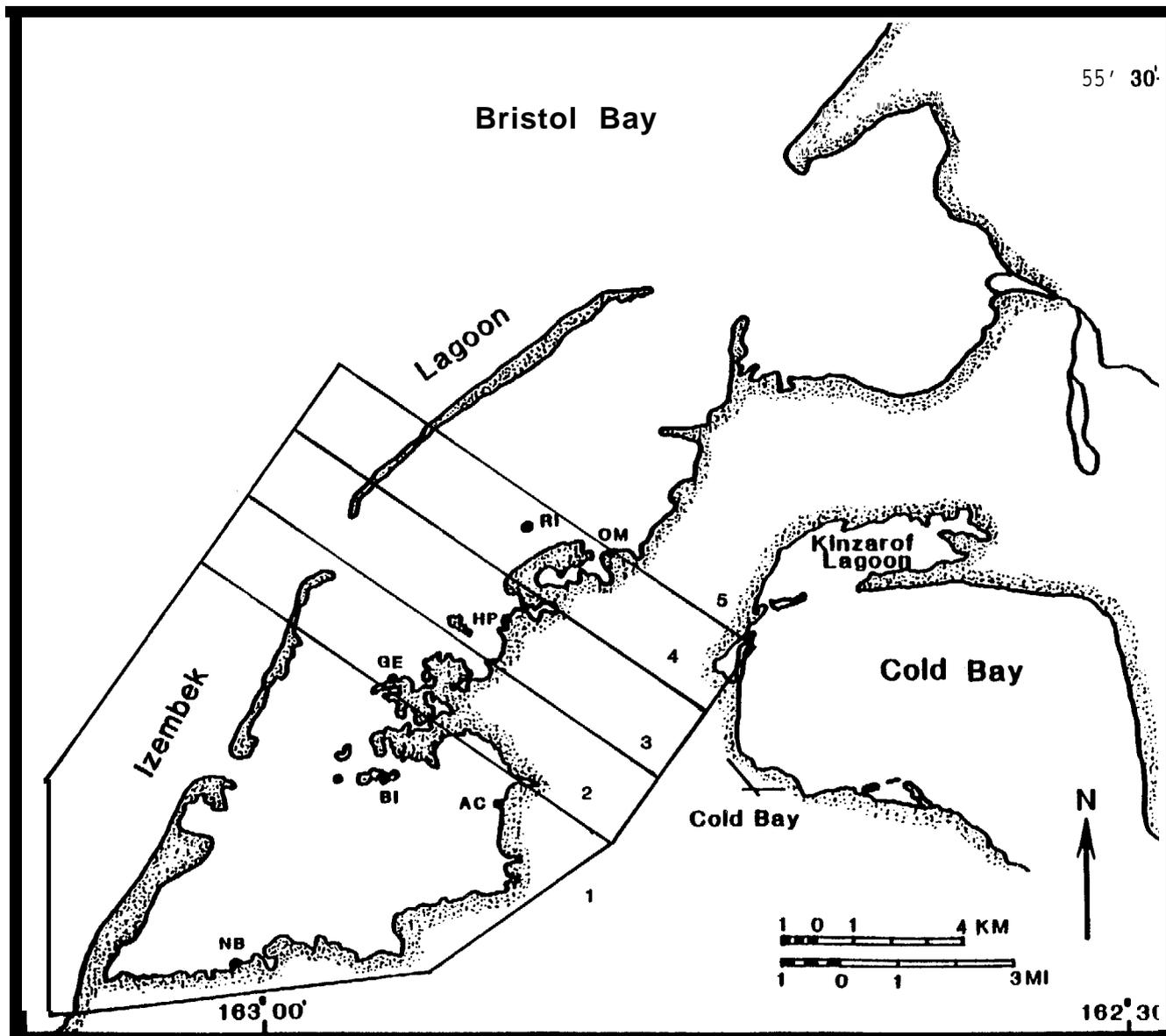


Figure 5.3. Number, position, and orientation of flight paths made by Arctic Tern, Cessna 206, Piper Navajo, DeHavilland Twin Otter, Grumman Goose fixed-wing aircraft, and a Bell 206-B Jet Ranger helicopter during experimental overflights at Izembek Lagoon, Alaska, between 18 September and 31 October, 1986.

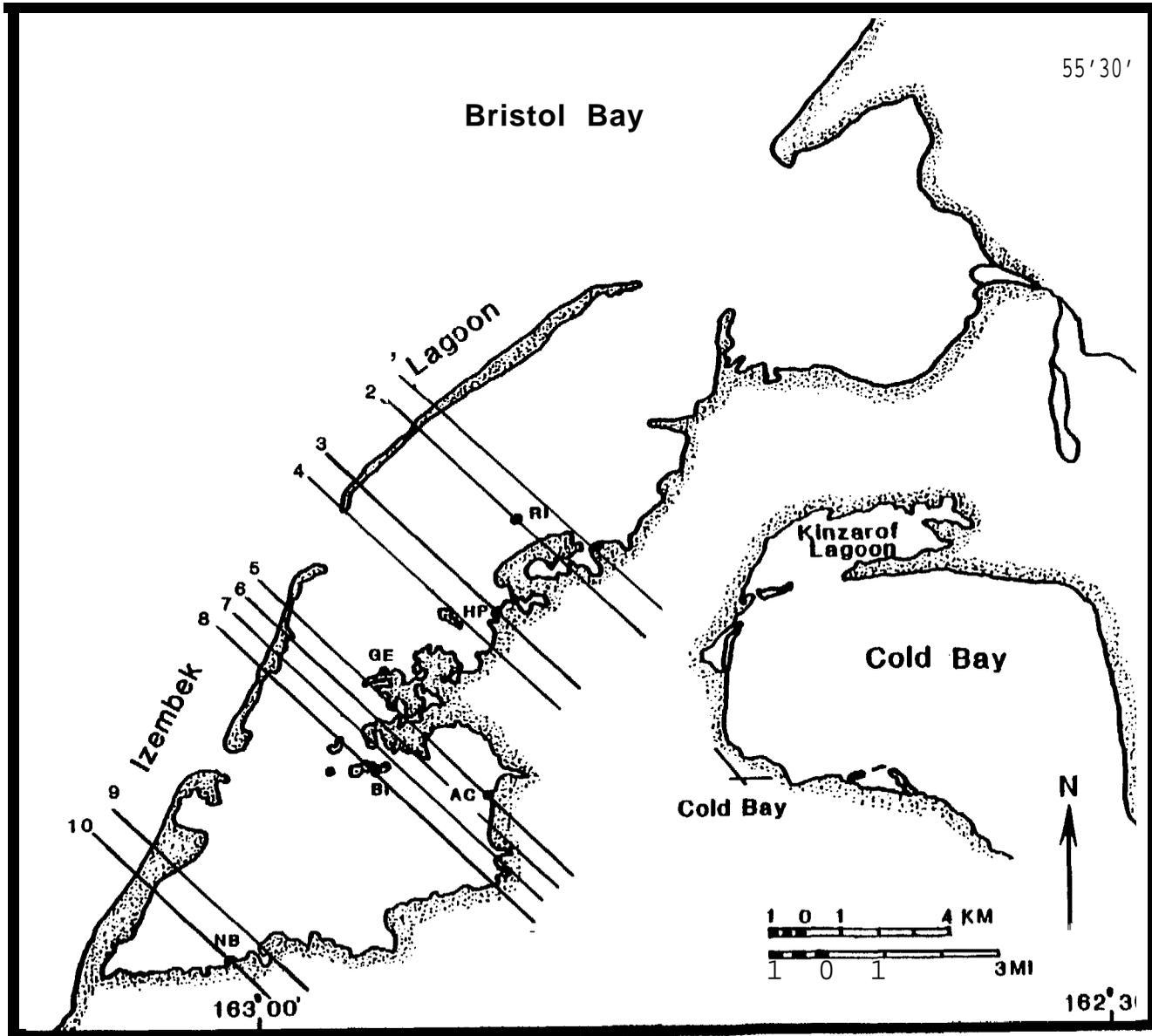


Figure 5.4. Number, position, and orientation of flight paths made by a Sikorsky HH-3F during experimental overflights at Izembek Lagoon, Alaska, on 26 September, 1986.

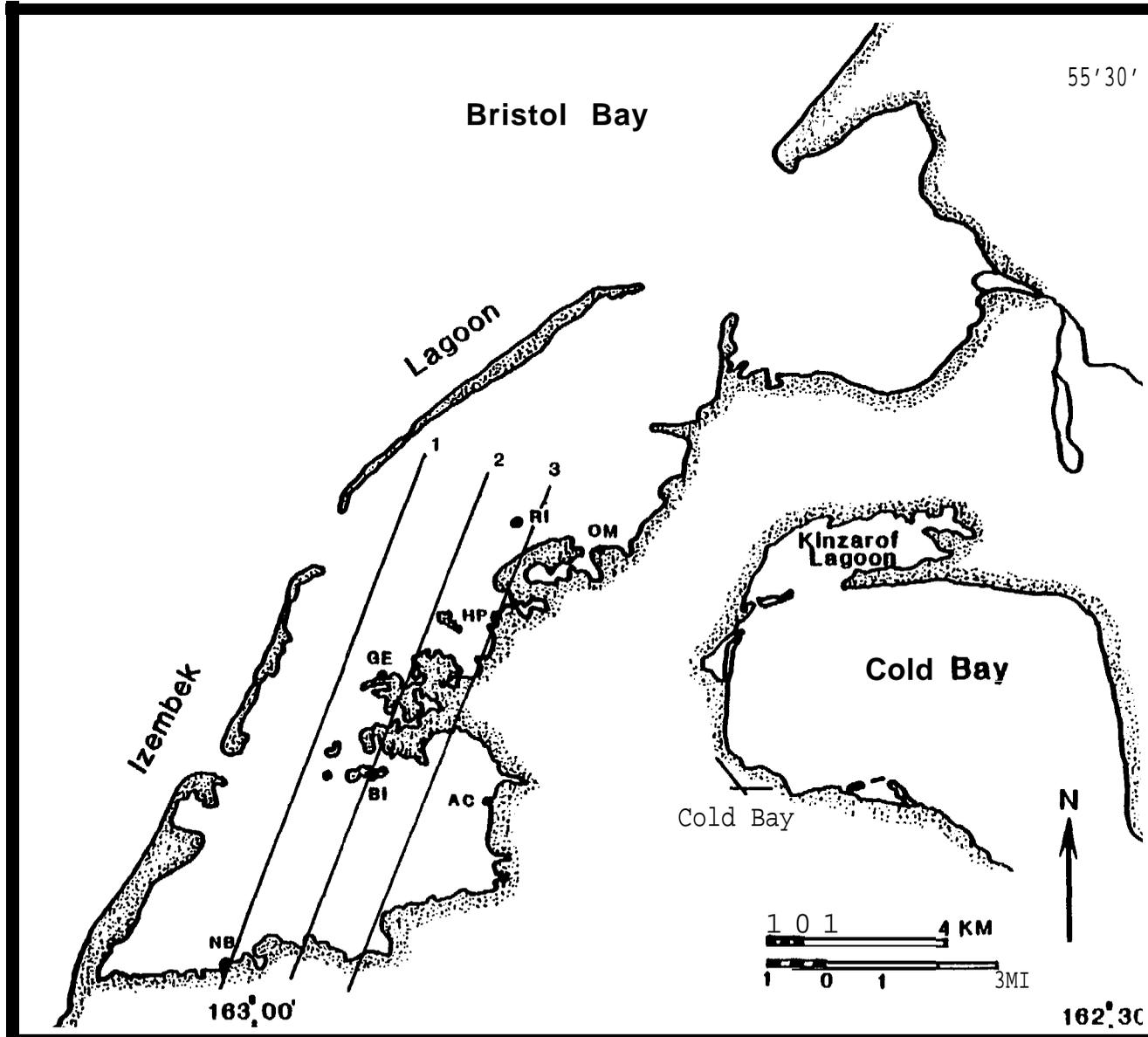


Figure 5.5. Number, position, and orientation of flight paths made by Piper 150, Cessna 206 fixed-wing aircraft and Bell 206-B Jet Ranger and Bell 205 helicopters during experimental overflights at Izembek Lagoon, Alaska, between 23 September and 18 October, 1987.

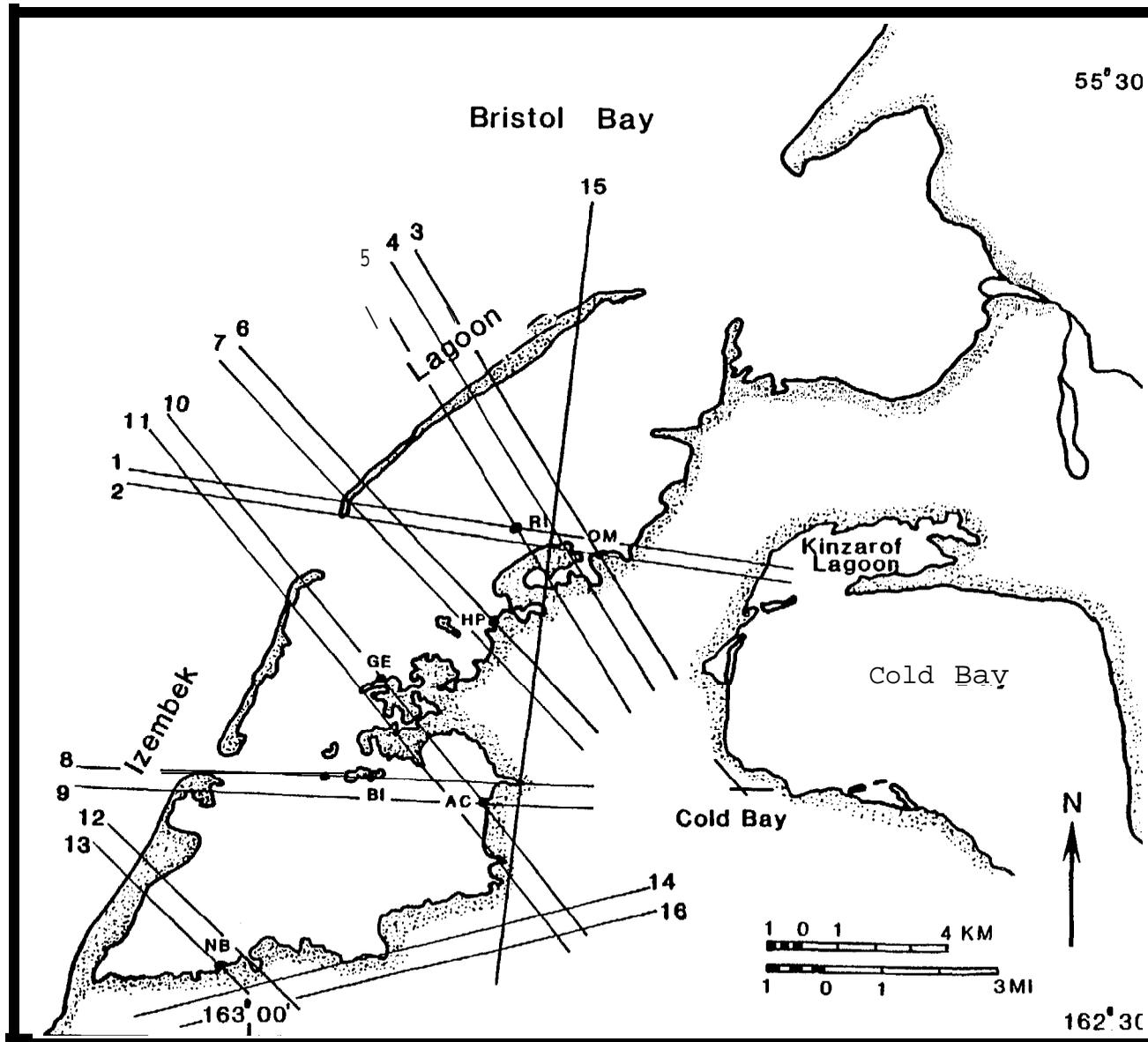


Figure 5.6. Number, position, and orientation of flight paths made by a Hercules C-130 during experimental overflights at Izembek Lagoon, Alaska, on 1 and 15 October, 1987.

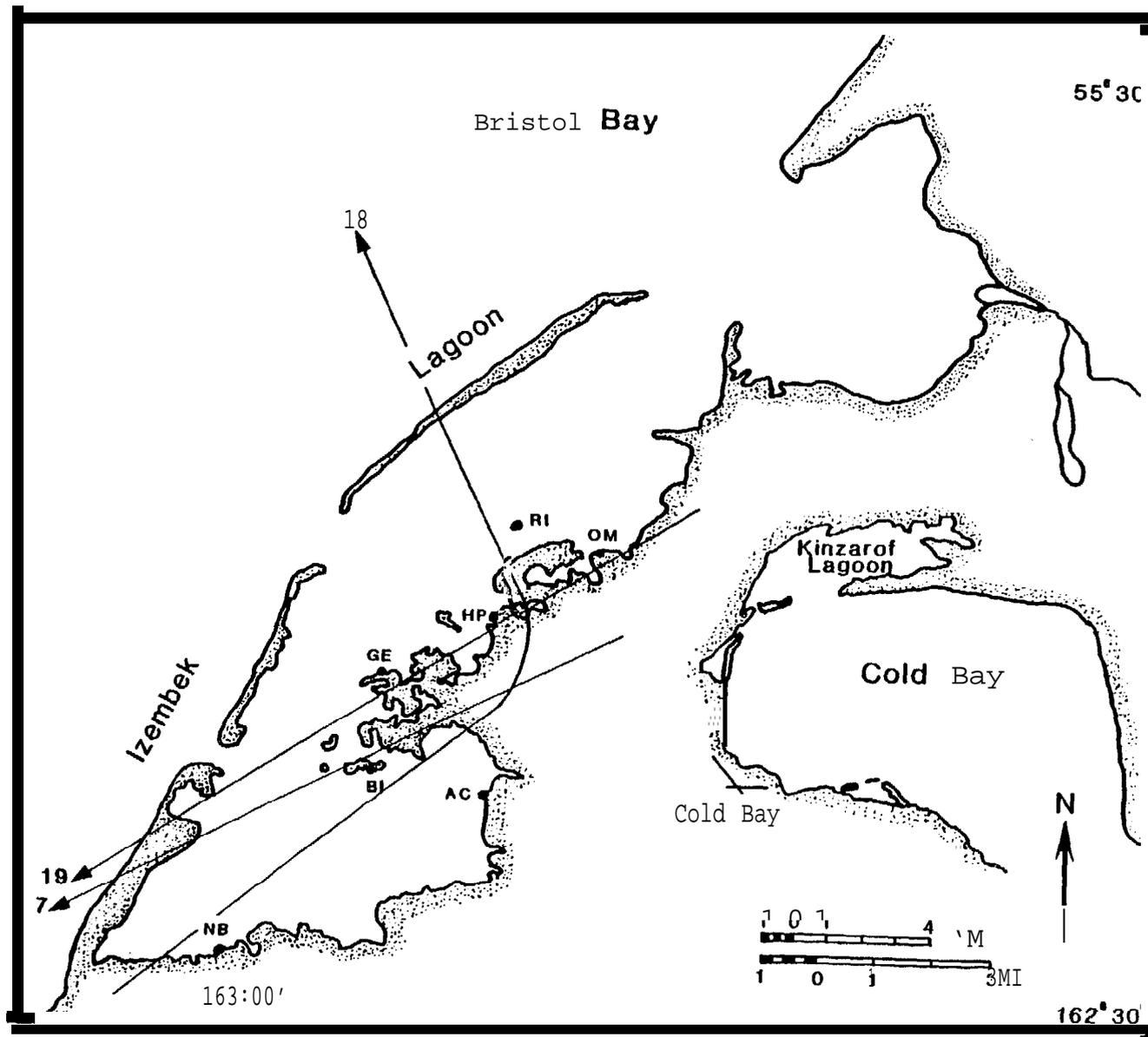


Figure 5.7. Number, position, and orientation of flight paths made by Piper 150, Cessna 206, and Piper Navajo twin fixed-wing aircraft, and Hughes 500-D helicopter during experimental overflights at Izembek Lagoon, Alaska, between 29 September and 19 October, 1988.

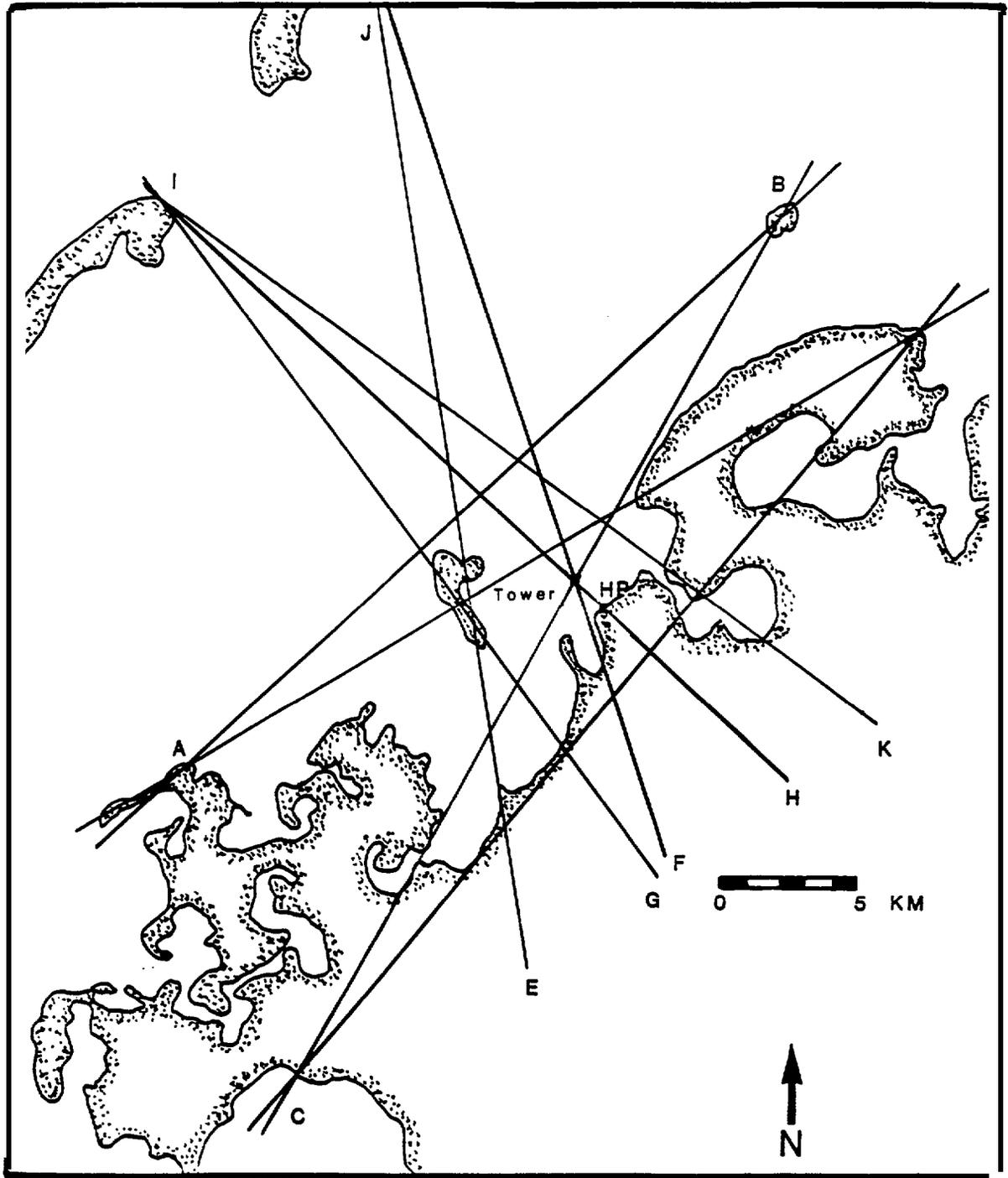
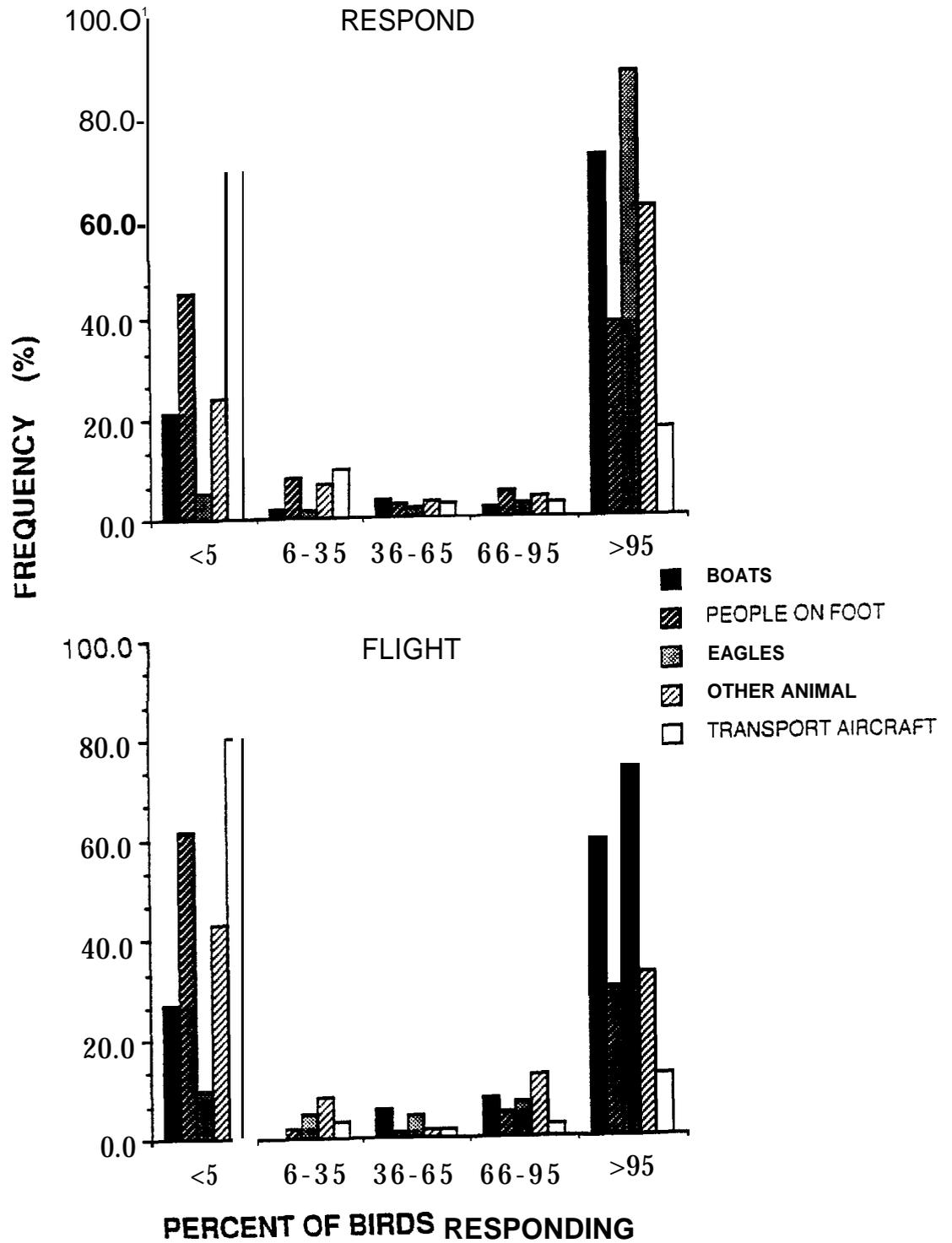


Figure 5.8. Frequency distribution of the percentage of birds in a flock that responded or took flight to various disturbance types at Izebek Lagoon, Alaska, in fall of 1985-87. Transport aircraft include jets and multi-engine airplanes.



Mathematical analysis of the two data sets was different. The first method used least squares linear regression (REG procedure, SAS 1986) to find variables that best predicted the proportion of brant that responded in each flock. Response was defined as any level of response (alert response or greater) or as flight response (rise, circle or depart). The equation derived used the **logit** transformation, $\log(P/(1-P))$, of the proportion (P) of individuals responding in each flock. One hundred percent response was assigned a value of 5.293 ($=\log(0.995/0.005)$) and 0% response a value of -5.293. All logs are natural logarithms. The response proportion can be obtained from the **logit** value by calculating $P = \exp(\text{logit}) / (1 + \exp(\text{logit}))$.

The second method involved analysis of a category variable that related to whether or not a flock showed a response. Alert (RESPOND) response was coded either 1 or 0 depending if at least 10% of the flock showed any type of response. FLIGHT response was either 1 or 0 if at least 10% of the flock flew in response to the aircraft. An equation was determined that best predicted the frequency of RESPOND or FLIGHT categories; that is, the probability that a flock would show a response. Logistic regression (CATMOD procedure, SAS 1986) determined coefficients for these equations, also expressed in the logit scale, using maximum likelihood methods for analyzing factors entered as direct variables with the ML and NOGLS options (see SAS 1986:222).

