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THE BALD EAGLE

(*HALIAEETUS LEUCOCEPHALUS ALASCANUS* (TOWNSEND))

AS AN AIRCRAFT HAZARD AT PORT HARDY AIRPORT

by

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ABSTRACT

A significant bird hazard to aircraft occurs at times at Port Hardy Airport through the presence of numbers of northern bald eagles in the vicinity of the airport and its approaches. This study investigated bald eagle abundance, distribution, movement patterns, productivity and feeding habits within the airport vicinity and satellite region. Findings were analyzed in the light of comparable ecological information available on the species. The study extended from October 1972 to October 1974.

The resident summer and winter population within the airport vicinity approximated 3 eagles. Numbers increased gradually from late August until early November (when salmon were spawning in the Keogh River) and when 11 eagles were continuously present.

The maximum number of eagles at any one time was 35. Even a relatively small spawning run of salmon was adequate to attract the eagles and the very large runs did not attract eagles in the same ratio.

Eagle numbers decreased from early November until the herring spawning season in March and April when at least 5 eagles were continuously present.

The potential hazard to aircraft, expressed as the maximum number of eagle sightings and the number of eagles, observed per hour, was greatest during the fall salmon spawning season and the spring herring spawning season for each of the 5 observation areas within the airport vicinity. The population within the study area (200-250 resident eagles) was sufficiently large to dismiss a killing program, even if this was socially acceptable.

Mean nesting density in the study area was at least .1 active nest/lineal km of coastline with .2 active nest/lineal km of coastline in the airport vicinity. Fifty seven per cent of the nests failed but those that produced young averaged 1.4 young/nest. Five active nests were within the area of airport activity and they did not differ in success rate or fledged young per successful nest from nests more remote.

Statistical analysis of distribution data within the airport vicinity revealed that eagle use was significantly greater in the Keogh River mouth region and significantly lower in the inland region than in the remaining observation areas. The aggregation area along the Keogh River in the southeast flight path for runway 1028 presented the greatest hazard to aircraft. Direct eagle flights across the flight path occurred at frequent intervals in September and October and were often at the same elevation as approaching or departing jet aircraft. Since it is not likely that the behaviour of the eagles can be changed, ways of altering the flight paths of the aircraft were considered so as to lessen the frequency

of interaction. This can be done by extension of runway 1028 (by about 610m) to allow approaching or departing Boeing 737 jets to pass over, instead of through, the hazardous zone above the Keogh River.

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The kind hospitality of Sue Baxter and Bruce Manley helped to make my stay at Port Hardy a very enjoyable one.

Finally, I must thank my parents and sister for their continuous encouragement throughout the study.

INTRODUCTION

This is a study arising from the bird hazard to aircraft in the airspace over an airport. To my knowledge it is unique in that the hazard arises from the bald eagle *Haliaeetus leucocephalus alascanus*, a bird regarded as endangered over most of North America but abundant in the vicinity of the study site - Port Hardy airport on the northern end of Vancouver Island (latitude $50^{0}43'12''$N, longitude $127^{0}29'10''$W).

Birds have constituted a hazard to aircraft at airfields in many parts of the world and there is an extensive literature on the problem with various solutions sought and tested. In general the approach to hazard abatement has been to reduce the number of birds present in the airport vicinity (Pearson, 1967). Many techniques have been tried including shooting the birds (Solman, 1970); the use of frightening devices such as detonators (Murton and Wright, 1968); flushing devices such as patrols of the airport; model aircraft flown over the bird aggregations; and the use of trained falcons (Solman, 1970). The most fruitful general approach has been to alter the attractiveness to birds of the airport and surrounding area.

The most effective solution to a bird hazard problem at an airport can only be determined after the biological and physical dimensions of the problem are known. The best strategy, biologically and economically, is situation specific. Thus, it is necessary to determine the species involved; the numbers of individuals involved; the general size of the population and the area from which it is drawn; the seasonal and diel distribution of the bird activity in relation to aircraft movement; the details of bird movement and aggregation; and the nature of the attraction which brings birds to the area and thus governs not only their length of stay but also their activity which creates the hazard.

In the present instance it was already known that the major hazard species was the bald eagle, that it occurred in the vicinity of the airport all year round but that numbers changed with the biological cycle through the season. It was also known that aggregations of eagles and their activity were associated with the spawning of salmon in a river close to the end of the main airport runway. This occurred between the end of August and the end of October.

My study was designed to determine the details of the problem as outlined above and provide a solution which preferably did not involve killing the eagles.

Bald eagles have collided with aircraft at Port Hardy at least twice during recent years. One of these strikes occurred in the late fall of 1975 and involved a small twin engine plane. The aircraft was landing at the time and struck the eagle as it flew up from its perch at the edge of the runway. The aircraft sustained no damage, but the eagle broke its wing. A second collision occurred just prior to this study and involved a Pacific Western Airlines twin engine Convair. The strike occurred just above the runway, killing the eagle and causing considerable damage to the wing of the aircraft. Although strikes have been infrequent, they do confirm the potential hazard to aircraft resulting from eagle activity near the airport.

PART I THE STUDY AREA

The study area was centered upon the northern part of Vancouver Island. Detailed observations were extended over an area of 4,470 sq.km (1,726 sq.mi.) adjacent to Port Hardy. The southern boundary was arbitrarily set at latitude 50^{0}19'N (Fig.1). The remaining boundaries were established by the seacoast and adjacent islands.

In order to provide levels of detail required to gain an understanding of the eagle population, the larger area was subdivided into 3 smaller ones. These zones were:

1.1 PORT HARDY AIRPORT CONTROL ZONE

This zone, based upon criteria established to govern the approach and departure of aircraft, was a circular region with an 8 km radius centered at the airport control tower (Fig.2). It included 20,332 hectares equally divided between land and water. The zone consisted of a heavily forested coastline area where eagles were numerous because of the abundance of food and ideal nesting conditions. The zone also included very productive sections of the Keogh River in terms of salmon stocks and contained several bald eagle breeding territories. In addition to the Keogh River, the Quatse and Tsulquate Rivers traverse the control zone. Each supports a population of anadromous salmon and trout.

Since all air traffic within the zone must report and abide

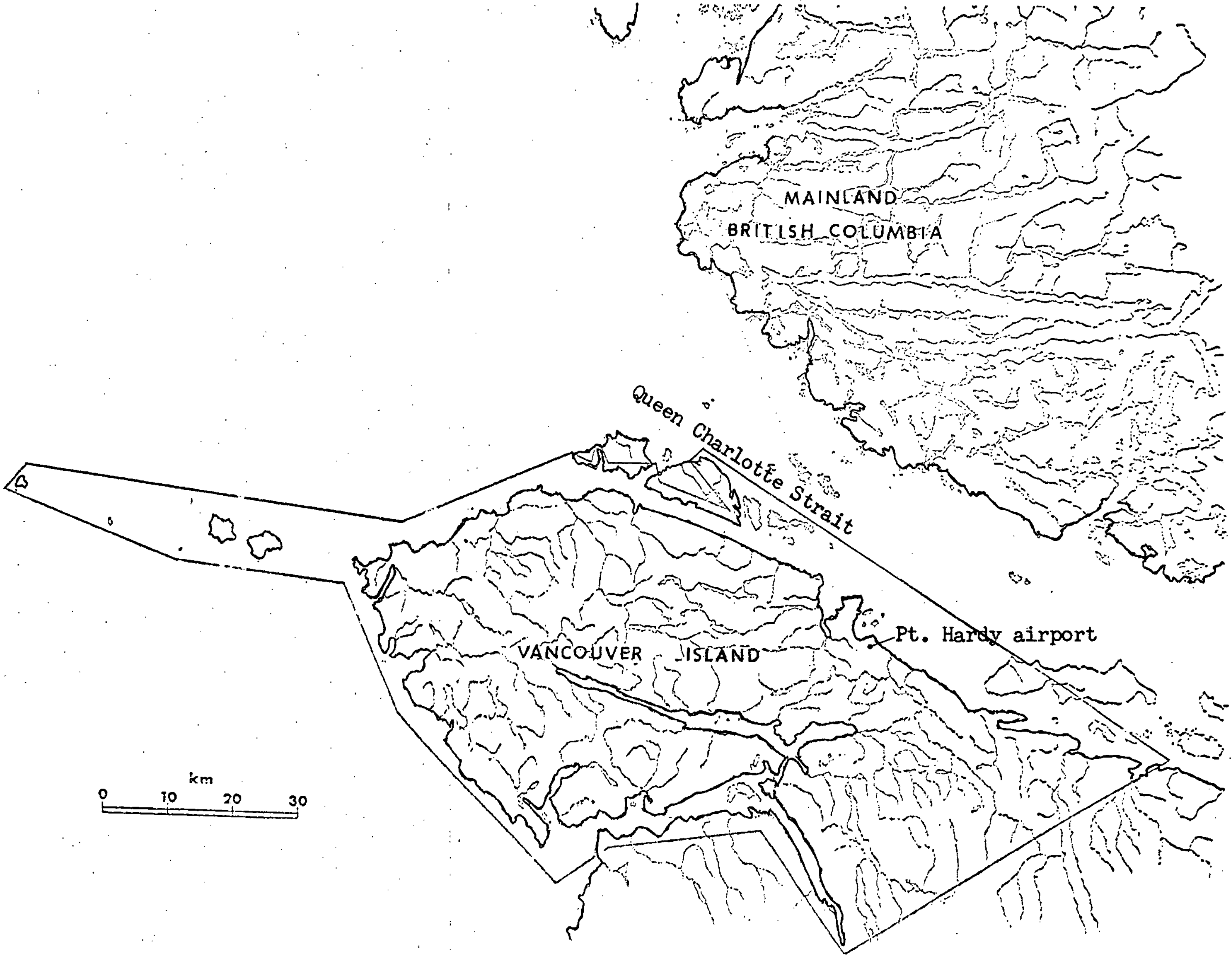


Figure 1 The Study Area

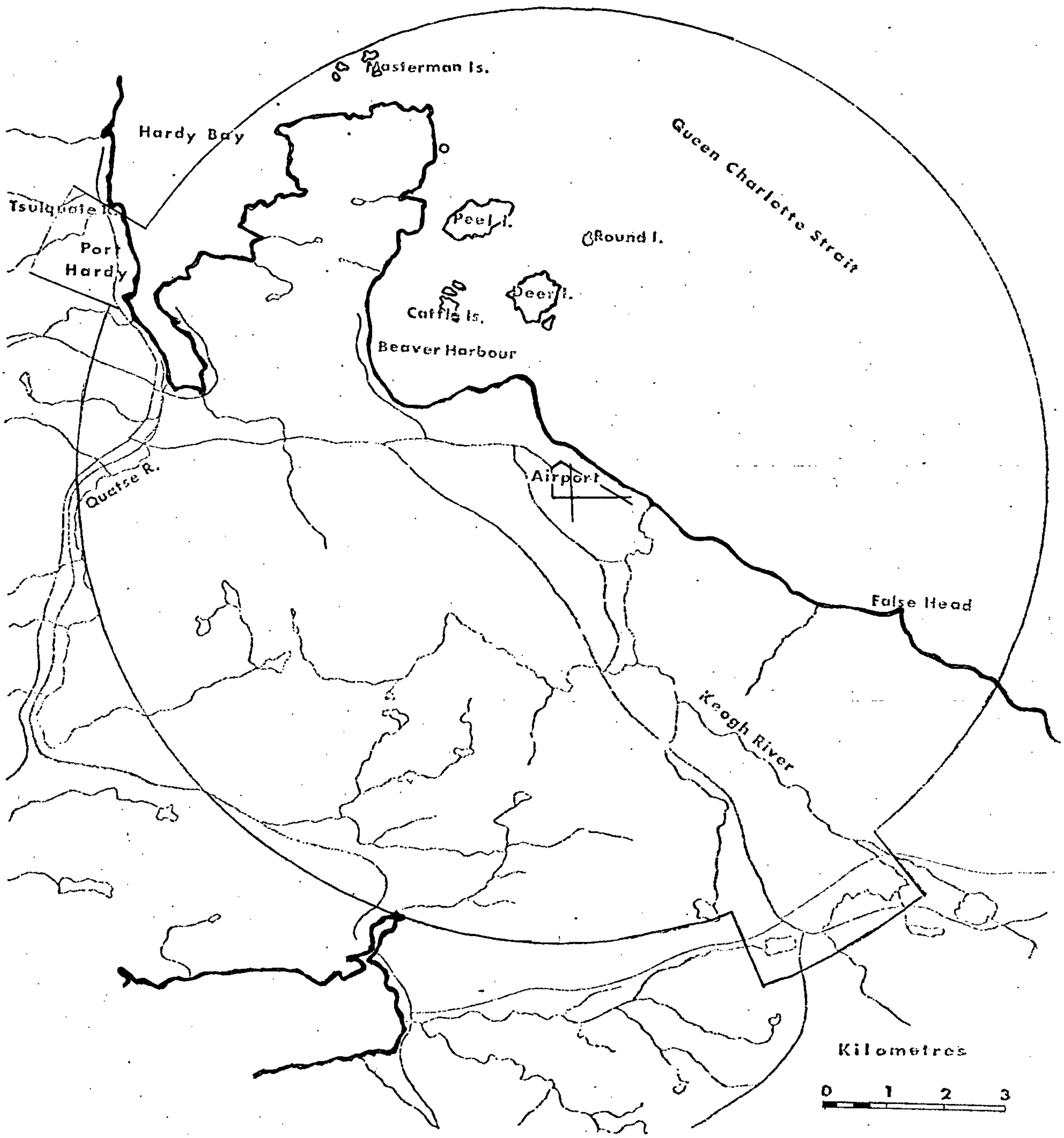


Figure 2 Airport Control Zone

by Ministry of Transport regulations in approaches to and departures from the airport, it was possible to obtain details on flight paths used.

1.2 PORT HARDY AIRPORT VICINITY

The airport vicinity was defined as a circular region within the control zone with a 3,811m radius and an area of 2,282 hectares (8.8 sq.mi.) centered at the control tower (Fig.3). The airport vicinity was that part of the control zone within which the flight paths of aircraft and eagles tended to converge. It was small enough to allow comprehensive coverage of eagle activity on a daily basis and included the airport runways and all flight path clearings and thus the areas of greatest bird hazard to aircraft. It contained the tidal portions of the Keogh River within which salmon were most concentrated and available. Almost the entire airport vicinity was visible from the control tower.

1.3 REGIONAL STUDY AREA

In order to estimate the size and productivity of the eagle population having potential access to the airport, surveys were extended to a larger region from Port Alice in the south to Telegraph Cove in the east, to Triangle Island in the west, and in the north to Cape Sutil (Fig.1). These boundaries were arbitrary and based upon best judgement of myself and others familiar with movement of eagles in this area. Detailed surveys were conducted along the coast of Vancouver

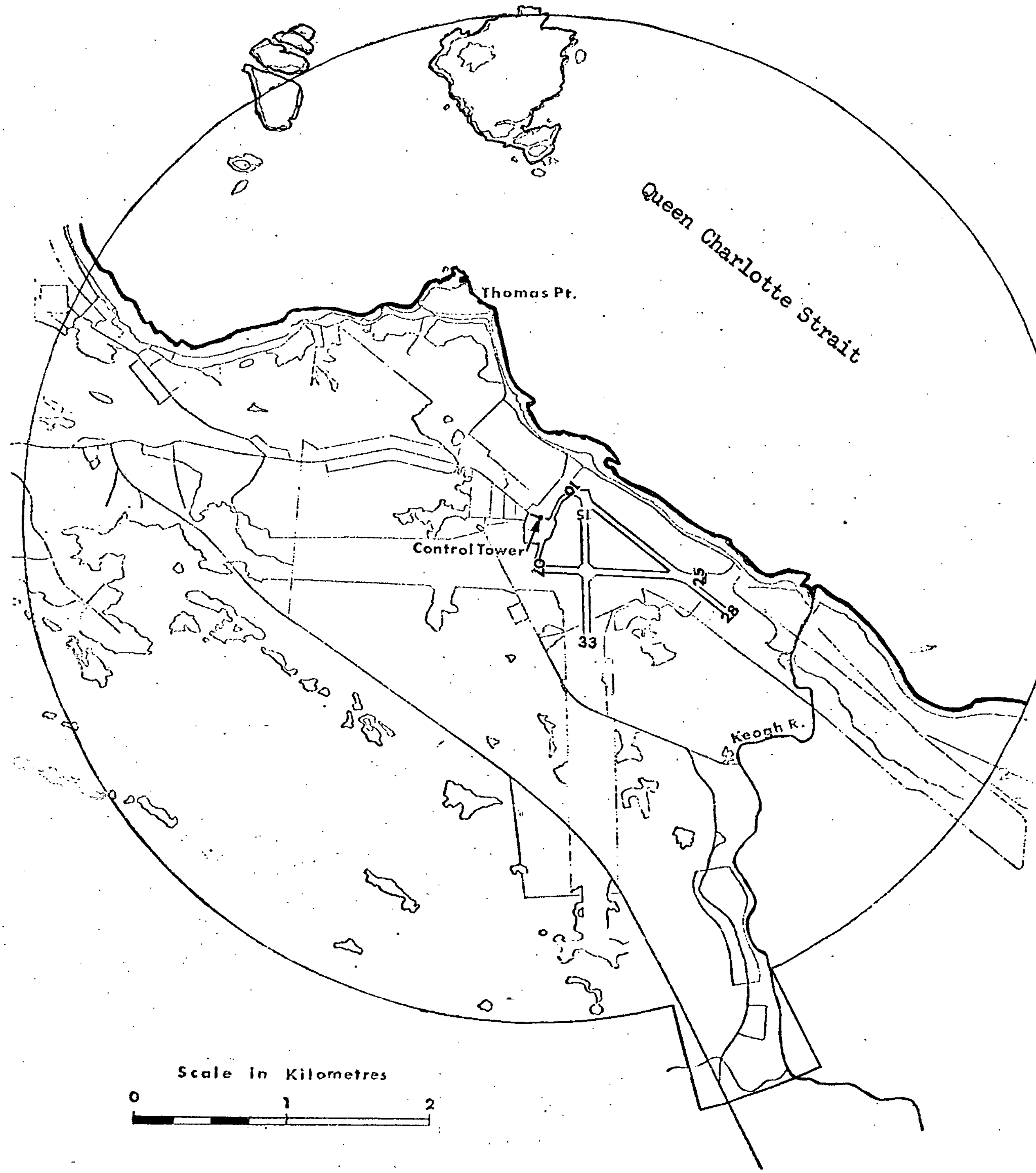


Figure 3 Airport Vicinity

Island from Ledge Point near Port McNeill in the east, to Cape Sutil in the north, to Cape Scott in the west, and to the mouth of Colonial Creek near Port Alice in the south. Islands adjacent to the northeast and northwest coast of Vancouver Island were also surveyed in detail.

