Exxon Valdez Oil Spill
Restoration Project Annual Report

Distribution, Abundance, and Composition of Harlequin Duck Populations in Prince William Sound, Alaska

Restoration Project 95427
Annual Report

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Study History: Restoration Project 95427 continues the harlequin duck (*Histrionicus histrionicus)* studies begun by the Alaska Department of Fish and Game in 1992 with Bird Study Number 11 (Injury Assessment of Hydrocarbon Uptake by Sea Ducks) and Restoration Study Number 71 (Harlequin Duck Restoration and Monitoring). The preceding studies attributed the spill to causing a decline in the 'resident' population of harlequin ducks inhabiting heavily oiled areas of western PWS and to lower reproductive success of birds surviving or avoiding initial exposure. Little information, however, was collected on sex and age composition, seasonal movements, or proportions of paired birds; data necessary for examining the growth potential of a population. Restoration Project 94427 (Experimental Harlequin Duck Breeding Survey) developed age and sex criteria to classify the composition of the spring (breeding) and fall (molting) population; designed a sampling scheme to estimate abundance; and conducted brood surveys to estimate productivity in oiled areas of western Prince William Sound.

Abstract: In response to declines in harlequin duck numbers following the *Exxon Valdez* oil spill in 1989, we continued harlequin duck surveys in 1995 in nearshore waters of Prince William Sound (PWS), AK. The purpose of our study was to determine whether low reproductive success in oiled areas of western PWS resulted in changes in population structure and breeding propensity. Two study areas were compared, one in oiled waters of western PWS (WPWS) and one in unoiled eastern PWS (EPWS). As in past years, no productivity was observed in WPWS. We attributed low productivity to the following differences between populations: 1) Males comprised a significantly greater proportion of the WPWS population during early spring and fall; 2) The ratio of paired to non-paired females was significantly lower in WPWS; and 3) A greater proportion of flightless females was observed in WPWS in late July. Fewer breeding females, a higher proportion of males, and no observations of harlequin duck broods lead us to conclude that productivity is lower in WPWS than EPWS.

Key Words: *Exxon Valdez* oil spill, harlequin duck, *Histrionicus histrionicus,* population monitoring, Prince William Sound, restoration, seaducks.

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EXECUTIVE SUMMARY

Harlequin ducks *(Histrionicus histrionicus)* occur year-round in intertidal and shallow, subtidal zones (nearshore waters) of Prince William Sound (PWS), Alaska. In 1989, large numbers of harlequin ducks died in PWS as a direct result of oil exposure following the *T/V Exxon Valdez* oil spill (EVOS). Post-spill studies report a decline in the number and productivity of harlequin ducks inhabiting oiled areas of western PWS (WPWS). Continued decline in the harlequin duck population may result in a significant reduction or loss of this resource in PWS.

Harlequin duck population levels are sensitive to adult female survival, breeding propensity (% breeding annually), and the number of breeding individuals. Demographic characteristics of the harlequin duck population influence productivity. Age and sex ratios and numbers of breeding pairs are useful indicators of population growth or decline. Past surveys reveal little about the sex and age structure of harlequin ducks in WPWS. Lack of information makes it difficult to predict future trends in harlequin numbers.

The objectives of this study are to:

1. Compare population composition (number of breeding pairs, subadult males, adult males, and females) between oiled and unoiled areas in spring.
2. Estimate density for oiled and unoiled survey sites in spring and fall.
3. Compare annual changes in density and population structure for oiled and unoiled survey sites in spring.
4. Compare sex ratios of molting flocks in oiled and unoiled areas.
5. Compare annual changes in density and sex ratios for oiled and unoiled survey sites during the molt.
6. Compare production between oiled and unoiled areas.

We surveyed near-shore habitats from May through September, 1995. Surveys were conducted simultaneously in EPWS and WPWS during three spring and three fall periods. Spring surveys were timed to monitor harlequin ducks during the breeding season, while fall surveys coincided with molting and brood-rearing. From early spring to fall populations are dynamic. Numbers decline in early spring as breeding birds move to mountain streams and up river systems to nest. Numbers increase from late June through September as birds return to coastal areas to molt. Repeat surveys were used to detect seasonal changes in population composition and numbers.

Transects were established in areas previously surveyed and known to support harlequin ducks. Surveys were conducted from an open skiff within 100 meters of shore at a pace, course, and distance that assured complete coverage of the survey area and maximized the opportunity to observe ducks. Ducks were counted and classified by sex. During spring surveys sub-adult males were distinguished from adult males based on plummage characteristics, and the number of breeding pairs was recorded.

Low reproductive success of harlequin ducks in PWS since the spill should have resulted in changes in age and sex structure towards a greater proportion of adult males. The ratios and timing of changes in population structure and abundance should be indicative of the current

breeding behavior of the population. The ratio of subadult to adult males serves as an index of recruitment, an indication of past breeding success. Brood surveys identify current breeding success and serve as an index of productivity.