After numerous trials with many combinations of variables, a single consistent set of variables was selected that was often significant across aircraft types and meaningful in the management context of the study. Lateral distance, lateral distance squared, altitude, and altitude squared were used to determine a quadratic response surface to disturbance in the logit scale. Lateral distance was measured in miles and altitude measured in thousands of feet. Each aircraft type was analyzed separately.

Unexplained or residual variation was examined with stepwise linear regression (STEPWISE procedure, SAS 1986). The residual was calculated for each case as the **logit** of the percent of brant responding minus the predicted **logit** response using the least squares regression with the logit transformation. Variables considered included tide height (**ft**), tide flow (**ft/hr**), time of day (09 to 18 hr), flock size, date (**Sept** 1st= 1), presence or absence of social facilitation (1,0), presence or absence of feeding behavior (1,0), tide stage of low, flood, ebb, and high (1 to 4), presence or absence of stimulus upwind from flock (1,0), number of consecutive days of stimulus presentation (days 0 to 4), and year (1 to 4 for 1985-1988).

Table 5.2. Frequency of potential incidental and experimental disturbance events for all geese during fall at Izembek Lagoon, Alaska, 1985-1987.

Year	Total hours of observation	Days in blind	Mean number of disturbances per hour	HUMAN DISTURBANCES												NATURAL DISTURBANCES					Total		
				Fixed-wing aircraft						Rotary-wing			Other			Bird							
				A	S	A	T	AG	AH	AM	AJ	A	HS	HK	HL	B	G ^b	P ^c	E	F		O	M
Incidental																							
1987	853.7	48	1.0 (2.0) ^a	n 127	60	0	19	72	140	67	-	-	-	19	32	11	193	36	31	8	56	871	
				X 14.6	6.9	0	2.2	8.3	16.1	7.7	-	-	-	2.2	3.7	1.3	22.2	4.1	3.6	0.9	6.4		
1986	79a.6	32	1.1 (2.3)	n 93	75	14	52	72	61	19	-	-	7	24	23	23	275	30	10	1	77	856	
				x 10.9	8.8	1.6	6.1	8.4	7.2	2.2	-	-	0.8	2.8	2.7	2.7	32.1	3.5	1.1	0.1	9.0		
1985	259.5	25	1.2 (2.0)	n 18	33	7	3	6	1	7	0	7	-	-	10	13	62	11	8	6	1	311	
				% 5.8	10.6	2.3	0.1	19.6	22.5	2.3	-	-	3.2	4.2	19.9	3.5	2.6	1.9	0.3	0.3			
Totals	1911.8		1.1 (2.1)	n 238	168	21	74	205	271	93	-	-	17	56	117	45	476	72	42	10	133	2038	
				% 11.7	8.2	1.0	3.6	10.1	13.3	4.6	-	-	0.8	2.7	5.7	2.2	23.4	3.5	2.1	0.5	6.5		
Experimental																							
1988				n 9	7	7	8	-	13	2	-	161	-	4	-	-	-	-	-	-	-	355	
				% 27.3	33.0	-	-	3.7	0.6	-	45.3	-	1.1	-	-	-	-	-	-	-	-		
1987				n 76	-	-	-	61	-	-	114	562	-	-	-	-	-	-	-	-	-	813	
				% 9.4	-	-	-	7.5	-	-	14.0	69.1	-	-	-	-	-	-	-	-	-		
1986				n 228	209	58	-	37	-	-	404	-	61	-	-	-	-	-	-	-	-	997	
				% 22.9	21.0	5.8	-	3.7	-	-	40.5	-	6.1	-	-	-	-	-	-	-	-		
1985				n 131	-	-	-	-	-	-	6	9	-	-	-	-	-	-	-	-	-	200	
				% 65.5	-	-	-	-	-	-	34.5	-	-	-	-	-	-	-	-	-	-		
Totals				n 532	287	58	-	111	2	-	748	562	65	-	-	-	-	-	-	-	-	2365	
				% 22.6	12.1	2.5	-	4.7	0.1	-	31.6	23.3	2.7	-	-	-	-	-	-	-	-		

Fixed-wing aircraft: AS - Single-engine propeller (e.g. Piper 150, Cessna 206, Cherokee Chief); AI - Twin-engine propeller (e.g. de Havilland Twin Otter, Piper Navajo); AG - Grumman Goose; AH - Heavy twin-engine propeller (e.g. NAMCYS-11, Douglas DC3); AM - Multi-engine propeller - (e.g. Lockheed c-130 Hercules, Electra L-188); AJ - Jet (e.g. Boeing 727,200, Gulf stream II); A - Unidentified aircraft.

Helicopter: HS - Small (e.g. Bell 206-B, Hughes 500-0); HK - Large (e.g. Bell 205); HL - Larger (e.g. Sikorsky, HH-3F, Aerospatiale Dauphin).

Other: B - Boats; G - Gunshots; P - Person.

Bird: E - Eagle (e.g. bald eagle); F - Falcon (e.g. gyrfalcon, peregrine falcon); O - other birds (e.g. rough-legged hawk, northern harrier, common raven).

Mammal: M - Mammals (e.g. wolf, red fox, river otter, brown bear).

U - Unidentified cause.

(.) = mean number of potential disturbances per hour including experimental overflights.

^b Includes eight combined gunshot and person disturbances.

^c Includes one vehicle disturbance.

RESULTS

Frequency of incidental disturbance

During September to November, 1985 to 1987, 2,038 incidental (independent) disturbance events were recorded in 1,911.8 hr of daylight observation (Table 5.2; see Appendix Tables D5-D7 for annual summaries). An event is defined as an observation of a flock's behavioral response -- including no detectable change in behavior (no response) -- to a potential disturbance stimulus.

Mean number of incidental disturbance events was similar in all years, averaging **1.07/hr** of observation (Table 5.2). Aircraft (53%, **n=1,070** of 2,038) caused the most frequent human-induced disturbances and bald eagles (23%, n=476) were the most common natural stimulus each year (Table 5.2) and among study areas. Aircraft accounted for 83% of all **human-induced** disturbances and occurred at an average rate of **0.57 events/hr** (Table 5.3). Jets (25%), single-engine (22%), **multi-engine** (19%), and small twin-engine (17%) aircraft dominated the list. Helicopters accounted for 1.6% of all aircraft disturbance events. Other human-induced events such as hunters and/or gunshots (6%), boating (3%), and persons on foot (2%) were of less importance during the study period.

Most human-related disturbance was confined to the central portion of the lagoon. Aircraft incidence occurred primarily within the Instrument Flight Rules (**IFR**) and Visual Flight Rules (**VFR**) corridors (Figure 5.9). Large aircraft (jet, multi-engine, and heavy twin-engine) used the IFR and VFR 1 and 2 corridors, while smaller commuter airplanes (Piper Navaho Twin and Cherokee Chief) also used the VFR 3 corridor. Rates of all other human-related events, including hunting, boating, or people on foot, were greatest near GP, HP, and **OM** study areas (Figure 5.10). These areas are within 1 km of the road from Cold Bay. On four occasions, large fishing boats from the Bering Sea were observed motoring through the central portion of the lagoon. None were present longer than 24 hr.

The study occurred during a time of relatively few **human-induced** disturbances. Mean frequency of aircraft take-off and **landings at** the Cold Bay airport per month in fall during years of the study (1985-1988) were 10 to 31% lower than the 13-year mean for 1976-1988 (Table 5.4). In fall of 1984 during a time of increased petroleum exploration, aircraft traffic was 33-49% greater than for any year of this study and 27% higher than the 13-year mean (Table 5.4). Spring traffic at the Cold Bay airport was similar to that of fall, and both levels were higher than during winter.

Table 5.3. Rate of potential disturbance events for all geese at Izembek Lagoon, Alaska, during fall from 1985 to 1987. No experimental disturbances are included.

Disturbance type	Disturbances per hour of observation			
	1985	1986	1987	Total
<u>Human</u>				
Aircraft				
single-engine	0.07	0.12	0.15	0.12
twin-engine	0.15	0.11	0.07	0.10
multi-engine ^a	0.25	0.16	0.11	0.15
jet	0.27	0.08	0.16	0.14
helicopter	0.04	0.01	0.00	0.01
unidentified	0.03	0.02	0.08	0.05
Subtotals	0.81	0.50	0.57	0.57
People on foot^b	0.28	0.06	0.05	0.08
Boats	0.05	0.03	0.02	0.03
Totals	1.14	0.58	0.64	0.68
<u>Natural</u>				
Eagle	0.03	0.34	0.23	0.25
Falcon	0.02	0.04	0.04	0.04
Other animals	0.01	0.01	0.05	0.03
Totals	0.06	0.39	0.32	0.32
<u>Unknown</u>	0.00	0.10	0.06	0.07
Grand totals	1.19	1.07	1.02	1.07

^aIncludes heavy twin-engine aircraft.

^bIncludes gunshots and one vehicle event.

Figure 5.9. Potential aircraft disturbance events recorded per hour of observation at each blind and approximate locations of Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) corridors at **Izembek Lagoon, Alaska**, during fall of 1985-87.

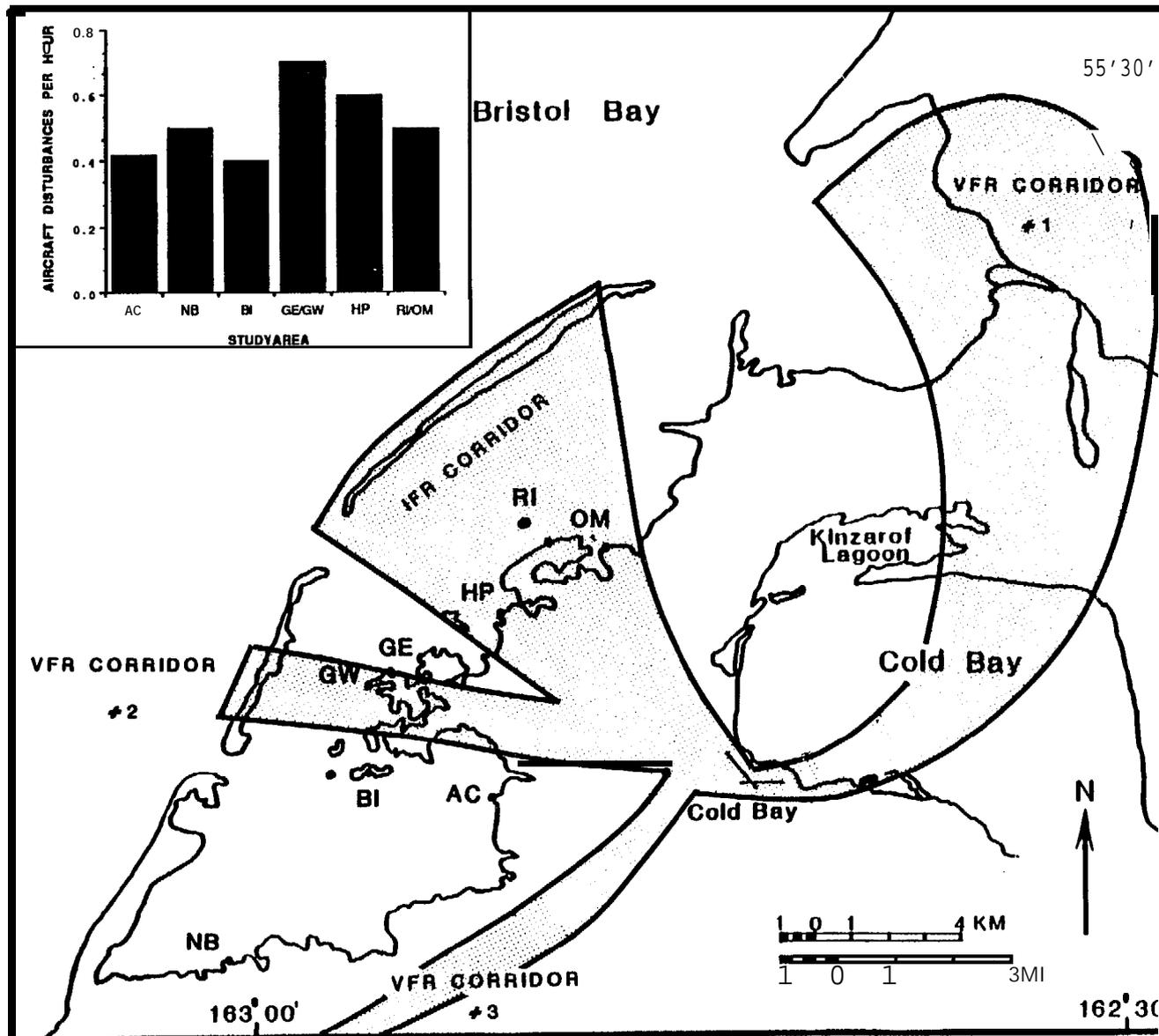


Figure 5.10. Approximate locations and frequency of potential human-related (excluding aircraft) disturbances per hour of observation at Izembek Lagoon, Alaska during fall of 1985-87.

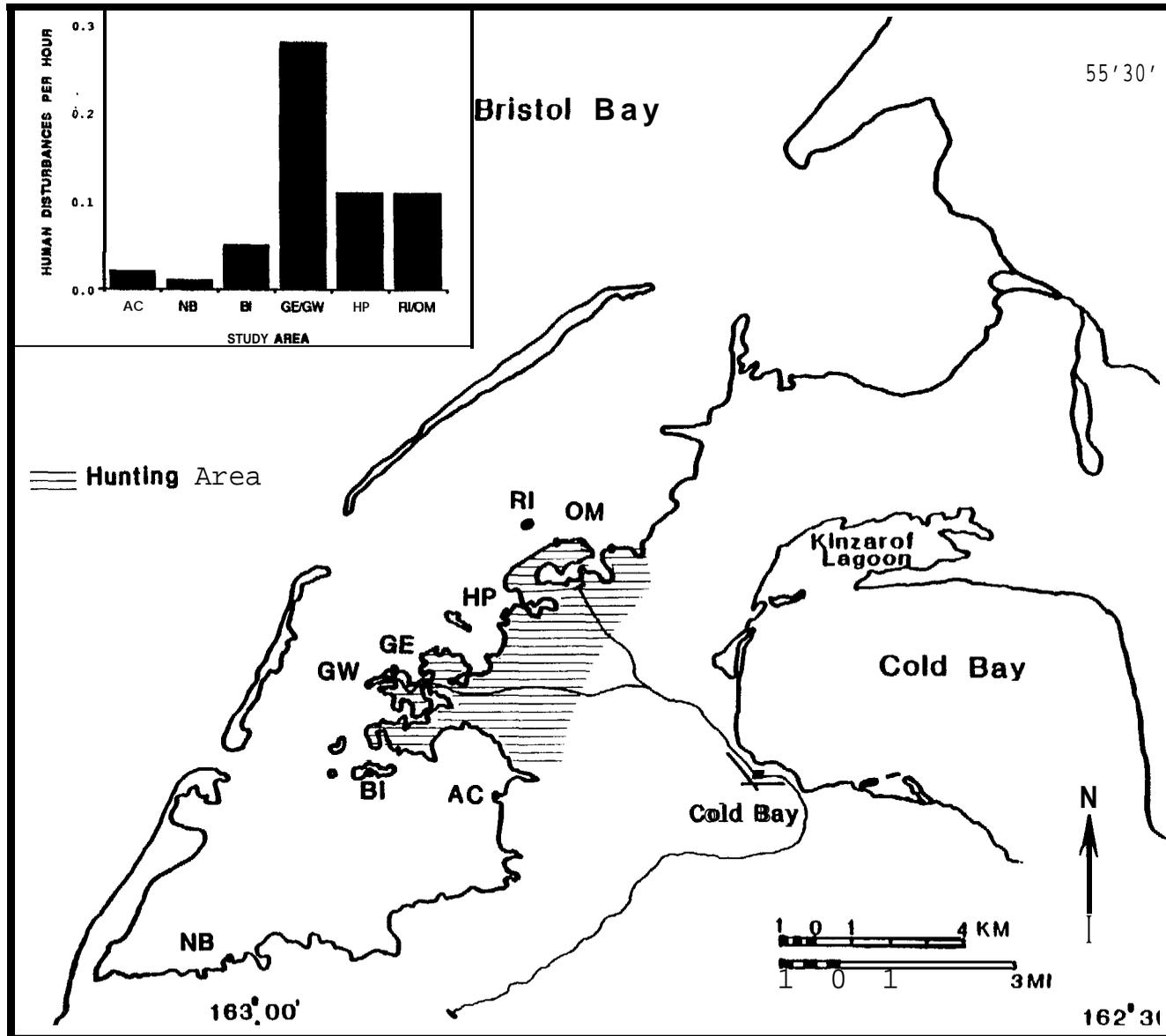


Table 5.4. Occurrence of aircraft landings and take-offs at Cold Bay airport, Alaska, during fall (September-November), winter (December-February), and spring (March-May) of 1984-1988 and combined years of 1976-1988. Data compiled from Federal Aviation Administration records (J. Yakal and J. Maxwell pers. cam.).

Season	Year					
	1984	1985	1986	1987	1988	1976-88
Fall	1151	762	652	766	581	841
SE	261	248	152	254	140	153
range	849-1309	488-964	482-781	485-977	409-692	409-1309
Winter	708	476	449	ND	ND	532
SE	90	104	60			93
range	604-763	383-589	381-491			316-763
Spring	819	670	708	568	ND	738
SE	457	141	249	144		104
range	528-1346	574-831	550-995	466-733		393-1346

ND No data.

Waterfowl hunting at Cold Bay was reduced compared with years prior to the study. A 1982-3 survey of recreational activities made at INWR indicated that 25% of the local population and up to 2,000 non-residents participated in waterfowl hunting (USFWS 1985). The closure of emperor goose hunting in 1986 and the shorter hunting season and smaller bag limits for brant in 1987 may have reduced hunting efforts by locals, as well as decreased numbers of non-resident hunters. Other human activities near the lagoon were minimal during the study period and were believed to be lower than in other years (USFWS 1985, C.P. Dau pers. comm.).

Bald eagles were the most frequent cause of disturbance unrelated to human activity, accounting for 79% (Table 5.2) of all known natural disturbances and occurred at an average rate of **0.25/hr** of observation (Table 5.3). Bald eagles preyed on geese both fall and spring. The highest rate of eagle disturbances occurred in the, southern end of the lagoon which

contained the greatest concentrations of geese (Table 5.5). Eagles were present in low numbers (c10 birds) in September and increased to more than 25 birds by mid- to late-October. The rate of eagle disturbances per hour of observation rose from **0.11/hr** before 9 October to **0.52/hr** after that date.

Table 5.5. Rate of eagle disturbances per hour of observation within study areas of **Izembek** Lagoon, Alaska, during fall of 1985-1987. Location of study areas are shown in Figure 2.1.

Study area	Mean number of eagle disturbances per hour of observation
Norma Bay	0.57
Applegate Cove	0.34
Banding Island	0.17
Grant Point ^a	0.05
Halfway Point	0.22
Round Island ^b	0.13

^a Includes observations from GW and GE (see Figure 1.2 for locations).

^b Includes observations from RI and OM (see Figure 1.2 for locations) .

Gyrfalcons and peregrine falcons (**Falco peregrinus pealei**) were the next most numerous (12%) cause of known natural disturbance. They were sometimes seen attacking brant, although actual predation by falcons was not observed. Brant were wary of any large animal or potential predator, including brown bear, river otter (**Lutra canadensis**), sea otter, red fox, wolf (**Canis lupus**), walrus (**Odobenus rosmarus**), tundra swan, rough-legged hawk (**Buteo lagopus**), northern harrier (**Circus cyaneus**), and common raven (**Corvus corax**).

Response of brant to disturbance

When" **brant** reacted to a stimulus their initial response was a raised head and stretched neck alert posture. This may be an orienting response to locate and identify the stimulus (**Gabrielsen** et al. 1985). As brant became more disturbed, they began to call and walk or swim together in a tight group. When more alarmed, geese flew from the stimulus. Sometimes flocks returned to the original location if the stimulus passed rapidly; however, approach of slow moving stimuli, such as people on foot or boats, often caused geese to leave the area.

Table 5.6. Response (% of individuals in a flock that reacted) of brant, Canada, and emperor geese to incidental disturbances at Izembek Lagoon, Alaska, 1985-1987. Response includes experimental aircraft overflights for Canada and emperor geese but not brant.

Disturbance Type	Average % respond			Average duration (s) of response			Average % of flight			Average duration (s) of flight		
	avg	SE	n	avg	SE	n	avg	SE	n	avg	SE	n
<u>Brant</u>												
single-eng	52	3	223	131	12	76	38	3	223	82	6	55
twin	25	3	221	99	12	35	14	2	221	92	25	6
multi-engine	19	2	243	94	15	15	9	2	243	60	15	6
jet	27	3	243	94	9	36	16	2	243	78	11	17
helicopter	57	9	26	266	150	4	39	9	26	93	39	2
boat	75	6	52	223	21	22	69	6	52	138	14	17
person	45	4	146	139	20	15	35	4	146	89	17	14
eagle	92	1	339	213	13	157	83	2	339	116	9	81
other animal	67	4	116	111	20	23	45	4	116	64	12	21
unknown	91	3	95	175	17	45	88	3	95	116	18	31
<u>Canada geese</u>												
single-eng	29	3	165	108	9	28	9	2	165	68	25	4
twin	15	3	157	80	12	17	4	1	157			
multi-engine	14	4	73	56	11	6	7	3	73	55	25	2
jet	12	5	31	40	20	2	6	4	31			
helicopter	31	2	339	93	5	97	8	1	339	92	29	9
boat			0						0			
person	85	6	29	48	14	3	66	9	29			
eagle	95	1	232	164	11	102	79	2	232	71	7	60
other animal	61	11	20	114	39	6	31	10	20	45		1
unknown	83	6	34	84	15	10	72	7	34	116	59	5
<u>Emperor geese</u>												
single-eng	53	8	35	229	29	15	32	8	35	202	22	9
twin	25	8	27	64	17	4	4	4	27			
multi-engine	27	11	15	48	13	2	20	11	15	35		1
jet	29	18	4	46	14	2	0	0	4			
helicopter	68	5	73	143	12	26	47	6	73	136	13	14
boat	8	5	6				8	5	6			
person	43	23	3	40	20	2	0	0	3			
eagle	64	10	22	100	19	8	45	10	22	49	14	6
other animal	50	29	4				251	2	5	4		
unknown	90	10	3				90	0	3			

Response of geese to aircraft included three increasing levels of flight duration. Rise flights lasted an average 21 sec. Circle flights averaged 90 **sec** before the flock landed in the same area or a short distance away from the original location. After landing the birds continued to call and move around for a few minutes before resuming normal behavior. Birds that departed the area were considered to show the highest level of response. Depart flights averaged 126 sec although this was underestimated because some flight times were censored when birds were lost from view.

The entire flock (>95%) responded to 48% of all events and took flight in 35% of these (Figure 5.8). Eagles caused the greatest response in flocks of brant. Over 90% responded to eagles with an average duration of 213 sec response including 116 **sec** in flight (Table 5.6). The percent of birds that responded to eagles is likely overestimated because the observer could not always detect eagles until birds were disturbed. Eagles often evoked such a strong reaction in a flock of brant that other nearby flocks also reacted. As eagles soared on updrafts along shoreline bluffs, they often displaced large flocks of geese from nearshore eelgrass beds.

Boats caused a similar high level of response from brant with 75% of the individuals in a flock responding for an average 223 **sec** and 138 sec of flight (Table 5.6). Like eagles, boats tended to cause displacement of flocks. Other avian and mammalian causes of disturbance also alarmed a majority (67%) of the birds, but a smaller proportion took flight compared with the response to eagles or boats (Table 5.6). This was in part due to the fact that brant remained on the water in reaction to falcons instead of flying as they do in response to eagles.

People on foot caused a 48% response for an average duration of 139 **sec** with 89 sec flight. We observed a shifting of brant away from nearshore (<0.5 km) areas at Halfway Point study area. Prior to the beginning of hunting on 1 October, 70% (**n=66**) of the flocks were found <0.5 km from shore, but after 1 October, 42% (**n=72**) of the flocks occurred close to shore.

Aircraft caused less response from brant than other incidental stimuli; however, response was highly dependent on aircraft type and proximity to the flock. The distance at which brant responded to aircraft was greater than response distance for any other stimuli (Table 5.7). First reaction by brant to incidental aircraft occurred at 1.9 km compared to 0.9 km for boats, 0.7 km for eagles, 0.4 km for people on foot, and 0.2 km for other natural disturbances.

Table 5.7. Distance (km) from the flock to various **types** of disturbance stimuli at the time of first response and flight response **compared among** brant, Canada, and **emperor** geese at **Izembek Lagoon**, Alaska.

Disturbance type	Brent			Canada			Emperor		
	mean	SE	n	mean	SE	n	mean	SE	n
DISTANCE AT FIRST RESPONSE :									
<u>Human</u>									
All aircraft	1.9	0.2	48	1.7	0.2	184	1.3	0.2	60
People on foot ^a	0.4	0.2	2						
Boats	0.9	0.1	9						
<u>Natural</u>									
Eagle	0.7	0.2	u	0.7	0.2	10			
other	0.2	0.1	5						
DISTANCE AT FLIGHT:									
<u>Human</u>									
All aircraft	1.1	0.2	36	2.0	0.2	21	1.7	0.2	29
People on foot ^a	0.2	0.2	4						
Boats	0.7	0.1	9						
<u>Natural</u>									
Eagle	0.6	0.2	27	0.6	0.2	23			
Other	0.4	0.1	5						

^a **Includes** gunshots and one vehicle event.

Given the **observed** frequency of incidental disturbance events at **Izembek**, the total time brant were interrupted from normal behavior per hour of observation was calculated for each disturbance type. The rate of disturbance events per hour was multiplied by the proportion of events that caused a response and then multiplied by the average duration of response. Brant were interrupted by all disturbance types for a total of 89 **sec/hr**, 2.5% of the observed time (Table 5.8). Time in

flight averaged 43 **sec/hr**. Disturbance by eagles (49 **sec/hr**) caused the greatest interruption of normal behavior compared with **all** other incidental disturbance types. Aircraft (20 **sec/hr**) caused the greatest interruption of all human disturbance stimuli (Table 5.8).

Table 5.8. **Average** interruption time (rate x % responding x duration) by **brant per hour** of **observation** for various incidental **disturbance** types at **Izembek** Lagoon, Alaska.

Disturbance Type	Rate/hr	Average percent responding		Average duration (s) of response		Average interruption time(sec/hr)		
		alert	fly	alert	fly	alert	fly	
<u>Human</u>								
Aircraft	0.57	31	19	116	81	20	9	
People on foot^a	0.08	45	35	139	89	5	2	
mats	0.03	75	69	223	138	5	3	
Total	0.68	35	24	129	90	31	15	
<u>Natural</u>								
Eagle	0.25	92	83	213	116	49	24	
other	0.07	67	45	111	64	5	2	
Total	0.32	86	73	200	105	55	25	
<u>Unknown</u>	0.07	91	88	175	116	11	7	
Grand total	1.07	51	40	164	100	89	43	

a **Includes** gunshots **and** one **vehicle** event.

Response of Canada and emperor geese to disturbance

Like brant, Canada and emperor geese were disturbed by eagles, other animals, people, and aircraft [Table 5.6). Eagles caused less of a response in emperor geese (64% of individuals in a flock) as compared to brant (92%) and Canada geese (95%). Canada geese showed greater response at 85% to

persons on foot (hunters and gunshots) compared to 45% for brant and 43% for emperor geese. This may be related to the greater hunting pressure on this species at **Izembek** compared to brant (**C.P. Dau**, USFWS, **unpubl.** data). Emperor geese, which were off limits to hunters after 1985, were more tolerant of people on foot. Using data grouped by aircraft altitude and lateral distance, brant and emperor geese reacted similarly to aircraft overflights and were more disturbed than Canada geese (Table 5.9).

Table 5.9. Percent of geese (Canada geese, emperor geese and brant) that responded or flew to aircraft overflights at standardized lateral distance (LD) and altitude (ALT). Lateral distance of 0 included 0.0 to 0.3 km (0.0 to 0.2 mi), LD of 0.8 km (0.5 mi) included 0.5 to 1.1 km (.3 to .7 mi), and LD of 1.6 km (1.0 mi) ranged from 1.3 to 1.9 km (0.8 to 1.2 mi.).