The lower reaches of all major rivers along the northeast and northwest coast of Vancouver Island were included. The land area adjacent to roads joining Winter Harbour, Holberg, San Joseph, Port Hardy, Coal Harbour, Juene Landing, Rumble Beach, Port Alice, Port McNeill, Beaver Cove, and Telegraph Cove formed another part of the area studied.

1.4 FAUNA

A knowledge of the fauna provides a view of the potential prey animals available to bald eagles. I had special interest in any local concentrations of food organisms or any physical conditions which might lead to the frequent or periodic availability of food in amounts likely to encourage the aggregation of numbers of eagles. In this review, I have confined myself to those species that offer potential food sources for the eagle.

The bald eagle often feeds largely by scavenging. Large mammals are used by eagles as carrion. However, although black bear, black-tailed deer, hair seals, northern sea lion, and a variety of small whales are present, they are widely distributed, are only sporadically available and are not a regular reason for eagle concentration near the airport. Marine birds on the other hand do concentrate between December and February in waters adjacent to the airport, are hunted by eagles and appear to attract eagle activity though I was unable to develop a statistical expression of this effect.

Species concentrating were surf scoters (Melanitta perspicillata), white-winged scoters (Melanitta deglandi), and greater scaups (Aythya marila).

It was not possible to estimate the biomass of bird carrion available to eagles, or the distribution of dead birds within the area. There was no indication of a concentration of carrion near the airport that would attract eagles. Eagles are known to hunt and kill diving ducks and other marine birds.

The waters adjacent to the airport vicinity including the Keogh, Quatse, and Tsulquate Rivers support a variety of fish. The abundance of spawning salmon in the Keogh River was of particular importance to the present study. Preliminary research (L.G.L. Limited, 1973) indicated that a close relationship might exist between bald eagle abundance, distribution, and activity during the spawning season and the availability of salmon as a food source in the Keogh River. The Keogh is an important spawning river for pink salmon (Oncorhynchus gorbusha Walbaum). In even years (ie. 1972, 1974, etc.), the number of pink salmon entering the Keogh to spawn generally exceeds 75,000 and can be as high as 150,000 (Zyblut, 1972). These numbers can account for up to 10% of all pink salmon spawning in approximately 60 rivers and streams in the Johnstone Strait area (ibid). In odd years (ie. 1973, 1975, etc.), the number of pink salmon entering the Keogh is usually less than 10,000, but on occasion may rise as high as 35,000 (Zyblut and Anderson, 1973). These regular fluctuations between even and odd years are a direct result of the pink salmon's 2 year life cycle.

Up to 3,000 coho (*Oncorhynchus kisutch* Walbaum) and 5,000 chum salmon (*Oncorhynchus keta* Walbaum) may spawn annually in the Keogh River (G. Zealand *pers. comm.*). Chum salmon serve as a food source to eagles. Eagles no doubt feed on some coho salmon although I have no evidence to support this.

The Quatse and Tsulquate Rivers also include important spawning grounds for pink and chum salmon. The distribution and abundance of spawning salmon and their availability as a food source to eagles is considered in 3.5.

Offshore waters included within the control zone support important but diminishing concentrations of Pacific herring (*Clupea pallasii* Valenciennes). Coho, pink, and spring (*Oncorhynchus tshawytscha* Walbaum) salmon use this area as a schooling ground prior to the annual spawning migration. These shallow waters along the coastline contain a large variety of other fish, including many kinds of sculpins, some of the flatfishes, seaperch, smelt, cod, and rockfish (Sebastodes sp.).

The Keogh and Quatse Rivers contain coastal cutthroat (Salmo clarki clarki Richardson), dolly varden (Salvelinus malma Walbaum), and rainbow trout (Salmo gairdneri Richardson) and also support an annual steelhead trout (Salmo gairdneri Richardson) run.

The variety of coastal habitat within the control zone, along with a marked variation in exposure, supports a diverse assemblage of both intertidal and subtidal faunal communities. Univalve and bivalve molluscs, and echinoderms predominate in the inter-tidal zone of the sandstone shelves and rocky coastline, while bivalves and crustaceans are abundant along the gravel and sand beaches. The importance of marine invertebrates as a food source is discussed in section 3.5.

PART 2 STUDY METHODS

2.1 STUDY PERIOD

The two-year study period began on 28 October 1972 and terminated on 31 October 1974. This period included 3 consecutive salmon spawning seasons. The author spent a total of 111 days in the field collecting data. Trips to the study area during 1972, 1973, and 1974 covered every month, with concentration during the autumn and winter period wherein eagles were most numerous in the airport vicinity. The majority of data collection occurred between February and October 1974 when 19 trips, covering every month, were made into the study area.

2.2 CONTROL TOWER OBSERVATIONS

The Port Hardy airport control tower provided an ideal vantage point from which to observe eagle activity within the control zone. Adult and immature birds could normally be distinguished within 1.6 km of the tower. Under favourable conditions, eagles could be sighted within 4.5 km of the tower.

The first careful documentation of eagle activity within the control zone covered the period from October 1971 to May 1972. Eagle sightings were recorded in a log continuously from October 28, 1972 until October 31, 1974. Data recorded included the date, time, location, activity, weather conditions,

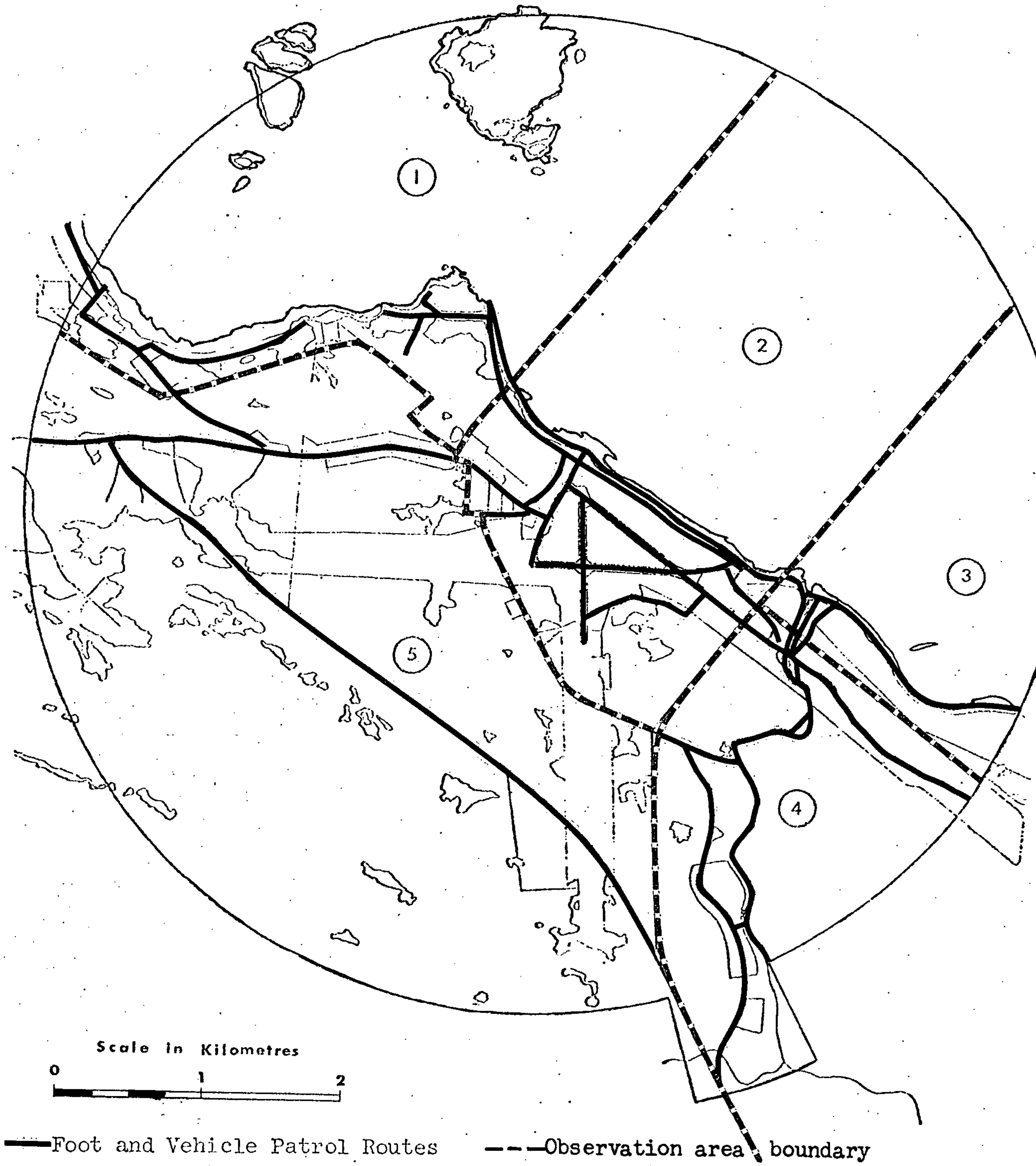


Figure 4. Airport vicinity observation areas and ground survey routes.

number of eagles and their age category. A rating scale was developed whereby light activity was defined as 1 to 2 eagles observed during an 8 hour period, moderate as 3 to 5 eagles, heavy as 6 to 10, and extensive as more than 10. From May to October 1972, only unusual sightings were recorded by control tower personnel.

2.3 GROUND SURVEYS

Systematic ground surveys were carried out to determine bald eagle abundance, distribution, feeding behaviour, and other activity patterns. Other factors, such as nest sites and the salmon spawning sequence, were documented concurrently. Ground surveys were made on foot and by vehicle. Three ground survey areas were delineated.

2.3.1 Airport Vicinity

The airport vicinity, which received the most comprehensive surveys, was divided into 5 observation areas of comparable size as shown in Figure 4. During each trip to the study area an attempt was made to survey all observation sites using predetermined routes. The amount of time spent in each area varied according to aircraft travel through that area. Coverage was greatest in those areas which were most frequently used by jet and other aircraft. Jet approaches and departures were restricted to runway 1028 (area 2)(Fig. 3) and the corresponding flight paths in areas 1, 3 and 4. Area

5, located inland and not utilized by jets, received the least coverage. Observation points and viewing procedures were selected for each survey route. Seventy-five percent of the airport vicinity could not be viewed from the ground because of tall trees.

Eagle sightings were recorded either in field note books or on tape. Data included standard information plus activity, location, and at times estimates of altitudes although the latter were difficult to approximate accurately. An estimate of the minimum number of adult and immature eagles continuously frequenting the airport vicinity was made following each ground survey. This estimate was arrived at by taking the total number of sightings and allowing for repeat sightings of the same birds. This was accomplished by considering the total number of eagles in any area at any one time, individual characteristics (eg. absence of certain primary or tail feathers, coloration patterns, etc.) and the observed movement of the same birds between different areas.

The potential hazard to aircraft arises primarily from the number of eagles in the airport vicinity, the number of eagle flights per day across runways and their approaches, and the altitude of these flights. In an attempt to assess this hazard, the maximum number of eagle sightings in each of the 5 observation areas was recorded. Each eagle flight across the observation area was regarded as a separate observation whether or not the same birds were involved. Thus this figure is a product of eagle numbers and their flight frequency. My concern was with potential contacts between eagles and aircraft.

In order to provide a standard measurement of eagle abundance for any of the 5 observation areas at any time (and of cumulative activity in the air over the airport), the number of eagles/sightings observed per hour of observation time was calculated for both the minimum number of eagles and the maximum number of eagle sightings. This was accomplished by dividing the number of eagles/sightings observed in an area by the number of hours spent observing in that area. This standard measurement was applied to the monthly totals of the minimum number of eagles using the airport vicinity as outlined below:

$$\text{No. of eagles observed/hr./area} = \frac{A + I + U}{T}$$

where A = no. of adults/area/month

I = no. of immatures/area/month

U = no. of unknown/area/month

T = total observation time/area/month

The maximum number of eagle sightings made per hour on a daily basis was determined using the formula given above by substituting total sightings for the number of different individuals.

In order to identify aggregation areas within each observation area, the location of individual eagles when first observed was plotted on a daily basis. Areas with sighting frequencies (sightings/day) at least 5 times that occurring in the remainder of the observation area were delineated as aggregation areas. Composite maps were prepared for the fall of 1972 and 1973, the first 8 months of 1974, and the fall of 1974. A similar method was used throughout the remainder of the study area to identify important areas of use.

Blinds were constructed and used for observations near the mouth of the Keogh River and in the southeast flight path for runway 1028. All nest trees adjacent to the airport were examined in detail. Nest tree data included location, species, tree height, height of nest, distance from coastline, and food remains at the base of the tree.

2.3.2 Control Zone

The airport control zone (excluding the airport vicinity) served as the second major ground survey area. Foot patrols were carried out in the Quatse River area, the Keogh River area, and along the coastline from the airport to False Head. All roadways within the control zone were included except for one short restricted logging road. An attempt was made to patrol all major roadways during each trip to the study area. Data were collected and recorded using the technique outlined in 2.3.1.

2.3.3 Regional Study Area

The regional study area (excluding the control zone) comprised the remaining ground survey area (4,267 sq. km). It was regarded as potentially important as a source of eagles moving into the airport area. Data were collected and recorded using methods outlined in 2.3.1.

2.4 BOAT SURVEYS

Boat surveys were conducted along coastal regions in the control zone and regional study area and consisted of travelling parallel to the shoreline at a distance usually varying from 100 to 300 m. This method allowed a careful surveillance of the coastal regions for bald eagle nests and eagle activity. Boat surveys extended over 470 km representing 62% of the total coastline within the regional study area. The remaining 28% was too exposed for small craft access and was surveyed only by air.

2.5 AERIAL SURVEYS

Aerial surveys were conducted in both the control zone and regional study area by flying parallel to the coastline a short distance offshore at an elevation of approximately 100 m above sea level. This method allowed a careful examination for bald eagle nests and eagle activity. Aerial surveys were conducted on at least 1 day of each month in 1974 from April through August to determine nesting success. The possibility of detrimental effects upon eagle productivity resulting from disturbance created by near passage of a helicopter was a consideration which limited the collection of data on productivity and nesting success to certain areas.

2.6 MARKING AND TELEMETRIC PROJECT

An attempt was made to capture, band, mark for visual recognition, and release eagles frequenting the airport region in order to obtain details on distances the airport was drawing in known birds.

The numbers required to gain useful results and the difficulties in capturing forced abandoment of this approach. For the same reasons, attempts to use radiosondes attached to eagles in order to improve data on eagle activity patterns had to be abandoned.

2.7 FOOD RELATIONSHIPS

Seasonal feeding habits and the availability of food to bald eagles were recorded throughout the study period. These studies were part of an investigation to determine the environmental factors that attract eagles or facilitate their use of the airport control zone.

Data on feeding habits were based upon direct observations, nest contents, and analysis of food remains at the base of or adjacent to nest trees. Seasonal food habits could not be determined by stomach analyses because the birds could not be shot. All sightings involving feeding activity were recorded.

Thorough checks for remains of food items were carried out near the base of 10 out of the 17 nest trees in the control zone. Three of the 17 nest trees were climbed. All 17 nests (9 of which were active in 1974) within the control zone were examined carefully by helicopter. Food items contained within each nest were recorded.

The availability of fish, birds, and other food items was documented seasonally as outlined below. Emphasis was placed on spawning salmon because of their importance in the diet of bald eagles within the study area. Annual stock escapements were recorded by Federal Fisheries personnel for pink, chum, and coho salmon to all spawning rivers within the control zone. In addition, I made regular patrols along spawning channels to determine the approximate number of spawners and pre-spawners (using methods similar to those proposed by Sheridan, 1962), the stage of spawning, and the condition of spawners for each species. A number of patrols were conducted in conjunction with the Federal Department of Fisheries. River levels were recorded regularly during the salmon spawning season. The concentrated schooling of salmon prior to upstream migration was also documented.

The presence of Pacific herring (Clupea pallasii) was documented in Beaver Harbour during the spring spawning period. I made no attempt to assess the availability of other species of fish.

Occurrences of large numbers of sea birds within the airport vicinity were recorded as potential food sources.

2.8 FLIGHT PATH RECORDING

The approach and departure flight paths of Boeing 737 aircraft at Port Hardy airport were documented during 1973 and 1974. Recordings were made both in-flight and on the ground. This project was undertaken to permit determination of the areas wherein aircraft approach and departure paths were congruent with eagle flight paths.

Three methods were used to document flight path regimes. The first and most precise involved recording altimeter readings during approaches and departures at various distances from the airport. Distances were determined by noting the exact location directly beneath the jet at the time of each altimeter reading. Data from this method were collected by the author when observing from the cockpit during 16 approaches and 4 departures.

The second in-flight method involved recording altimeter readings at various distances from the airport as shown by a range instrument in the cockpit. This method was used during 3 approaches at some distance from the airport when it was impossible to fix an exact location by ground reference.

The third method consisted of estimating altitudes from the ground as the jet passed over predetermined locations during 9 approaches and 5 departures. An approaching and a departing jet were photographed as they passed over these locations and the actual altitudes were subsequently determined from the photographs.

Ascent and descent patterns varied due to factors such as fuel loads, passengers loads, weather conditions and it was necessary to document this variability in flight paths.

A number of approaches and departures were monitored both on the ground and in flight without recording altitudes. Instead, flight path routes were recorded as well as any eagles observed.

PART 3 RESULTS

3.1 ABUNDANCE

Accurate numerical information on numbers, distribution, and behaviour of eagles adjacent to the airport is essential not only to document the extent of the potential hazard but also to provide the baseline against which the results of possible mitigative actions can be measured.

3.1.1 Airport Vicinity

The average number of eagles sighted/day (on a monthly basis) from the control tower on or near runways and their approaches from October, 1971 through October, 1974 is graphed in Figure 5. Figure 6 shows the minimum number of adults and immatures continuously frequenting the airport vicinity and their total from July, 1972 to October, 1974, (excepting January through August, 1973 when the author was not in the field). The minimum number of eagles was determined using the method outlined in 2.3.1.

The "resident" summer and winter eagle population within the airport vicinity approximated 3 individuals (2 adults, 1 immature) during the study period. Thus the major hazard resulted from immigrant birds.

While the number of eagles present is an important part of the bird hazard problem, the hazard itself arises from eagle activity across the flight path areas. The maximum number of eagle sightings/hr. for any given day (as defined in 2.3.1) for each observation area during the period October 1972 through October 1974 is given in Fig. 7.

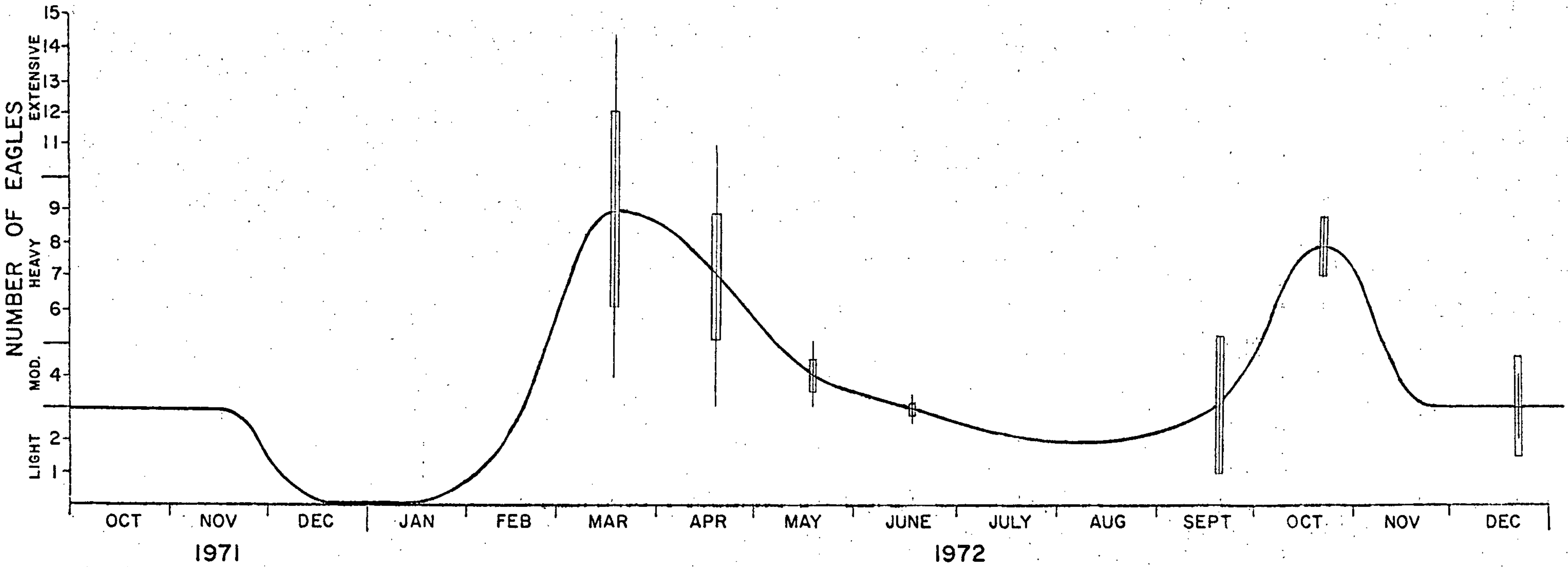
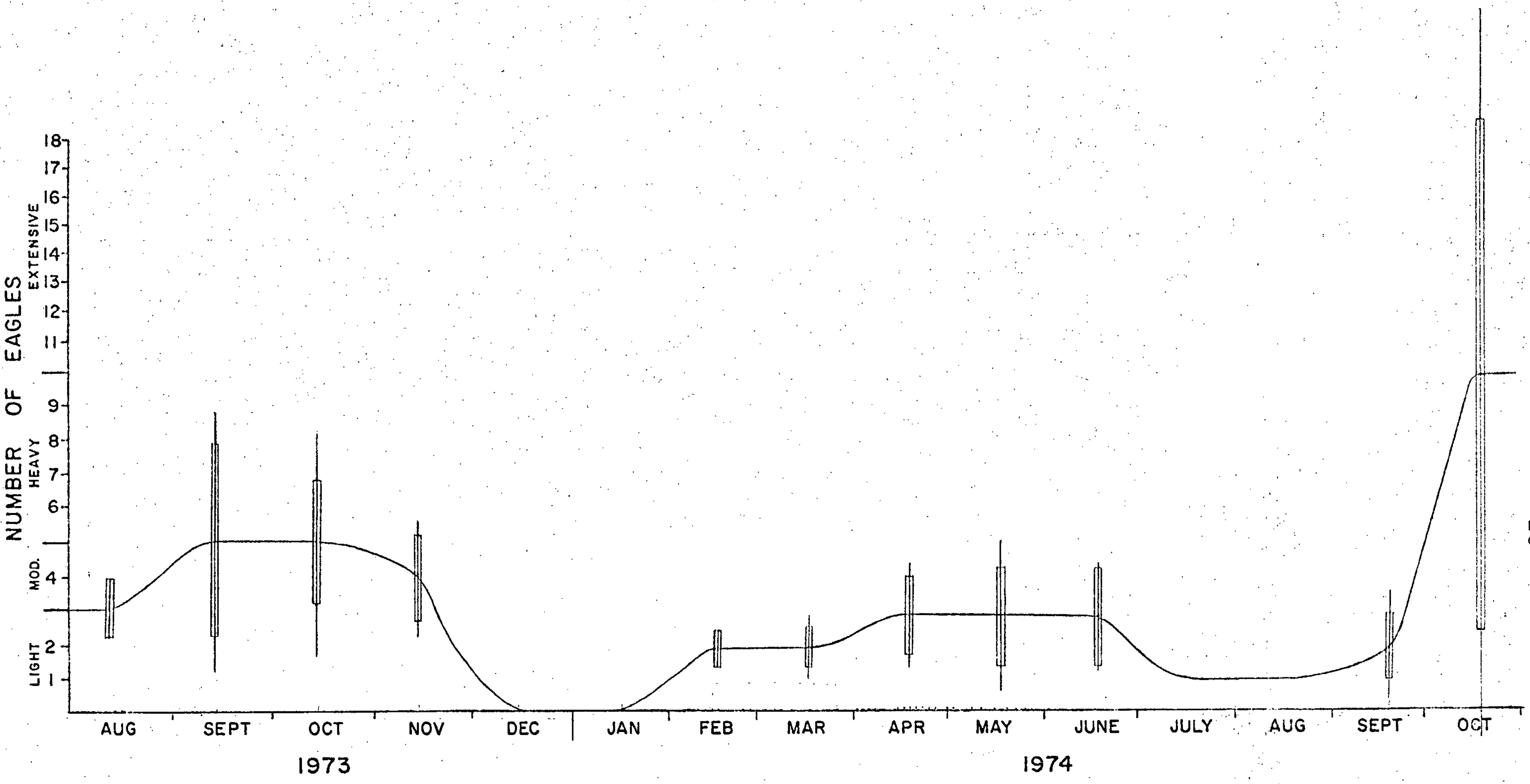


Figure 5. Average number of eagles sighted/day from the control tower on or near runways and their approaches from October, 1971 - October, 1974. Single bars show standard deviation on either side of the mean, double bars show 1.96 standard deviation/ $\sqrt{\text{sample size}}$.



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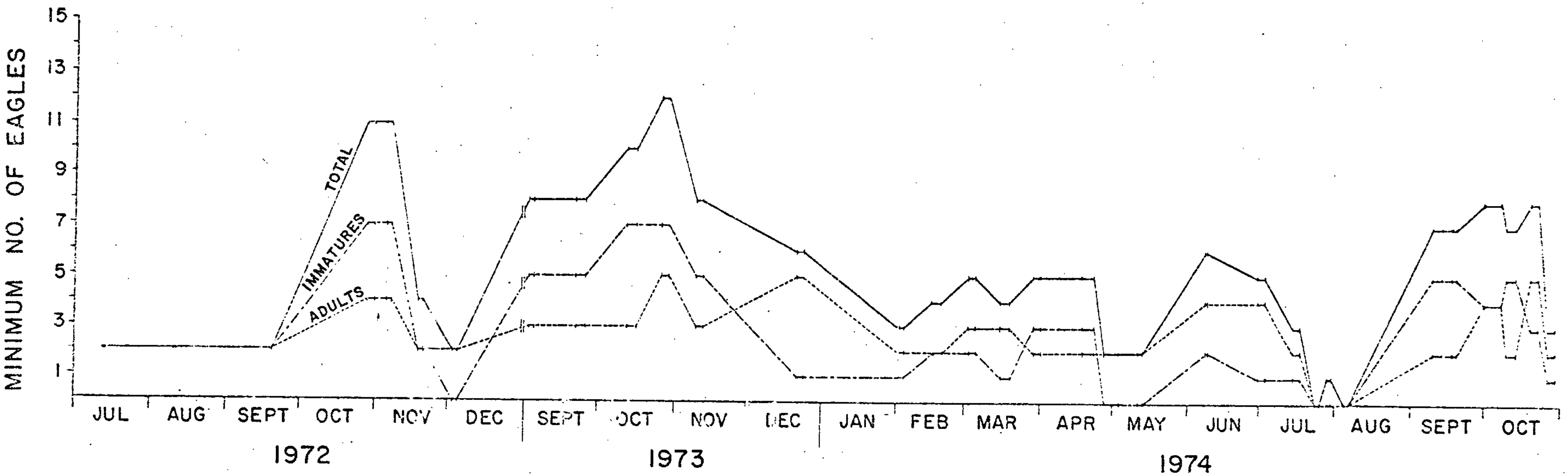


Figure 6 . Minimum number of eagles continuously frequenting the airport vicinity from July, 1972 - October, 1974.

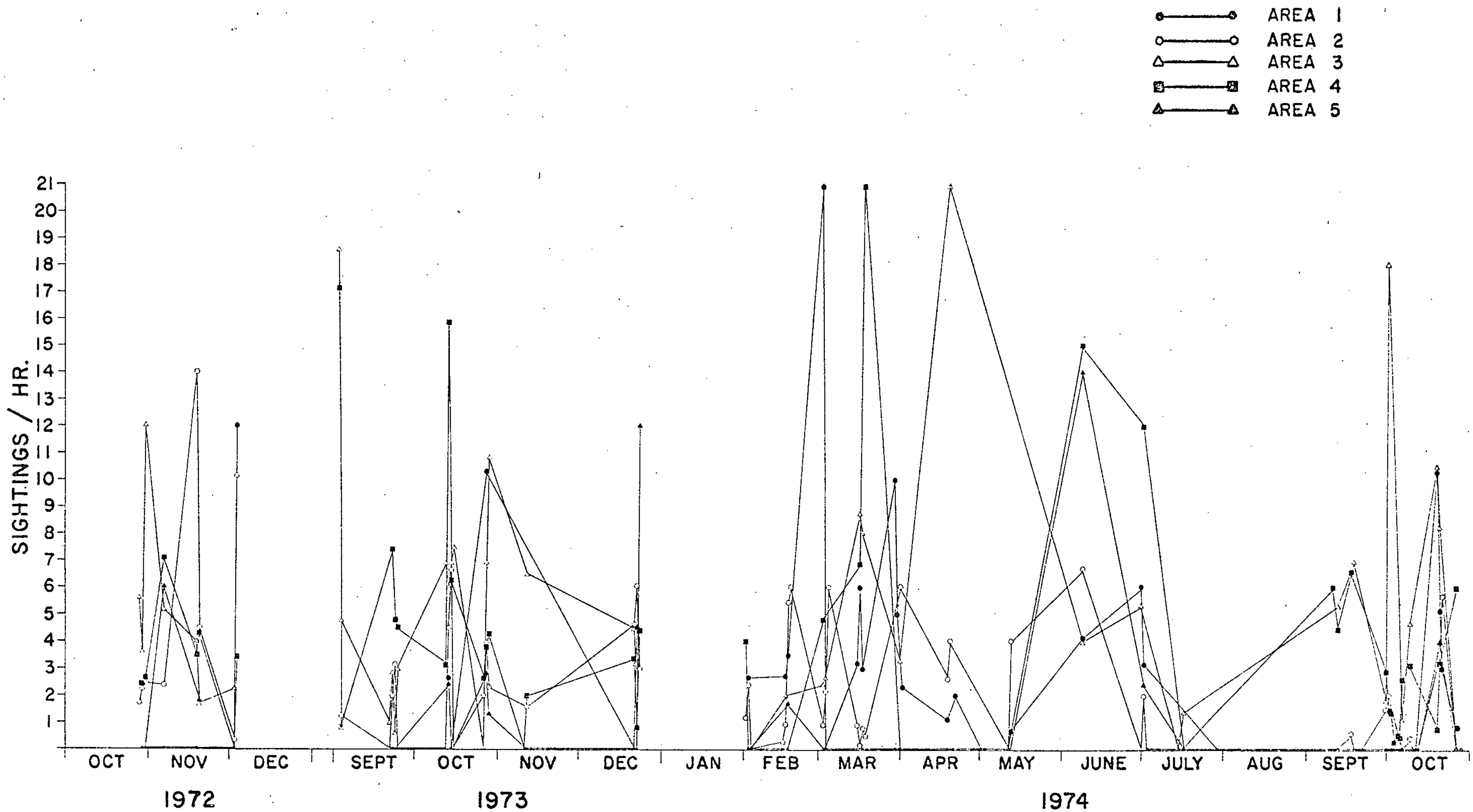


Figure 7. Sightings/hour for airport vicinity observation areas based on the maximum number of eagles using each area from October, 1972 - October, 1974.

These data show the frequency of eagle occurrence within each area and suggest that use was generally greatest during the fall salmon spawning season and the spring herring spawning season. Fall values peaked at 14.0/hr. in November 1972, 18.5/hr. in September 1973, and 18.0/hr. in October 1974. Spring values peaked at 21.0/hr. during March and April 1974.

Successive counts from the 1972 salmon spawning season were averaged (September through December; 4.8 sightings/hr) and compared statistically with average counts from the winter of 1974 (January through February; 2.1 sightings/hr.), the spring herring spawning season of 1974 (March through April; 5.0 sightings/hr.), and the summer of 1974 (May through August; 3.3 sightings/hr.) to reveal significant differences between seasons. The null hypothesis adopted assumed a normal abundance for all 4 seasons ($H_0: u_1 = u_2 = u_3 = u_4$) at the p= .05 and p= .10 confidence levels. Seasonal abundance values were compared using the student's t distribution formula

$$\bar{x} - t \frac{s}{\sqrt{n}} < u < \bar{x} + t \frac{s}{\sqrt{n}}$$

where u = population mean,

s = sample standard deviation, and

t = student's t variable.

Abundance values lying outside of the range determined by the above relationship were considered to be significantly different.

Winter abundance during 1974 was significantly different (ie. lower) from all other seasons and abundance values from the fall of 1972 and spring of 1974 were significantly different (ie. greater) from summer and winter values at the p = .10 confidence level but not at the .05 level. Accordingly, H_0 was rejected.

The number of eagles, known to be different individuals, observed per hour for each of the 5 observation areas, was also greatest during the fall and spring. Average sightings per hour on a monthly basis reached 5.8 for area 2 in November 1972, 4.2 for area 4 in October 1973, and 21.0 for area 3 in April 1974.

3.1.2 Control Zone

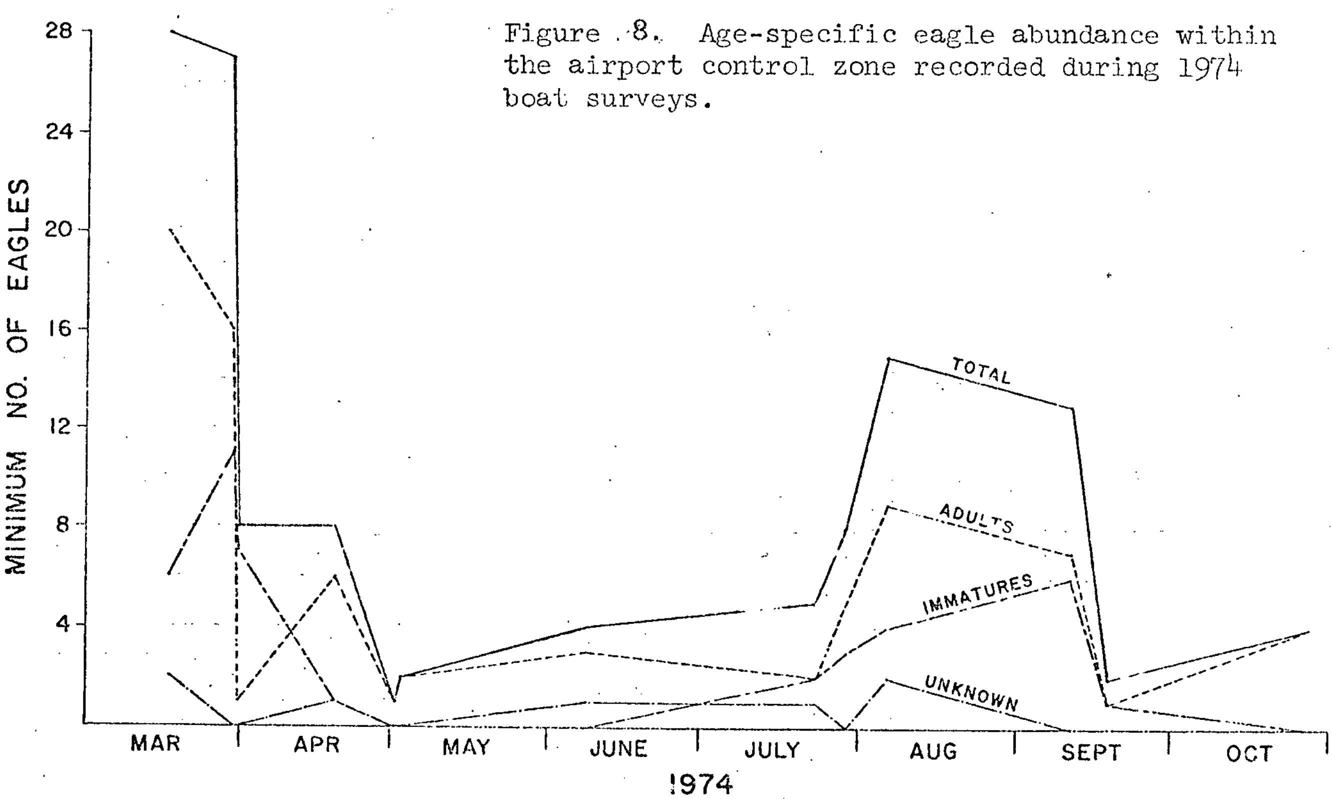
Age-specific abundance data determined during 1974 boat surveys are presented in Fig. 8. Control zone abundance appeared to be highest in spring and summer. Eagle numbers peaked in March when 28 individuals were observed in 1 day.