LD	ALT	Canada			Emperor			Brant		
		response % (SE)	flight % (SE)	n	response % (SE)	flight % (SE)	n	response % (SE)	flight % (SE)	n
<u>simile-emine</u>										
0	500	80 (8)	40(13)	13				96 (2)	76 (6)	50
0	1000	39(12)	1 (1)	14	75(25)	63(24)	4	72 (5)	41 (6)	65
0.8	1000	8 (5)	1 (1)	23	100 (o)	o (o)	3	44 (6)	15 (5)	54
1.6	1000	11 (9)	11 (9)	u	100	0	1	25 (9)	3 (2)	25
<u>Twin-engine</u>										
o	500	31(10)	o (o)	17	73 (21)	o (o)	4	79 (5)	32 (7)	42
o	1000	18(10)	o (o)	11	27(27)	o (o)	3	64 (6)	14 (6)	31
0.8	1000	22(15)	12(11)	9	100	0	1	39 (11)	6 (6)	17
1.6	1000	0 (o)	o (o)	5				1 (1)	o (o)	10
<u>Multi-engine transport</u>										
o	500									
0	1000	60(25)	60(25)	5	100 (2)	100 (2)	2	100 (o)	88(11)	9
0.8	1000	41(15)	o (o)	8	50 (o)	o (o)	2	62(12)	47(12)	17
1.6	1000	20(20)	20(20)	5				55(20)	50(22)	6
<u>Helicopters</u>										
0	500	57(10)	24 (9)	20	83(12)	83(12)	10	92 (4)	84 (5)	53
o	1000	31 (9)	4 (4)	25	83(17)	37(20)	6	90 (3)	74 (5)	82
0.8	1000	24 (6)	7 (4)	44	69(12)	18(10)	14	72 (4)	47 (4)	120
1.6	1000	7 (5)	5 (5)	19	98 (3)	50(29)	4	38 (7)	15 (5)	43

Response to experimental aircraft overflights

The regression equations for **logit** of response (Table 5.10) and logistic regression equations for probability of 10% response (Table 5.11) produced similar results. Both methods were able to explain about the same percent of the variation, at least as measured in the **logit** scale. The logistic regression was less useful in that the equations did not estimate the actual percent of response above the 10% level. In effect, the procedure assumes either 100% or 0% response. Consequently, the proportion of total variance explained by the lateral distance and altitude factors was slightly less for the logistic regression approach (r^2 in Table 5.11 compared with r^2 in Table 5.10). For the larger fixed-wing aircraft, the poorer fit of logistic regression was particularly noticeable.

The response surface equations (Table 5.10) produced reasonably consistent shapes. This allowed comparisons of aircraft types even when experimental flight distances and altitude differed among aircraft. Graphs drawn in three dimensions (front and side views in Figures 5.11-5.12) show the response surface transformed back from the **logit** scale for each stimulus type. The network of intersecting lines represents the percent response on the vertical axis at 0.4 km (0.25 mi) increments of lateral distance and 76 m (250 ft) increments of aircraft altitude.

For the smaller fixed-wing aircraft, goose response was low both at greater lateral distances and greater altitudes. Response was least to the Navajo twin-engine aircraft and greatest for the Bell 205 helicopter. For fixed-wing aircraft, flight response declined more rapidly with increasing altitude than did the alert response. For all rotary-wing aircraft, increasing altitude did not appreciably decrease alert or flight responses. In fact, for Bell 205 and Hughes 500-D helicopter overflights the probability of flight response increased with altitude over the range of most of the data from 152 m (500 ft) to 610 m (2,000 ft).

The equations representing the percent alert response did not differ as much among types of fixed-wing or types of rotary-wing aircraft as did the flight response. Flight response to the Cessna 206 was greater than response to the smaller fixed-wing aircraft and the Navajo twin even though alert response measures were similar. The Bell 205 differed slightly from the other helicopters in the shape of its response surface showing increased response at greater altitude. Response to the Bell 205 was greater than for all other types.

Table 5.10. Coefficients of least squares regression equations that predict **logit transformation of the response of brant** to overflights by various aircraft based on lateral distance (miles) and altitude (1000 feet). standard errors of the coefficients and **significance (*)** at $P < 0.05$ are indicated.

	Coef	SE	Coef	SE	Coef	SE	Coef	SE
LOGIT TRANSFORMATION FOR THE PROPORTION OF BRANT THAT SHOW ANY RESPONSE:								
	<u>Piper 150</u>		<u>Cessna 206</u>		<u>Navajo twin</u>		<u>C-130 cargo</u>	
n =	237		100		145		69	
r ² =	.413		.354		.496		.444	
intercept	6.38*	(0.94)	8.28*	(1.91)	5.78*	(1.02)	3.05	(4.46)
lat. dist	-8.03*	(1.34)	-8.67*	(1.48)	-15.35*	(2.13)	-6.73*	(1.89)
lat. dist ²	2.03*	(0.61)	1.71*	(0.36)	6.56*	(1.62)	1.08	(0.66)
alti	-3.35*	(1.85)	-7.33*	(3.33)	-3.80*	(1.87)	2.86	(5.59)
alti ²	0.21	(0.82)	1.87	(1.07)	0.98	(0.68)	-0.89	(1.56)
	<u>Bell 206B</u>		<u>Huches 500D</u>		<u>Bell 205</u>			
n =	387		70		419			
r ² =	.298		.195		.561			
intercept	2.90*	(0.67)	6.59*	(1.76)	4.77*	(0.40)		
lat. dist	-5.09*	(0.41)	-3.68	(4.67)	-6.61*	(0.50)		
lat. dist ²	0.57*	(0.07)	-2.13	(4.91)	0.71*	(0.20)		
alti	0.68	(1.09)	-1.85	(3.25)	1.92*	(0.53)		
alti ²	-0.14	(0.31)	0.52	(1.51)	-0.38*	(0.16)		
LOGIT TRANSFORMATION FOR THE PROPORTION OF BRANT THAT TAKE FLIGHT:								
	<u>Piper 150</u>		<u>Cessna 206</u>		<u>Navajo twin</u>		<u>C-130 cargo</u>	
n =	237		100		145		69	
r ² =	.322		.455		.251		.336	
intercept	5.25*	(0.92)	8.79*	(1.83)	1.87	(1.00)	8.14	(4.78)
lat. dist	-4.98*	(1.30)	-8.36*	(1.42)	-8.76*	(2.08)	-5.93*	(2.02)
lat. dist ²	1.47*	(0.59)	1.72*	(0.34)	4.64*	(1.58)	0.98	(0.71)
alti	-9.83*	(1.80)	-9.81*	(3.18)	-6.70*	(1.82)	-6.49	(5.99)
alti ²	3.04*	(0.80)	2.26*	(1.03)	1.81*	(0.67)	1.52	(1.67)
	<u>Bell 206B</u>		<u>Huches 500D</u>		<u>Bell 205</u>			
n =	387		70		419			
r ² =	.207		.222		.527			
intercept	2.17*	(0.71)	4.10	(2.58)	4.34*	(0.48)		
lat. dist	-4.00*	(0.43)	-11.55	(6.83)	-8.95*	(0.60)		
lat. dist ²	0.42*	(0.07)	2.88	(7.19)	1.57*	(0.24)		
alti	-2.58*	(1.16)	-1.30	(4.75)	1.59*	(0.63)		
alti ²	0.70*	(0.33)	0.80	(2.22)	-0.29	(0.19)		

Table 5.11. Coefficients (Coef) of logistic regression equations that predict the response of brant to overflights by various aircraft based on lateral distance (miles) and altitude (1000 feet). Standard errors (SE) of coefficients and significance based on chi-square tests at $P < 0.05$ are indicated. Proportion of variance explained by the regression model (r^2) was calculated in the same logit scale as in Table 5.10.

	Coef	SE	Coef	SE	Coef	SE	Coef	SE
PROPORTION OF FLOCKS IN WHICH AT LEAST 10% OF THE INDIVIDUALS SHOW RESPONSE:								
	<u>Piper 150</u>		<u>Cessna 206</u>		<u>Navajo twin</u>		<u>C-130 cargo</u>	
n =	237		100		145		69	
r^2 =	.343		.272		.251		.307	
intercept	4.12*	(0.83)	4.88*	(1.43)	3.95*	(1.38)	1.98	(3.28)
lat.dist	-3.94*	(0.99)	-4.34*	(1.09)	-9.67*	(2.16)	-2.27	(1.48)
lat.dist ²	0.72	(0.50)	0.82*	(0.23)	3.85*	(1.62)	0.20	(0.56)
alti	-2.56	(1.44)	-4.33*	(2.23)	-1*00	(3.17)	0.86	(4.31)
alti ²	0.43	(0.62)	1.15	(0.70)	-0.04	(1.91)	-0.46	(1'.32)
	<u>Bell 206B</u>		<u>Hughes 500D</u>		<u>Bell 205</u>			
n =	387		70		419			
r^2 =	.150		.159		.483			
intercept	1.74*	(0.40)	6.41*	(2.94)	3.90*	(0.76)		
lat.dist	-3.31*	(0.45)	-7.80	(7.59)	-4.67*	(1.09)		
lat.dist ²	0.63*	(0.13)	3.82	(6.59)	0.45	(0.47)		
alti	0.50	(0.62)	-3.79	(4.19)	0.91	(1.27)		
alti ²	-0.08	(0.18)	1.64	(2.01)	0.25	(0.55)		
PROPORTION OF FLOCKS IN WHICH AT LEAST 10% OF THE INDIVIDUALS TAKE FLIGHT:								
	<u>Piper 150</u>		<u>Cessna 206</u>		<u>Navajo twin</u>		<u>C-130 cargo</u>	
n =	237		100		145		69	
r^2 =	.265		.424		.063		.088	
intercept	2.68*	(0.65)	6.10*	(1.70)	3.59*	(1.26)	3.02	(3.85)
lat.dist	-2.78*	(0.96)	-7.88*	(1.94)	-8.56*	(4.43)	0.19	(2.59)
lat.dist ²	0.50	(0.53)	1.59*	(0.39)	1.45	(7*75)	-1.79	(1.82)
alti	-3.57*	(1*37)	-6.37*	(2.54)	-7.59*	(3.47)	-2.75	(5.33)
alti ²	0.69	(0.69)	1.49	(0.79)	2.66	(2.19)	0.62	(1.72)
	<u>Bell 206B</u>		<u>Hughes 500D</u>		<u>Bell 205</u>			
n =	387		70		419			
r^2 =	.165		.175		.458			
intercept	1.63*	(0.41)	2.88	(1.54)	2.50*	(0.44)		
lat.dist	-3.46*	(0.60)	-6.76	(4.25)	-5.23*	(0.76)		
lat.dist ²	0.51	(0.29)	2.X2	(4.61)	0.75*	(0.37)		
alti	-1.17	(0.63)	-1.58	(2.58)	1.35*	(0.59)		
alti ²	0.34	(0.18)	0.81	(1.20)	-0.21	(0.19)		

Figure 5.11 Response surfaces depicting the percentage of brant responding to aircraft overflights at various conditions of altitude and lateral distance. The flat area in the foreground indicates combinations where no response occurs. Response increases towards 100% as altitude and/or lateral distance decreases.

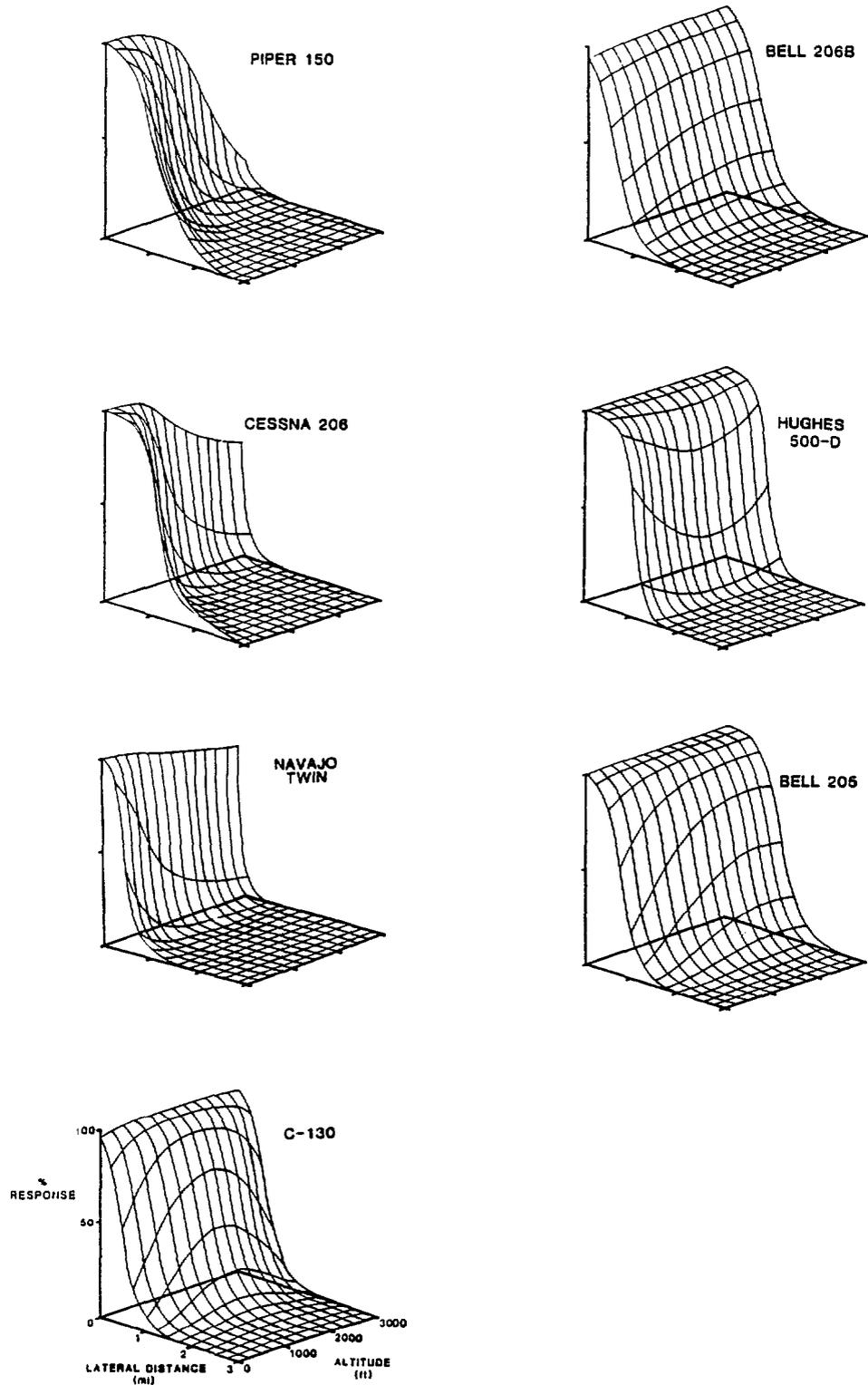
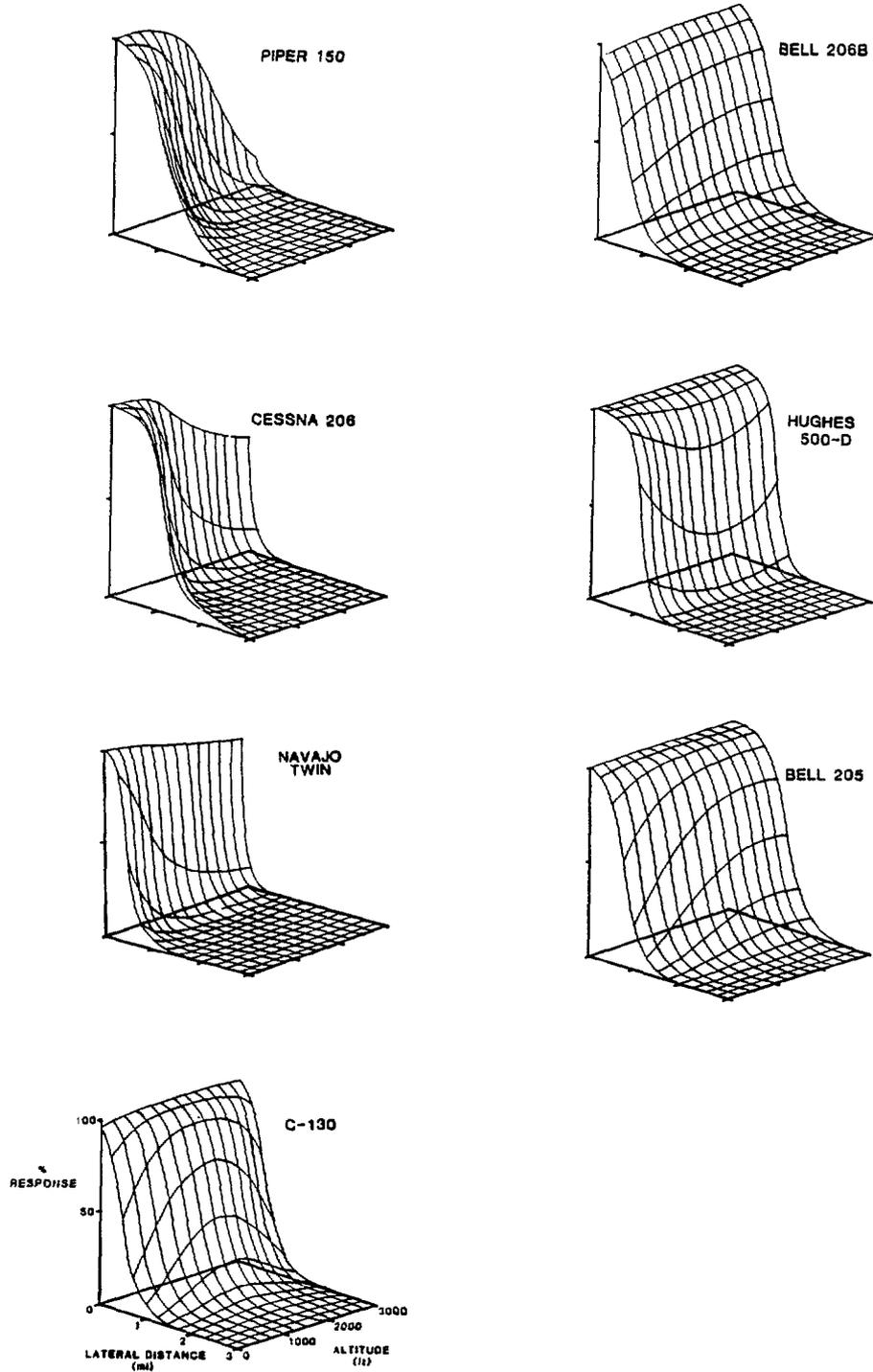


Figure 5.12 The same response surfaces as in Figure 5.11 viewed from a different side depicting the percentage of brant responding to aircraft overflights at various altitude and lateral distance combinations.



Comparisons between aircraft types can be examined more directly in two dimensions by comparing lines drawn to represent lateral distance and altitude combinations that result in a particular level of response (Figure 5.13). A series of these lines would construct a contour plot of the three dimensional response surface viewed from a perspective of looking straight down towards the altitude and lateral distance axes. The size and orientation of the lateral distance and altitude defined area between the axes and the 50% response line (solid line for fixed-wing, dashed line for rotary-wing) provides another method to visualize comparisons among aircraft types (Figure 5.13). Any combination of lateral distance and altitude that falls to the right of and above the line indicates less than 50% response would be expected. Points to the left and below the 50% line indicate conditions with a greater than 50% probability of response.

Stepwise regression on residuals identified a variety of other factors in addition to altitude and lateral distance that were significant predictors of response to the various aircraft types (Table 5.12). None, however, were entirely consistent and none explained a large proportion of the variation. For the seven aircraft and two response measures, 14 stepwise regressions were run.

The factor that was most often significant (8 times, Table 5.12) was social facilitation. That is, prior flight response by adjacent flocks correlated with an increased percent of birds responding to aircraft overflights. Also, flocks of brant engaged in foraging were more likely to respond (significant 4 times, Table 5.12) to aircraft compared with flocks with more birds engaged in resting or maintenance behaviors. Flock size, tide stage, date, and time of day did not often enter as significant correlates.

The number of consecutive days of repeated aircraft overflights correlated with residual response for two of the three helicopter types (Table 5.12). Habituation to stimuli could not be tested for fixed-wing aircraft because schedules did not include large enough samples on sequential days of stimulus presentation. Repeated fixed-wing overflights were usually separated by six or more days. In contrast, the chartered helicopter overflights were conducted intensively for three to six day periods. The Hughes 500-D was flown on three consecutive days, the Bell 205 over 6 days including one skipped day, and the Bell 206-B was flown on three consecutive days one year, and six days with two skipped days in another year.

The greatest habituation was shown for percent flight response to Hughes 500-D overflights. Average value of observed minus predicted response decreased for successive days

Figure 5.13 Lines indicate the combination of lateral distance and altitude that is expected to cause 50% response or 50% flight response in flocks of brant exposed to overflights of various types of aircraft. The equations are based on data mainly in the range from 500 to 1500 ft altitude and 0.0 to 1.2 mi lateral distance shown at the left central portion of the graph. Extrapolation of the lines to the periphery of the graph is not reliable and comparisons should be limited to the left central portion.

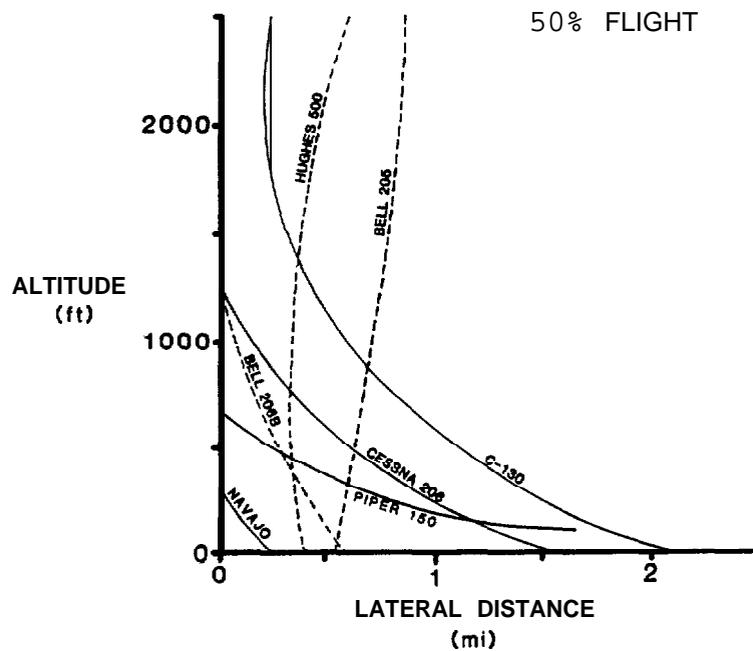
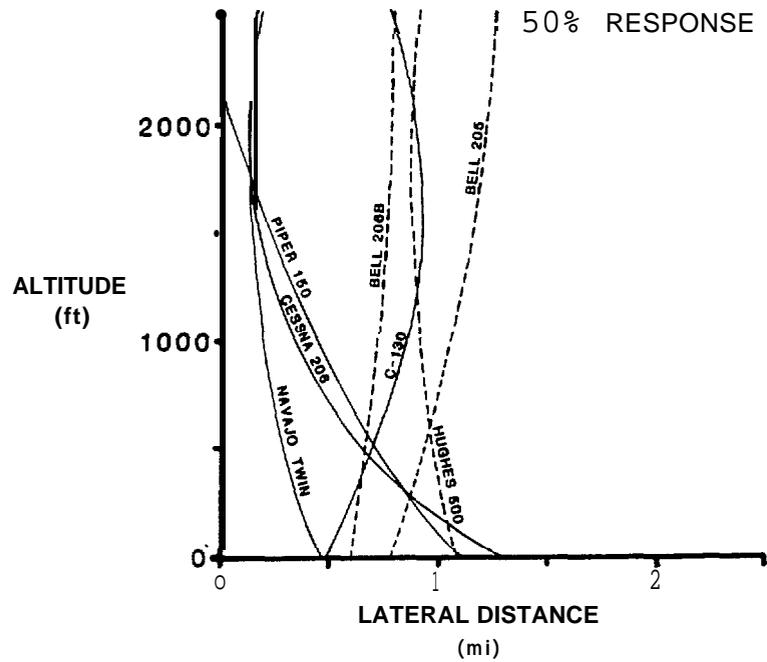
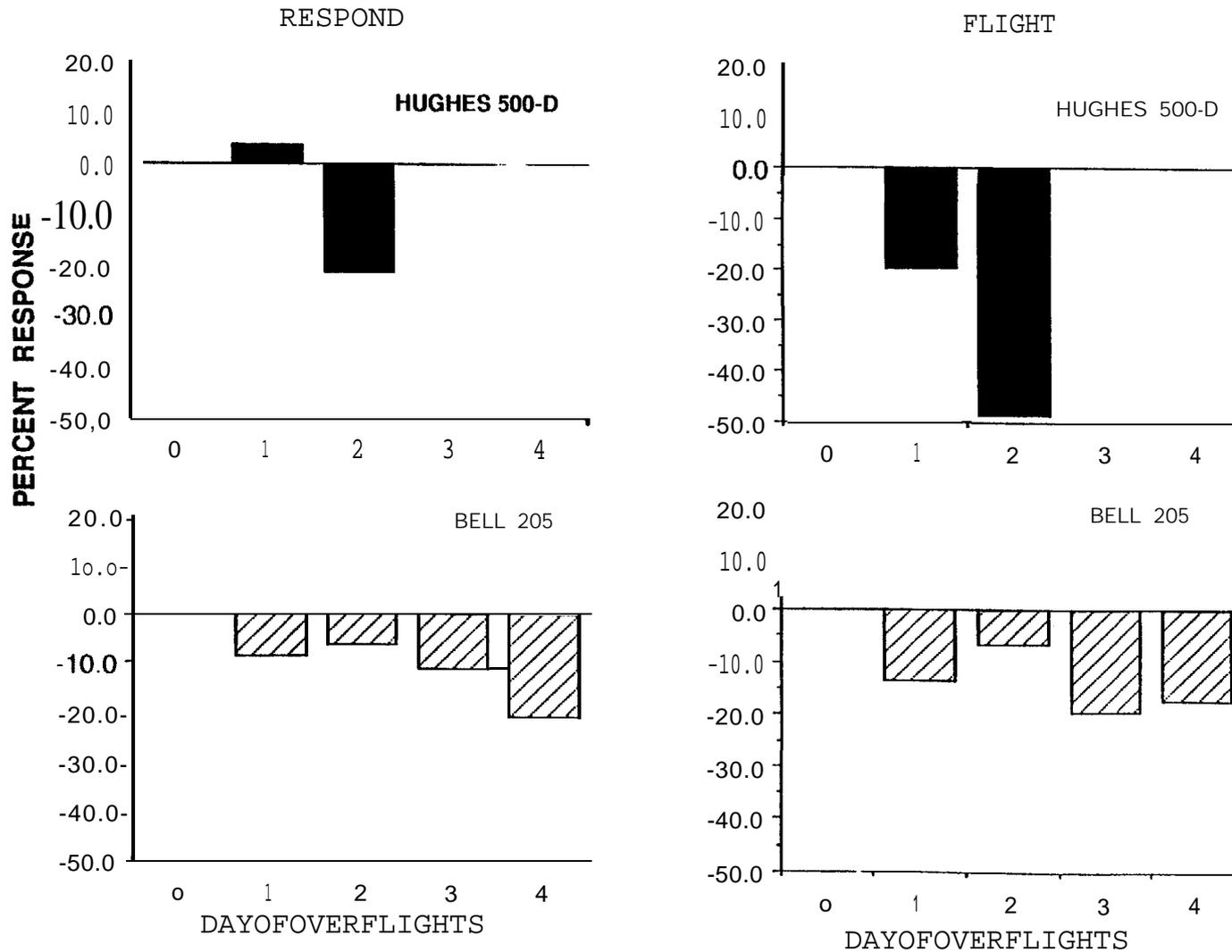


Table 5.12. Variables correlated with **brant** response to experimental aircraft overflights. **Analysis** involved **stepwise multiple** regression (forward **entry** of variables at **P<0.05**) to **explain** residuals of percent **response**. Residuals were calculated in the logit scale based on **observed** proportion of **brant responding minus** predicted response **based** on lateral **distance**, altitude, and aircraft **type** (Table 5.10) . Variables available for entry to predict the **residuals** included **lateral distance**, altitude, tide height, tide flow, **time** of day, flock size, year, date, behavior, social facilitation, tide stage, and days of habituation.