3.1.3 Regional Findings

Observations recorded during ground, boat, and aerial surveys indicated that the resident bald eagle population within the regional study area numbered between 200 and 250.

During 1974, 196 individuals were noted during aerial surveys (163 adults, 23 immatures, 16 unknowns) and 109 during boat surveys excluding Quatsino Narrows (70 adults, 23 immatures, 16 unknowns). The resident population appeared to be composed primarily of adult birds as evidenced by the above observations;

Figure 8. Age-specific eagle abundance within the airport control zone recorded during 1974 boat surveys.



83% of the eagles sighted during aerial surveys and 64% during boat surveys were adults. However, aerial surveys were biased for adults since they concentrated on nests attended by adults. Boat surveys were not biased for adults or immatures and hence gave the most reliable age ratios.

Results from 5 separate boat surveys of Quatsino Narrows from April 22 - 30, 1974 yielded an average of 96 eagles with a range from 35 to 133. The 2 largest counts of 130 and 133 are likely a reliable indication of the total concentration at the time. Immatures were more abundant than adults in this grouping, representing at least 54% of all age-specific sightings. (This was to be expected since many adults were incubating eggs or establishing territories during this period).

Eagles observed at Quatsino Narrows represented not only the small resident population but more importantly, a gathering of eagles from adjacent regions, particularly Quatsino Sound and the adjoining inlets. This gathering represented only a portion of the population within the regional study area. At least 58 additional eagles were observed on both the east coast (Goletas Channel) and the west coast (Quatsino Sound and adjoining inlets) of Vancouver Island during the time of the Quatsino Narrows surveys.

3.2 DISTRIBUTION AND AIRCRAFT HAZARD

In order to document areas of significant hazard to aircraft, it was necessary to determine the seasonal distribution of eagles near the airport and compare this with the flight paths used by approaching and departing jets. Furthermore, in order to identify the source of local concentrations it was necessary to investigate bald eagle distribution throughout the regional study area.

3.2.1 Airport Vicinity

Control tower observations indicated continual eagle use of the airport vicinity from October 1971 through October 1974 with 5 areas of preferred use depending on the season:

1. airspace directly over and adjacent to the runways and infield;
2. runways (especially near intersection of 1028 and 2507);
3. Thomas Pt. area;
4. coastal region from Thomas Pt. to the mouth of the Keogh River; and
5. mouth and lower reaches of the Keogh River.

Eagle use of the airspace over and adjacent to the runways and infield was continual throughout the year with greatest activity occurring during spring and fall when more than 6 eagles were often recorded at a time. Eagles were most often observed perched on the runways during the fall. Up to 6 eagles at a time were seen during this time of the year. Eagle use of the Thomas Point area, as determined by control tower observations, was greatest during the spring and summer when at least 3 eagles were often seen soaring in the area. The coastal region from Thomas Point to the mouth of the Keogh River was used regularly as a travel route. Its importance to eagles was greatest during the summer and winter when their diet was composed primarily of marine fish, birds, and invertebrates in the absence of spawning salmon and herring. Eagle use of the mouth and lower reaches of the Keogh River was by far the greatest during the fall in conjunction with the salmon spawning season. Up to 12 eagles were often observed soaring in the area near the peak of the pink salmon run.

It was thought that seasonal distribution would be reflected in sightings/hr. (Fig. 7) for each of the 5 observation areas. These data were subjected to the student's t test between areas and between seasons to reveal significant differences. Successive counts from each observation area during the 1972, 1973, and 1974 salmon spawning seasons (September through December) were averaged and compared with counts from each of the observation areas during the winter of 1974 (January through February), the spring herring spawning season of 1974 (March through April), and the summer of 1974 (May through August). Similarly, counts between observation areas during the same season were also tested.

The average abundance values and standard deviations for each of the 5 observation areas during all 4 seasons were calculated to be 3.4 sightings/hr (s = 1.2), 2.5 sightings/hr (s = .2), 4.4 sightings/hr (s = 2.5), 3.3 sightings/hr (s = 1.5), and 1.1 sightings/hr (s = .7) for observation area 1, 2, 3, 4 and 5 respectively. The average abundance values and standard deviations for all 5 observation areas during each of the 4 seasons were calculated to be 3.3 sightings/hr (s = 1.4), 1.8 sightings/hr (s = .7), 3.7 sightings/hr (s = 2.6), and 2.8 sightings/hr (s = 1.8) for the fall, winter, spring, and summer respectively.

The null hypothesis adopted assumed a normal distribution for all observation areas and for all seasons at the p = .10 confidence level. Average abundance values during all 4 seasons for observation areas 3 and 5 were significantly different (ie. greater and lower respectively) than those for the remaining 3 observation areas. Average abundance values for all 5 observations areas during the winter and spring of 1974 differed significantly (ie. lower and greater respectively) than those recorded during summer and fall. Accordingly, H_0 was rejected.

Aggregation areas within the airport vicinity which coincided with flight paths of approaching or departing jets created a significant hazard. Minimum sightings plotted on a daily basis for the fall of 1972, 1973 and 1974 indicated 2 aggregation areas; one in observation area 3 and the other in observation area 4 as shown in Fig. 9. The aggregation area in observation

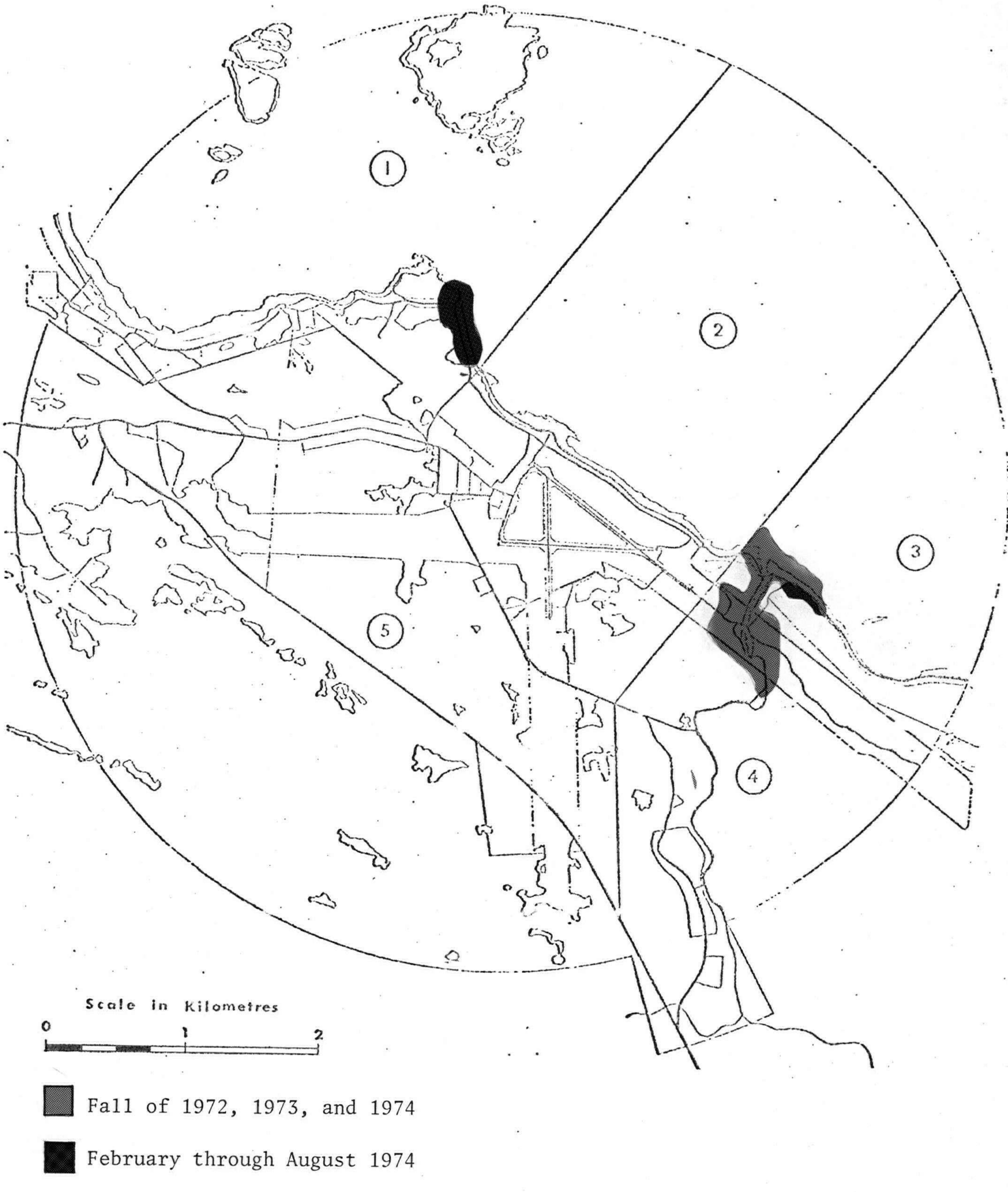


Figure 9. Aggregation areas within the airport vicinity observation areas during the fall of 1972, 1973, and 1974 and from February through August 1974.

area 3 was centered upon the mouth of the Keogh River and the adjacent coastline. This area of eagle activity was located approximately 800 m directly off the east end of a runway not used by jets and therefore did not present a major hazard.

The aggregation area in observation area 4 was located within the flight path for runway 1028 in the vicinity of the Keogh River. The availability of salmon at shallow rapids and pools, the open nature of the flight path, and the excellent view from tall trees along the clearing lines, all contributed to prominent eagle use in the area. This aggregation presented the greatest hazard to aircraft of any since it was located in an active flight path a very short distance (<700m) from the end of runway 1028, the only runway used by Boeing 737 jets.

Eagle activity in this area was strongly influenced by the availability of spawning salmon which was controlled by time of year and river stage. Direct flights across the flight path occurred continually from September through October and were often at the same elevation as departing or approaching jet aircraft.

Results from jet flight path recording exercises outlined in section 2.8 are presented in Figs. 10 and 17. These findings indicate that approaching and departing jets were flying directly

Figure 10. Boeing 737 jet approach pattern to runway 1028 from the southeast. (Best line fit for all data points)

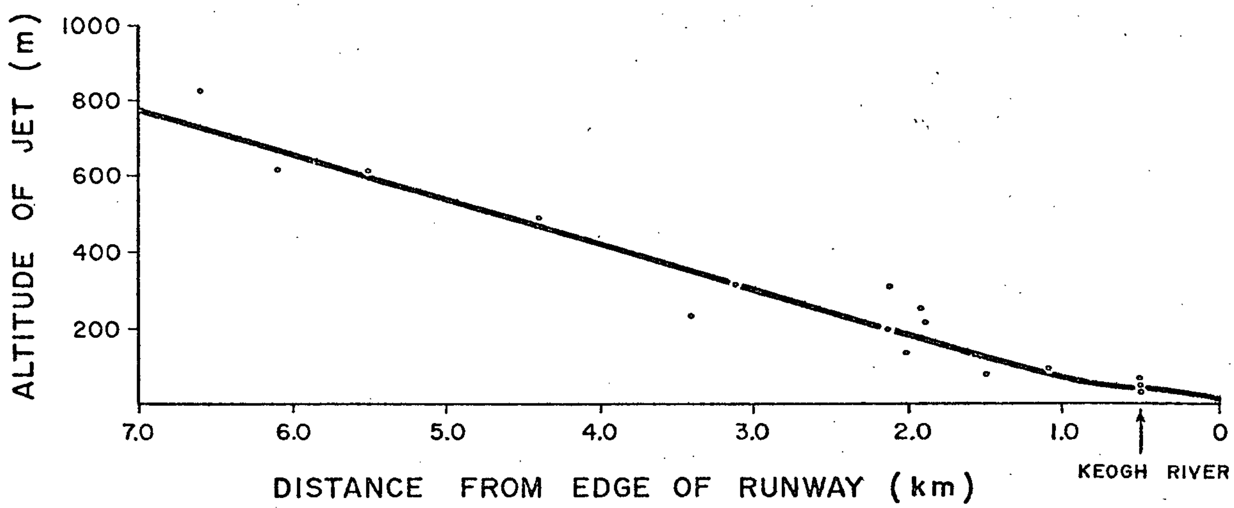
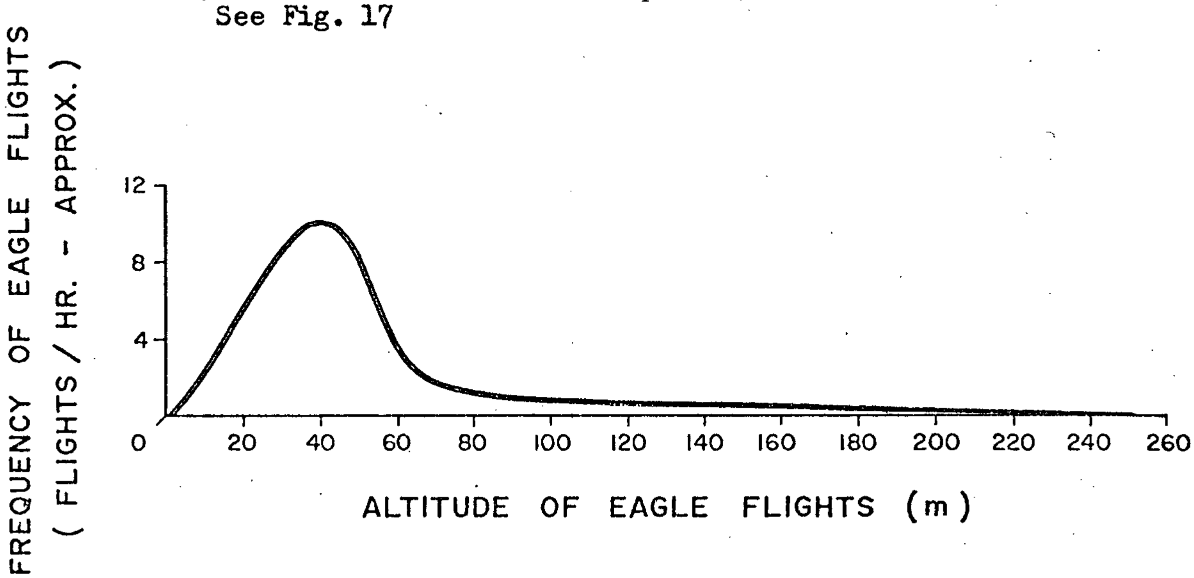


Figure 11. Frequency and altitude of eagle flights over the Keogh River during the fall of 1972, 1973, and 1974. (Best line fit for all data points)
See Fig. 17



through the hazardous zone above the Keogh River. This led to a near-strike incident in late September 1973 when the pilot flying a jet departing towards the southeast had to take evasive action to prevent a collision with several eagles circling above the Keogh River.

The majority of autumn eagle activity (approximately 80%) in the flight path consisted of direct flights above the river. Average flight elevation appeared to vary in response to water level and number of salmon present. Figure 11 gives a frequency curve of eagle flight altitudes over the Keogh River during the fall of 1972, 1973, and 1974. Most flights occurred between 2 and 60 m. Flights were most frequent at approximately 40 m above the river which coincided with the approximate altitude of approaching jets when over the river (Fig. 10). Additional data on flight patterns are presented in 3.6.

Increased salmon abundance and availability resulted in a decrease in the average elevation of direct flights, extended perching near tops of tall trees on both sides of the flight path, and frequent perching along the river bank especially during low water conditions.

Soaring often occurred high over the river when clear skies prevailed along with brisk southeast winds and cool temperatures. Soaring was observed up to 250 m which marked the upward limit of the aggregation area above and adjacent to the Keogh River (Fig. 17).

An area of moderate use was recorded along the lower reaches of the Keogh River excluding the flight path clearing and river mouth. This linear region received regular useage during the fall but substantially less than in the flight path or at the river mouth. Eagle activity in this part of the airport vicinity did not coincide with jet flight paths and therefore did not present a hazard.

Aggregation areas identified by plotting minimum sightings on a daily basis from February through August 1974 occurred in both observation areas 1 and 3 as shown in Figure 9. Eagle concentration in observation area 1 was near Thomas Point and did not present a major hazard to aircraft since it was removed from the northwest flight path for runway 1028.

The aggregation area in observation area 3 was located just southeast along the coastline from the mouth of the Keogh River. Eagle use at this location was concentrated around a successful nest and presented a minor hazard to aircraft since it was adjacent to the east flight path for runway 1028.

An area of moderate use was recorded along the coastline in observation area 2. This region was employed regularly throughout the year as a travel route. Eagles flying to and from the coastline over runway 1028 presented a hazard to landing and departing aircraft.

3.2.2 Control Zone

Eagle distribution in the control zone falls into 2 categories on a year-round basis. During the nesting season, all but a few adult eagles were at their nesting territories. They spent almost all of their time at these sites and usually did their feeding within 3 km of the nest. During this period, immatures were present in small numbers and were dispersed apparently at random along the coastline.

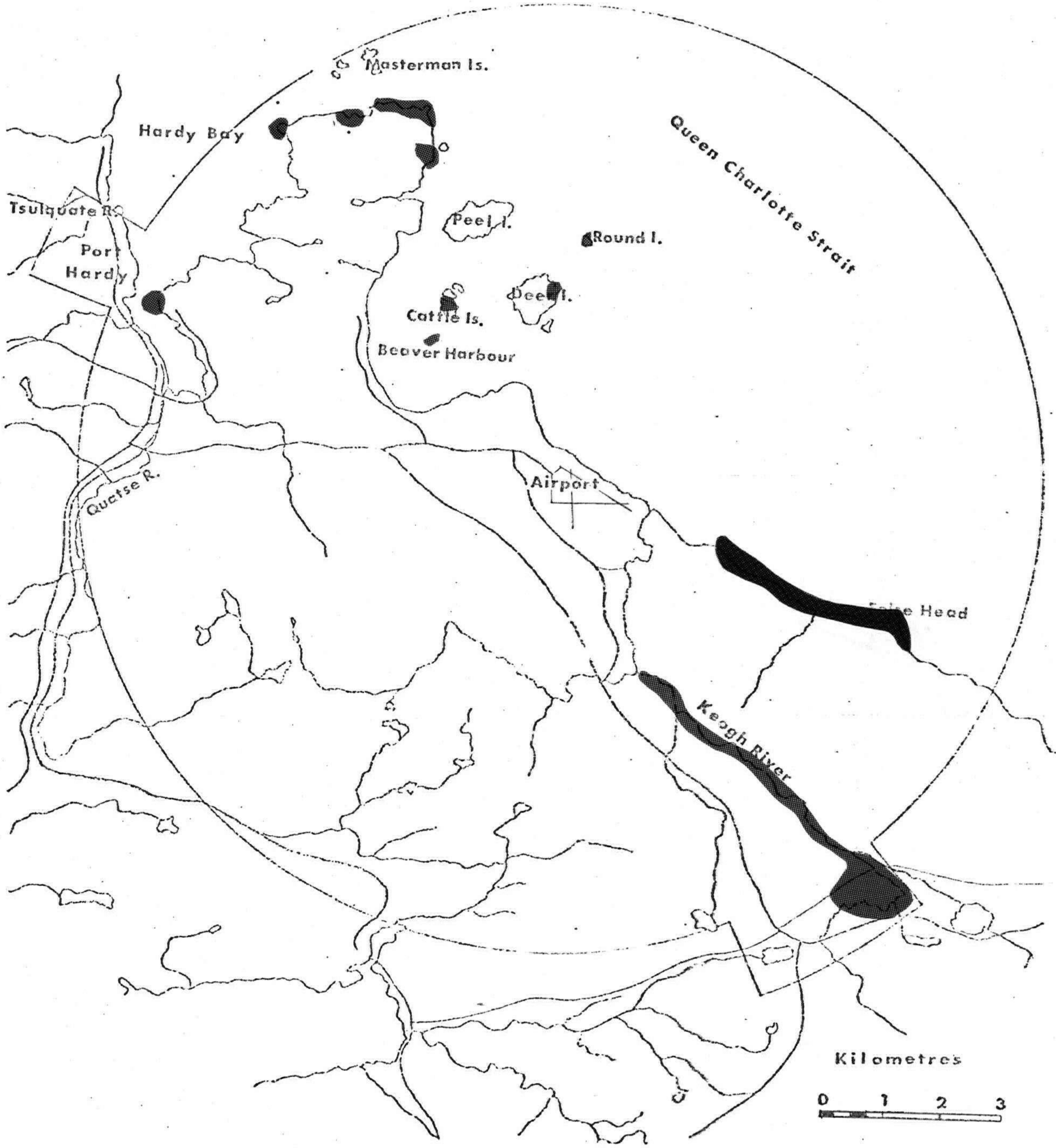
During the non-nesting season (ie. August through March), eagle distribution was primarily regulated by the location of readily available food sources and coastline locations offering vantage points.

Aggregation areas determined from ground, boat, and aerial surveys during 1972, 1973, and 1974 are shown in Figure 12. Only 1 area presented a significant hazard to aircraft since the eagles generally moved at elevations below aircraft traffic. The exception was the coastline from Pillar Point to False Head along which low flying aircraft regularly travelled to and from nearby settlements to the southeast.

3.2.3 Regional Findings

Six sub-areas were delineated within the regional study area for assessment of distribution: Quatsino Narrows and 5 relatively homogeneous physiographic regions (Fig. 13).

There was a concentration of bald eagles at Quatsino Narrows



Potential hazard to aircraft

Figure 12. Aggregation areas within the control zone based on results from ground, boat, and aerial surveys during 1972, 1973, and 1974.

during the latter part of April 1974. At least 130 eagles were observed using the Narrows over a 3 day period which represented approximately one half of the total estimated population inhabiting the regional study area.

The distribution of eagles throughout the remainder of the regional study area was expressed in the form of composite maps combining the locations of individual eagles when first observed during ground, boat, and aerial surveys. All regions were surveyed during the nesting season from April to August except for the Scott Islands and the northwestern tip of Vancouver Island which were surveyed during October.

Results from such surveys showed that eagles were normally located within nesting territories or concentrated at feeding locations. Three aggregation areas were recorded during the early part of the 1974 nesting season. The first was centered on the northwest corner of Hurst Island while the second was located on the east side of Nigei as shown in Figure 13. The third aggregation area, which attracted by far the greatest number of eagles, was located at Quatsino Narrows as described above.

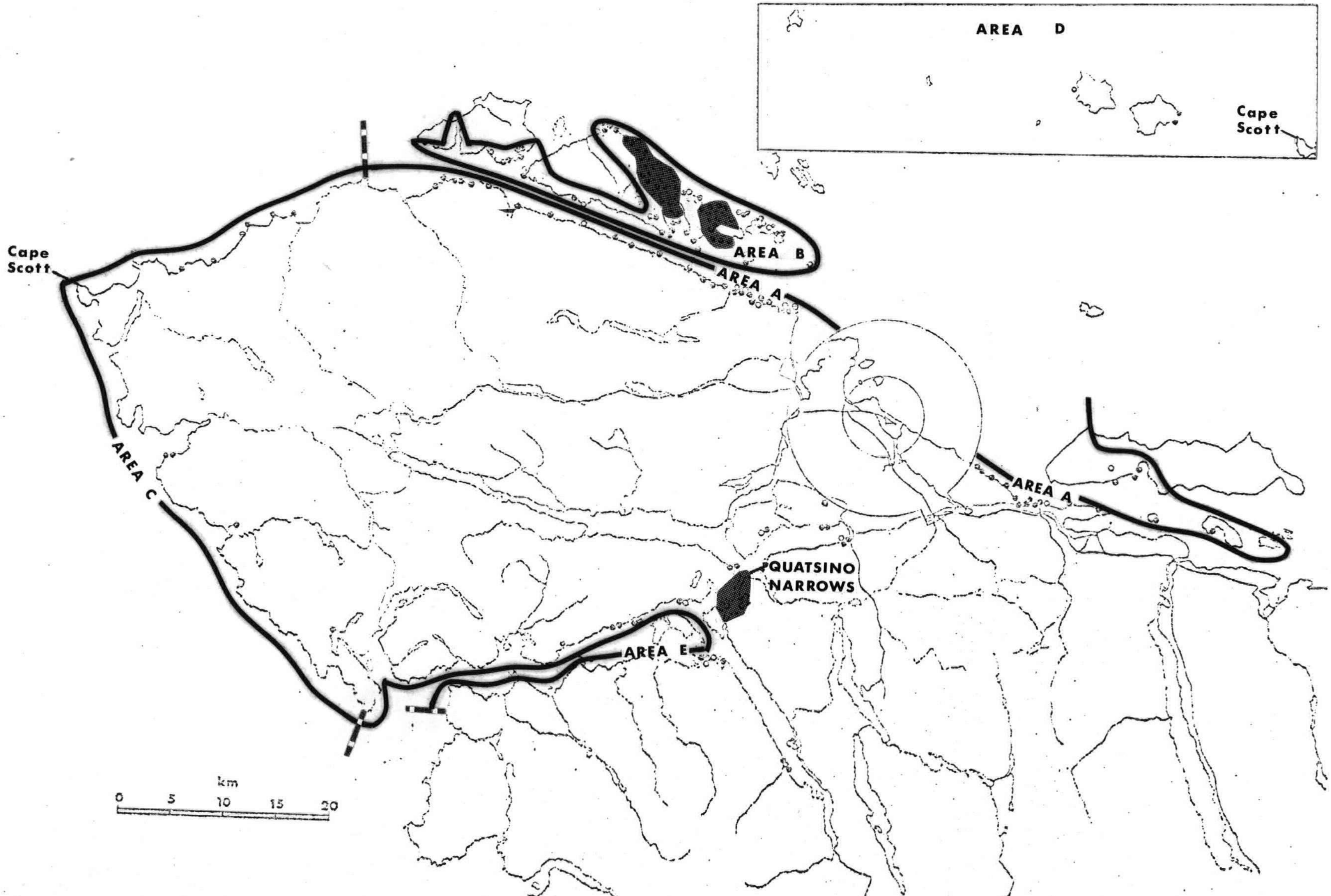


Figure 13. Aggregation areas within the regional study area based on results from ground, boat, and aerial surveys during the 1974 nesting season and delineation of 6 sub-areas comprising the regional study area.

3.2.4 Comparison Between Areas

In order to compare seasonal distribution between different parts of the study area, distribution as expressed by the number of eagles recorded per lineal km of coastline was determined monthly where possible for the control zone, Quatsino Narrows, and the 5 areas comprising the remaining part of the regional study area.

Each of these 5 areas was characterized by a relatively homogeneous coastline, topography, and degree of exposure (Fig. 13). They were designated as: area A, the northeast coastline from Ledge Point near Port McNeill to Cape Sutil (most northerly point on Vancouver Island) exluding the airport control zone but including the largest of the Pearse Islands, Cormorant Island, and part of Malcolm Island; area B, the islands forming the north side of Goletas Channel; area C, the northwestern tip of Vancouver Island from Cape Sutil to Cape Scott to Cape Parkins; area D, the Scott Islands including Triangle Island; and area E, Quatsino Sound and the adjoining inlets.

Seasonal distribution results (as expressed by the number of eagles recorded per km of coastline) for the control zone, Quatsino Narrows, and the remaining 5 areas within the regional study area during 1974, are given in Table 1. All regions, except areas C and D, were covered by both boat and aerial surveys. Eagle density was greatest in Quatsino Narrows during

Table 1. Seasonal distribution of eagles within the study area as expressed by the average number of eagles recorded per lineal km of coastline during 1974 boat and aerial surveys.

LOCATION	FEBRUARY A	FEBRUARY I	FEBRUARY U	FEBRUARY T	MARCH A	MARCH I	MARCH U	MARCH T	APRIL A	APRIL I	APRIL U	APRIL T
Control Zone	.06**	.11	.22	.39	.95*	.65*	.47	2.07*	.15	.06*	.02	.23
Quatsino Narrows									(4.62)*	(4.38)*	2.69	(11.69)*
Vancouver Island:												
a.									.21	0	0	.21*
b.									.57*	.35	.12	1.04
c.												
d.												
e.									.21*	.04	.08	.33*

LOCATION	MAY A	MAY I	MAY U	MAY T	JUNE A	JUNE I	JUNE U	JUNE T	JULY A	JULY I	JULY U	JULY T
Control Zone	(.07)*	0*	0	.07	.30	.06*	0	.36	.43	(.07)*	.07	.57
Quatsino Narrows	.18*	0*	0	.18	.15	(.15)	0	.30				
Vancouver Island:												
a.	(.37)*	(.12)	.02	.51	.27	.08	00	.35	.23	.15	.30	.68*
b.					(.65)	(0)	.01	(.66)	(1.04)*	(.39)	.13	(1.56)*
c.												
d.												
e.	.21*	.03	0	.24	(.08)	.08	0	(.16)				

LOCATION	AUGUST A	AUGUST I	AUGUST U	AUGUST T	SEPTEMBER A	SEPTEMBER I	SEPTEMBER U	SEPTEMBER T	OCTOBER A	OCTOBER I	OCTOBER U	OCTOBER T
Control Zone	.21	.12	.08	.41	.03*	.03*	0	.06	(.17)	0*	0	(.17)
Quatsino Narrows	(.41)	(.41)	0	(.82)								
Vancouver Island:												
a.					.04*	.07	0	.11*				
b.												
c.									.09	0	0	.09
d.									.06	(.03)	0	.09
e.	.08	.14	0	.22					(.01)*	0	0	(.01)*

NOTE: All values are based on the greatest daily total of the minimum number of eagles (as defined in 2.3.1) for any given segment of coastline.

KEY:

A - adults
I - immatures
U - unknowns
T - total

Vancouver Island:
a. N.E. Coast
b. N.E. Islands
c. N.W. Coast
d. Scott Islands
e. Quatsino Sound

*...significantly different between months at .05 significance level for a given age class or their total.

()...significantly different between locations within same month at .05 level for a given age class or their total.

April, when an average of over 11 eagles per km of coastline was recorded. The next highest density was registered in the control zone with an average of over 2 eagles per km of coastline. Eagle density was also high in area B during April and July, when averages of over 1 and 1.5 eagles per km of coastline respectively were recorded. The lowest eagle density was documented during October in part of area E with an average of only .01 eagle per km of coastline.

Distribution data from Table 1 were tested statistically through both a 1 - factor and a 2 - factor analysis of variance to reveal significant location and monthly differences. The distribution data of unaged birds as a category was not compared between months or locations but these data were incorporated into the total monthly values for each location. The null hypothesis adopted for both analyses assumed a normal distribution of eagles along the coastline at all locations and at all times at the .05 significance level (H_0: $u_1 = u_2 = u_3 = u_4 = u_5 = u_6 = u_7$).

The 1 - factor analysis of variance involved calculation of monthly distribution means ($\bar{x}$) and sample standard deviations (s) for adults, immatures, and their total at each of the 7 locations. Distribution values lying outside of the range determined by the relationship $\bar{x} \pm 1.96\ s/\sqrt{n}$ were determined to be significantly different between months (Table 1). Likewise, the distribution means and standard deviations for adults, immatures, and their total were calculated for each month (where possible) and inserted into the above relationship to reveal significant differences between locations within the same month (Table 1).

Thirty five percent of the distributions compared between months were significantly different causing rejection of the null hypothesis and confirmation of significant seasonal differences within all locations except areas C and D which were surveyed only once.

Thirty one per cent of the distributions compared between locations within the same month were significantly different causing rejection of the null hypothesis and confirmation of significant distributional differences between locations.

The 2 factor test was conducted in order to simultaneously make inferences about the unexplained variation in both monthly distributions for the same location and location distributions for the same month. The analysis was limited to a comparison of total distributions between April and June since these were the only months in which data were collected from all locations with the exception of areas C and D which were surveyed only once. A 2 - factor anova table was constructed to determine the sample mean ($\bar{x}$) for each factor (ie. month and location), the grand mean ($\bar{\bar{x}}$), the sum of squares for each factor ($f\,\Sigma(x_1 - \bar{\bar{x}})^2$) and their total, the error sum of squares, and the mean and error mean squares.

Two values of the F statistic were calculated, 1 for the month factor (F=.65) and 1 for the location factor (F=.91), by dividing the appropriate mean square by the respective error mean square. To determine significant difference in the distribution results, the critical value for 1 numerator and 4 denominator degrees of freedom was taken from a standard F distribution table and compared with the calculated values of F. Both calculated values of F (.65, .91) were greater than the $F_{.05}$ value from the table (7.71) resulting in a failure to reject the null hypothesis. The test failed to yield a conclusion except that additional data are needed to arrive at a decision regarding the null hypothesis.

3.3 ABUNDANCE AND DISTRIBUTION OF NESTS

Since the number of eagles using the Port Hardy area depended in part on the number of nesting pairs along the adjacent coastline, it was necessary to examine this and to search for any patterns of nest distribution which might indicate potential densities.

3.3.1 Airport Vicinity and Control Zone

Eighteen nests were found along the 40 km of coastline with an average of .5 nest/km of coastline. The locations of nests and their state of use during the 1974 nesting season are shown in Figure 14. Table 2 outlines the distribution of both active and inactive nests within the airport vicinity, control zone, and regional study area. The airport vicinity and control zone supported .2 active nest/km of coastline with an average inter-active nest distance of 2.2 km.

During the 1974 nesting season, the average direct distance between any active nest and the closest active nest was 1.9 km with a range from 1.2 km to 2.5 km.

All nest trees were located within a short distance of the coastline. The 5 nest trees on the islands of Beaver Harbour tended to be closer than the remaining 12 nest trees on the coast of Vancouver Island. The average distance of all nests from the coastline was 102 m with a range from 3 to 309 m.

3.3.2 Regional Findings

Ninety nine bald eagle nests were located in the regional

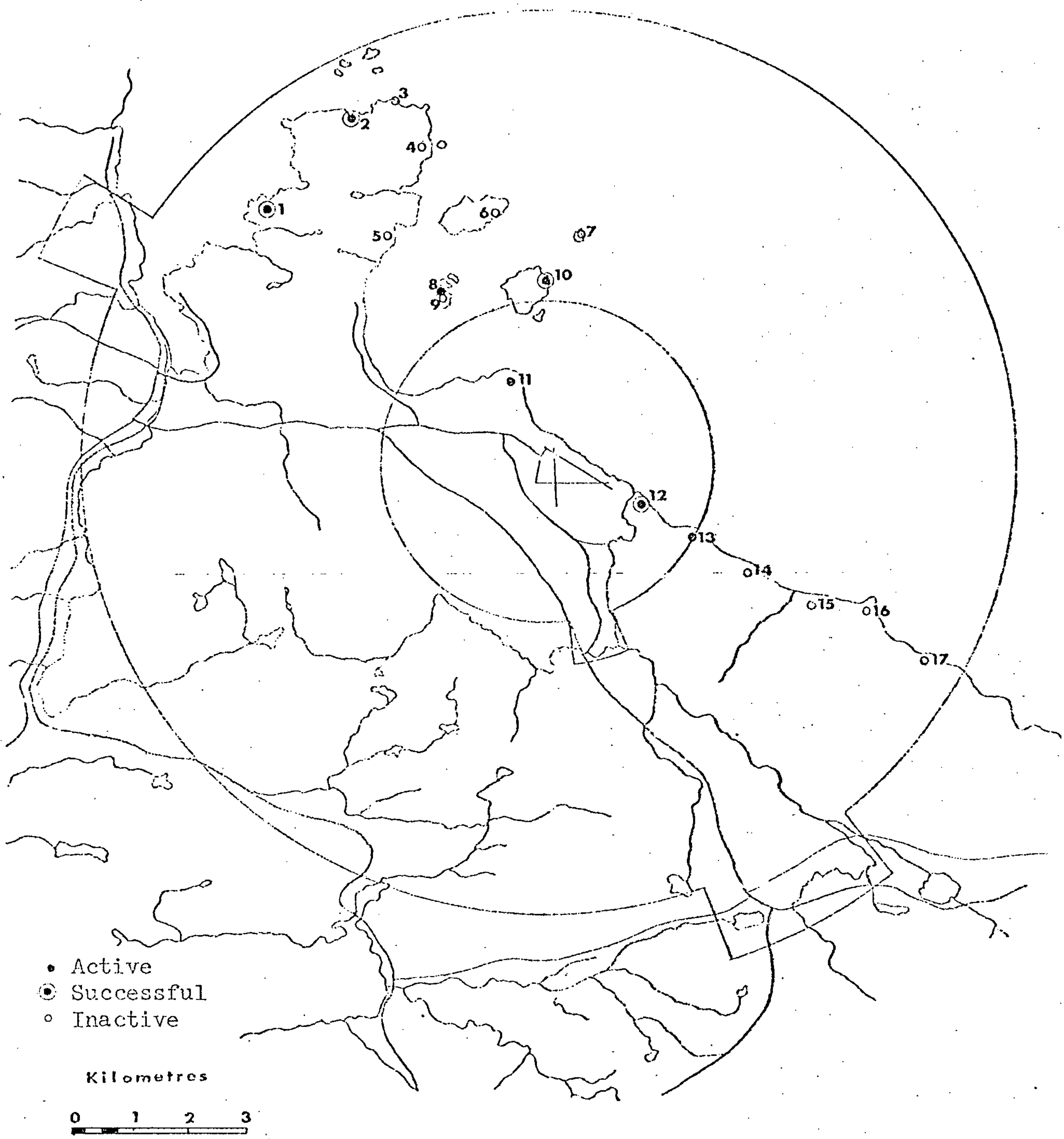


Figure 14. Nest located within the airport control zone and their state of use during the 1974 nesting season.

study area of which at least 34 were active. Table 2 outlines the abundance and distribution of both active and inactive nests during the 1974 nesting season. The north-west coastline (area C) and the Scott Islands (area D) were surveyed in October following the 1974 nesting season and therefore the number of active nests was not determined. Nest distribution was fairly even throughout area C except in the San Josef Bay region where there was a notable absence of nests despite many kilometers of coastline. Within area D, nests were evenly distributed on Lanz Island but were concentrated along the west and south shoreline of Cox Island. Nest distribution was fairly even throughout area E except for Holberg Inlet where only 1 nest was located along 81.3 km of coastline and Quatsino Narrows where 4 nests were situated along only 13.0 km of coastline. In total, 116 nests were located along the 736 km of coastline within the entire study area. The average inter-nest linear distance was 2.6 km.