Aircraft	Behavior	Variable	Coeff	r ²	P>F
Piper 150 n=237	response	year	1.07	0.040	0.01
		time of day	-0.62	0.060	0.01
	flight	behavior upwind	1.26 -1.93	0.016 0.026	0.05 0.02
Cessna 206 n=100	-	social	1.81	0.046	0.03
	flight	social	1.51	0.035	0.06
Navajo n=145	response	days	-0.32	0.083	0.01
		tide stage	1.48	0.031	0.03
	flight	social	1.90	0.030	0.04
C-130 n=69	response	social	3.93	0.126	0.01
		behavior	2.76	0.3.25	0.01
		days	-0.12	0.046	0.04
	flight	upwind	-3.93	0.111	0.01
Bell 206B n=387	response	year	-1.82	0.057	0.01
		social	1.09	0.014	0.02
	flight	year social	-2.02 1.08	0.064 0.012	0.01 0.03
Hughes 500 n=70	response	behavior (hab) days	2.89 -1.56	0.082 0.106	0.02 0.01
		flight	(hab) days	-2.42	0.136
Bell 205 n=419	-	social	1.71	0.096	0.01
		hab days	-0.31	0.017	0.01
	flight	social. (ha) days	1.90 -0.35	0.089 0.019	0.01 0.01
		behavior tide flow	-0.89 -0.68	0.015 0.012	0.01 0.02

Figure 5.14 Average residual response, the difference of observed minus predicted behavioral response or flight response, for flocks of brant exposed to repeated days-of numerous aircraft overflights by Hughes 500-D or Bell 205 helicopters.



of overflights for the Hughes 500 and the Bell 205 helicopters (Figure 5.14). The Bell 206-B residual response was dominated by a lower response in 1987 compared with other years, an influence we can not explain, and average changes with repeated days were opposite but not significant.

DISCUSSION

Incidental disturbance

The rate of all potential disturbance events, averaging 1.1 per hour of observation, was similar in all years of the study (Table 5.2). There was, however, annual variation in rates of disturbance between specific disturbance types. Most noticeable of these was the difference in rates of persons on foot (0.30 vs 0.06 and **0.05/hr**) and eagle (0.03 vs 0.34 and **0.23/hr**) disturbance events between 1985, and 1986 and 1987, respectively (Table 5.3). Differences can be explained, for the most part, by changes in the location of study areas and length of the observation period. In 1985 all observations were made primarily from GE located in the central portion of the lagoon, the area of greatest human disturbance (Figure 5.10) and fewest eagle disturbances (Table 5.5), whereas in 1986 and 1987 observations were made from several areas in the central and southern portions of **Izembek** Lagoon (Appendix D; Tables **D5-D7**). Slight variation in rates of aircraft disturbance between years was probably due to changes in the frequency and scheduling of aircraft traffic in and out of the Cold Bay airport (Table 5.4) and time of day of observations.

Disturbances were primarily confined to diurnal periods. Human disturbances were curtailed or non-existent at night. Aircraft traffic in and out of Cold Bay was rare at night (less than two per week) (J. Maxwell pers. **comm.**). Night vision scopes were ineffective for observing birds at night, due to the low magnification (7-9X), poor lighting, and inclement weather conditions. When flocks of brant were detected (generally heard) taking flight at night, it was not possible to separate natural flight movements from flight caused by a disturbance stimulus.

The "observed rate of aircraft events (**0.57/hr**) at **Izembek** was influenced by the location of the IFR corridor which concentrated the flight paths of larger aircraft over the Round Island and Outer Marker area (Figure 5.9). Most commercial flights remained above 457 m (1,500 ft) over the lagoon. Departing jets were at greater altitudes of 605 to 1,524 m (3,000 to 5,000 ft) by the time they cross the lagoon, and most commercial jet flights did not greatly disturb geese (Table 5.6). Cargo aircraft that gained altitude more slowly

after leaving the **Cold Bay** runway caused more disturbance response although cargo flights were infrequent during the study .

Table 5.13 compares the rates of disturbance for brant in this study with levels reported in other studies. Frequency of disturbance events per hour of observation at **Izembek** Lagoon was between levels reported for molting brant on the North Slope of Alaska (Simpson et al. 1980) and wintering **dark-bellied** brant in England (Owens 1977). Similar low rates of disturbance on the North Slope of Alaska and Yukon Territory, Canada were found for fall staging lesser snow geese (Davis and **Wiseley** 1974). Rates of disturbance to greater snow geese (**C. c. atlanticus**) observed during fall staging at **Montmagny, Quebec**, were nearly double the rates at **Izembek** (**Belanger** and **Bedard** 1989).

Table 5.13. Comparison of rates of disturbance of brant and other waterfowl as reported in this and other study locations.

Species	Season	Location	Source	<u>Events per hour</u> total ^a flight ^b	
Brant	Fall	Izembek LagCon, Ak	This report	1.07	0.50
Brant	winter	south eastern England	-1979		0.70
Brant	Summer	North Slope of Alaska	Simpson et al. 1980	0.35	
Lesser snow geese	Fall	North Slope of Alaska and Yukon T.	Davis and Wiseley 1974	0.35	
Greater snow geese	Fall	Montmagny, Quebec	Belanger and Bedard 1989		1.46
Greater snow geese	Spring	Montmagny, Quebec	Belanger and Bedard 1989		1.02

^a Events defined as all detectable potential **disturbances**

^b **Events** defined as only those causing flocks to show a flight response.

Izembek Lagoon differed from all the areas mentioned above in the frequency of disturbances not related to humans. The rate of disturbance caused by eagles and other animals (**0.3/hr**) at **Izembek** was three times greater than for brant on the North Slope of Alaska (**0.1/hr**) (Simpson et al. 1980). Non-human disturbances caused the longest average duration of response in flightless brant (Simpson et al. 1980) ; and at **Izembek** Lagoon, natural disturbances also caused the greatest duration of response and accounted for 62% of the total interruption of normal behavior (89 sec/hr of observation). Eagles were the most important source of disturbance for all geese.

Despite the higher rate of disturbance at **Izembek**, the duration of time that brant were interrupted from normal behavior at **Izembek** (2.5% of 1,912 hr observed) was comparable to molting brant on the North Slope (3% of 198 hr). This suggests that staging brant are more tolerant or show a less prolonged (but perhaps energetically more costly) response to disturbance than flightless birds. Selection may work to favor certain traditional molting areas because predators are scarce when brant are flightless. However, at staging and wintering areas, natural predators can be avoided and although eagles elicited flight response in **brant**, they caused little direct mortality to brant.

The presence of existing disturbance, either by natural or human causes, does not mean additional disturbance can be tolerated. The ability of geese to adjust to any additional energetic costs or displacement caused by aircraft disturbance is not ensured by their ability to tolerate existing levels of disturbance.

Observed rates of disturbance from boating (**0.03/hr**) and persons on foot (**0.08/hr**) were low, but because these events caused a consistent and prolonged response in **brant**, they have potential for causing severe impacts should their frequency increase. Disturbance can have more pronounced effects (displacement) on the distribution of birds (Tuite et al. 1983, **Korschgen** et al. 1985, Norriss and Wilson 1988). The number of ducks (non-breeding birds) using lakes decreased in the Mackenzie valley of Canada as fixed-wing overflights and landings increased (**Schweinsberg** et al. 1974). In Great Britain, increased human pressure has been linked to declines and desertions of white-fronted geese (*Anas albifrons*) (**Ogilvie** 1968) .

Some tolerance of non-threatening activities (vehicles) has been noted (Murphy et al. 1986), and birds adjusting their patterns of use to periods of decreased disturbance, such as night feeding, has been documented (Madsen 1985, Morton et al. 1989) . At San Quintin, Mexico, brant generally avoided areas with frequent disturbance, caused mainly by boats and hunters,

until forced to use these areas because of food depletion elsewhere (Kramer et al. 1979) .

Increased flight caused by disturbance may lead to separation of family members (Jones and Jones 1966) or increased hunting mortality (**Bartelt** 1987). Our data indicates that disturbance at **Izembek** affects time spent feeding and time in flight. There is potential, however, for displacement of geese should disturbance increase above current levels.

It is not known whether brant would respond differently to causes of disturbance in spring. Eagles are present in spring and cause disturbance in brant. **Belanger** and Bedard (1989) found that greater snow geese at **Montmagny**, Quebec, were more frequently disturbed in **fall** than in spring. They suggested that the greater number of geese and larger flock size in fall may facilitate increased disturbance responses observed during this period. Owens (1977) and Madsen (1985) also found that larger flocks of geese reacted at greater distances than smaller flocks. Average number of brant present at **Izembek** in spring is less than fall and may contribute to lower response to disturbance.

Experimental disturbance

Sample sizes of greater than 70 flocks were needed to obtain significance in t-tests or **chi-square** tests on regression coefficients relating lateral distance and aircraft altitude to response by brant. Samples of over 200 flock responses were needed to obtain small standard errors for regression coefficients. It appeared that reasonable shapes for response surfaces were obtained for sample sizes down to about 70 flock; however, several smaller data sets could not be reliably analyzed.

Numerous overflights and observations are necessary. The use of data from many flocks, several study locations, different presentation times, and a variety of conditions seemed to better fit the regression analysis. The most carefully controlled and repetitious series of stimulus presentations at one study area using the Hughes 500-D produced a data set that was minimally related to helicopter lateral distance or to any other predictive factors that we were able to measure.

Questions of sampling design for aircraft overflight studies were not completely resolved during our study. The practice of starting overflights high and working down in altitude until some assumed threshold of sensitivity is surpassed is clearly unworkable for helicopters because

altitude either had little influence on the proportion of brant that responded or the response was actually increased with altitude. In future studies, stimulus presentation schedules should probably be strictly random. We adopted this strategy as the study progressed.

The confounding factors of social facilitation and behavior prior to response were identified as important effects. Although our experimental overflights were not designed to quantify the magnitude of these influences, future study designs should either control for or attempt to estimate their influence. Habituation was identified as another factor influencing the response of brant. It was detectable as a 20% decrease in average response after four or five days of Bell 205 overflights. The greater habituation for the Hughes 500-D helicopter is based on less reliable data.

The ability of brant to habituate to disturbance is likely to depend in part on the predictability of the location and constancy of the source. Murphy et al. (1989) reported that brant nesting near an oil production area on the North Slope of Alaska accommodated to relatively predictable sources of activity (i.e. oil pad activities or vehicular traffic), but reacted more strongly to less predictable sources of disturbance like aircraft or pedestrians. Similarly, brant at **Izembek** Lagoon were more disturbed by less predictable sources of disturbance such as eagles, boats, or aircraft. The extent of habituation to repetitive aircraft overflights is unknown and needs further research.

Tide-related factors were not very important. We had thought that brant flocks would show greater tendency to fly during flooding tides since they soon had to move to find more suitable foraging sites. This did not occur. Analytical problems exist, however, with finding a suitable numeric value to meaningfully express a specific combination of tide height and flow that perhaps depends as well on date, flock location, relative tide height, and duration of prior feeding.

Results of data analysis using logistic regression and least squares regression using the logit transformation were similar. The agreement in the relative magnitude and significance level of the regression coefficients between the analyses confirmed that the least squares procedure after **logit** transformation was reasonable and that the lack of linear relationships and of normally distributed data did not mask underlying patterns. The maximum likelihood solutions for the category of response (CATMOD) are more robust and mathematically more appropriate, therefore the standard errors on coefficients from the logistic regression equations are probably more reliable. Efforts to improve response category measures to include more levels of response caused numeric

overflow problems for the CATMOD procedure program perhaps due to sample size limitations.

The main finding shown by the response surfaces was that **brant** response to helicopters, unlike fixed-wing aircraft, was not reduced with increasing altitude of the aircraft.

CHAPTER 6: ACOUSTICS OF AIRCRAFT OVERFLIGHTS

Noise may be an important factor influencing the response of brant to aircraft overflights. Jenssen (1980) categorized the effects of noise on animals as either primary or secondary. Primary effects range from momentary masking of auditory signals that may inhibit an animal from hearing calls from another animal, to physical impairment or complete loss of hearing. Secondary effects are indirect non-auditory effects causing behavioral or physiological change. Noise as a factor modifying and perhaps interfering with normal brant behavior is the concern of this study. At present, knowledge and understanding of the types of noise that may disturb free-living animals is quite limited (Fletcher 1980). This is partly because response of birds to noise is so variable among species (Burger 1981a) .

The influence of aircraft noise on avian species has recently received attention (Manci et al. 1988) . Research has concentrated on observations of the behavioral response of species to aircraft overflights or determination of effects on reproduction where a direct impact of disturbance can be measured by loss of eggs or young. Thick-billed murres (Uris lomvia) on Svalbard Island, Norway, flushed from nests when exposed to Bell 212 helicopter flights or to tape recordings of helicopter noise (Fjeld et al. 1987). Although loss of eggs was not caused directly by murres flushing from their nests, eggs and chicks were lost from increased predation by glaucous gulls (Larus hyperboreus). Burger (1981b), on a refuge near New York's Kennedy International Airport, observed that more nesting herring gulls (Larus argentatus) flew from nests and flew longer from supersonic (108 dB) than subsonic (92 dB) transports. Eggs were sometimes broken as birds flushed from nests or unprotected eggs were eaten by other gulls. In Arizona, Ellis (1981) found that nesting peregrine falcons and other raptors were disturbed by noise (82-114 dB) produced by jets flying at low altitudes, but no loss of eggs or young was detected.

Behavioral response of brant to overflights was dependent on the aircraft type as well as altitude and lateral distance (previous chapter). Helicopters caused more disturbance than small single-engine aircraft. The intensity, duration, and frequency of noise generated by aircraft may be important factors influencing the response. For brant or other related species, few studies were found in the literature that have quantified both specific characteristics of noise stimuli and the intensity and duration of behavioral response to noise.

If aircraft noise is a major determinant of the behavioral response of brant, then the noise produced by an aircraft, measured at standardized conditions of altitude and lateral distance, may be useful for predicting the amount of disturbance a specified aircraft will have on staging brant.

Research was initiated in 1987 to investigate effects of aircraft noise on brant. Noise produced by various types of aircraft was measured and correlated with the observed behavioral response of brant. Noise measurements in 1988 emphasized collecting noise data in synchrony with observed individual flock responses. These data have not been thoroughly analyzed due to the complexity of predicting noise level at the flock for those locations away from the receiving microphone. When analyzed, these data may provide a more direct measure of threshold level of noise correlated with behavioral response.

METHODS

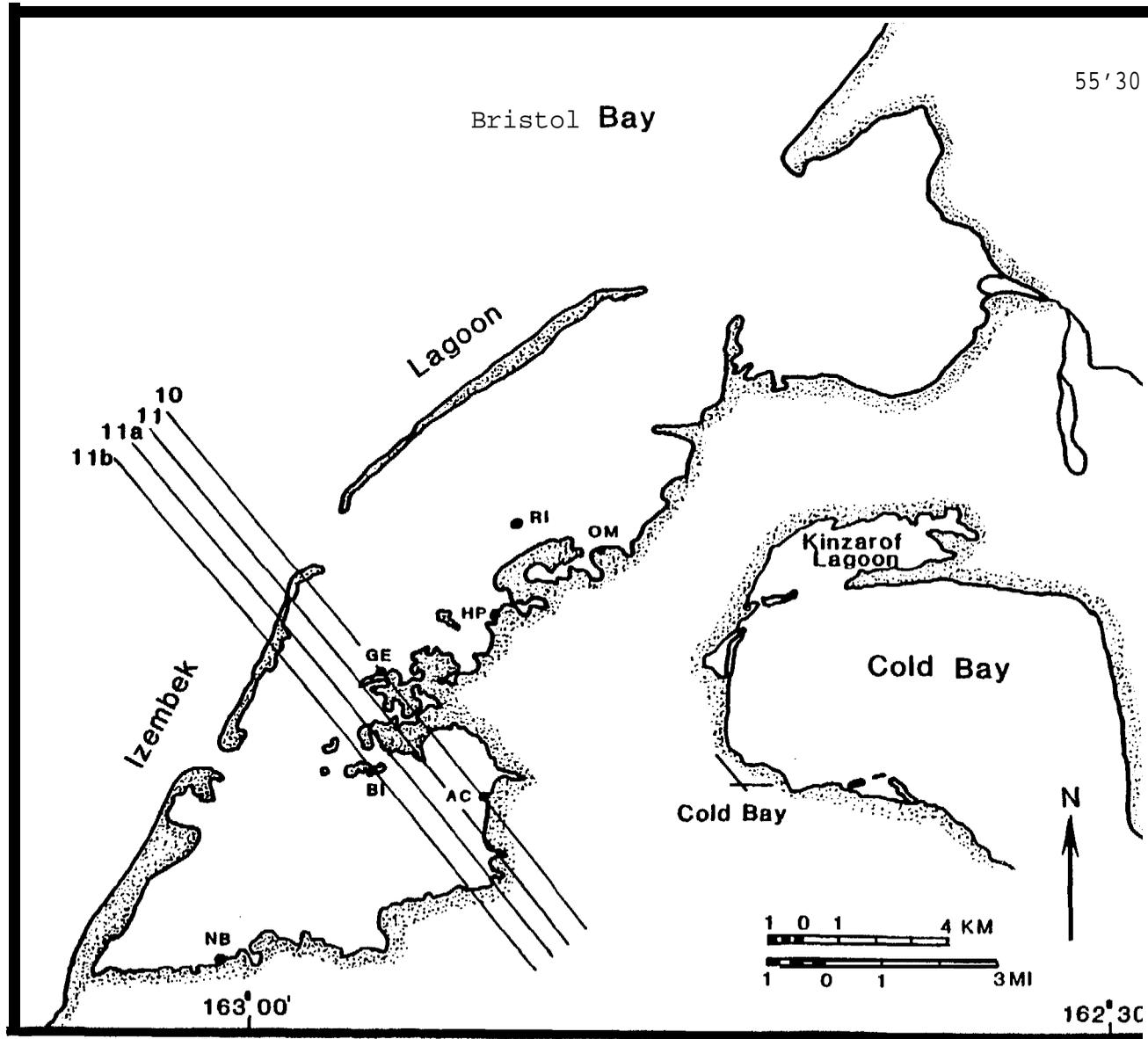
Aircraft noise was measured at **Izembek** Lagoon on six days between 5 October and 1 November 1987 and seven days between 29 September and 19 October 1988. Noise levels were measured for 2 types of single-engine propeller aircraft, a Piper 150 Super Cub on floats and a Cessna 206 on amphibious floats, and for three types of helicopters, a Hughes 500-D, a Bell 206-B Jet Ranger, and a Bell 205. Aircraft were flown at typical cruising speed ranging between 41 m/sec (80 kts) and 64 m/sec (**125 kts**).

The three helicopters differed in size and carrying capacity. The Hughes 500-D is a single engine 280 kw helicopter with a five-blade main rotor and four-blade tail rotor. The Bell 206-B is slightly larger than the Hughes and has two-blade main and tail rotors. This 315 kw single-engine aircraft is capable of carrying 725 kg. The largest **helicopter** measured was a Bell 205 with two-blade main and tail rotors-and a **1,045** kw engine capable of lifting 2,270 kg.

Acoustical measurements were made from two different sites. In 1987 measurements were made on land at Grant Point peninsula" approximately 18 m above the mean high tide level (Figure 6.1). Aircraft were flown along four flight lines at 0.92 km (0.5 mi) intervals. In 1988 the microphone was situated 2 m above the water surface on a metal tower that was 0.7 km from shore. Overflights were conducted along flight lines oriented in a variety of directions (Figure 5.7).

Noise was received through a **Bruel** and Kjaer (**B+K**) type 4921 outdoor microphone and analyzed on a Larson-Davis 3100

Figure 6.1. Number, position, and orientation of flight paths made by Piper 150, Cessna 180, and Cessna 206 fixed-wing aircraft, and Bell 206-B Jet Ranger and Bell 205 helicopters during acoustical measurements at Izembek Lagoon, Alaska between 5 October and 1 November, 1987. Study areas were the same as those described in Figure 2.1.



real time analyzer (RTA). A 23 cm (9 in) diameter windscreen made of polyurethane foam was placed over the microphone element to attenuate low frequency wind noise. The RTA measured a sample of noise every 0.5 sec in 30 one-third octave bands with band centers extending from 10 Hz to 10 kHz. Noise measurements consisted of Flat-, A-, and C-weighted sound pressure levels (SPL_i) averaged over the sample time for each one-third octave frequency band. Background noise levels were measured and stored in the RTA prior to an overflight. This ensured the measured noise level was that of the aircraft.

For each passby overflight, the integrated total sound energy (Leq), maximum instantaneous sound energy ($Lmax$), and sound exposure level (SEL) produced by the aircraft were calculated. Leq is a measurement of average sound level across all one-third octave bands for a 0.5 s sample. $Lmax$ is maximum Leq measured during the passby. SEL is the total noise exposure integrated over all one-third octave bands and over all time intervals during the passby. Leq is calculated as:

$$Leq = 10 \log_{10} [\text{sum of } \exp_{10} (SPL_i/10)]$$

where the sum is over all i frequencies of the one-third octave bands. SEL is defined as:

$$SEL = 10 \log_{10} [\text{sum of } \exp_{10} (t) (Leq_j/10)]$$

where the sum is over all j intervals from start to finish of the passby and t equals the sample period.

Lack of information on the audible frequency range of brant made selection of a particular standard frequency weighting scale (i.e. A-, C-, Flat-weighting) difficult. In general, the audible frequency range of birds (40 Hz-21 kHz) is similar to a human (20 Hz-16 kHz), although birds are less sensitive to higher and lower tones within their hearing range (Schwartzkopff 1973). The range of hearing sensitivity of brant may be comparable to the range of 3 Hz-8 kHz measured for mallards with a range of maximum sensitivity between 2 and 3 kHz (Schwartzkopff 1973). All noise measurements in this report are expressed as decibels in the A-weighted scale, unless otherwise noted. The A-weighted scale is the inverse of human hearing and assigns lower weights to lower frequency tones and higher weights to higher frequency tones.

Categories of behavioral response by brant were the same as those previously described. The average noise measurements of aircraft were compared with the average behavioral response by brant to these same aircraft for the same conditions of lateral distance and altitude. The behavioral data were averaged from all flocks over any date, time, or location in the lagoon.

RESULTS

Noise measurements of aircraft

The Bell 205 helicopter consistently produced more noise (L_{max} and SEL) than any other aircraft (Figure 6.2). The Hughes 500-D was the next loudest aircraft. The Cessna 206 was the loudest fixed-wing aircraft and generated noise levels (L_{max}) similar to the Bell 206-B helicopter. During flights at 157 m (500 ft) and 0.0 km lateral distance to the microphone, the Bell 205 produced an average L_{max} of 84.4 dB, which was 7-10 dB higher and 5.4 times the acoustical energy of the Hughes 500-D. The Hughes produced 77.1 dB with 1.7 times the energy of the Bell 206-B helicopter that measured 74.9 dB. Average noise level of the Cessna 206 (76.6 dB) was 6-8 dB greater than the Piper 150 (69.6 dB), the quietest aircraft tested. The Bell 205 produced 30 times the sound energy of the Piper 150.

Noise from aircraft decreased with increasing lateral distance or altitude (Figure 6.2). At greater lateral distances, however, the noise level often increased with increasing altitude rather than following the expected decrease (Table 6.1). This pattern was most evident in aircraft that generated more noise. At 0.9 km lateral distance, L_{max} for the Bell 205 at 152 m and 610 m altitude decreased from 73.6 to 72.0 dB, whereas at 1.9 km, for the same increase in altitude, L_{max} increased from 65.4 to 72.0 dB (Table 6.1).

The distribution of one-third octave frequency bands of noise measured from fixed- and rotary-wing aircraft overflights at 305 m and 0.0 km are shown in Figure 6.3. Helicopters produced greater noise across the lower frequencies (<80 Hz) than the single-engine aircraft. The mid-range frequencies (80 Hz-1.6 kHz) were dominated by the Bell 205 helicopter. No particular aircraft type was characterized by high frequency noise (>1.6 kHz). The Piper 150 produced the least amount of noise at most frequency bands.

Ambient noise ranged from 34 to 59 dB. Wind velocity was the dominant contributor to ambient noise level (Figure 6.3) and had the greatest effect on frequencies below 100 Hz. Noise of surf along the barrier islands could also have considerable influence on ambient noise levels (Johnson et al. 1989). During overflights with wind speeds above approximately 10 m/sec (20 kts), ambient noise masked low frequency noise of most aircraft. With calm winds of <3 m/sec (6 kts), background noise levels were low ranging from 34-40 dB. During these favorable conditions for sound measurements, aircraft at any altitude were detectable up to 2.8 km (1.5 mi). The louder

Figure 6.2. Comparison of maximum noise (Lmax) and sound exposure level (SEL) produced by passby overflights of various aircraft at different altitudes and lateral distances from the microphone at Izembek Lagoon, Alaska. Standard error bars are indicated for replicated passby measurements. Noise measurements are expressed in A-weighting.

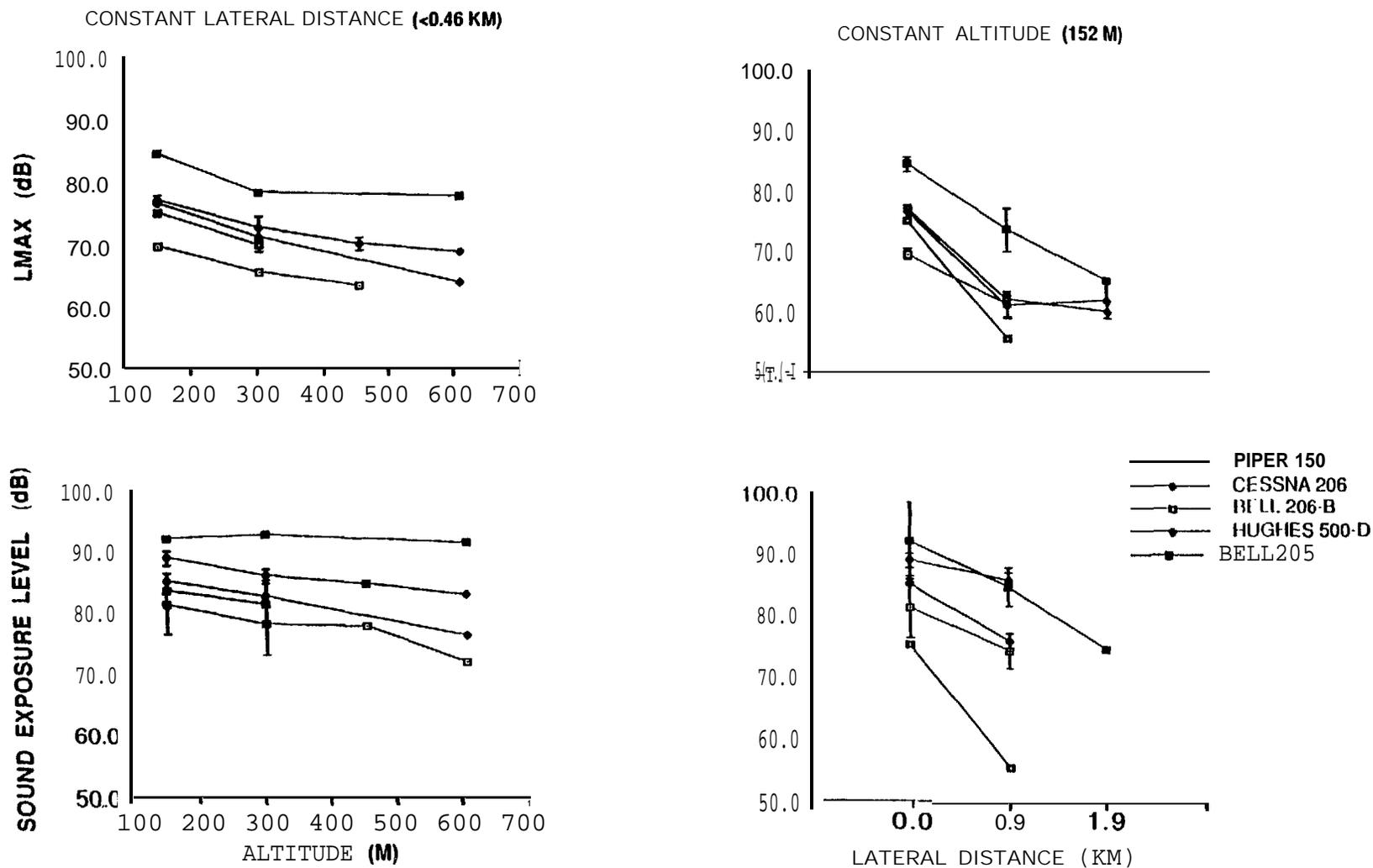


Figure 6.3. Noise frequency distribution (1/3 octave bands) of ambient noise and of various aircraft during passbys at 305 m altitude and 0.0 to 0.3 km lateral distance from the microphone. Height of microphone was 18 and 2 m above the water surface for noise measurements of the Cessna 206, Bell 206-B and 205 helicopters, and Piper-150 and Hughes 500-D helicopter, respectively. Noise measurements are expressed in Flat-weighting.