It was not possible to accurately delineate the actual size or shape of any established territory during the present study.

Table 2. Abundance and distribution of active and inactive nests within the study area during the 1974 nesting season.

Area	Length of Coastline (km)	No. of Nests	Nests/km	No. of Active Nests	Active Nests /km	Average Distance Between Active Nests
Control Zone	40.0	18	.5	9	.2	2.2
Mouth of Keogh S.E. Boundary	7.4	6	.8	2	.3	1.3
Vancouver Island Coastline	28.2	12	.4	7	.2	2.3
Vancouver Island Component	736.0	116	.2	-	-	-
Area A N.E.Coastline	98.4	25	.3	7	.1	4.0
Area B N.E.Islands	117.3	18	.2	8	.1	4.8
Area C N.W.Coastline	113.8	15	.1	-	-	-
Area D Scott Islands	36.4	9	.2	-	-	-
Area E Quatsino Sound & Adjoining Inlets	336.0	31	.1	10	.03	7.9

3.4 PRODUCTIVITY

The annual recruitment to the bald eagle population was estimated within the control zone and regional study area. This information was of particular importance for the airport vicinity and control zone, where the occurrence of additional eagles increased the potential hazard to aircraft.

3.4.1 Airport Vicinity and Control Zone

Table 3 shows the state of the nests, whether active, inactive, successful, or unknown during the 1974 nesting season. The term "active" was used to describe those nests containing adults in incubating posture during April. "Inactive" described those nests which did not contain incubating adults and those which were evidently in a state of obsolescence. "Successful" referred to those nests which produced young.

Nest abandonment was calculated using the equation,

$$\text{Nest abandonment} = \frac{(Ta - Ts)}{Ta} \times 100\%$$

where Ta is the total number of active nests and Ts is the total number of successful nests. Nesting success, defined as the average number of birds raised per successful nest, and nest abandonment are given in Table 3. Nesting success and nest abandonment within the airport vicinity and control zone did not differ significantly from the regional study area.

Table 3. State of eagle nests, nesting success, and nest abandonment within the study area during the 1974 nesting season.

No. of Nests	No. Active Nests	No. Inactive Nests	No. Unknown Nests	No. Nesting Pairs	No. of Successful Nests	No. of Young Fledged
A. Airport Vicinity and Control Zone						
17	9	8	0	9	4	6
B. Regional Study Area						
99	24	41	34	24	10	12

Average Nesting Success	Average Nest Abandonment
1.35 young/nest	56.9%

Nine of the 17 nests located within the airport vicinity and control zone during 1974 were active. Of the 9 active nests, 4 were successful, namely nests 1, 2, 10 and 12 which produced 2, 2, 1, and 1 young respectively (Fig. 14).

It will take a more extended study than the present one to determine the significance of this level of fledgling young on the potential hazard to aircraft at the airport. Nest 12 was situated between 2 flight paths and less than 1 km from the airport runways. It can be concluded that established nests were successfully producing young and that proximity to the activities of the airport was not inhibiting success. These young were thought to remain in the area until late fall.

Since only 1 fledgling in the control zone was marked and only 1 radio-tracked, it was not possible to accurately determine the contribution of locally raised birds to the annual fall assemblage of eagles around the airport. However, this concentration was composed primarily of immatures and most likely included control zone offspring. Immatures comprised an average of 62% of the eagles concentrated at the Keogh River during the fall of 1972, 1973, and 1974 and were abundant at other salmon rivers along the north coast of Vancouver Island at the same time. This compares with a proportion of immature to adult eagles of 33% for the total population of the study area.

3.4.2 Regional Findings

Table 3 shows the state of the nests as well as nesting success and nest abandonment within the regional study area during the 1974 nesting season.

The annual recruitment to the eagle population throughout the regional study area was estimated to be approximately 18 young. This calculation was made by expanding the inactive/active/successful nest ratio to include unknown nests. Some of these young birds likely move to the Port Hardy airport during spring and fall and thus increase the potential hazard to aircraft. However, the contribution of birds raised in the regional study area to the annual spring and fall concentration of eagles around the airport could not be determined.

Clutch size was determined for a number of nests in isolated areas where disturbance other than that created by counting eggs was minimal or non-existent. Productivity in terms of the number of young fledged compared to the number of eggs laid is given in Table 4.

Table 4. Productivity of selected eagle nests within the regional study area during the 1974 nesting season.

Nest No.	No. Eggs Laid	No. Young Fledged
26	2	1
30	2	1
36	2	2
44	2	0
46	2	1
52	2	1
234	12	6

Productivity:

$$\frac{\text{Total No. of Young Fledged}}{\text{Total No. of Eggs Laid}} \times 100\% = \frac{6}{12} \times 100\% = 50\%$$

Considering all 14 successful nests in the study area (Table 3), 4(29%) apparently produced 2 young each, while 10 (71%) apparently produced 1 young each. It is possible that there were more than 4 nests containing 2 young since 1 of the 2 young may have fledged before the surveys. The mean clutch size recorded elsewhere in the bald eagle's range is almost invariably 2 eggs (Beebe, 1974). Nests containing 2 or 1 young generally occur about equally on the Pacific Coast, nests containing 3 young are rare (ibid.). The 14 successful nests in total produced 18 young resulting in an average of 1.3 young/nest.

The egg-laying period in the study area extended from late March until early May.

3.5 FOOD RELATIONSHIPS

The relationship between the presence, abundance and availability of food and the occurrence, profusion and behaviour of eagles was examined in order to determine the importance of food sources within the airport vicinity and control zone as an attractant to eagles throughout the study area. Where a ready and abundant food source was present and accompanied by larger numbers of eagles than were present where no such food sources occurred, it was assumed that a cause-effect relationship existed.

Direct observations throughout the study period indicated that the subsistence diet of eagles, feeding within the airport vicinity and control zone, was almost entirely composed of fish, birds, and marine invertebrates.

The availability of fish, birds, and other substenance items within the airport vicinity and control zone is discussed in section 1.4.

Eagles susbsist primarily on pre-spawning, spawning, and spent salmon from early September until late November. Although concentrated schooling of pink and chum salmon occurred near the surface of the water in the mouth of the Keogh River, there is little indication that these salmon are frequently captured by eagles. Tight schools of pink salmon were observed during the early part of September while chum schooling was not observed until the end of September. Coho salmon did not appear to school in tight groups.

In order to determine if a relationship existed between the abundance of salmon in the Keogh River (serving as a food source to eagles) and the numbers of eagles within the airport vicinity, the minimum number of eagles recorded was compared to the estimated salmon escapement as shown in Figure 15. Similar figures were prepared for the fall of 1972 and the fall of 1974. Eagle abundance values from these figures were plotted against the corresponding pink salmon escapement levels (ie. the number of this species of salmon entering the river) to produce a scatter diagram (Fig. 16). Regression lines indicate a positive correlation between eagle abundance and estimated pink salmon escapement. Summary results of escapement levels in 3 of the 4 spawning rivers within the control zone, during 3 successive salmon spawning seasons, are given in Table 5. (Eagle abundance was compared with escapement levels for pink salmon only since eagle use of chum and coho spawners was limited).

When computing the correlation between eagle abundance and salmon escapement during 1972 and 1973, escapement levels were lagged by 1 month to take into account the importance of spent pink salmon in the diet of eagles, especially as the river level progressively increases during October. (The effect of river stage on the availability of salmon is discussed later in this section). Eagle abundance climaxed near the end of the pink run during 1972 and 1973, approximately 1 month after the peak in those runs.

Figure 15. Minimum number of eagles continuously frequenting the airport vicinity in relation to the estimated salmon escapement to the Keogh River during the fall of 1973.

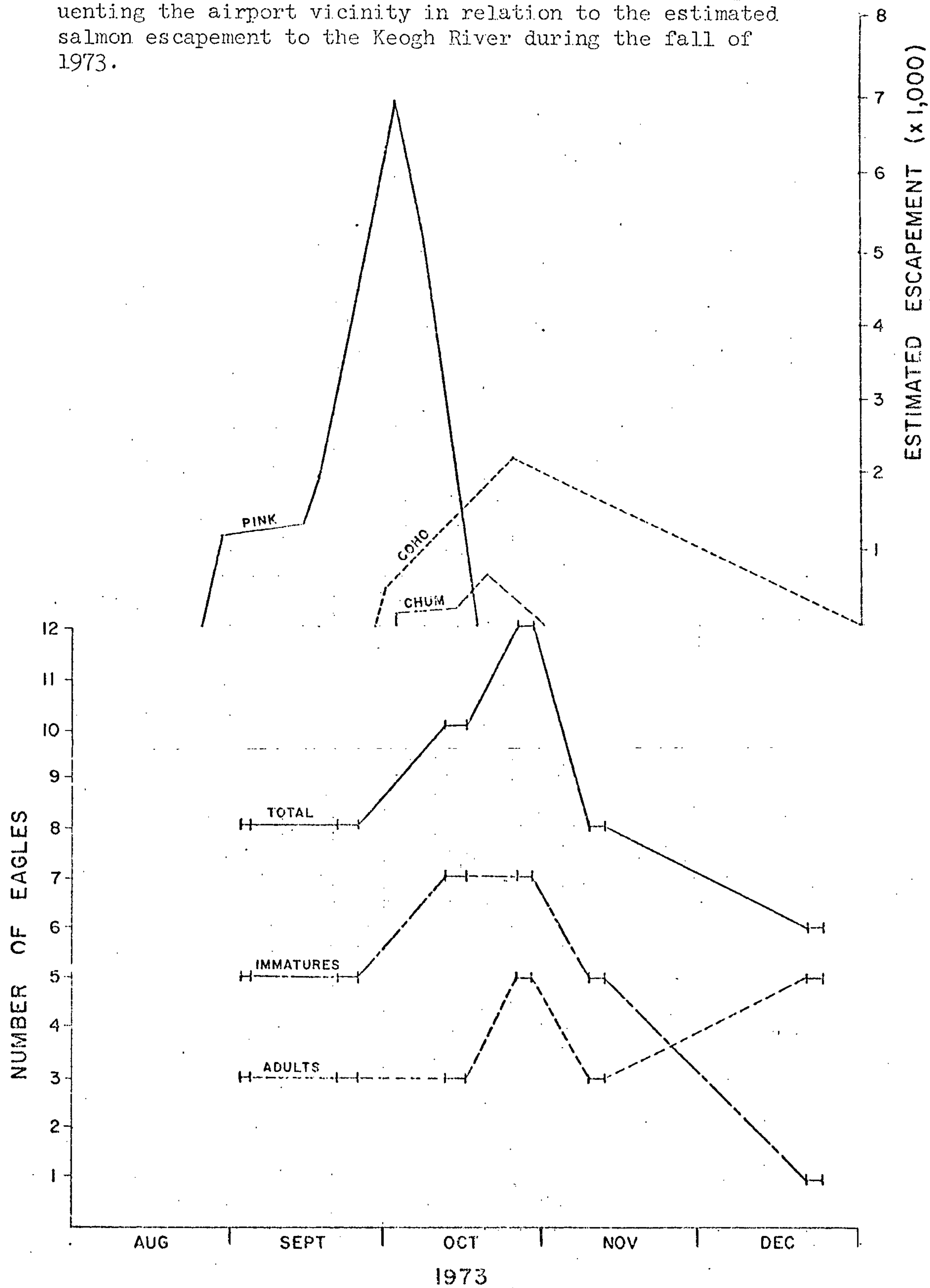
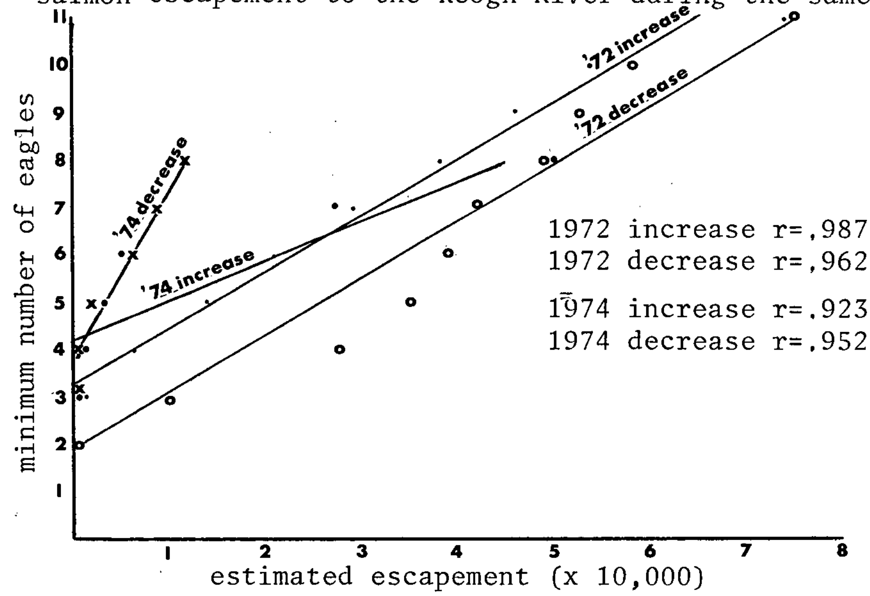
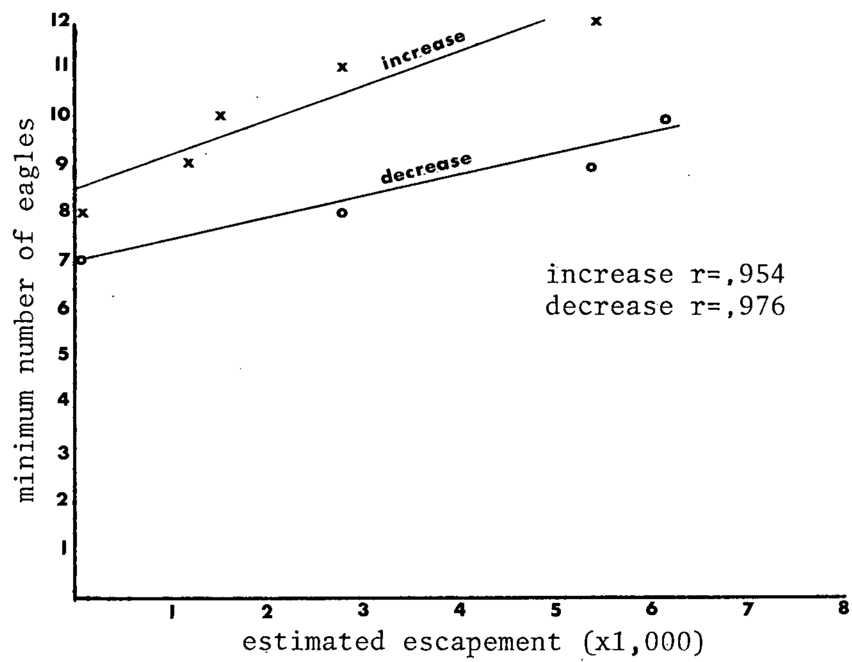


Figure 16. Scatter diagram showing regression lines for correlation between the abundance of eagles in the airport vicinity during the fall of 1972, 1973, and 1974 and the estimated pink salmon escapement to the Keogh River during the same period.



A. 1972 + 1974



B. 1973

Table 5. Particulars of spawning pink, chum, and coho salmon in the Keogh, Quatse, and Tsulquate Rivers during the fall of 1972, 1973 and 1974.

A) 1972

SPECIES	ARRIVAL IN STREAM	DURATION START	DURATION PEAK	DURATION END	TOTAL ESCAPEMENT
Keogh River					
Pink	25/8/72	20/9/72	3/10/72	3/10/72	75,000
Chum	3/10/72	10/72	19/10/72	3/10/72	5,000
Coho	27/9/72	10/72	6/11/72	31/12/72	2,000
Quatse River					
Pink	9/72	9/72	10/72	11/72	16,000
Chum	10/72	10/72	11/72	11/72	2,500
Tsulquate River					
Pink	8/72	8/72	9/72	11/72	4,500
Chum	10/72	10/72	10/72	11/72	550

B) 1973

SPECIES	ARRIVAL IN STREAM	DURATION START	DURATION PEAK	DURATION END	TOTAL ESCAPEMENT
Keogh River					
Pink	25/8/73	20/9/73	2/10/73	18/10/73	7,000
Chum	2/10/73	10/73	20/10/73	31/10/73	700
Coho	28/9/73	10/73	25/10/73	31/12/73	2,200
Quatse River					
Pink	8/9/73	15/9/73	5/10/73	11/73	1,000
Chum	10/10/73	15/10/73	31/10/73	11/73	600
Tsulquate River					
Pink	3/9/73	3/9/73	28/9/73	20/10/73	7,000
Chum	4/10/73	4/10/73	25/10/73	11/73	425

C) 1974

SPECIES	ARRIVAL IN STREAM	DURATION START	DURATION PEAK	DURATION END	TOTAL ESCAPEMENT
Keogh River					
Pink	1st large escapement 7,8/9/74 24/8/74	17/9/74	11/10/74	23/10/74	55,500
Chum	30/9/74	10/74	20/10/74	31/10/74	400
Coho	19/9/74	10/74	near end of Oct.	31/12/74	200
Quatse River					
Pink	7/9/74	15/9/74	4/10/74	15/11/74	66,000
Chum	8/10/74	10/10/74	20/10/74	1/11/74	400
Tsulquate River					
Pink	7/9/74	15/9/74	30/9/74	11/74	11,000
Chum	2/10/74	5/10/74	15/10/74	30/10/74	500

The peak in the pink run was coincident with the peak in eagle abundance during 1974 when the river level remained very low into October. Accordingly, escapement levels were not lagged.

The coefficient of linear correlation (r) was computed from eagle abundance and salmon escapement data for two intervals during each salmon spawning season, the period when the number of pink spawners in the Keogh River was increasing and the period when the number of pink spawners was decreasing. Calculated correlation coefficient values were all slightly less than 1.0 as shown in Figure 16 indicating a very strong correlation between both the rate of increase in eagle abundance and the rate of increase in pink spawners as well as between the rate of decrease in eagle abundance and the rate of decrease in pink spawners.

The increase and decrease in eagle abundance each fall was not directly correlated with the actual number of pink salmon in the Keogh River. Fall eagle abundance varied little compared to the great variation in salmon escapement levels between even and odd years. This indicates that there was a plentiful food supply even in odd years when the total number of spawning salmon was much smaller. It also suggests that eagles were attracted from a limited area since the abundance of salmon in the Keogh River could have supported a much greater number of eagles.

It was observed that of the 3 species of salmon in the Keogh River, pink spawners were most accessible to eagles due to their small size (average weight 1.4-1.8 kilograms), large numbers, and tight schooling characteristics. Pink salmon were most vulnerable to predation towards the end of the spawning season when many became so weak that they were swept downstream, often near the surface of the water. From their strategic perches along the river bank, eagles easily located and subsequently preyed on dying fish. As mentioned earlier, eagle abundance was generally greatest near the end of the pink salmon spawning run indicating the importance of dead and dying pinks as a food source.

The preferred spawning grounds for pink spawners were in the lower reaches of the Keogh, beginning at the mouth. In even years, pink spawners may on occasion extend all the way up to Keogh Lake, but in odd years they occur only in the first few miles of river.

The small number of coho spawners in the Keogh were generally in good condition and rarely seen during patrols along the river. It is thought that very limited active eagle predation occurs on this species because of its superior strength, large size, protective camouflage, limited numbers, and preference for deep water. Only fully mature coho were observed, ranging in size from approximately 2.5 kg. to 6.5 kg. Coho preferred spawning grounds a considerable distance upstream from the mouth. Eagles no doubt fed on some dead and/or dying spawners and possibly on some incoming coho at the river mouth under low river and low tide conditions.

Chum salmon appeared to be more vulnerable to eagle predation than cohos because of their slower speed. However, eagle predation on chum was limited due to their large size and sufficiently high river levels during the chum run. In late October, eagles were observed feeding regularly on dead chums. Similar to pink salmon, chum also preferred the lower reaches of the river for spawning. Surveys at several locations along the entire 32 km length of the Keogh River indicated that only limited spawning (likely coho) occurred in the upper 18 km of river. Almost all of the pink, chum, and coho spawned within the lower 14 km.

The level of the Keogh River greatly influenced the upstream migration and availability of spawning salmon to eagles. River levels were generally very low during September when most pink spawners entered the Keogh. River stage was particularly important at the river mouth and just upstream. The annual concentration of eagles in this area (Fig. 9) during the spawning season was in large part due to the easy accessibility of incoming salmon, especially during low tide conditions and low river levels. Under these conditions, much of the extensive sandstone shelf at the mouth was exposed, forcing incoming salmon into narrow, shallow channels where they were highly vulnerable to eagles perched nearby.

In September it was often necessary for salmon to enter the river at the time of high tides, since low tide conditions (low river levels plus impassable waterfalls at the edge of the shelf) were prohibitive to upstream migration. As the river level dropped with the tide receding, schools of pink salmon were trapped in shallow pools along the lower .5 km of river. Under these conditions, eagles were able to take salmon from these schools but this type of predation was limited by the dark colouration of river water and the thick canopy partially covering the river just upstream from the mouth.

When rainfall increased river levels during September and October, salmon migrated upstream in large numbers even though river levels remained relatively low. These conditions led to a change in the feeding behaviour of eagles. Instead of feeding mostly on incoming pinks near the river mouth, eagles began feeding at various locations upstream, where still relatively low water conditions and the great number of salmon resulted in an easily accessible food source. This was particularly noticeable in the west half of the flight path clearing where there were several shallow pools and adjoining rapids (Fig.10). Salmon were often partially exposed when swimming upstream between pools. Several strategic locations were found along the lower stretches of the Keogh where eagles had spent considerable time watching salmon. The change in feeding behaviour appeared to be accompanied by an increased frequency of eagle flights across the airfield.

A marked increase in the level of the Keogh River occurred during early fall each year at approximately the same time and this was thought to trigger upstream migration of coho and chum salmon. Although the increased level resulted in more salmon in the river, it made it difficult for eagles to prey on incoming and spawning salmon due to the depth and speed of the river water. The increased river level also quickly swept away the remains of spent salmon from along the river bank. As a result, the feeding behaviour of eagles changed once again. Instead of feeding on pink spawners at various points upstream, eagles began feeding primarily on dead and dying pinks at the river mouth. By early November, river levels had decreased again; few, if any pink spawners remained and eagles appeared to be feeding exclusively on dead and dying chum salmon. Thus for 2 months (September and October) the pink salmon in the Keogh River produced a surplus of food for the eagles concentrated at the airport. Feeding on spent salmon continued well into November at the mouth and along the lower reaches of the river.

Coho spawners peaked during late October or early November and remained in the Keogh River for some time. There was no evidence found of eagles feeding on either live or dead coho salmon. The total number of coho in the river gradually decreased through November and December.

Eagles did not feed on salmon from the Keogh River to any significant extent after the last of the chum had been consumed by mid-November. It is possible that remains of spawning salmon left by black bear along the river bank may have been searched out and eaten prior to and following this date.

Salmon spawning in the Quatse and Tsulquate River also attracted eagles but apparently to a lesser degree than salmon in the Keogh River. It was not possible to determine the number of eagles attracted to the former 2 rivers, but each yielded fewer sightings/hour than the Keogh.

A variety of sea birds was present in the control zone throughout the year and thus provided a continual potential source of food.. Likewise, the many different types of intertidal invertebrates were available as potential food items and were regularly used during the periods of the year when tides low enough to expose them occurred during daylight hours.

During the period between the salmon spawning season and the herring spawning season (December through February), eagles within the control zone fed primarily on wintering sea birds and marine fishes.

With the beginning of the herring spawning season in late March, eagles once again had access to a concentrated food source. While extensive spawning grounds were at one time located around the perimeter of most islands in Beaver Harbour, they are now restricted to regions north of Deer Island and south of the Cattle Islands.

Eagles were observed capturing herring from tight schools near the Cattle Islands and a number of fish were found beneath trees on the Islands. Herring appear to be the staple diet of eagles during the latter part of March and the early part of April. Herring-spawn attached to Macrocystis beds was taken extensively by gulls, however, eagles were not observed feeding on the spawn. Eagle numbers in the vicinity of the airport again increased at this time. Details were discussed earlier.

From the end of the herring spawn in late April until the beginning of the salmon spawning season in late August, the main components of the eagles' diet appeared to be sea birds, marine fishes, and intertidal invertebrates. During this period eagles were dispersed along the coastline.

Feeding habit information based on the analysis of food remains at the base of nest trees and nest contents is given in Table 6. This evinces the food available and brought to the nest during the period of nest occupancy by the eaglets (May - August). Marine fishes accounted for 23% of the food remains at 10 nests within the control zone during 1974. These fish included herring, cod, rockfish, salmon, and dogfish. Birds accounted for 34% of the food remains and included scoters, gulls, a rhinoceros auklet, and a great blue heron. Marine invertebrates accounted for the largest percentage (42%) of the food items and included abalone, other univalves, bivalves, barnacles, crabs, and sea urchins. One unidentified mammal was found accounting for 1% of the food remains. All these figures are percentage by occurrence.

Although many marine invertebrate food items were found, they were generally very small and in volume probably ranked third in importance after birds and marine fishes. Some food items such as carrion taken from seals can be completely digested and therefore would not be detected by the method used. Eagles supplement their diet throughout the year by feeding on carrion, particularly along the coastline.

Table 6. Food remains found at ten bald eagle nests within the control zone during 1974.

FOOD ITEM		OCCURRENCE	
		NUMBER	PERCENT
Fishes:			
herring (*Clupeidae*)		5	5.8
pacific cod (*Gadus macrocephalus*)		6	7.0
rockfish (*Sebastodes* sp.)		4	4.7
salmon (*Oncorhynchus* sp.)		1	1.2
dogfish		2	2.3
unidentified fish		2	2.3
	Total	20	23.3
Birds:			
rhinoceros auklet		1	1.2
scoter (*Melanitta* sp.)		2	2.3
great blue heron (*Ardea herodias*)		1	1.2
gull (*Larus* sp.)		2	2.3
unidentified bird		23	26.7
	Total	29	33.7
Invertebrates:			
abalone (*Haliatus*)		5	5.8
bivalves		10	11.6
univalves (Gastropoda) (3 limpets)		10	11.6
barnacles		5	5.8
crabs		3	3.5
sea urchins		3	3.5
	Total	36	41.8
Mammals:			
unidentified mammal		1	1.2
	Total	1	1.2
	GRAND TOTAL	86	100.0

3.6 EAGLE FLIGHT PATTERNS

The autumn aggregation of eagles in the flight path for runway 1028 in the vicinity of the Keogh River presented the greatest hazard to aircraft. This hazard arose since the aggregation was located in an active flight path less than 700m from the end of runway 1028, the only runway used by Boeing 737 jets. My findings indicated that approaching and departing jets were flying directly through the airspace used by eagles when flying above the river.

Approximately 80% of autumn eagle activity in the flight path consisted of direct flights above the river. The remaining 20% consisted of soaring high over the river when clear skies prevailed along with brisk southeast winds and cool temperatures. Soaring was observed up to 250m which marked the upward limit of the aggregation area above and adjacent to the Keogh River.

Figure 17 gives a frequency-altitude profile of direct eagle flights above the Keogh River in the flight path during the fall of 1972, 1973, and 1974. As stated in 2.3.1, my altitude data are based on estimates due to the difficulty of accurately approximating the elevation of swiftly flying birds. However, it was usually possible to compare the altitude of eagle flights with the altitude of known reference points (e.g. river bank,tree height,jet altitude) in order to obtain a reliable estimate.

Essentially all direct eagle flights above the river occurred between 2 and 60m. Flights were most frequent in the 35-40m and 40-45m range which coincided with the approach altitudes of jets when over the river (30-60m). This potential for mid-air strikes had to be substantially reduced in order to provide a significant and long term solution to the airport's bird hazard problem.

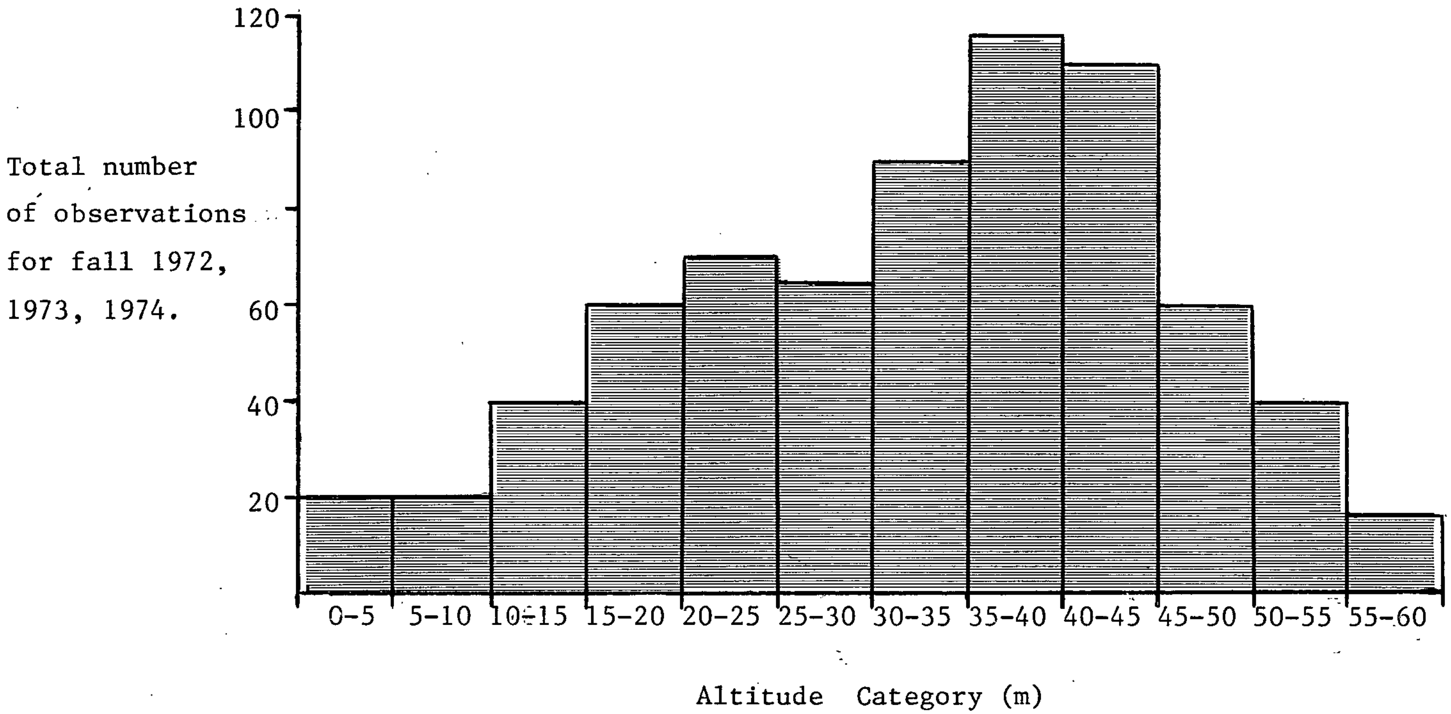


Figure 17. Frequency-altitude histogram of direct eagle flights above the Keogh River in the southeast flight path for runway 1028 during the fall of 1972, 1973, and 1974.

PART 4 DISCUSSION

This study has revealed that the Port Hardy airport is situated in an area of high eagle density year-round. Nesting density in the entire study area was at least .1 active nest/lineal km of coastline with a higher density in the immediate vicinity of the airport (.2 active nest/lineal km of coastline). Densities reported at Barkley Sound (Hancock 1970, Retfalvi 1977) and Karluk Lake (Anonymous 1958, Hensel and Troyer 1964/1965, Robards and King 1966) exceed those near Port Hardy airport. These were .53 eagles/km^2 and .78 eagles/km^2 respectively.

Despite the difference in density, nesting success was similar to that recorded for stable populations in Florida and at Karluk Lake. In my study area 57% of the nests failed but those that produced young averaged 1.4 young/nest. Comparable figures have been recorded at Karluk Lake where 42% of the nests failed in 1962 and the mean young per successful nest during 1959, 1961, and 1962 was .9, .6 and 1.4 respectively (Hensel and Troyer, 1964). Broley (1947) showed that 56 nests in 1946 produced an average of 1.8 birds per nest. Robbins (1960) recorded what he termedea good reproduction success in 1959 at Everglades National Park when 18 young were raised in 11 nests (1.6 per nest).

There were 5 active nests within the orbit of Port Hardy airport activity and they did not differ in success rate or fledged young per successful nest from nests more remote. It can be concluded that airport activity does not itself reduce the rearing success of the bald eagles.

Studies of the relationship between the number of eagles using the airport vicinity during the autumn period when the salmon were entering the Keogh River demonstrated a positive correlation. Findings revealed that even a relatively small spawning run of salmon was adequate to attract the eagles and that the very large runs did not attract additional eagles in the same ratio.

The concentration of eagles at the airport contained a disproportionate number of immatures, suggesting that the adults were less attracted to the food concentration.

It is important to recognize that the largest number of eagles in the vicinity of the airport (35) could have been drawn from a relatively small area adjacent. These findings suggest that elimination or substantial reduction of the number of eagle nests within 8 km of the airport (control zone radius) would probably significantly reduce the number of eagles present there. This might be a practical approach to mitigating the problem without reducing the population of the entire study area by more than approximately one tenth. Removal would probably have to be done annually.

There is no evidence as to the distance from which the eagles are drawn to the herring spawn in February and March. This concentration, however, has different flight patterns and does not cross the aircraft flight path as frequently as does the autumn concentration and therefore is less hazardous.

The terms of reference of this study were to seek a solution which did not necessitate killing eagles. The studies of flight frequencies, altitudes, and directions suggest such a solution. The curve of altitude of aircraft landing and take-off paths reveals a concentration between 30 and 210m above the Keogh River. Similarly, the curve of eagle flight altitudes above the river demonstrated highest frequencies between 2 and 60m. Eagle flights were most frequent at approximately 40m above the river which coincided with the approximate altitude of approaching jets when over the river. Since it is not likely that the behaviour of the eagles can be changed it is useful to consider ways of altering the flight paths of the aircraft so as to greatly lessen the frequency of interaction.