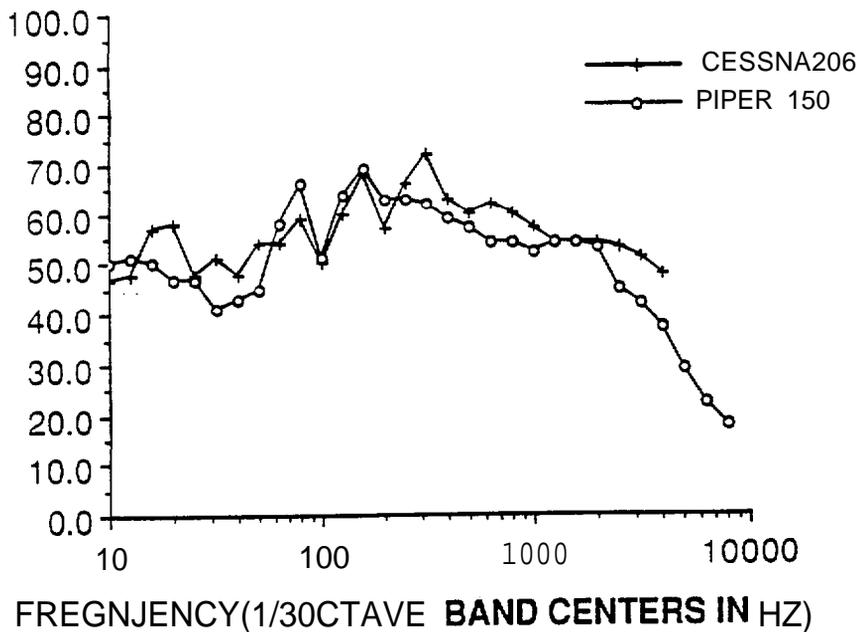
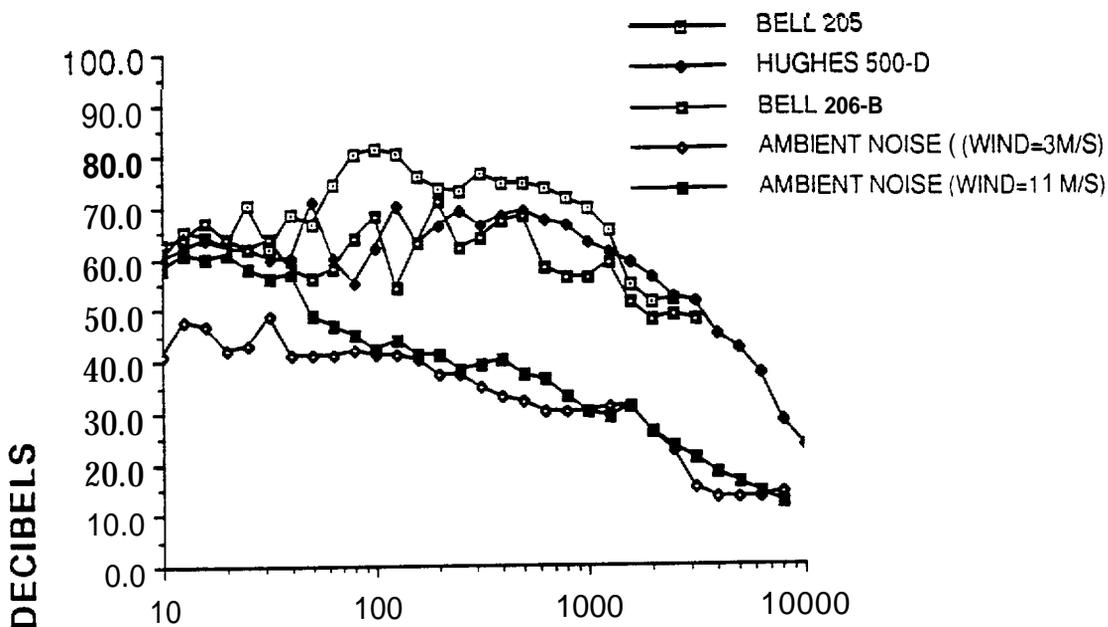


Table 6.1. Mean maximum noise (L_{max}), sound exposure level (SEL), and percent attenuation (Att) from maximum levels of a Cessna 206 airplane and Bell 205 helicopter at Izembek Lagoon, Alaska, during fall of 1987 and 1988. Noise measurements are expressed in A-weighting.

Altitude (m)	Lateral distance (km)	n	Cessna 206				Bell 205				
			L_{max} (dB)	Att (%)	SEL (dB)	Att (%)	n	L_{max} (dB)	Att (%)	SEL (dB)	Att (%)
152	0.0	2	76.6		84.9		3	84.4		95.0	
305	0.0	2	72.1	6	82.7	3	2	78.2	7	92.7	2
610	0.0	2	64.0	16	76.3	10	1	77.9	8	91.3	4
152	0.8	1	61.0	19	75.7	11	4	73.6	13	84.0	12
305	0.8	1	62.3	19	76.1	10	2	70.7	16	82.8	13
610	0.8	1	<47 ^a		<69 ^a		1	72.0	15	80.5	15
152	1.6	1	61.9	19	69.6	4	1	65.4	23	74.6	22
305	1.6	1	<47 ^a		<69 ^a		1	68.8	19	77.9	18
610	1.6	1	<47 ^a		<69 ^a		1	72.0	15	84.4	11

^aMeasurements could not be distinguished from background noise (L_{max} of 47.3 dB and SEL of 69.1 dB).

Bell 205 was measured to 5.6 km (3 mi) away. When flying over water at altitudes >305 m and upwind of the microphone, the Bell 205 aircraft was detected at a distance of 7.4 km (4 mi).

Behavioral response of brant

Average noise levels (L_{max} and SEL) produced by aircraft were correlated with several of the average behavioral responses measured at the same conditions of altitude and lateral distance. L_{max} was positively correlated with percent of response (Spearman's rank correlation, $r_s=0.83$, $P<0.001$, $n=31$), with percent of flight response ($r_s=0.87$, $P<0.001$, $n=31$), and with average total duration of response ($r_s=0.58$, $P<0.001$, $n=31$) (Figure 6.4).. For these responses, SEL showed

very similar correlations (Figure 6.5).

Average duration of flight was not correlated with L_{max} ($r_s = -0.004$, $P < 0.49$, $n = 25$). This indicated that once brant initiated flight, the duration of their response was not influenced by maximum noise level.

Average distance between the aircraft and the flock at the time of first response ($r_s = 0.31$, $P < 0.06$, $n = 28$) and the distance at time of flight response ($r_s = 0.32$, $P < 0.06$, $n = 26$) were also not strongly correlated with L_{max} . Brant did respond at greater distance to the Bell 205, the loudest aircraft, than other aircraft. Nevertheless, comparing response distance within each aircraft type, the average distance of response often increased with greater altitude and lateral distance even though noise level declined (Table 6.2). Before concluding that something other than noise level may therefore be causing flocks to respond, it is particularly important to realize that the average distance at first response is a biased measure: distance at response is missing when the flock does not respond.

As indicated by the behavioral response surfaces (Figures 5.11-5.13; previous chapter) and the average responses shown in Table 6.2, the percent response by brant decreased with greater lateral distance and greater altitude for fixed-wing aircraft. Noise measurements also decreased with greater lateral distance and greater altitude from the aircraft to the microphone.

In the case of helicopters, the behavioral response by brant decreased with greater lateral distance but it stayed the same or increased with greater altitude. Noise levels measured from the Bell 205 or Hughes 500-D followed the same pattern: the noise level actually increased with increasing altitude. For example, at 1.6 km lateral distance, flight response increased from 9 to 75% and noise (L_{max}) changed from 65.4 to 72.0 dB (Table 6.1) as altitude increased from 152 to 610 m. The correlation between the increased behavioral response and noise level in spite of greater actual distance between the flock and aircraft provides some evidence that noise is a causative factor in behavioral response.

If brant respond primarily to an auditory stimulus then a specific threshold noise level may be associated with response. A threshold level was estimated by assuming a linear relationship between noise and response level and extrapolating to find the noise level at 0% response. The threshold for alert response occurred at or above a L_{max} of 49 dB or a SEL of 68 dB. Flight response occurred at a L_{max} of 58 dB or SEL of 74 dB (Figures 6.4, 6.5).

Figure 6.4. Comparison of aircraft noise Lmax measurements to average response by brant to the same aircraft at similar altitude and lateral distance to the flock. Noise measurements are expressed in A-weighting.

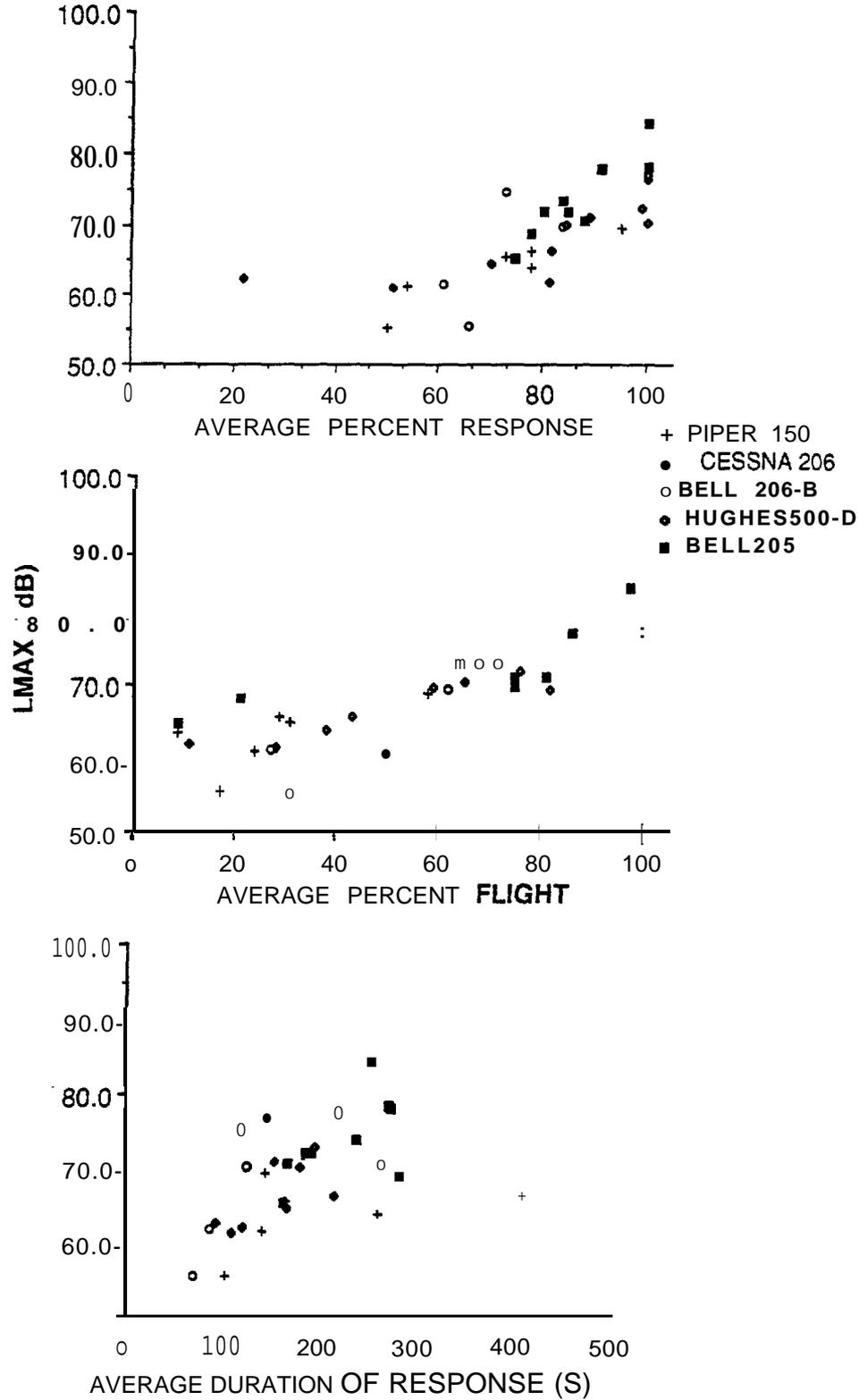


Figure 6.5. Comparison of aircraft noise SEL measurements to various categories of response by brant at similar altitude and lateral distance to the flock. Noise measurements are expressed in A-weighting.

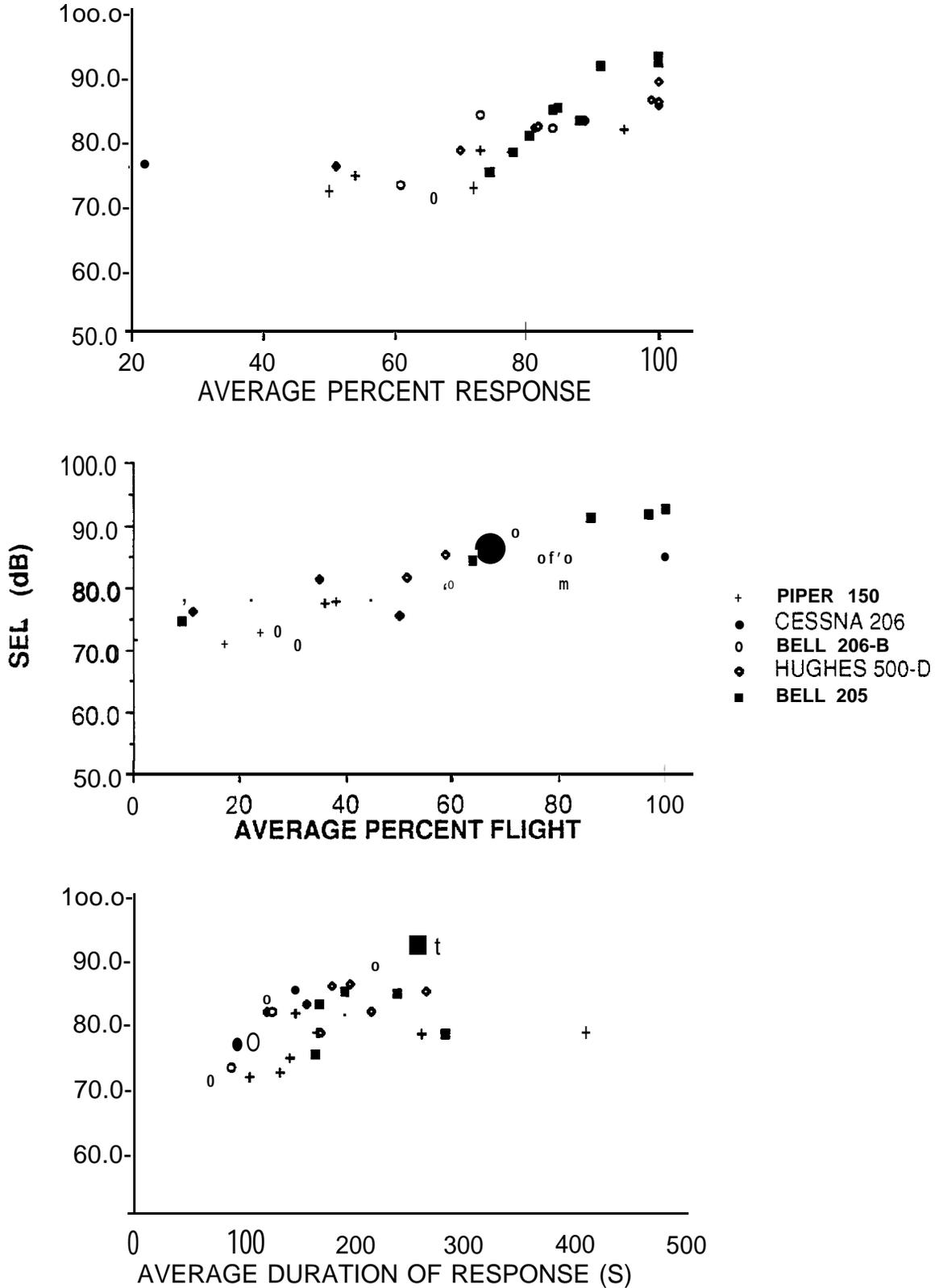


Table 6.2. Comparison of average behavioral disturbance response by flocks of brant to the noise levels produced by various aircraft overflights at certain categories of altitude and lateral distance.

Aircraft type	Lmax dB	SEL dB	n	RESPONSE									FLIGHT									
				X response			duration			distance			% flight			duration			distance			
				avg	SE	n	avg	SE	n	avg	SE	n	avg	SE	n	avg	SE	n	avg	SE	n	
<u>152 m / 0.0 km</u>																						
Piper 150	69.6	81.2	5	95	3	21	145	17	11	0.9	0.2	8	58	10	21	185	2	2	0.4	0.1	3	
Cessna 206	76.6	84.9	2	100	0	18	145	16	16	0.9	0.1	3	100	0	18	81	10	14	0.6	0.0	14	
Bell 206-B	74.9	83.4	1	73	11	16	119	17	6	1.1	0.1	6	68	12	16	71	18	4	0.4	0.1	4	
Hughes 5000	77.1	88.7	5	100	0	8	219	31	8	0.9	0.1	8	72	16	8	171	13	6	0.5	0.0	6	
Bell 205	84.4	91.9	3	100	1	29	252	30	23	2.0	0.2	16	97	3	29	138	10	22	1.4	0.1	24	
<u>152 m / 0.8 km</u>																						
Piper 150	61.3	74.2	4	54	10	71	141	25	9	0.6	0.4	4	24	9	21	186		1	0.6		1	
Cessna 206	61.0	75.7	1	51	15	12	110	37	4	0.9	0.1	3	50	15	12	65	14	2	0.5	0.0	4	
Bell 206-8	55.4	70.5	1	66	13	13	70	15	6	0.9	0.4	5	31	13	13	61	6	2	0.8	0.3	2	
Hughes 5000	70.4	85.4	2	100	0	13	180	12	11	1.0	0.1	13	59	14	13	174	16	8	0.6	0.1	9	
Bell 205	73.6	84.4	4	84	7	26	238	40	14	1.7	0.2	19	64	9	26	92	11	9	1.1	0.2	14	
<u>305 m / 0.0 km</u>																						
Piper 150	65.4	78.0	4	73	8	31	165	26	12	0.5	0.2	11	31	8	31	153	47	4	0.7	0.3	4	
Cessna 206	71.1	82.7	4	89	7	21	155	35	11	0.9	0.2	11	65	10	21	106	20	10	0.6	0.1	14	
Bell 206-B	70.0	81.4	2	84	5	51	124	14	20	1.0	0.4	3	62	7	51	70		1	0.6		1	
Hughes 5000D	72.6	85.9	3	9	9	1	9	196	16	8	1.1	0.3	9	76	14	9	173	9	6	0.8	0.1	5
Bell 205	78.2	92.7	2	100	0	22	272	37	15	2.1	0.3	11	100	2	22	100	20	13	1.3	0.1	18	
<u>305 m / 0.8 km</u>																						
Piper 150	55.3	71.3	1	50	7	43	103	13	13	1.4	0.4	4	17	5	43							
Cessna 206	62.3	76.1	2	22	14	9	93	25	3	1.5	0.3	3	11	11	9	101		1	0.9		1	
Bell 206-B	61.6	72.8	1	61	6	62	88	13	20	1.4	0.2	5	27	6	62							
Hughes 5000D	64.6	78.0	4	70	15	10	168	28	9	0.9	0.3	10	38	16	10	247	60	4	0.5	0.2	4	
Bell 205	70.7	82.8	2	08	4	47	167	15	40	2.0	0.2	26	75	6	47	100	9	29	1.3	0.1	36	

DISCUSSION

Differences in noise were found among aircraft. Each type of aircraft engine generates a characteristic broad-band spectrum of noise. **Piston-** and turbine-powered propeller aircraft produce the greatest noise during take off with noise energy concentrated in the lower frequencies. The turboprop is typically quieter than the piston engine (Manci et al. 1988). Helicopters generate noise from many sources including the main and tail rotors, exhaust, gear train, and compressor (Newman et al. 1984). The whirl sound is produced by the interaction between wind vortices and successive sweeps of the rotor blade.

The Bell 205 helicopter produced the greatest amount of noise. One reason for the large difference in noise levels between the Bell 205 and the other helicopters was a larger noise component of blade-vortex interaction commonly known as "blade slap." Blade slap makes its largest contribution at the higher harmonics of the blade passage frequency (300-600 Hz) (Schmitz and Yu 1986). Although distinguishable in all the helicopters, blade slap was especially noticeable in the Bell 205. At low altitudes the blade slap was focused in front of the helicopter. Sudden fluctuations of sound intensity (noise bursts) were also most apparent for the Bell 205 helicopter. These were likely caused by turns or adjustments in altitude during flight in combination with effects of wind and turbulence.

Under certain conditions the Bell 205 was observed to cause considerable flight response in brant up to 2.5-3.5 km away. Some small (<100 birds) flocks even took flight and landed two or more times during the approach of the Bell 205 helicopter, the only aircraft observed to cause that response.

The Hughes 500-D was quieter than the Bell 205 at similar altitudes and lateral distance. The amount of noise (**SEL**) produced by the Hughes 500-D was 6-7 **dB** greater than reported levels from overflights at similar altitudes (152 and 305 m) and lateral distances (0.0 km) (Newman et al. 1984). The Bell 206-B helicopter and Cessna 206 generated similar levels of noise (**L_{max}** and **SEL**). Noise levels (**SEL**) of the Bell 206-B were within 2 **dB** of levels produced by the slightly larger Bell 206-L Long Ranger at similar altitudes (152 and 305 m) and lateral distances (0.0 km) (**Yoshikami** 1985).

Wind causing upward-refraction conditions for noise transmission (Harrison et al. 1980) probably influenced the perceived reduced attenuation of noise from aircraft at higher altitudes. **Wind** can cause shadow zones that reduce noise

transmission of aircraft at low altitudes. When the altitude of the aircraft increases the shadow zone effect is eliminated and the perceived noise **may** become louder even though the **slant** distance has become greater. Reduced attenuation of noise from the larger aircraft (Bell 205, Hughes 500-D, Cessna 206) at higher altitudes is probably more noticeable due to the greater noise produced by these aircraft. Noise measurements during both windy and overwater conditions possibly enhanced the reduced attenuation of noise at greater altitudes, or the increased attenuation at low altitudes.

It is possible that both visual and auditory stimuli from aircraft influence the behavioral response of brant. A strong positive correlation exists between response and noise level. Nevertheless, the lateral distance and altitude of an aircraft from the flock also correlate with response. The slant distance at the time of response did not correlate well with response or noise level but was instead quite constant (Table 6.2). This suggests that visual detection or some distance threshold could be an important factor. However, bias in the sampling exists and without simultaneous measurement of both noise and behavior (as in 1988), it was not possible to make a conclusion. The increased behavioral response and greater noise measured under the specific situation of reduced noise attenuation provide the **most** direct evidence that noise is indeed involved in the response. The rate of change in noise level should be a consideration for future work.

The greater distance at first response for the Bell 205 helicopter and other aircraft is probably related to the greater noise produced, particularly at lower frequencies. Low frequencies show less atmospheric absorption than higher frequencies and thus they propagate further. Madsen (1985) found that pink-footed geese (*Anser brachyrhynchus*) reacted to helicopters up to 20 km away. **Fjeld** et al. (1987) observed response **in** a thick-billed **murre** colony from a Bell 212 up to 6 km away. Helicopters are potentially more disturbing than fixed-wing aircraft because of the large amount of noise produced at low frequencies. **Fjeld** et al. (1987) found that thick-billed murrelets were disturbed by the auditory stimulus of helicopters but that in some cases the response depended on whether the aircraft was approaching with a direct heading or at a non-threatening flight orientation approximately parallel to the colony.

Although the response of geese or other birds to noise during staging or non-breeding seasons has not been previously studied, the studies of bird response to aircraft noise that have been completed document much higher noise levels at which the birds' respond. Threshold noise levels for nesting birds may be slightly higher than during other times in their annual cycle (Dunnet 1977, Schrieber and Schrieber 1980, Murphy et al.

al. (1984) found that great egrets (Casmerodius albus, snowy egrets (Egretta thula), and cattle egrets (Bulbulcus ibis) initiated alert movements when noise generated from F-16 overflights reached 60-65 dBA and birds began changing their position at 70-75 dBA. Black-crowned night herons (Nycticorax nycticorax) and great egrets were not disturbed by Cessna 172 overflights (altitude 42-244 m) with noise levels of 61 dB to a maximum of 88 dBA (Grubb 1978). Fjeld et al. (1987) suggested that the threshold of response for nesting thick-billed murres occurred at 72 dB.

All these values are much greater than approximate threshold levels of 49 dB for alert and 58 dB for flight response in brant at Izembek. Further analysis of data collected in fall of 1988 may provide a better definition of threshold levels and contribute more precise information on the types of frequencies and levels of noise that cause a response in brant.

CHAPTER 7: ENERGETIC COST OF DISTURBANCE

The objective of this chapter is to evaluate the effects of aircraft disturbance on the **bioenergetics** of fall staging Pacific black brant at **Izembek** Lagoon. Aircraft overflights often cause temporary alert and flight responses in flocks of brant. If sufficiently frequent, such responses will cause alteration of the normal pattern of behavioral activities and average daily time and energy budgets of brant would be altered. This chapter determines the likely magnitude of such changes and the extent to which disturbance can be tolerated at **Izembek** without preventing brant from adequate preparation for the energetic demands of migration. Because direct experiments were not feasible, a model was used to predict the energetic cost of differing frequencies of disturbance.

The simulation model serves to better organize and understand components that contribute to energetic balance and allows a means for assessing the impact of disturbance on brant. The accuracy of the model is highly dependent on the data entered. This model is limited by lack of information on several aspects of energetic intake and expenditure. The amount of forage intake is assumed to be constant and independent of the weight of the bird. This assumption causes heavier adult brant to be more influenced by disturbance than lighter birds, a result which is probably not realistic. The lower critical temperature and energetic cost of thermoregulation for brant is unknown. The influence of wind and role of water temperature on heat loss in birds has received little study. These factors could be of major importance at **Izembek**. Also, the energetic cost of thermoregulation during body feather molt which occurs at **Izembek** has not been studied. Still, despite these limitations, the model is a best estimate of effects of disturbance on brant given the available data.

Izembek Lagoon provides the most important food resources for brant to gain nutrient reserves prior to their transoceanic flight to wintering areas. Brant typically leave **Izembek** on weather systems that provide the advantage of a tail wind (C.P. Dau, **USFWS, unpubl. data**) and flocks fly nonstop, 5,000 km, from **Izembek** to wintering areas beginning at San Quintin, Mexico (**Voelzer** 1987). Landfalls can occur in coastal areas of southern British Columbia, Washington, Oregon, and California, but the majority of the population is believed to fly directly to Mexico. The duration of flight to San Quintin is about 60 hr (Kramer et al. 1979) at a flight speed of 83 km/hr under favorable conditions. Similarly, **Ebbinge** (1989) estimated a

4,000-4,500 km migration by European dark-bellied brant took 50 hr with an assumed flight speed of 90 **km/hr.**

METHODS

Model structure

A **bioenergetic** model (Figure 7.1), based on one proposed by **McKnight** and Taylor (1989) using program STELLA on a Macintosh SE 20 computer, allows energy intake and expenditures to be traced graphically through a network of paths. The model simulates energy flow from food resources ingested by a bird through allocation of that energy to individual expenditures by the bird. When the sum of energy expenditures exceeds energy gains, the bird's ability to gain weight for migration is reduced.