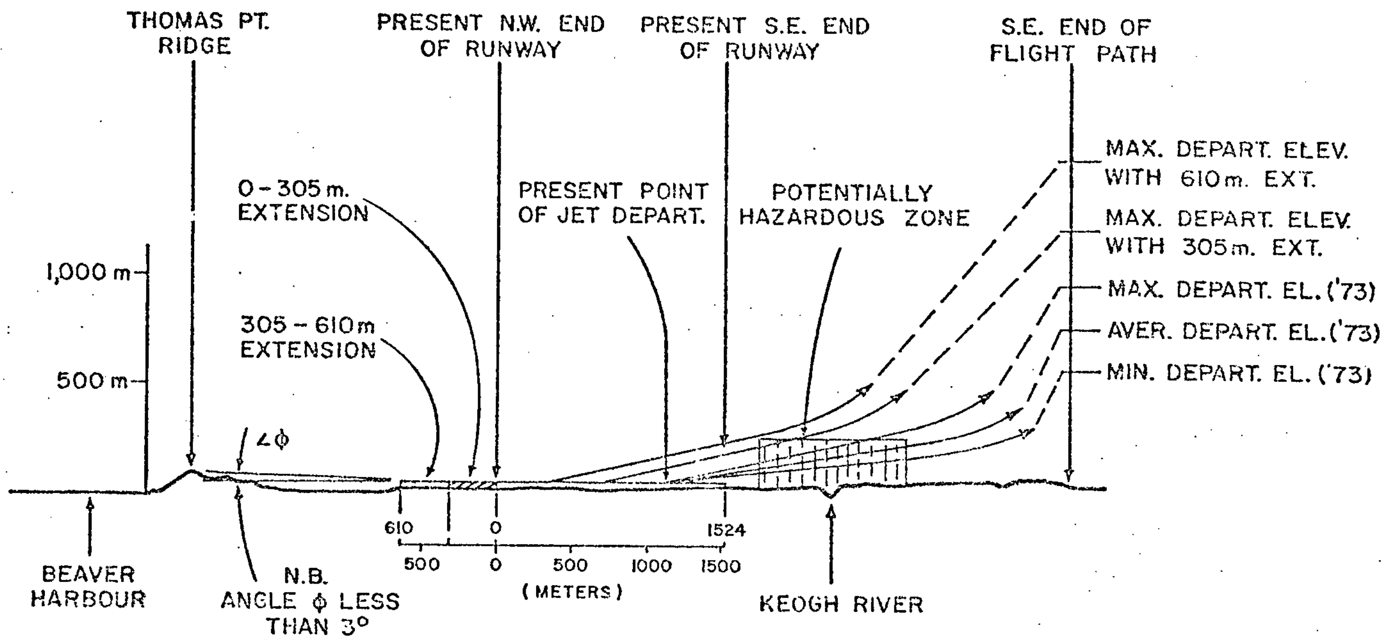
This can be achieved by extension of runway 1028 in the north-west direction for a distance of approximately 610m. The runway extension would allow Boeing 737 jets taking off to the southeast to pass over, instead of through, the hazardous zone above the Keogh River. They would thus have a greater chance of being above any eagles soaring or flying up and down the river.

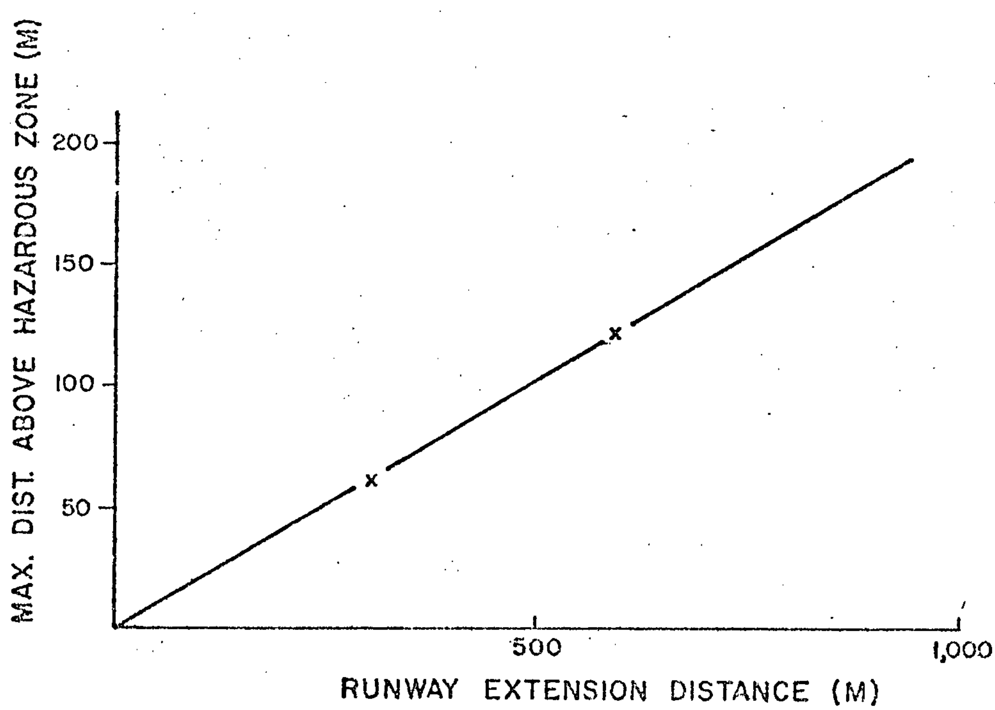
The greatest eagle hazard to jet aircraft occurred during the take-off and climb-out regime when full power was used to gain altitude quickly. An eagle strike at this time would likely result in a crash. A strike during the approach and landing regime would be less dangerous due to the decreased power requirement and proximity of the runway. For these reasons, major emphasis was placed on the eagle hazard to aircraft during take-off and climb out.

The rationale behind the runway extension is presented in Figure 18. During the study, the take-off altitude over the Keogh ranged between 120 and 210m (as checked from the cockpit). A 610m runway extension would allow this altitude to be increased to between 300 and 450m. The gain in elevation over the Keogh River achieved by lifting off from a point 600m further from the river would minimize the potential hazard during departures.

Similarly, if aircraft landing from the southeast could land 600m farther down the runway, it would then be possible for them to approach at a higher altitude over the Keogh River. During the study, the approach altitude over the Keogh was approximatley 30 - 60m. An additional 610m of runway would allow jet traffic to approximately double its height over the Keogh. Although this would not remove approaching aircraft

Figure 18. Relationship between runway extension distance and ascent pattern of Boeing 737 jet.





entirely from the zone of eagle soaring, it would put the aircraft above most of the flights up and down the Keogh River. A runway extension of 610m would still allow for the minimum glide path slope of 3 degrees for aircraft approaching from the northwest. However, low hills located to the northwest would interfere with any large extensions beyond the 610m distance.

Approaches and departures at the northwest end of runway 1028 are largely free of the eagle problem, because of the eagles' close association with the Keogh River.

My studies have also revealed that there is a strong seasonality to the hazard with concentration during the September through November period when eagles are crossing the southeast approach to runway 1028 in their movements along the Keogh River. This suggests a further strategy of whenever possible routing aircraft in and out by the northwest end of runway 1028 during that period to avoid the concentration area.

BIBLIOGRAPHY

AMADON, D. and L. BROWN. 1968. Eagles, Hawks and Falcons of the World. 2 Volumes. Magraw Publishing Company, 350 West 42nd Street, New York 10036.

ANONYMOUS. 1952-1958. Karluk bald eagle studies. U.S.Dept. Int., Fish and Wildlife Service, Kodiak Nat. Wildlife Narrative Report. Sept. - Dec.

ARNOLD, L.W. 1955. The bald eagle and its economic status. U.S. Department of the Interior, Fish and Wildlife Circular. 51 p.

BEEBE, F.L. 1974. Field Studies of the Falconiformes of British Columbia. British Columbia Provincial Museum No. 17 Occasional Paper Series. 163 p.

BENT, A.C. 1937. Life Histories of North American Birds of Prey. 2 Volumes, Dover Publications, Inc. New York, New York.

BIRD, W.H. 1965. Bird strike hazards CAN be reduced. Fifth National Conference on Environmental Effects on Aircraft and Propulsion Systems, Trenton, N.J. September 15, 1965 (mimeographed).

BLOKPOEL, H. 1973. Bird migration forecasts for military air operations. Canadian Wildlife Service Occasional Paper 16, 18 p.

______. 1974. Migration of Lesser Snow and Blue Geese. Part I. Canadian Wildlife Service. Report Series Number 28. 30 p.

BROLEY, C.L. 1947. Migration and Nesting of Florida Bald Eagles. Wilson Bull. 59: 3 - 20.

BUCKLE, D.J., J.M. GERRARD, P. GERRARD, W.J. MOHER, P.N. OBERHOLTZER, J. STILBORN, and D.W.A. WHITFIELD. 1970. Bald Eagle Behaviour Study, Part 1. Unpublished report. 41 p.

BUNNELL, Dr. F., GREG JONES - personal communications.

CANADIAN AIR TRANSPORTATION ADMINISTRATION. 1970. Planning guidelines for the use of land outside the airport property boundary. 31 p.

CANADIAN WILDLIFE SERVICE, 1971. Studies of bird hazards to aircraft. C.W.S. Report Series Number 14. 105 p illustr.

COWAN, McTAGGART, Dr. I. and C.J. GUIGUET. 1965. The Mammals of British Columbia. B.C. Provincial Handbook No. 11, Victoria, B.C.

CRAIGHEAD, F. 1949. The ecology of raptor predation in fall and winter. Ph.D. Thesis. University of Michigan. 295 p.

CRAIGHEAD, J.J. 1949. The ecology of raptor predation in spring and summer. Ph.D. Thesis. University of Michigan. 264 p.

CUTHBERT, J.T. 1972. Port Hardy Airport Eagle Study. Unpublished report prepared for the Department of Biology, University of Victoria, Victoria. 42 p.

________. 1973. The Bald Eagle as an Aircraft Hazard at Port Hardy Airport - Final Report for Period September 1 - November 30, 1973. Unpublished report prepared for L.G.L. Limited, Edmonton. 267 p.

________. 1974. Bird Problems at Airports - the Ecological - Ethological Approach. Unpublished report prepared for the Department of Graduate Studies, University of British Columbia, Vancouver. 5 p.

________. 1974 (ed.) Life History of the Northern Bald Eagle Haliatus leucocephalus alascanus. Unpublished report prepared for the Department of Graduate Studies, University of British Columbia, Vancouver. 57 p.

________. 1974. Bibliography of the Bald Eagle up to 1974. Unpublished document prepared for the Department of Graduate Studies, University of British Columbia, Vancouver, 40 p.

________. 1977. The Bald Eagle (Haliatus leucocephalus alascanus) as an Aircraft Hazard at Port Hardy Airport. Unpublished report prepared for Associate Committee on Bird Hazards to Aircraft, National Research Council, Ottawa and Canadian Wildlife Service, Department of Fisheries and the Environment, Ottawa, 320 p.

FAWKS, E. 1960. A Survey of wintering bald eagles. Iowa Bird Life. XXX, 1960. pp. 56 - 59.

FRIIS, L.K. Environment Contamination by Pesticides in British Columbia 1966-1974 - PART 2: Birds, Mammals. Wildlife Management Report No. 12. British Columbia Fish and Wildlife Branch. 39 p.

GODFREY, W.L. The Birds of Canada. 1966. National Museums of Canada, Ottawa, Canada.

GREWE, A.H.Hr. 1966. Some aspects in the natural history of the bald eagle Haliatus leucocephalus, in Minnesota and South Dakota. Ph.D. Thesis. University of South Dakota. 71 p.

GUNN, W.W.H. and V.E.F. SOLMAN. 1967. A bird warning system for aircraft in flight. pp. 87 - 96 2 pls. and 111 - 116 in: The problems of birds as pests. (ed. R.K. Murton and E.N. Wright). Academic Press, London, England: XIV + 254, illustr.

HANCOCK, D. 1964. Bald eagles wintering in the southern Gulf Islands, British Columbia. Wilson Bull. 76: 111 - 120.

__________. 1965. West coast eagle survey. Can. Audubon. 27(2): 37 - 41.

__________. 1966. David Hancock reports on the Bald Eagle research project. Can. Audubon. 28(1): 88 - 92.

HANCOCK, D. 1970. Adventure with Eagles. The Wildlife Conservation Centre, Saanichton, B.C. 40 p.

HENSEL, R.J. and W.A. TROYER. 1964. Nesting Studies of the Bald Eagle (Haliaetus leucocephalus) in Alaska. Condor 66: 282 - 286.

_______. 1965. Nesting and productivity of bald eagles in the Kodiak National Wildlife Refuge, Alaska.

KRAJINA, V.J. 1964. Ecology of the forests of the Pacific Northwest. University of British Columbia, Dept. of Biology and Botany. Vancouver, B.C. 94 p.

L.G.L. LIMITED. 1973. Bald eagles at Port Hardy Airport-Final Report for 1972. Unpublished report submitted to Associate Committee on Bird Hazards to Aircraft. National Research Council, Ottawa. 22 p.

__________. 1973. Bald Eagles at Port Hardy Airport - a final report for 1973. Unpublished report submitted to Associate Committee on Bird Hazards to Aircraft. National Research Council, Ottawa. 23 p.

LYONS, T. - personal communication.

MARSHALL, D.B. and P.R. NICKERSON. 1976. The Bald Eagle: 1776 - 1976. National Parks and Conservation Magazine. July 1976. pp. 14 - 19.

MUNRO, D.A. and R.D. HARRIS. 1963. Some aspects of the bird hazard at Canadian airports. Symposium of the Problem of Birds on Airports. Institut National de la Recherche Agronamique, Paris, pp. 173 - 206.

MUNRO, J.A. 1938. The northern bald eagle in British Columbia. The Wilson Bulletin. March, 1938. pp. 28 - 35.

MURIE, O.J. 1940. Food habits of the northern bald eagle in the Aleutian Islands, Alaska. Condor 42: 198-202.

MURTON, R. and E. WRIGHT (Eds.) 1968. The problems of birds as pests. Academic Press. London.

PEARSON, E.W. 1967. Birds and airports. Proceedings: Third Vertebrate Pest Conference. San Francisco, California.

PROCEEDINGS OF THE WORLD CONFERENCE ON BIRD HAZARD TO AIRCRAFT. 1969. Queen's University. National Research Council of Canada. September 2 - 5, 1969.

RETFALVI, T.L. 1965. Breeding behaviour and feeding habits of the bald eagle Haliaeetus leucocephalus on San Juan Islands, Washington. M.Sc. Thesis. University of British Columbia.

________. 1977. Surveys of bald eagles in Barkley Sound, British Columbia. 1970 - 1973.

ROBBINS, C.S. 1960. Status of the Bald Eagle Summer of 1959. U.S. Dept. Interior Fish and Wildlife Service, Wildlife Leaflet 418: 1 - 8.

ROBARDS, F.C. and J.G. KING. 1966. Nesting and productivity of bald eagles, southeast Alaska. USDl, Bureau of Sport Fisheries and Wildlife, Juneau, Alaska (mimeo).

SEUBERT, J.L. 1964. Final report, biological studies of the problem of bird hazard to aircraft. July 1, 1963 - June 30, 1964. Prepared for Federal Aviation Agency under project agreement. FAA/BRDA-90. June, 22 p.

SHERIDAN, Wm. L. 1962. Variability in Pink Salmon Escapements Estimated from Surveys on Foot. United States Fish and Wildlife Service Special Scientific Report - Fisheries No. 403. 7 p.

SOLMAN, V.E.F. 1966. The ecological control of bird hazards to aircraft. Proceedings Third Bird Control Seminar, Bowling Green State University, Bowling Green, Ohio, September 13, 1966. pp. 38 - 52.

__________. 1968. Bird control and air safety. Transactions. 33rd North American Wildlife and Natural Resources Conference, Houston, Texas, March 12, 1968. pp. 328-336.

__________. 1969. Airport design and management to reduce bird problems. Department of Transport. Prepared for the World Conference on Bird Hazards to Aircraft at Kingston, Ontario. September 1969. 7 p.

__________. 1969. Photography in bird control for air safety. Jour. Biological Photographic Assoc., 37(3), pp.150-155.

__________. 1970. Bird hazards to aircraft. Proceedings for Fifth Bird Control Seminar, Bowling Green State University, Bowling Green, Ohio, September 15 - 17: 39 - 45.

__________. 1970a. Current work on bird hazards to aircraft. Proc. Fourth Vertebrate Pest Conference, Sacremento, Calif. pp.184 - 187.

__________. 1970b. How we reduce bird hazards to aircraft? Tenth National Conference on Environmental Effects on Aircraft Propulsion Systems, Trenton, N.J. May 19, 1970. No. 24, pp. 1 - 11.

__________. 1971. Bird hazards to aircraft. Ontario Naturalist 9(4): 28 - 33. Ontario. August 30, 1973. 11.p.

__________. 1973. Birds and aircraft. Biol. Can.5(2): 79 - 86.

__________. 1973. Bird strikes and air safety. Prepared for 4th Annual Seminar, The Society of Air Safety Investigators, Toronto.

__________. 1973. Influence of garbage dumps near airports on the bird hazard to aircraft problem. Proc. Nat. Conf. on Urban Engineering Terrain Problems, Montreal, Que., Canada, May 7, 1973. National Res. Council, Ottawa, Canada.

__________. 1973. Aircraft and Wildlife. Transactions of Symposium on 171 Wildlife in an Urbanizing Environment, Springfield, Mass. U.S.A. November 27 - 29, 1973.

SPRUNT, A. IV. 1963. Bald eagles aren't producing enough young. Audubon Magazine Volume 65(1). pp. 32 - 35.

TRANSPORT CANADA. 1973. Minimum requirements for airports. 10 p.

_________. 1973. Aerodome standards, physical characteristics and zoning requirements. 43 p.

TRENHOLME, N. and R.W. CAMPBELL, 1975. Survey of bald eagle populations in the southern Gulf Islands.

WHITFIELD, D.W.A., D.W. DAVIS, J.M. GERRARD, and W.J. MAHER. 1969. Golden eagles in central Saskatchewan. The Blue Jay. June, 1969. pp. 74 - 79.

WHITFIELD, D.W.A., J.M. GERRARD and W.J. MAHER. 1969. Bald eagle survey in central Saskatchewan and Manitoba. Unpublished report. 22 p.

WHITFIELD, D.W.A., J.M. GERRARD, P.N. GERRARD, AND W.J. MAHER. 1973. Bald Eagle Behaviour Study Part II. Unpublished report. 90 p.

ZEALAND, G. - personal communication.

ZYBLUT, E.R. 1972. 1972 report on the even-year Pink Salmon stocks of the Johnstone Strait Study area. Canada. Dept. of the Environment, Fisheries Service, Pacific Region. Technical Report. 1972 - 1974.

ZYBLUT, E.R. and A.D. ANDERSON. 1973. 1973 report on the odd-year Pink Salmon stocks of the Johnstone Strait study area. Canada. Dept. of the Environment, Fisheries Service, Pacific Region. Technical Report. 1973 - 1976.