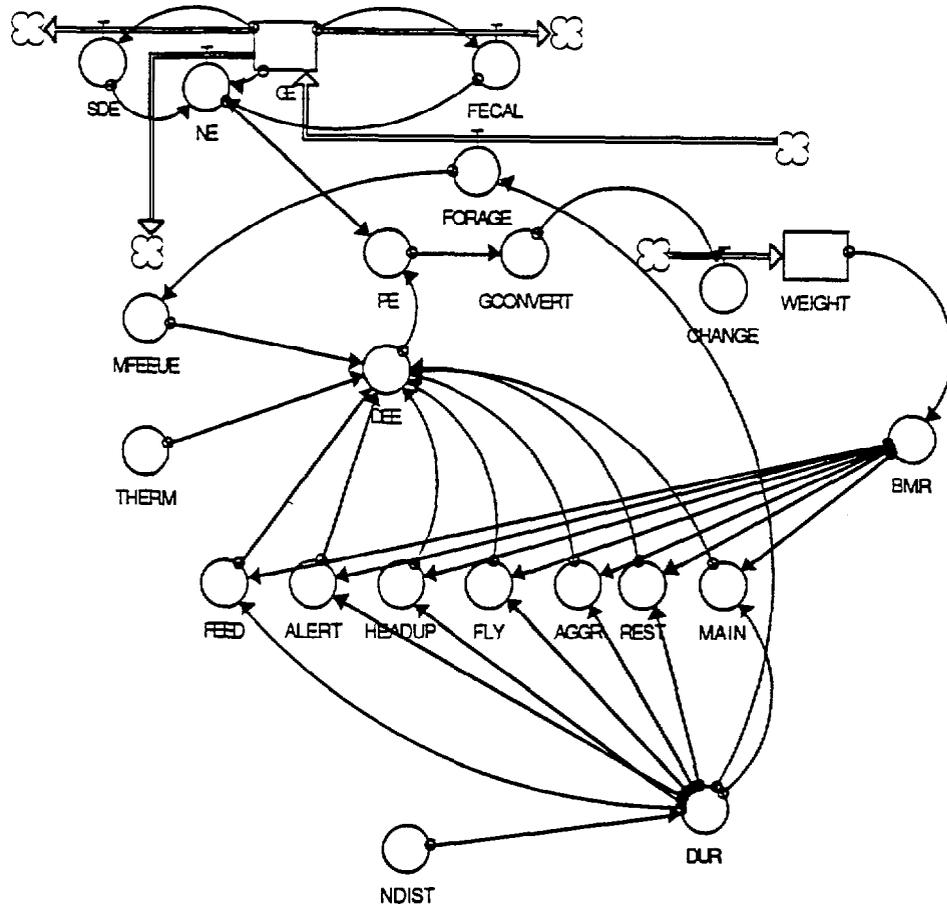
The model is structured as a series of equations and operates on a **daily** time step. It contains three **submodels**: one dealing with foraging and energy intake, another for adding the daily energy costs, and a final **submodel** for determining conversion of the energy gained or lost per day into kg of body weight. A brief presentation of values, equations, and conversions derived from published literature is included. The series of equations of energy relationships incorporated into the STELLA program were also written in TrueBasic to accommodate modifications, provide compact output tables, and include a standard (10% increase) sensitivity analysis on each parameter.

Model formulation

Body weight and body composition

Data on body weight and body composition of brant were collected at **Izembek** Lagoon and San Quintin over the last 10 years (**D.V.** Derksen and L. Fredrickson, **unpubl.** data) . A total of 274 brant were collected for body weight from September to November at **Izembek**, and 388 were weighed during November at San Quintin. Analysis of body composition was made on 28 brant shot at **Izembek** and 33 collected from San Quintin. By comparing body weights and lipid reserves of brant collected on various dates, an average pattern of physiological condition could be determined.

Figure 7.1. Diagram produced by the STELLA program showing the bioenergetic model for brant staging at Izembek Lagoon, Alaska, and the list of equations that are components of the model from Mcknight and Taylor (1989).



- $GE = GE + dt * (-FECAL - SDE + FORAGE - NE)$
INIT(GE) = FORAGE
- $WEIGHT = WEIGHT + dt * (CHANGE)$
INIT(WEIGHT) = -1.633
- $AGGR = (0.005 + 0.01 * DUR) * 2.2 * BMR$
- $ALERT = (.021 + (0.36 * DUR)) * 2.2 * BMR$
- $BMR = 307 * WEIGHT^{0.734/4} * .184$
- $CHANGE = GCONVERT$
- $DEE = THERM + REST + FEED + MAIN + ALERT + HEADUP + FLY + AGGR + MFEED$
- $OUR = NDIST * 189 / (60 * 60 * 24)$
- $FECAL = GE * 0.63$
- $FEED = (.254 - DUR) * 1.7 * BMR$
- $FLY = (0.013 + 0.53 * OUR) * 11.0 * BMR$
- $FORAGE = .270 * 3.9 * (1 - DUR)$
- $GCONVERT = PE * 0.0000769$
- $HEADUP = (0.212 - DUR) * 2.0 * BMR$
- $MAIN = (0.228 + 0.10 * OUR) * 1.6 * BMR$
- $MFEED = .03 * FORAGE * 0.37$
- $NDIST = 0$
- $NE = GE - FECAL - SDE$
- $PE = NE - DEE$
- $REST = -(0.270 - DUR) * 1.0 * BMR$
- $SDE = GE * ((.009 * 0.13) + (.125 * .31) + (.152 * .23))$
- $THERM = 34$

Foraging and energy intake

Gross energy (GE) was estimated by multiplying daily total intake (g dry **wt/day**) by the caloric content of the food (**kcal/g**). Estimates of gross energy intake for geese vary widely among species and seasons. Highest ingestion rates have been found during spring and fall migration periods. During spring migration of dark-bellied brant in Europe, Drent et al. (1981) determined that forage intake was 270 g dry wt of **eelgrass/day**. On the wintering grounds in Europe, dark-bellied brant consumed between 100-122 g dry wt of eelgrass per day. Kiera (1984) found that molting brant on the North Slope of Alaska consumed 305 g dry **wt/day** of sedges and grasses. Because the estimate by Drent et al. (1981) involves intake at a staging area during migration this estimate was used for the **Izembek** model. **Ebbinge** et al. (1975) estimated that wintering barnacle geese consumed 135-158 g dry wt/day. In the same study, comparison of grazed with ungrazed vegetation within an **exclosure** resulted in an estimated maximum food intake of 255-340 g dry **wt/day**.

The diet of brant at **Izembek** Lagoon was entirely eelgrass during the fall staging period (see "**Diet** and Nutrition" section). Caloric content of eelgrass taken from **Izembek** Lagoon during October was 3.9 **kcal/g** (Morehouse 1974). Thus gross energy (GE) was determined as follows:

$$\begin{aligned} \text{GE} &= \text{gross energy} \\ &= \text{intake rate} * \text{caloric value of food} \\ &= 270 \text{ g dry } \mathbf{wt/day} * 3.9 \text{ kcal/g} \\ &= 1053 \text{ kcal/day.} \end{aligned}$$

For comparison, molting brant had a gross energy intake of 1100 **kcal/day** while consuming salt marsh plants along the arctic coastline (**Kiera** 1984).

Metabolizable energy (ME) represents the gross energy consumed minus the total amount of energy lost in fecal and urinary excretion, assuming a nitrogen balance. The efficiency of assimilation varies among bird species, primarily in response to food quality (**Ricklefs** 1974). **Morehouse** (1974) found that captive brant fed pelleted eelgrass collected in fall at **Izembek** Lagoon retained 37% of the organic matter.

$$\begin{aligned} \text{ME} &= \text{GE} * \text{assimilation rate} \\ &= 1053 * 0.37 \\ &= 389.6 \text{ kcal/day.} \end{aligned}$$

This is very similar to the estimate of 44% determined by Drent et al. (1981) for European brant feeding on **eelgrass** in spring. **Ebbinge** et al. (1975) estimated captive barnacle geese metabolized 33.2% while other birds metabolized 21.7%.

Specific dynamic energy (SDE) is the heat produced during digestion and absorption of nutrients from foods. SDE is not dependent on the species or the weight of the animal, but rather on the amount of food ingested and the fat, protein, and carbohydrate content of the ingested foods. SDE is energy in food that is lost or unavailable for most uses, although it is valuable in providing a large share of the heat needed to maintain body temperature. McKnight and Taylor (1989) estimated SDE from a formula used by Brackney et al. (1986), Ricklefs (1974), and Owen and Reinecke (1979).

$$\text{SDE} = \text{GE} * [(\% \text{ fat}/100) * 0.13 \\ + (\% \text{ protein}/100) * 0.31 \\ + (\% \text{ TNC}/100) * 0.23],$$

where TNC is total nonstructural carbohydrates.

Analyses of eelgrass from Izembek Lagoon indicated 0.9% fat, 12.5% protein, and 15.2% TNC (see "Diet and Nutrition" chapter). Thus,

$$\text{SDE} = 1053 * [(0.009*0.13)+(0.125*0.31) + (0.152*0.23)] \\ = 78.8 \text{ kcal/day.}$$

Whittow (1986) reported that SDE is approximately 16% of metabolizable energy. McKnight and Taylor (1989) determined SDE was 22% and Brackney et al. (1986) found that SDE equaled 18% of ME. In this model, SDE is 20.2% of ME.

Net energy (NE) is the balance of energy available to the bird. NE determines the energy available for flight and all other behavioral activities. If additional energy is required to maintain body temperature above the heat produced by SDE and muscular activity, it is taken from NE. NE also accounts for productive energy involved in the deposition of fat or growth of feathers (Whittow 1986).

$$\text{NE} = \text{ME} - \text{SDE} \\ = 389.6 \text{ kcal/day} - 78.8 \text{ kcal/day} \\ = 310.8 \text{ kcal/day.}$$

Energy expenditure. Daily energy expenditure has three components. These are the cost of behavioral activities (BE), metabolic fecal and endogenous urinary energy (MFEUE) cost, and cost of thermoregulation (TR) (King 1974, Owen and Reinecke 1979, Drent et al. 1981, Brackney et al. 1986, Gauthier et al. 1984).

No value for basal metabolic rate was found in the literature for brant therefore we used the equation of Aschoff and Pohl (1970) for BMR of non-passerines at night:

$$\text{BMR} = (307 * m^{0.734}) / 4.184$$

where, m is body weight in kg, and
BMR is expressed in **kcal/day**.

Using the average arrival (Sept 13) body weight of an adult male brant at **Izembek** Lagoon of 1.633 kg (Table 7.3) (**D.V. Derksen** and L. Fredrickson, **unpubl.** data), basal metabolic rate is

$$\begin{aligned} \text{BMR} &= (307 * 1.633^{0.734}) / 4.184 \\ &= 105.2 \text{ kcal/day.} \end{aligned}$$

Daily energy costs of behavioral activity are constructed as multiples of basal metabolic rate (**Wooley** and Owen 1978, Morton et al. 1989) and the proportion of the 24-hr day spent in each activity (Table 7.1). Because the estimates reported by **Wooley** and Owen included SDE (**Gauthier** et al. 1984), we subtracted 0.1 times BMR from each cost (see Brackney et al. 1986). **Wooley** and Owen (1978) estimated the cost of several behavioral activities in free-ranging black ducks by measuring heart rate with telemetry. We applied their estimates for alert at 2.2 times BMR, rest at 1.0 times BMR, feed at 1.7 times BMR, and **agonistic** at 2.2 times BMR. The brant behavior classified as head up (pause) foraging, which occurs alternately with head down active feeding, mostly involved searching and slow swimming. Its cost is estimated as 2.0 **times** BMR, which is slightly below **Wooley** and Owen's estimate of 2.2 times BMR for swimming behavior. Maintenance behavior of brant includes preening, stretching, and bathing. Because time spent preening is greatest, **Wooley** and **Owen's** estimate of preening at 1.6 times BMR for maintenance was used.

Many models have been proposed to estimate the cost of flight, which is by far the most energetically expensive behavioral activity. **Allometric** relationships predict the cost of flight as a function of body weight (Raveling and **Lefebvre** 1967, Hart and Berger 1972, **Kendeigh** et al. 1977) or body weight and wing length (Castro and Myers 1988). Most of the data on cost of flight has been collected on small passerine. With the equations of Castro and Myers (1988), flight **cost** for brant was unrealistically high at 16 to 32 times BMR. The cost of flight in the largest bird studied to date, the white-necked raven (**Corvus cryptoleucus**), was estimated at 11.0 times BMR (Hudson and Bernstein 1983). This value was used for brant. The conversion factors used for flight costs in other studies were 11.8 by Raveling and **Lefebvre** (1967), 11.9 by **Kendeigh** et al. (1977), and 14.8 by Hart and Berger (1972).

Table 7.1. Behavioral energetic costs and percent of time budget spent by brant in daily activities at **Izembek** Lagoon, Alaska.

Activity	Metabolic cost multiple of BMR ^a	Time activity as % of 24 h	cost kcal/day
Feed	1.7	25.4	45.4
Headup	2.0	21.2	44.6
Maintenance	1.6	22.8	38.4
Rest	1.0	27.0	28.4
Alert	2.2	2.1	4.9
Agonistic	2.2	0.5	1.2
Flight	11.0	1.3	15.0
		Total =	177.9

^a Basal metabolic rate (BMR) = 105.2 kcal/day where the weight of an after second year male is 1.633 kg.

Each behavioral activity is weighted by the proportion of the 24-hr time budget and the above multiples of BMR for the energetic cost, and summed to estimate the total energetic cost of behavioral activity.

$$\begin{aligned}
 \text{BE} &= \text{sum of proportions of 24 hr} * \text{energy cost} * \text{BMR} \\
 &= (\text{feed} + \text{headup} + \text{maintenance} + \text{rest} + \text{alert} + \\
 &\quad \text{agonistic} + \text{flight}) * \text{BMR} \\
 &= (0.254 * 1.7 + 0.212 * 2.0 + 0.228 * 1.6 + \\
 &\quad 0.270 * 1.0 + 0.021 * 2.2 + 0.005 * 2.2 + \\
 &\quad 0.013 * 11.0) * \text{BMR} \\
 &= 1.69 * 105.2 \\
 &= 178 \text{ kcal/day.}
 \end{aligned}$$

Metabolic fecal and endogenous urinary energy costs (MFEUE) have not been measured for brant and were estimated at 3% of ME (389.6 kcal) or 11.69 kcal as suggested by Miller and Reinecke (1984) and McKnight and Taylor (1989).

Thermoregulation (TR) is the most difficult parameter of energy expenditure to **quantify** (Owen and Reinecke 1979,

Brackney et al. 1986), and yet, it may play an important role in the energy budget, especially for small birds (**Kendeigh 1970, King 1974:22, Ricklefs 1974:169**). Additional energetic expenditure for generation of body heat is necessary only when heat lost to the environment exceeds the heat produced by SDE and muscular activity. Under standard laboratory still-air conditions, the ambient temperature below which additional energy is used for heat production to maintain body temperature is termed the lower critical temperature. Heat loss is determined by air and water temperatures, humidity, and wind conditions as well as insulation by feathers and body surface area. Ideally the calculations would include seasonal changes in thermal conductance due to fat deposition, variations in body size, and differences in conductance with stage of molt (Owen and Reinecke 1979).

For brant, Irving et al. (1955) reported a lower critical temperature (T_c) of 6° C during summer and winter. During summer, emperor geese have a lower critical temperature of -2° C (West and Norton 1975). Owen and Reinecke (1977) estimated that for a 1.5 kg duck acclimatized to 10° C, T_c would be close to 0° C. Only in November, after most brant have migrated, do mean minimum air temperatures fall as low as 2° C (Appendix A) ; however, if brant have a lower critical temperature at 6° C, then brant would expend energy for thermoregulation for most of their stay at **Izembek**. The cost of thermoregulation was set at 1.4 kcal/h (33.6 kcal/day) as determined for black ducks (**Albright et al. in Morton et al. 1989**). This estimate may be an over estimate of thermoregulatory cost because brant are about 500 g larger than black ducks (**Bellrose 1976**) ; however, weather conditions at **Izembek** are ideal for heat loss. Brant spend most of their time in the water at temperatures of 4-6° C (**D.H. Ward, USFWS, unpubl. data**) and with wind speeds averaging >15 kph (Appendix A). Adverse environmental factors require increased thermoregulation (Williams and Kendeigh 1982).

The total daily energy expenditure (DEE) is:

$$\begin{aligned} \text{DEE} &= \text{BE} + \text{MFEUE} + \text{TR} \\ &= 177.9 + 11.7 + 33.6 \\ &= 223.2 \text{ kcal/day} \end{aligned}$$

Drent et al. (1981) estimated DEE for a 1.350 kg brant at 201 kcal/day or 2.2 times BMR. Our estimate of 223.2 kcal/day at 2.1 times BMR is remarkably similar. Gauthier et al. (1984) reported DEE for fall staging greater snow geese was 2.3 times BMR to 2.5 times BMR.

Productive energy. Productive energy (**PE**) is the amount of energy available when intake (NE) exceeds required expenditure (DEE) . This energy is available for other processes such as

accumulation of fat, growth of feathers, and growth or replacement of other tissues. Productive energy is estimated by:

$$\begin{aligned} \text{PE} &= \text{NE} - \text{DEE} \\ &= 310.8 - 223.2 \\ &= 87.6 \text{ kcal} \end{aligned}$$

From examination of whole body composition of brant at **Izembek** Lagoon, their per cent total lipids increased between early and late sampling periods, while percent protein and percent water decreased (Table 7.2). This indicates that all productive energies were put into storage of lipids, and in addition, some weight of muscle and water content was also replaced by lipids. Brackney et al. (1986) also observed no evidence of growth (increased muscle as indicated by increased percent protein) in juvenile snow geese staging in fall on the North Slope of Alaska. The conversion of productive energy into grams of fat deposition [termed **GCONVERT** in the model (Figure 7.1)] involves 13 kcal per 1 g fat. This was derived by Drent et al. (1981) for fat accumulation in brant at **Terschelling**, The Netherlands, using a 75% efficiency of fat deposition having a stored energy of 9.5 kcal/g (**Ricklefs** 1974) .

Table 7.2. Percent body composition of brant at arrival (n=21) and departure (n=7) from **Izembek** Lagoon, Alaska, in fall and arrival (n=33) at San Quintin, Mexico (**D.V. Derksen** and L. Fredrickson, unpubl. data) .

Body composition	<u>Izembek Lagoon</u>		<u>San Quintin</u>
	arrival	departure	arrival
fat	13.8	40.6	16.5
protein	20.4	14.1	20.5
water	61.7	41.2	58.4

Disturbance. Behavioral response to aircraft was added to the model in units of 189 sec based on the average duration response to the approach of a Bell 205 helicopter at 305 m altitude and 0.0 km lateral distance (see previous chapter) . Behaviors observed during disturbance included cessation of feeding, alert stance, flight, and displacement activities. Landing after a circling flight, brant readjusted their

positions and engaged in displacement activities before returning to normal foraging. The distribution of behaviors during an average disturbance response was partitioned as 0.00 feeding, 0.00 headup, 0.10 maintenance, 0.00 rest, 0.36 alert, 0.01 **agonistic**, and 0.53 flight.

The normal behavioral time budget was modified by increments of 189 sec for each disturbance event in 24 hr (0.00219). For example, flight behavior normally occurred 0.013 proportion of the day, but with 10 disturbance overflights it was estimated to be 0.024 of the day $[0.013 * (1 - (10 * 0.00219)) + 0.53 * 10 * 0.00219]$. Time budgets were further modified for each disturbance event by replacing a proportion of time spent in feeding and similarly reducing intake energy available. This assumed that no compensatory feeding occurred. It may be possible for brant to make up the foraging time lost during disturbance by reducing time spent in other behaviors. However, as explained in discussion of the "**Behavior**" chapter, assuming an increase in proportion of feeding time from 0.254 to as high as 0.508 was not realistic. The actual amount of or limits to compensatory feeding either by increased time or rate of intake are unknown.

RESULTS

Body weight and lipid reserves

Body weight was related to date using linear regression (Figure 7.2). Each sex and age group was analyzed separately to obtain average weight gain per day (Table 7.3). Average weights graphed for each 10-day period indicated that linear increase throughout the staging period at **Izembek** is reasonable (Figure 7.2). The regression equation was solved to obtain average body weight on 13 September and on 5 November (Table 7.3), the midpoint of average dates of arrival to and departure from **Izembek** Lagoon for brant radio-tagged on the Yukon Delta in 1987 and 1988. These data establish expected average arrival and departure weights. Relatively constant and much reduced body weights are found throughout November for brant collected at San Quintin, Mexico (Figure 7.2). Body weights are quite variable in all groups with standard deviations of about 200 g (Tables 7.3, 7.4) and extremes that range from 1,000 to 2,200 g (Table 7.4).

The average **lipid** content of brant collected both early and late at **Izembek** and San Quintin, when considered with body weight data, allows change in total body weight and change in grams of lipids to be calculated. Adult male brant gain 309 g in body weight at an average rate of 5.7 g per day during their 54-day stay at **Izembek** (Table 7.3). They gain 563 g in lipids

Figure 7.2. Average body weights of brant collected at Izembek Lagoon, Alaska, and San Quintin, Mexico, calculated for each 10-day period beginning on Julian date 240 (= August 28) to Julian date 340 (= December 6). The dashed line shows the linear regression of weight gain for each age and sex group of brant collected at Izembek. Standard deviation bars are calculated for each 10-day period.

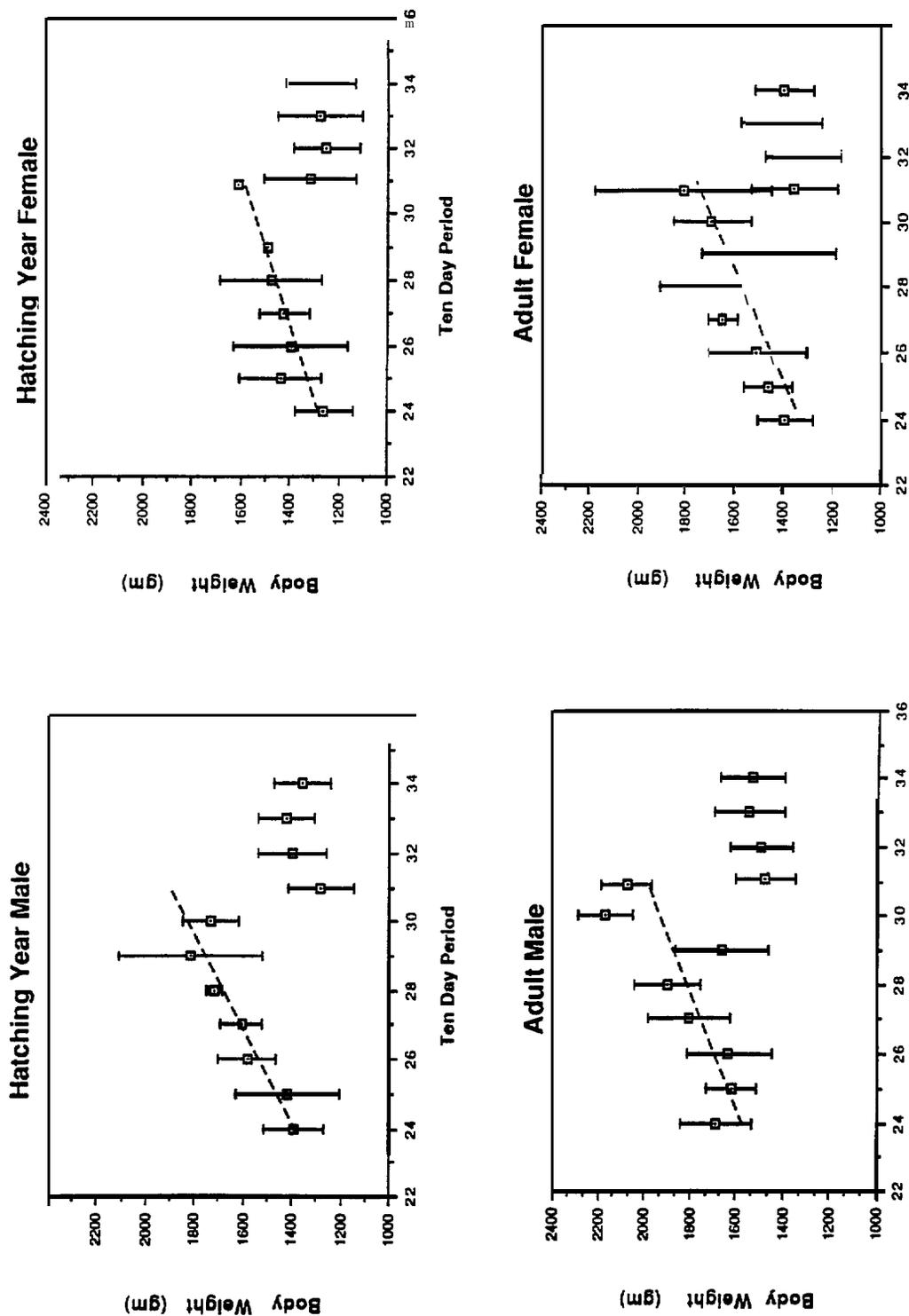


Table 7.3. **Body weight (g) gain for adult (AD) and hatching year (HY) brant** during an average 54 day fall staging period at **Izembek Lagoon, Alaska**, and body weight loss following migration to **San Quintin, Mexico**. Data from **D.V. Derksen and L. Fredrickson (unpubl. data)** .

Age/sex	Izembek Lagoon					San Quintin				
	wt 13 Sep	wt 5 Nov	g per day	SE slope	n	wt gain	wt loss	avg wt Nov	SD	n
AD male	1633	1942	5.73	1.15	85	309	445	1497	135	114
AD female	1462	1754	5.42	1.11	81	292	403	1351	173	107
HY male	1476	1860	7.11	1.19	54	384	495	1365	144	88
HY female	1346	1593	4.57	1.67	47	247	325	1268	165	79

Table 7.4. Minimum, maximum, and average body weights (g) of adult (AD) and hatching year (HY) brant at **Izembek Lagoon, Alaska**, during **September to November** and at **San Quintin, Mexico**, during November.

Age/sex	Izembek Lagoon					San Quintin				
	min	max	avg	SD	n	min	max	avg	SD	n
AD male	1125	2275	1727	222	87	1050	1775	1497	135	114
AD female	1080	2070	1537	203	84	900	1725	1351	173	107
HY male	1070	2130	1558	207	56	1000	1600	1365	144	88
HY female	(760) 1025	^a 1786	1411	191	47	(725) 900	^a 1600	1268	165	79

^aDesignates a single **extreme** value with the **next smallest** recorded helm.

during this time (Table 7.5) . The average amount of lipid lost between departure from **Izembek** and arrival at San Quintin is 541 g which compares quite well with the expected cost of 494 g of lipids for a 5,000 km **flight** at 83 **km/hr** for a 1,633 g bird (Table 7.5) . Expected cost of migratory flight is calculated as cost (g fat)= (1 g fat/ 9.0 **kcal**) times (distance/flight speed) times [(341.4 times body weight ^{.73}) / 1000] times 0.86 (**Calder 1974 in Vangilder et. al. 1986**) .

Disturbance effects

The energetic model predicted an adult male brant weighing 1,633 g on 13 September will gain 310 g before departure on 5 November (Table 7.6). If 10 disturbance responses occurred daily for the 54-day period of stay, the adult male brant will depart at 1,869 g or 0.962 of its expected departure weight of 1,943 g (24% less than the expected weight gain). Each additional daily disturbance during daylight would decrease total body weight at departure by 7.4 g (Table 7.6). The decrease in weight was nearly linear with increasing disturbance frequency (Figure 7.3). The loss of 7.4 g of lipids is equivalent to 53 minutes or 73 km of migratory flight. Any number over 11 daily disturbance flights would cause average weight gain in adults to fall below 5 g/day (Table 7.6). This arbitrary value of 5 g/day is a convenient point for the comparison of model responses. It is equal to a total weight gain of 270 g in 54 days which is 40 g below average weight gain shown by adult males.

Behavioral time budgets and periods of disturbance were split into daylight and dark periods. If all disturbances occurred during the darkness, weight loss was 24% less compared with only daylight disturbance, while loss was 16% less if disturbances occurred both during day and night (Figure 7.3). Adult brant with greater initial body weight showed 11% greater impact from disturbance (Figure 7.3) compared with hatching year brant.

Sensitivity analysis

Sensitivity analysis assessed the magnitude of a 10% increase in each of the 44 parameters (taken one at a time) used in the model. Parameter values are listed in Table 7.6 along with their relative influence on four of the output measures of the model. Some (17 of 44) parameters that always resulted in minor changes are omitted.

The total body weight gained by brant at **Izembek** with no added disturbance was highly sensitive to assimilation rate, total forage intake, and caloric value of eelgrass. A 10% increase in assimilation efficiency from 0.37 to 0.407 caused a 43.5% increase in total weight gain. It also predicted a 2.5 fold increase in the number of daily disturbance overflights before brant will fail to gain at least 5 g/day (Table 7.6). Increasing by 10% the total forage intake or the caloric value of eelgrass similarly caused large changes in weight gain and flights tolerated (Table 7.6).

Table 7.5. Comparison of average body weights and lipid weights for brant at Izembek Lagoon, Alaska, and San Quintin, Mexico, with the calculated energetic cost of migration.

	<u>Izembek Lagoon</u>			Expected migration cost ^a to: SQ (PS)	San Quintin November	Difference ^b	Net ^c
	arrive	depart	gain				
% lipid=	13.8%	40.6%			16.5%		
<u>Adult Male:</u>							
body wgt (g)	1633	1942	309		1497		
lipid wgt (g)	225	788	563	494 (287)	247	541	-47
<u>Adult Female:</u>							
body wgt (g)	1462	1754	292		1351		
lipid wgt (g)	202	712	510	458 (266)	223	489	-31
<u>Hatching Year Male:</u>							
body wgt (g)	1476	1860	384		1365		
lipid wgt (g)	204	755	551	478 (278)	225	530	-52
<u>Hatching Year Female:</u>							
body wgt (g)	1346	1593	247		1268		
lipid wgt (g)	186	647	461	428 (248)	209	438	-10

^a Calculated as $\text{cost} = [(d/v)c] / k$
(from Calder 1974 in Vangilder et al. 1986)

where $k = 9.0$ kcal from burning 1 g of fat (Ricklefs 1974),
 $d =$ distance San Quintin(SQ)= 5,000 km, Puget Sound (PS)= 2900 km
 $v =$ velocity= 83 km/h
 $c =$ cost of migration, kcal/h= $[(341.4 * M^{0.73})/1,000] * (0.86)$
 $M =$ body wt ingrains.

^b Difference in lipids between departure from Izembek and arrival at San Quintin.

^c Net balance of expected cost minus observed lipid cost.

Figure 7.3. Predicted change of body weight at departure on November 5 from Izembek Lagoon for adult and hatching (HY) year brant responding to increasing frequency of helicopter flights from 0 to 70 every day. The influence of the timing of disturbance during the day or night or both is included.

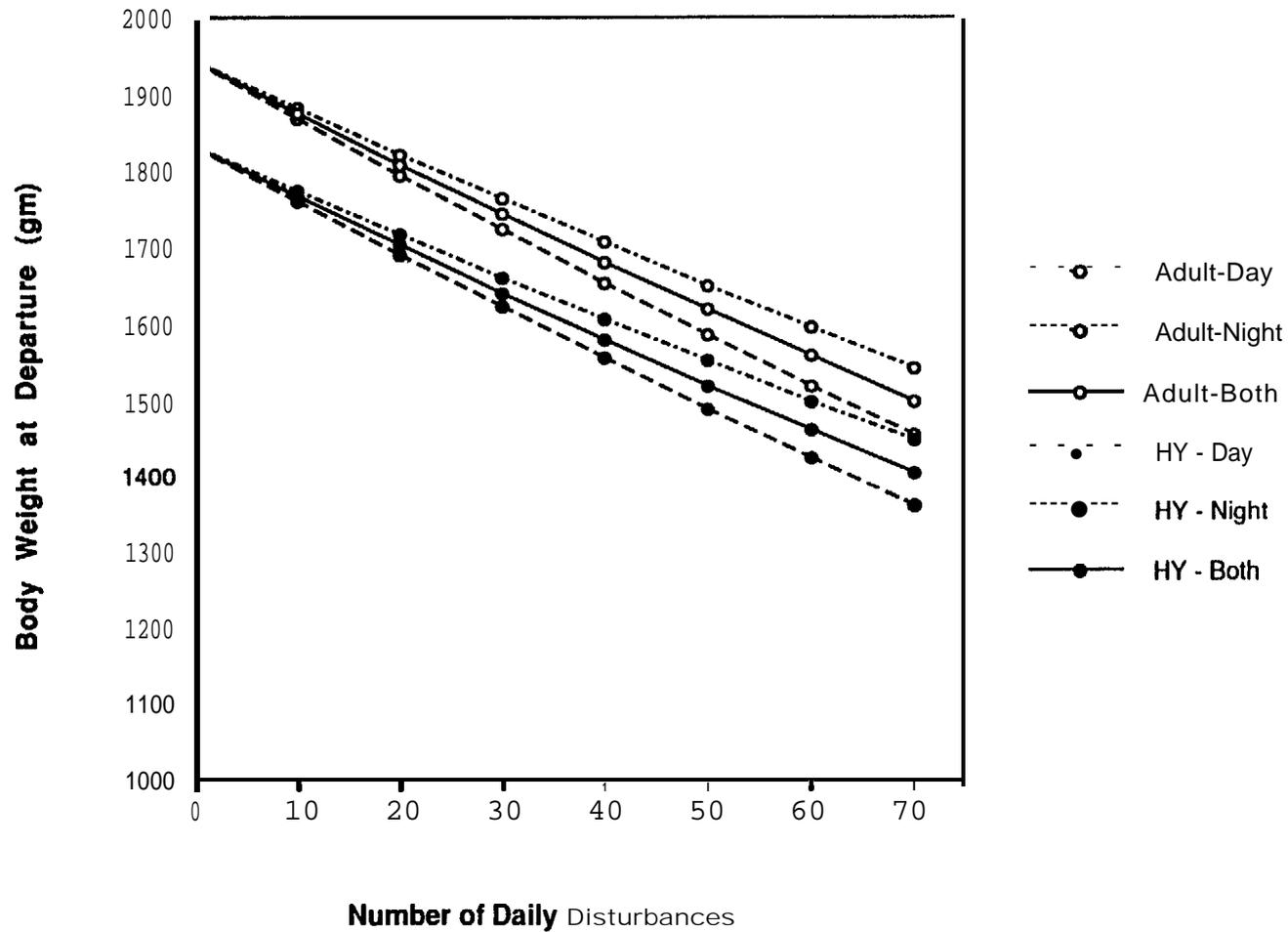


Table 7.6. Sensitivity of the energetic model relating to aircraft overflight disturbance to a 10% increase in the values of each parameter in the model changed one at a time. Sensitivity is expressed as the ratio of each new output value to the original predicted output value.

	Total wgt gain 54 days	Prop. of depart wgt. w/ 10 flights	Weight lost per # flights daily for gain of flight <5 g/day	
output value	310 g	0.962	-7.4 g	11
value >1.000 shins disturb. ef facts are:	less	less	greater	less
parameter and value increased by 10% :				
initial body weight =1633	0.855	1.062	1.036	0.401
% assimilation of forage =0.37	1.435	1.069	1.072	2.565
max forage intake =270	1.344	1.055	1.057	2.252
kcal per dry g of forage =3.9	1.344	1.055	1.057	2.252
EMR constant =307	0.783	0.963	1.032	0.185
EMR exponent =0.734	0.905	0.984	0.998	0.691
thermoregulation kcal/day=33.6	0.961	0.994	0.998	0.848
excretory cost kcal/day =11.7	0.987	0.998	0.998	0.949
cost of storing 1 g fat =13.0	0.922	0.990	0.919	0.707
duration of disturbance =189	1.000	0.996	1.099	0.909
prop. flight in disturb. =0.53	1.000	0.998	1.061	0.943
prop. alert in disturb. =0.36	1.000	1.001	0.984	1.016
prop. mint. in disturb. =0.10	1.000	1.000	0.994	1.006
cost of feeding behav =1.7	0.944	0.991	0.987	0.800
cost of headup behav =2.0	0.945	0.991	0.988	0.803
cost of maintenance behav =1.6	0.953	0.992	0.993	0.829
cost of rest behav =1.0	0.965	0.994	0.994	0.874
cost of alert behav =2.2	0.994	0.999	1.008	0.970
cost of agonistic behav =2.2	0.999	1.000	1.000	0.995
cost of flight behav =11.0	0.981	0.994	1.063	0.874
prop.day feeding behav =0.339	0.990	0.998	1.010	0.951
prop.day headup behav =0.247	0.989	0.998	0.993	0.965
prop. day maintenance =0.178	0.999	1.000	0.997	0.999
prop. day rest behav =0.195	1.008	1.001	0.999	1.030
prop. day alert behav =0.020	0.999	1.000	1.000	0.998
prop.day agonistic behav =0.005	1.000	1.000	1.000	1.000
prop.day flight behav =0.018	0.989	0.998	0.997	0.962

Change of intake energy had little influence on weight loss per aircraft disturbance. This is because intake increased for both disturbance and non-disturbance situations and this output value measured only the difference between the two. Weight loss per disturbance was most sensitive to 10% increases in duration of the disturbance response (**+9.9%**), cost of 1 g stored fat (-8.1%), percent assimilation of forage (+7.2%), metabolic cost of flight (+6.3%) and proportion of flight in disturbance response (**+6.1%**) (Table 7.6).

Sensitivity analysis showed the proportion of departure weight (0.962) attained when exposed to 10 daily overflight disturbances was further reduced by 10% increases in basal metabolic rate (-3.7%), cost of storing fat (-1.0%), and cost of feeding behaviors (-0.9%). Increases of 10% in initial body weight, percent assimilation, forage intake, or **caloric value** of forage each caused about 6% gains in proportion of predicted body weight at departure (Table 7.6) and more than made up for the cost of 10 disturbance responses.

DISCUSSION

Average body weight and lipid reserves among brant during fall staging at **Izembek** Lagoon and arrival at San Quintin were used to determine the average weight gain needed by brant to complete transoceanic migration to San Quintin. Although minimum values for these reserves have not been determined, our investigation of disturbance effects using energetic models made the assumption that depression of average weight gain or reduced body weight at departure were not desirable.

The model requires a balance between energetic intakes and costs. Anything that upsets the balance, such as increased disturbance, will change the expected weight gain. As shown by the sensitivity analysis, any inaccuracy in parameter estimates that change total energy intake, whether by increased amount, higher caloric content, or greater percent assimilation of forage, had the largest influence on the results. Certain parameters affecting energy expenditure were next most sensitive. Of these, the most important were **BMR**, cost of storing lipid, and costs of feeding behaviors.

The amount, quality, and assimilation of eelgrass had a surprisingly large effect on model output values. Small increases in forage intake caused **large** differences in weight gain. One consequence of this high sensitivity is that it is not useful to make definitive statements predicting the number of disturbances brant are able to tolerate. Some models are relatively insensitive (robust) to changes in input parameter

values and if so, stronger predictions can be made. With the brant energetic model however, this was not the case.

Another important consequence of model sensitivity to forage intake is that if brant are able to adjust their behavior and compensate for lost feeding time or increase forage intake, the detrimental influence of disturbance on energetic balance will readily be minimized. A 10% increase in forage intake caused a 34% increase in weight gain and a 2.25 fold increase in number of disturbances tolerated. Although nearly a doubling in feeding time was argued to be unlikely (see discussion of "Behavior" chapter) , a 10% increase may be feasible.

Several additional factors that make the model more realistic have not been included. Habituation of behavioral response to disturbance was documented for repeated helicopter overflights, therefore at least some decline in response by brant will occur over time. Also, only a portion of the brant are influenced by a single aircraft flight across the lagoon. If overflights are scattered over the total area of the lagoon, or better, if they are restricted to habitat areas used less frequently by brant, each overflight will only disturb a small fraction of the brant.

Some values were assumed for these factors to quickly assess their influence. Using best estimates for all input parameters, the model predicts 11 overflights can be tolerated and still maintain 5 g/day weight gain (Table 7.6). With 20% decreased response due to habituation, then 14 flights could be tolerated. If on average 10% of all brant in the lagoon are affected by a single flight, then 140 overflights per day could be tolerated. These assumptions demonstrate decreased likelihood that potentially harmful changes in behavioral time budget and energetic balance of an average male brant will be caused by aircraft disturbance at **Izembek** Lagoon. The effects on other age and sex classes of brant was not determined from this model.

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APPENDIX A

Table A1. Summary Of weather conditions at cold Bay, Alaska, 18 September - 21 October, 1985. Data taken from National Oceanographic and Atmospheric Administration weather summaries (U.S. Dept of Commerce 1985) .

	September ^a	October ^b
Temperature (°C)		
Mean maximum	11	9
Mean minimum	4	3
Mean mean	8	6
No. days with:		
Fog	8	8
Measurable rain	8	18
Measurable snow	0	3
Total precipitation (nun)	56	150
Wind		
Mean velocity (kph)	27	34
Mean peak gust (kph)	84	76
No. days mean velocity		
Less than 16.1 kph	6	1
Greater than 32.2 kph	3	8
Greater than 48.4 kph	0	2
No. days Wind from		
Northeast	2	0
southeast	6	6
Southwest	1	6
Northwest	4	8
Mean cloud cover (%)	83	90
No. days rated:		
clear	0	0
Partly cloudy	3	2
cloudy	13	19

^a Includes data from 18-30 September.

^b Includes data from 21-30 November.

Table A2. **Summary** of weather conditions at Cold Bay, Alaska, 6 **September** - 31 **October**, 1986. Data taken from National Oceanographic and Atmospheric Administration weather summaries (U.S. Dept of Commerce 1986) .

	September	October ^b
Temperature (°C)		
Mean maximum	12	9
Mean minimum	8	3
Mean mean	10 ^a	6 ^a
No. days with:		
Fog	13	9
Measurable rain	13	19
Measurable snow	0	0
Total precipitation (mm)	187 .2a	77. 0 ^b
Wind		
Mean velocity (kph)	17	24
Mean peak gust (kph)	84	63
No. days mean velocity		
Less than 16.1 kph	9	11
Greater than 32.2 kph	9	4
Greater than 48.4 kph	2	0
No. days wind from		
Northeast	1	3.
Southeast	22	10
Southwest	2	2
Northwest	6	16
Mean cloud cover (%)	88	91
No. days rated:		
clear	1	0
Partly cloudy	4	3
Cloudy	25	28

^a Above average.

^b Below average.

Table A3. Summary of weather conditions at Cold Bay, Alaska, 20 August -30 November, 1987. Data taken from National Oceanographic and Atmospheric Administration weather summaries (U.S. Dept of Commerce 1988).

	August ^a	September	October	November
Temperature (°C)				
Mean maximum	16	11	8	2
Mean minimum	8	6	2	-4
Mean mean	12 ^b	8 ^c	5 ^d	-1 ^d
No. days with:				
Fog	11	15	8	2
Measurable rain	2	25	29	6
Measurable snow	0	0	1	17
Total precipitation (mm)	3 ^d	106 ^b	140 ^b	79 ^d
Wind				
Mean velocity (kph)	15	29	27	24
Mean peak gust (kph)	42	63	60	51
No. days mean velocity				
Less than 16.1 kph	5	1	3	9
Greater than 32.2 kph	1	10	11	6
Greater than 48.4 kph	0	2	0	1
No. days wind from				
Northeast	1	1	1	4
southeast	3	6	10	2
southwest	0	7	10	5
Northwest	8	16	10	19
Mean cloud cover (%)	79	91	83	81
No. days rated:				
clear	1	0	0	2
Partly cloudy	3	4	8	8
cloudy	8	26	23	20

^a Includes data from only 23-31 August.

^b Includes data from only 1-16 November.

^c Above average.

^d Near average.

^e Below average.

Table A4 . Summary of weather conditions at Cold Bay, Alaska, 23 August - 16 November, 1988. Data taken from National Oceanographic and Atmospheric Administration weather summaries (U.S. Dept of Commerce 1988) .

	August ^a	September	October	November ^b
Temperature (°C)				
Mean maximum	13	11	8	5
Mean minimum	6	5^d	2	-2 ^e
Mean mean	9	8^d	9^c	0^e
No. days with:				
Fog	6	18	14	8
Measurable rain	6	20	23	13
Measurable snow	0	0	0	6
Total precipitation (mm)	2	3	99^c	83^e
wind				
Mean velocity (kph)	16	27	26	23
Mean peak gust (kph)	87	153	88	79
No. days mean velocity				
Less than 16.1 kph	4	5	5	3
Greater than 32.2 kph	2	7	6	4
Greater than 48.4 kph	0	2	1	0
No. days Wind from				
Northeast	1	1	7	1
Southeast	3	11	6	3
Southwest	3	5	5	3
Northwest	2	13	13	9
Mean cloud cover (%)	88	92	85	91
No. days rated:				
clear	0	1	0	0
Partly cloudy	1	3	7	3
Cloudy	8	26	24	13

^a Includes data from **only 23-31 August.**

^b **Includes** data from **only 1-16 November.**

^c **Above** average.

^d **Near** average.

^e **Below** average.

APPENDIX B

List of bird species observed at Izembek Lagoon, 1986-1986. Timing of stay for each species can be approximated from first and last dates of observation. The observation period was 23 August-15 November in 1988, 20 August-17 November in 1987, and 7 September-31 October in 1986. Status indicates relative abundance as A- abundant, VC- very common, C- common, U- unknown, and R- rare.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Common Loon (<u>Gavia immer</u>)	25 Aug	15 Nov	29 Aug	16 Nov	14 Ott	18 Ott	c
Pacific Loon (<u>G. pacifica</u>)	20 Ott	15 Nov	07 Nov	07 Nov	10 Sep	21 Ott	u
Red-throated Loon (<u>G. stellata</u>)	20 Ott	03 Nov	25 Ott	25 Ott			R
Red-necked Grebe (<u>Podiceps grisegena</u>)	12 Sep	14 Nov	19 Ott	01 Nov	09 Sep	26 oct	c
Horned Grebe (<u>P. auritus</u>)	24 Sep	13 Nov	23 Ott	25 Ott			A
Short-tailed Shearwater (<u>Puffinus tenuirostris</u>)	02 Sep	02 Sep	12 Ott	12 Ott	21 Sep	21 Sep	R
Fork-tailed Storm-Petrel (<u>Oceanodroma furcata</u>)	17 Sep	01 Ott					R
Pelagic/Red-faced Cormorant (<u>Phalacrocorax pelagicus/P. urile</u>)	29 Aug	12 Nov	27 Aug	01 Nov	20 Sep	30 Ott	c
Double-crested Cormorant (<u>P. auritus</u>)	02 Sep	12 Nov	01 Sep	01 Nov	27 Sep	27 Sep	u
Tundra Swan (<u>Cygnus columbianus</u>)	26 Aug	10 Nov	21 Aug	03 Nov	15 Sep	15 Ott	u
Aleutian Canada Goose (<u>Branta canadensis leucopareia</u>)			23 oct	23 Ott			

Table B1. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Cackling Canada Goose (<i>B. c. minima</i>)	02 Sep	28 Ott	20 Ott	20 Ott	17 Sep	02 Ott	R
Taverner's Canada Goose (<i>B. c. taverneri</i>)	23 Aug	14 Nov	23 Aug	17 Nov	08 Sep	31 Ott	A
Brant (<i>B. bernicla</i>)	23 Aug	15 Nov	20 Aug	16 Nov	08 Sep	31 Ott	A
Emperor Goose (<i>Chen canagica</i>)	02 Sep	15 Nov	28 Aug	17 Nov	08 Sep	31 Ott	A
Snow Goose (<i>C. caerulescens</i>)	12 Sep	04 Nov	25 Ott	26 Ott	23 Ott	23 oct	R
Gr. White-fronted Goose (<i>Anser albifrons</i>)	22 Sep	02 Nov	17 Sep	15 Ott	26 Sep	20 Ott	R
Mallard (<i>Anas platyrhynchos</i>)	24 Aug	14 Nov	24 Aug	12 Nov	14 Sep	31 Ott	A
Gadwall (<i>A. strepera</i>)	22 Sep	10 Nov	03 Sep	01 Nov			u
Northern Pintail (<i>A. acuta</i>)	24 Aug	06 Nov	20 Aug	07 Nov	18 Sep	23 oct	A
Green-winged Teal (<i>A. crecca carolinensis</i>)	29 Aug	11 Nov	24 Aug	09 Nov	13 Sep	30 Ott	VC
Common Teal (<i>A. crecca nimia</i>)	13 Ott	13 Ott	15 Ott	28 Ott			R
Eurasian Wigeon (<i>A. penelope</i>)	27 Sep	24 Ott	25 Sep	25 Nov			u
American Wigeon (<i>A. americana</i>)	02 Sep	20 Ott	01 Sep	25 Ott	16 Sep	22 Ott	c
Northern Shoveler (<i>A. clypeata</i>)	11 Sep	02 Nov	11 Ott	15 Ott			R
Canvasbacks (<i>Aythya valisineria</i>)			16 Nov	16 Nov			R

Table B1. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Greater Scaup (<u>A. marila</u>)	31 Aug	11 Nov	23 Aug	16 Nov	18 Sep	15 Ott	VC
Bufflehead (<u>Bucephala albeola</u>)	09 Ott	14 Nov	07 Ott	10 Nov			C
Common Goldeneye (<u>B. clangula</u>)	12 Ott	15 Nov	01 Ott	17 Nov	22 Ott	30 Ott	Vc
Oldsquaw (<u>Clangula hyemalis</u>)	12 Ott	12 Nov	21 Ott	13 Nov	15 Ott	31 Ott	u/c
Harlequin Duck (<u>Histrionics histrionics</u>)	03 Sep	13 Nov	29 Aug	17 Nov	24 Sep	31 Ott	VC
Steller's Eider (<u>Polysticta stelleri</u>)	25 Aug	15 Nov	23 Aug	16 Nov	10 Sep	31 Ott	A
Black Scoter (<u>Melanitta nigra</u>)	31 Aug	15 Nov	21 Aug	07 Nov	09 Sep	30 Ott	C
White-winged Scoter (<u>M. fusca</u>)	31 Aug	13 Nov	20 Aug	26 Ott	21 Sep	15 Nov	u
Surf Scoter (<u>M. perspicillata</u>)			25 Ott	25 Ott			R
Common Merganser (<u>Mergus merganser</u>)	24 Sep	14 Nov	17 Sep	07 Ott	04 Ott	14 Ott	u
Red-breasted Merganser (<u>M. serrator</u>)	07 Sep	14 Nov	23 Aug	25 Ott	14 Sep	08 Ott	u
Rough-legged Hawk (<u>Buteo lagopus</u>)	23 Aug	12 Ott	22 Aug	20 Sep	14 Sep	18 Sep	u
Golden Eagle (<u>Aquila chrysaetos</u>)	01 Ott	12 Ott					R
Bald Eagle (<u>Haliaeetus leucocephalus</u>)	29 Aug	15 Nov	20 Aug	17 Nov	18 Sep	28 Ott	C
Northern Harrier (<u>Circus cyaneus</u>)	25 Sep	07 Nov	10 Sep	24 Sep	27 Sep	11 Nov	R

Table B1. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Osprey (<u>Pandion hyliaetus</u>)	21 Ott	21 Ott					R
Gyr Falcon (<u>Falco rusticolus</u>)	24 Aug	14 Nov	20 Aug	08 NOV	09 Sep	31 Ott	C
Peregrine Falcon (<u>F. peregrinus</u>)	02 Sep	15 Nov	02 Sep	17 Nov	20 Sep	08 Ott	u
Merlin (<u>F. columbarius</u>)	03 Ott	24 Ott			18 Sep	28 Sep	R
American Kestrel (<u>F. sparverius</u>)			15 Sep	15 Ott			R
Willow Ptarmigan (<u>Lagopus lagopus</u>)	24 Au9	06 NoV	21 Aug	13 Nov	19 Sep	31 Ott	c
Rock Ptarmigan (<u>L. mutus</u>)	04 Sep	11 Nov	25 Sep	14 Nov			R
Sandhill Crane (<u>Grus americana</u>)	25 Aug	03 Sep	21 Aug	29 Aug			R
Semipalmated Plover (<u>Charadrius semipalmatus</u>)	26 Aug	29 Aug	20 Aug	13 Sep	28 Sep	28 Sep	R
Lesser Golden-Plover (<u>Pluvialis dominica</u>)	03 Sep	29 oct	21 Aug	17 Nov	10 Sep	20 Ott	c
Black-bellied Plover (<u>P. squatarola</u>)	13 Ott	18 Ott	26 Sep	26 Sep			R
Ruddy Turnstone (<u>Arenaria interpres</u>)	23 Aug	13 Ott	20 Aug	09 Ott	19 Sep	27 Ott	u
Black Turnstone (<u>A. melanocephala</u>)	26 Aug	20 Sep	13 Sep	24 Sep	10 Sep	15 Ott	R
Common Snipe (<u>Gallinago gallinago</u>)	29 Aug	22 Ott	27 Aug	15 Ott	08 Sep	05 Ott	u
Whimbrel (<u>Numenius phaeopus</u>)	30 Aug	02 Sep	24 Aug	10 Ott			R

Table B1. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Wandering Tattler (<u>Heteroscelus incanus</u>)	30 Aug	08 Ott					R
Lesser Yellowlegs (<u>Tringa flavipes</u>)	25 Aug	17 Sep					R
Greater Yellowlegs (<u>I. melanoleuca</u>)	23 Aug	12 Ott	20 Aug	12 Ott	27 Sep	11 Ott	u
Rock Sandpiper (<u>Calidris ptilocnemis</u>)	23 Aug	14 Nov	20 Aug	17 Nov	18 Sep	24 Ott	A
Sharp-tailed Sandpiper (<u>C. acuminata</u>)	02 Sep	14 Nov	17 Sep	02 Nov	14 Ott	31 Ott	u
Pectoral Sandpiper (<u>C. melanotos</u>)	05 Sep	10 Nov					R
Dunlin (<u>C. alpina</u>)	26 Aug	18 Sep	20 Aug	25 Ott			c
Western Sandpiper (<u>C. mauri</u>)	26 Aug	17 Sep	20 Aug	18 Sep			u
Semipalmated Sandpiper (<u>C. pusilla</u>)	26 Aug	26 Aug					R
Sanderling (<u>C. alba</u>)	30 Aug	24 Ott	29 Oct	16 Nov	10 Sep	31 Ott	U/R
Long-billed/Short-billed Dowitcher (<u>Limnodromus scolopaceus/L. griseus</u>)	25 Aug	06 Ott	20 Aug	09 Ott	07 Ott	18 Ott	u
Marbled Godwit (<u>Limosa fedoa</u>)	25 Aug	25 Aug					R
Bar-tailed Godwit (<u>L. lapponica</u>)			01 Sep	01 Sep			R
Red Phalarope (<u>Phalaropus fulicaria</u>)	04 Sep	05 Ott	15 Sep	22 Sep			R
Red-necked Phalarope (<u>P. lobatus</u>)	26 Aug	13 Ott	20 Aug	21 Ott	19 Sep	06 Ott	u

Table E1. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Pomarine Jaeger (<u>Stercorarius pomarinus</u>)			23 Sep	23 Sep			R
Parasitic Jaeger (<u>S. parasiticus</u>)			21 Aug	01 Ott			R
Glaucous Gull (<u>Larus hyperboreus</u>)	14 Nov	14 Nov			01 Ott	02 Ott	R
Glaucous-winged Gull (<u>L. glaucescens</u>)	23 Aug	15 Nov	20 Aug	17 Nov	08 Sep	31 Ott	A
Slaty-backed Gull (<u>L. schistisagus</u>)					19 Sep	19 Sep	R
Mew Gull (<u>L. canus</u>)	23 Aug	15 Nov	24 Aug	07 Nov	18 Sep	27 oct	u
Red-legged Kittiwake (<u>Rissa brevirostris</u>)	11 Sep	11 Sep					R
Black-legged Kittiwake (<u>R. tridactyla</u>)	04 Sep	12 Nov	15 Sep	29 Ott	21 Sep	31 Ott	u
Tern spp. (<u>Sterna spp.</u>)			23 Aug	04 Sep			R
Common Murre (<u>Uris aalge</u>)	19 Ott	02 Nov					R
Pigeon Guillemot (<u>Cepphus columba</u>)	30 Aug	11 Nov	08 oct	13 Nov			u
Marbled Murrelet (<u>Brachyramphus marmoratus</u>)	18 Ott	02 Nov	21 Ott	21 Ott			R
Cassin's Auklet (<u>Ptychoramphus aleuticus</u>)			03 Ott	21 Ott			R
Crested Auklet (<u>Aethia cristatella</u>)	02 Ott	02 Ott	05 Nov	05 Nov			R
Tufted Puffin (<u>Fratercula cirrhata</u>)	18 Sep	18 Sep					R

Table 61. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Horned Puffin (<u>E. corniculata</u>)	03 Sep	28 Ott					u
Snowy Owl (<u>Nyctea scandiaca</u>)			25 Sep	25 Sep			R
Short-eared Owl (<u>Asio flammeus</u>)	04 Sep	05 Ott	21 Aug	16 Nov	08 Ott	08 Ott	*
Belted Kingfisher (<u>Ceryle alcyon</u>)	25 Aug	20 Ott	20 Aug	10 Ott			R
Horned Lark (<u>Eremophila alpestris</u>)	21 Ott	21 Ott					R
Black-billed Magpie (<u>Pica pica</u>)	24 Aug	15 Nov	21 Aug	14 Nov	22 Sep	23 Ott	c
Common Raven (<u>Corvus corax</u>)	23 Aug	15 Nov	20 Aug	17 Nov	07 Sep	31 Ott	A
Black-capped Chickadee (<u>Parus atricapillus</u>)	27 Sep	27 Sep	30 Aug	15 Ott			R
American Dipper (<u>Cinclus mexicanus</u>)	24 Aug	09 Nov	20 Aug	30 Sep	07 Sep	20 Sep	R
Winter Uren (<u>Troglodytes troglodytes</u>)	27 Ott	27 Ott					R
Hermit Thrush (<u>Catharus guttatus</u>)	16 Sep	16 Sep					R
Gray-cheeked Thrush (<u>C. minimus</u>)	12 Sep	12 Sep					R
Swainson's Thrush (<u>C. ustulatus</u>)	10 Sep	10 Sep					R
Water Pipit (<u>Anthus spinoletta</u>)	23 Aug	27 Sep	20 Aug	24 Sep			c
Northern Shrike (<u>Lanius excubitor</u>)	03 Sep	15 Nov	23 Aug	13 Nov	03 Ott	25 Ott	c

Table B1. Continued.

Species	1988		1987		1986		Status
	First observed	Last observed	First observed	Last observed	First observed	Last observed	
Yellow Warbler (<u>Dendroica petechia</u>)	04 Sep	06 Sep	01 Sep	02 Sep			R
Wilson's Warbler (<u>Wilsonia pusilla</u>)	24 Aug	29 Aug	30 Aug	30 Aug			R
Rosy Finch (<u>Leucosticte arctoa</u>)	30 Ott	13 Nov	25 Ott	14 Nov	30 Ott	30 Ott	u
Common/Hoary Redpoll (<u>Carduelis flammea/C. hornemanni</u>)	24 Aug	11 Nov	22 Sep	05 Ott			c
Go[den-crowned Sparrow (<u>Zonotrichia atricapilla</u>)	24 Aug	20 Sep	26 Aug	26 Aug			R
Song Sparrow (<u>Melospiza melodia</u>)	23 Aug	09 Ott	17 Sep	17 Nov	22 Ott	22 Ott	R
Fox Sparrow (<u>Passerella iliaca</u>)	25 Aug	13 Ott	20 Aug	01 Nov			u
Savannah Sparrow (<u>Passerculus sandwichensis</u>)	23 Aug	24 Sep	20 Aug	26 Ott	08 Sep	20 Ott	A
Dark-eyed Junco (<u>Junco hyemalis</u>)	17 Ott	17 Ott					R
Lapland Longspur (<u>Calcarius lapponicus</u>)	26 Aug	29 Ott	20 Aug	08 Ott	08 Sep	20 Ott	A
Snow Bunting (<u>Plectrophenax nivalis</u>)	13 Sep	14 Nov	21 Aug	17 Nov	12 Sep	31 Ott	c

* Short-eared Owls were rare in 1986 and 1988, but very common in 1987.

APPENDIX C

Table C1. Frequency and mean number of brant (B), Canada (C), and emperor (E) geese within five study areas of Izembek Lagoon, Alaska, from 23 September to 21 October, 1985.

Area	Size (km ²)	Species	Total % of		Total.	% of count with	Mean no. of geese/ km ²	No. of geese present		
			days with geese	days with geese				Mean	SD	Range
Grant Point (East)	2.3	B	18	100	130	98	640	1500	1200	0-7000
		c		22		4	40	100	10	0-100
		E		17		4	10	7	4	0-10
Halfway Point	4.2	B	13	100	42	98	390	1600	1200	0-6000
		c		62		40	220	900	700	0-2800
		E		62		26	20	100	90	0-250
Outer Marker	3.9	B	12	100	41	98	590	2300	2000	0-8100
		c		25		15	10	50	40	0-100
		E		33		22	5	20	15	0-50
Applegate Cove (North)	3.9	B	3	100	14	100	480	1890	605	400-2375
		c		67		64	600	2350	459	0-3050
		E		0		0	0	0		
Quarter Point	3.5	B	4	100	17	59	100	300	300	20-800
		c		75		53	40	100	100	0-340
		E		50		47	10	40	20	0-80
Total	17.7	B	20	100	244	95	90	1600	1400	0-8100
		c		65		19	50	800	1000	0-3050
		E		50		13	3	40	60	0-250

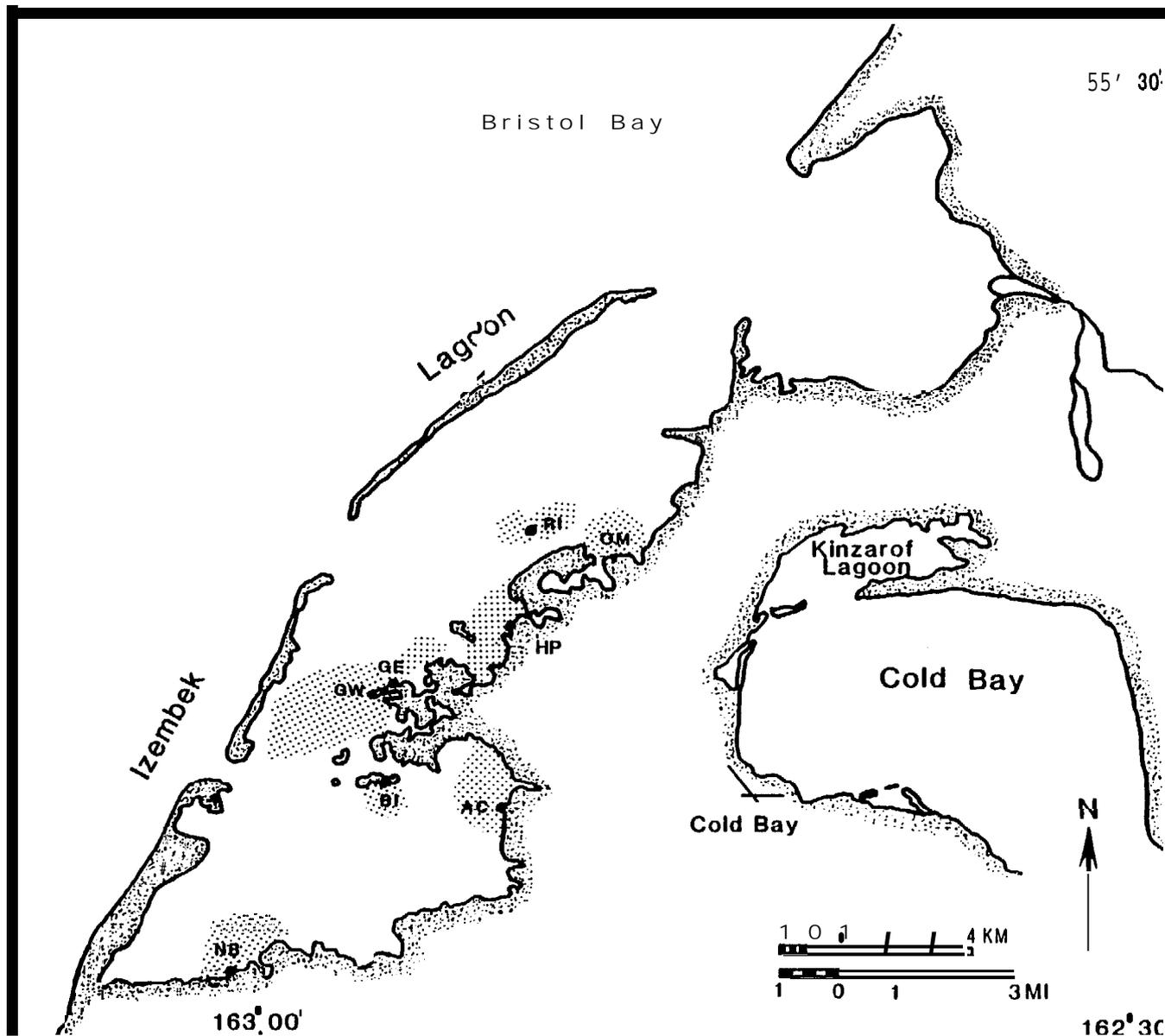
Table C2. Frequency and mean number of brant (B), Canada (C), and emperor (E) geese at seven study areas at ~~Izembek~~ Lagoon, ~~Alaska~~, from 18 ~~September~~ to 31 October, 1986.

Area	Size (km ²)	Species	Total days with geese	% of days with geese	Total count	% of count with geese	Mean no. of geese/ km ²	No. of geese present		
								Mean	SD	Range
Norma Bay	10.9	B	22	100	121	100	600	6800	3500	600-1910C
		c		95	120	97	130	1400	1100	0-5000
		E		9	121	2	0	0	1	0-5
Applegate Cove	5.4	B	26	100	110	88	600	3000	3000	0-1470C
		c		100	98	85	300	1400	2300	0-6400
		E		0	93	0	0	0	0	0-0
Halfway Point	7.0	B	21	100	95	63	400	3100	2600	0-11800
		c		100	96	93	300	1900	1200	0-5600
		E		95	95	66	20	150	180	0-1030
Round Island (East)	2.1	B	17	76	103	55	400	800	1500	0-11100
		c		12	79	5	5	10	40	0-200
		E		47	80	19	5	10	30	0-160
Banding Island	1.8	B	12	92	77	66	530	900	1300	0-5800
		c		0	77	0	0	0	0	0-0
		E		0	77	0	0	0	0	0-0
Grant Point (West)	23.3	B	14	86	69	87	190	4450	8200	0-4000C
		c		14	71	4	0	2	10	0-100
		E		12	62	63	10	180	220	0-900
Round Island (west)	1.8	B	10	70	43	44	90	160	510	0-3200
		c		7	30	0	0	0	0	0-0
		E		8	31	3	0	0	2	0-9
Totals	52.3	B	122	92	618	81	61	3200	4300	0-4000C
		c		62	571	52	16	850	3.200	0-6350
		E		36	559	22	1	50	130	0-1030

Table a. Frequency and mean number of brant (B), Canada (C), and emperor (E) geese within six study areas of Izembek Lagoon, Alaska, from 3 September to 7 November 1987.

Area	Size (km ²)	Species	Total days with geese	% of days with geese	Total count	% of count with geese	Mean no. of geese/ km ²	No. of geese present		
								Mean	SD	Range
Halfway Point	4.2	B	37	100	144	100	1900	7700	4300	400-20000
		C		70	144	72	200	1000	1300	0-6250
		E		65	144	57	20	100	140	0-650
Norma Eay	5.5	B	18	100	104	100	1200	6500	4730	400-20800
		C		89	104	75	200	1100	1400	0-9000
		E		0	104	0	0	0	0	
Applegate Cove	5.4	B	14	100	53	100	1240	6700	4900	500-22500
		C		86	53	70	150	800	1100	0-4500
		E		14	53	4	0.1	1	10	0-50
Banding Island	1.8	B	12	100	48	85	1400	2500	2900	0-10800
		C		0	48	0	0	0	0	
		E		0	48	0	0	0	0	
Grant Point (East)	2.3	B	18	100	81	99	700	1500	1500	0-7800
		C		17	81	7	10	20	80	0-400
		E		39	81	20	5	20	30	0-200
Outer Marker	4.1	B	20	100	84	98	680	2800	3000	0-12200
		C		90	84	74	120	500	800	0-4000
		E		80	84	56	1	100	100	0-500
Total	23.3	B	45	100	514	98	220	5200	4600	0-22500
		C		80	514	56	30	600	1100	0-9000
		E		84	514	29	1	30	90	0-650

Appendix Figure C1. Location of observation blinds and study areas under view during hourly counts of geese at Izembek Lagoon, Alaska. Study areas included Norma Bay (NB), Applegate Cove (AC), Banding Island (BI), Grant Point West (GW), Grant Point East (GE), Halfway Point (HP), Round Island (RI), and Outer Marker (OM).



APPENDIX D

Table D1. Summary of experimental aircraft overflights flown at Izembek LagCon, Alaska, from 30 September to 13 October, 1985. Flight paths are shown in Figures 5.1 and 5.2.

Aircraft type	Altitude (m)	No. of flight lines	No. of flocks observed		
			Brant	Canada	Emperor
<u>Fixed-wing aircraft^a</u>					
Cessna 150/180/185	76	1	1	0	0
	91	2	2	2	2
	152	7	30	2	2
	250	2	3	0	0
	305	8	35	5	2
	457	4	17	0	0
	610	4	12	1	0
	762	2	5	0	0
	subtotals	30	105	10	6
Cessna 206	250	1	1	0	0
	305	1	2	1	0
	610	1	2	1	0
	762	2	5	0	0
	Totals	35	115	12	6
<u>Rotary-wing aircraft^b</u>					
Bell 206-B	500	2	13	3	
	1000	6	31	3	0
	2500	1	1	0	0
	3000	4	14	4	0
	Totals	13	59	10	0
<u>All aircraft</u>	Grand Totals	48	174	22	6

^a See Figure 5.1.

^b See Figure 5.2.

Table D2. Summary of experimental aircraft overflights flown at Izembek Lagoon, Alaska, from 18 September to 31 October, 1986. Flight paths are shown in Figure 5.3 unless otherwise noted.

Aircraft type	Altitude (m)	No. of flight lines	No. of flocks observed		
			Brant	Canada	Emperor
<u>Fixed-wing aircraft</u>					
Single-engine	46	2^a	7	1	0
Arctic Tern	61	4^a	10	1	0
Cherokee Chief	91	7^a	14	0	0
Cessna 185/206	152	12^a	25	15	1
	243	1^a	4	2	0
	305	16	49	32	2
	365	1^a	1	0	0
	457	3^a	3	3	0
	610	5^a	13	12	6
	760	9^a	21	5	0
	Subtotals	60	147	71	9
Piper Navajo	152	19	77	32	7
	305	10	54	12	1
	Subtotals	29	131	44	8
Grumman Goose ^b	152	1	4	3	1
	305	4	7	8	1
	610	4	8	8	1
	914	4	6	10	1
	Subtotals	13	25	29	4
Twin Otter ^c	91	6	18	1	0
	305	1	3	0	0
	Subtotals	7	21	1	0
Hercules C-130 ^b	305	1	14	6	2
	517	1	6	3	0
	610	3	5	1	0
	Subtotals	5	25	10	2
	Totals	114	354	155	23

Table D2. Continued.

Aircraft type	Altitude (m)	No. of flight lines	No. of flocks observed		
			Brant	Canada	Emperor
<u>Rotary-wing aircraft</u>					
Bell 206-B	91	13	84	15	3
	213	2 ^a	3	3	0
	258	1 ^d	0	1	0
	274	1 ^d	4	0	0
	305	30	139	48	15
	457	1	3	3	0
	610	11	57	14	7
	subtotals	59	290	84	25
Sikorsky HH-3F ^e	457	3	45	15	1
	Totals	62	335	99	26
<u>All aircraft</u>	Grand totals	176	689	254	49

- a **Some overflights** did not follow the **standardized** flight lines depicted in Figure 5.3. One single-engine overflight at 91, 457 and 610 m, one Bell 206B helicopter overflight at 213 m, and five **single-engine** overflights at 157 m were flown along different flight paths.
- b Flight paths were oriented east/west across **most** of lagoon.
- c Flight **paths** were oriented north/south at 3.2 km intervals across the entire lagoon.
- d **During** one overflight the **aircraft** was **ascending** when flocks were being **observed**.
- e Flight paths are shown in Figure 5.4.

Table D3. Summary of experimental aircraft overflights flown at Izembek Lagoon, Alaska, from 23 September to 18 October, 1987. Flight paths are shown in Figures 5.5 unless otherwise noted.

Aircraft type	Altitude (m)	No. of flight lines	No. of flocks observed		
			Brant	Canada	Emperor
<u>Fixed-wing aircraft</u>					
Piper-150/Cessna 206	76	1	1	0	0
	152	8	27	2	0
	305	15 ^a	52	0	0
	subtotals	24	80	2	0
Hercules C-130 ^b	305	3	38	19	4
Totals		27	118	21	4
<u>Rotary-wing aircraft</u>					
Bell 206-B	91	7	23	11	4
	152	10 ^c	26	11	5
	305	8	17	7	1
	457	2	7	2	0
subtotals		27	73	31	10
Bell 205	91	19 ^d	92	30	0
	152	30 ^{a,e,f}	98	24	3
	305	25 ^f	98	30	4
	457	12 ^e	55	18	1
	610	14	53	22	0
	671	2 ^a	5	4	0
	762	2	3	1	0
	914	4	9	3	0
1,219	1	6	1	0	
Subtotals		109	419	133	8
Totals		136	492	164	18
<u>All aircraft</u>	Grad totals	163	610	185	22

^a One on flightline 14.

^b See Figure 5.6.

^c One off regular flightlines.

^d Two on regular flightline 14.

^e One on flightline 16.

^f One on flightline 15.

Table D4. Summary of experimental aircraft overflights flown at Izembek Lagoon, Alaska, from 29 September to 19 October, 1988. Flight paths are shown in Figure 5.6.

Aircraft type	Altitude (m)	No. of flight lines	No. of flocks observed		
			Brant	Canada	Emperor
<u>Fixed-wing aircraft</u>					
Piper-150	76	1	3	3	2
	152	6	15	8	4
	305	4	13	8	6
	457	2	8	6	3
	610	1	2	1	1
	subtotals	14	41	26	16
Cessna 206	152	4	4	0	0
	305	2	6	2	1
Piper Navajo	76	2	8	7	1
	152	6	23	16	6
	305	2	6	5	2
	Subtotals	10	37	28	9
	Totals	30	88	56	26
<u>Rotary-wing aircraft</u>					
Hughes 500-D	76	2	7	1	2
	152	7	23	14	8
	305	7	22	17	10
	457	5	14	16	5
	610	1	4	7	4
	Totals	22	70	65	29
<u>All aircraft</u>	Grand totals	52	158	121	55

Table D5. Frequency of potential (incidental and experimental) disturbance events for all geese at Izembek Lagoon, Alaska, from 23 September to 21 October 1985.

Study area	Total hours of observation (%)	Days in blind	Mean h/d in blind	Mean number of disturbances per hour	HUMAN DISTURBANCES										NATURAL			Total
					Fixed-wing aircraft				Helicopter		Other				Birds		Mamma 1	
					AS	AT	AM	AJ ^a	H	G	P	B	V	E	F	M		
Grant Point E.	120.7 (46.1)	23	4.1	2.2 (1.5) ^b	n	96	24	29	30	9	43	8	10	0	5	5	2	261
					%	58.2	44.4	34.9	29.7	10.6	50.6	66.7	66.7	0	41.7	62.5	100.0	41.9
Halfway Point	44.4 (17.0)	14	3.2	2.9 (2.1)	n	28	9	12	18	23	34	3	1	0	1	0	0	129
					x	17.0	16.7	14.5	17.8	27.1	40.0	25.0	6.7	0	8.3	0	0	20.7
Outer Marker	54.7 (20.9)	15	3.7	2.0 (1.6)	n	15	9	24	24	12	5	1	4	0	6	3	0	103
					%	9.1	16.7	28.9	23.7	14.1	5.9	8.3	26.6	0	50.0	37.5	0	16.5
Applegate Cove ^c	12.9 (4.9)	3	4.3	11.0 (3.7)	n	6	8	12	14	34	1	0	0	0	0	0	0	75
					%	3.6	14.8	14.5	13.9	40.0	1.2	0	0	0	0	0	0	12.1
Grant Point U.	13.7 (5.2)	5	2.8	2.4 (1.9)	n	18	2	1	5	7	0	0	0	0	0	0	0	33
					x	10.9	3.7	1.2	5.0	8.2	0	0	0	0	0	0	0	5.3
Quarter Point	15.3 (5.8)	4	3.8	1.2 (1.2)	n	2	2	5	10	0	2	0	0	1	0	0	0	22
					%	1.2	3.7	6.0	9.9	0	2.3	0	0	100.0	0	0	0	3.5
Total	261.7	25	3.7	--	n	165	54	83	101	85	85	12	15	1	12	8	2	623
					%	26.6	8.7	13.3	16.2	13.6	13.6	1.9	2.4	0.2	1.0	1.3	0.3	

Fixed-wing aircraft: AS - Single-engine propeller (e.g. Arctic Tern); AT - Small and heavy twin-engine propeller (e.g. Piper Navaho NAMC YS-11, Douglas DC3); AM - Multi-engine (e.g. Lockheed C-130, Electra L-188); AJ - Jet (e.g. Boeing 727)

Other: G - Gunshots; P - Person; B - Boats; V - Vehicle.

Bird: E - Eagle (e.g. bald eagle); F - Falcon (e.g. gyrfalcon, peregrine falcon); O - Other birds (e.g. rough-legged hawk, northern harrier, common raven).

Mammal: M - Mammals (e.g. wolf, red fox, river otter, brown bear).

^a Includes eight unidentified aircraft.

^b() = Mean number of disturbances per hour excluding experimental overflights.

^c Includes observations from Applegate Cove (South) and Norma Bay.

Table D6. Frequency of potential (incidental and experimental combined) disturbance events for all geese at Izembek Lagoon, Alaska, from 18 September to 31 October 1986.

Study area	Total hours of observation (%)	Days in blind	Mean h/d in blind	Mean number of disturbances per hour	HUMAN DISTURBANCES													NATURAL DISTURBANCES						Total
					Fixed-wing aircraft							Helicopter			Other			Bird						
					AS	AT	AO	AG	AH	AM	AJ	A	HS	HL	B	G ^d	P	E	F	o	u			
Grant Point U.	61.5 (7.7)	14	4.4	2.5 (1.2) ^a	n 9	23	7	1	7	11	7	0	34	14	20	3	0	7	2	0	8	153		
					x 2.6	8.5	25.9	1.3	10.5	9.2	9.1	0	8.4	20.6	64.5	11.5	0	2.2	5.6	0	8.3	7.5		
Round Island E.	108.6 (13.6)	14	7.8	1.5 (0.7)	n 34	12	4	4	12	12	11b	2	36	3	0	9	4	6	3	0	14	166		
					x 9.9	4.4	14.8	5.1	17.9	10.1	14.3	8.3	8.9	4.4	0	34.6	12.9	1.9	8.3	0	14.4	8.2		
Halfway Point	113.6 (14.2)	21	5.4	3.5 (1.6)	n 55	53	1	19	10	49	37	0	91	6	0	6	21	18	14	1	20	401		
					x 16.0	19.6	3.8	24.1	14.9	41.2	18.0	0	22.5	8.8	0	23.1	67.7	5.6	38.9	8.3	20.6	19.8		
Applegate Cove	151.1 (18.9)	23	6.6	2.3 (1.1)	n 53	59	4	9	12	5	6	0	92	17	0	1	0	84	2	3	1	34LS		
					% 15.5	21.9	14.8	11.4	17.9	4.2	7.8	0	22.8	25.0	0	3.9	0	26.3	5.6	25.0	1.0	17.2		
Banding Island	86.1 (10.8)	12	6.6	2.6 (1.1)	n 36	44	4	2	9	12	4	5	55	0	2	3	2	21	4	0	17	220		
					x 10.5	16.3	14.8	2.5	13.4	10.1	5.2	20.8	13.6	0	6.5	11.5	6.6	6.6	11.1	0	18.6	10.8		
Norma Bay	196.6 (24.6)	22	8.9	2.9 (1.8)	n 122	78	7	32	12	16	2b	13	73	0	3	0	0	164	10	8	31	571		
					% 35.6	28.9	25.9	40.5	17.9	13.4	2.6	54.2	18.1	0	9.7	0	0	51.4	27.8	66.7	34.0	28.2		
Other ^c	81.1 (10.2)	23	3.5	2.1 (1.1)	n 34	1	0	12	5	14	10b	4	23	20	6	4	4	19	1	0	3	168		
					% 9.9	0.4	0	15.1	7.5	11.8	13.0	16.7	5.7	41.2	19.3	15.4	12.9	6.0	2.8	0	3.1	8.3		
Total	798.6	32	6.2	--	n 343	270	27	79	67	119	77	24	404	68	31	26	31	319	36	12	94	2027		
					% 16.9	13.3	1.3	3.9	3.3	5.9	3.8	1.2	19.9	3.4	1.5	1.3	1.5	15.7	1.8	0.6	4.7			

Fixed-wing aircraft: AS - Single-engine propeller (e.g. Arctic Tern); AI - Small twin-engine propeller (e.g. Piper Navaho); AO - Twin Otter;

AG - Grumman Goose; AH - Heavy twin-engine (e.g. YS-11); AM - Multi-engine (e.g. Lockheed C-130, Electra L-188);

AJ - Jet (e.g. Boeing 727); A - Unidentified aircraft.

Helicopter: HS - Small (e.g. Bell 206); HL - large (e.g. Sikorsky HH-3F).

Other: B - Boats; G - Gunshots; P - Person.

Bird: E - Eagle (e.g. bald eagle); F - Falcon (e.g. gyrfalcon, peregrine falcon); O - Other birds (e.g. rough-legged hawk, northern harrier, common raven).

u - Unidentified cause.

^a () = Mean number of potential disturbances per hour excluding experimental overflights.

^b Includes one or more disturbances caused by small jet aircraft (e.g. Rockwell Sabreliner).

^c Includes Grant Point East, Round Island West, Applegate Cove North, Quarter Point, and Outer Marker study areas.

^d Includes six combined gunshot and person disturbances.

Table D7. Frequency of potential (incidental and experimental combined) disturbance events for all geese at Izembek Lagoon, Alaska, from 1 September to 2 November 1987.

Study area	Total hours of observation (%)	Days in blind	Mean h/d in blind	Mean number of disturbances per hour	HUMAN DISTURBANCES											NATURAL DISTURBANCES					Total	
					Fixed-wing aircraft					Helicopter			Other			Bird			Mammal			
					AS	AT	AH	AU	AJ	A	HS	HK	B	G ^b	P	E	F	o	M	u		
Halfway Point	201.3 (23.6)	38,	5.3	2.3 (1.3) ^a	n 42	8	0	64	SO	1	43	125	4	3	0	79	15	B	0	28	470	
					% 16.0	9.9	0	41.0	27.2	1.3	37.7	22.2	14.8	21.4	0	26.7	37.5	22.2	0	50.9	23.9	
Applegate Cove	152.9 (17.9)	22	6.9	2.7 (1.1)	n 28	19	0	25	22	19	33	184	2	4	2	55	3	7	2	6	411	
					% 10.7	23.5	0	16.0	12.0	24.1	28.9	32.7	7.4	28.6	4.3	18.6	7.5	19.4	25.0	10.9	20.9	
Grant Point E.	106.4 (12.5)	21	5.1	1.6 (1.3)	n 18	9	1	18	47	7	8	20	13	s	7	6	1	1	3	3	167	
					% 6.9	11.1	16.7	11.5	25.5	8.9	7.0	3.6	48.1	35.7	14.9	2.0	2.5	2.8	37.5	5.5	8.5	
Outer Marker	111.8 (13.1)	20	5.6	2.5 (1.8)	n 3	0	0	3	24	44	14	30	37	0	0	35	40	8	s	D	4	274
					% 11.5	0	SO	SO	15.4	23.9	17.7	26.3	6.6	0	0	74.5	13.5	20.0	13.9	o	7.3	13.9
Norma Bay	142.6 (16.7)	18	7.9	2.9 (0.7)	n 94	33	1	12	10	27	0	94	0	2	1	105	9	11	3	13	414	
					% 35.9	40.7	16.7	7.7	5.4	34.2	0	16.7	0	14.3	2.1	35.5	22.5	30.6	37.5	23.6	21.1	
Bonding Island	75.1 (8.8)	1s	5.0	2.4 (0.7)	n 43	11	0	9	1	2	D	99	2	0	0	9	3	2	0	1	182	
					% 16.4	13.6	0	5.8	0.5	2.5	0	17.6	7.4	0	0	3.0	7.5	5.6	0	1.8	9.3	
Round Island	58.4 (6.8)	7	8.3	0.7 (0.7)	n 7	1	1	4	10	9	0	0	0	0	2	2	1	2	0	0	39	
					X 2.7	1.2	16.7	2.6	5.4	11.4	0	0	0	0	4.3	0.7	2.5	5.6	0	0	2.0	
Grant Point U.	5.4 (0.6)	4	5.4	1.7 (1.1)	n o	o	0	0	0	0	0	3	6	0	0	0	0	0	0	0	9	
					% 0	o	0	0	0	0	0	0.5	22.2	0	0	0	0	0	0	0	0	0.5
Total	853.9	48	6.2		n 262	81	6	156	184	79	114	562	27	14	47	296	40	36	8	55	1967	
					% 13.3	4.1	0.3	7.9	9.4	4.0	5.8	28.6	1.4	0.7	2.4	15.0	2.0	1.8	0.4	2.8		

Fixed-wing aircraft: AS - Single-engine propeller (e.g. Arctic Tern); AT - Small twin-engine propeller (e.g. Piper Navajo); AH - Heavy twin-engine (e.g. YS-11); AM - Multi-engine (e.g. Lockheed C-130 Hercules, Electra L-188); AJ - Jet (e.g. Boeing 727, Rockwell Sabreliner); A - Unidentified.

Helicopter: HS - Small (e.g. Bell 206); HK - Large (e.g. Bell 205).

Other: B - Boats; P - Person; G - Gunshots.

Bird: E - Eagle (e.g. bald eagle); F - Falcon (e.g. gyrfalcon, peregrine falcon); o - Other birds (e.g. rough-legged hawk, northern harrier, common raven).

Mammal: M - Mammals (e.g. wolf, red fox, river otter, brown bear).

U - Unidentified cause.

^a () mean number of potential disturbances per hour excluding experimental overflights.

^b Includes 2 combined gunshot and person disturbances.