No broods were identified in WPWS, while ten broods were identified in EPWS. We identified differences between EPWS and WPWS populations that may result from low productivity in WPWS. These are: 1) Males comprised a significantly greater proportion of the WPWS population during the first spring survey; 2) The ratio of paired to non-paired females was significantly lower in WPWS; 3) Males comprised a significantly greater proportion of the WPWS population during the fall; 4) A greater proportion of flightless females was observed in WPWS in late July; 5) The return of postbreeding males was earlier and more condensed in EPWS; and 6) The return of postbreeding females began later in WPWS.

Fewer breeding females, a higher proportion of males, and no observations of harlequin duck broods lead us to conclude that productivity has been and remains lower in WPWS than EPWS.

The density of harlequin ducks was consistently greater in EPWS. Habitat differences between EPWS and WPWS may explain higher densities in EPWS and lower productivity of harlequin ducks in WPWS. Substantially less kilometers of streams in WPWS implies fewer streams available for nesting and ultimately less production. Further, we speculated that individual streams in the spill area may not be as desirable for nesting due to their length, gradient, or volume of discharge. Differences in the availability of food sources necessary for achieving breeding condition or brood rearing may also inhibit nesting in WPWS.

Eventhough we did not observe harlequin broods in WPWS during 1995, the presence of first and second year males in the spring suggests successful reproduction in previous years (1993 and 1994). Whether these recruits are the progeny of pairs that nest in areas other than WPWS but inhabit WPWS during the non-breeding period, or they immigrate from elsewhere is not known.

Between late June and late July, males and females returned to EPWS at a much greater rate than WPWS. This earlier influx of post- breeding males and females into EPWS may signify a return of birds that nest in close proximity to the coast. As no females and fewer males returned to WPWS during this time we believe this signifies a smaller coastal breeding population. The lack of broods, presence of subadults, and delayed return of post-breeding birds to WPWS may indicate that breeding birds in WPWS travel further to nesting areas than do breeding birds in EPWS.

We compared the number of ducks observed in identical shoreline segments from similar time periods in WPWS and EPWS. We did not detect variation in harlequin duck counts when comparing fall surveys in 1994 and 1995 for WPWS, fall surveys in 1991, 1993 and 1995 for EPWS, and spring surveys in 1992 and 1995 for EPWS.

As an exercise to demonstrate the analysis we plan to conduct with additional years of survey data, we performed a power analysis to illustrate the probability of detecting variation in growth rates of harlequin duck populations in EPWS and WPWS. Annual monitoring of population structure and reproductive success of harlequin ducks will allow us to assess trends and suggest factors that limit recovery. This will provide a more reliable basis for restoration planning and be consistent with an adaptive management approach that allows more efficient allocation of efforts and enrichment of knowledge over time (e.g. for a long-term monitoring program).

INTRODUCTION

Harlequin ducks (*Histrionicus histrionicus)* occur year-round in intertidal and shallow, subtidal zones (nearshore waters) of Prince William Sound (PWS), Alaska (Isleib and Kessel 1973). In 1989, large numbers of harlequin ducks died in PWS as a direct result of oil exposure following the *T/V Exxon Valdez* oil spill (Ecological Consulting Inc. 1991, John Piatt, USFWS, pers. comm.). Post-spill studies reported a decline in numbers (Klosiewski and Laing 1994, Patten 1995, Patten et al. 1995) and productivity (Patten 1995, Patten et al. 1995) of harlequin ducks inhabiting oiled areas of western PWS. Patten (1995) and Patten et al. (1995) suggested the decline was the result of high initial mortality, continued ingestion of oil resulting in sub-lethal impairment of reproduction, and displacement of birds to unoiled areas. Detectable levels of hydrocarbons were found in esophageal foods and tissues of harlequin ducks collected in 1989, 1990 and 1993 (Patten 1995, Patten et al. 1995). However, no conclusive evidence exists for relating histological or physiological injury to oil ingestion by harlequin ducks. However, numbers may continue to decline resulting in a significant reduction or loss of this resource from PWS.

Harlequin ducks are typical of other sea ducks in that they are relatively long lived, and exhibit delayed sexual maturity and low annual production (Goudie et al 1994). Thus, population levels are sensitive to adult female survival, breeding propensity (% breeding annually), and the number of breeding individuals (Goudie et al. 1994). Demographic characteristics of the harlequin duck population can influence productivity. Age and sex ratios and numbers of breeding pairs (population structure) are useful indicators of population growth or decline. Unfortunately, pre- and post-spill surveys (Dwyer et al. 1976, Sangster et al. 1978, Hogan and Murk 1982, Irons et al. 1988, Hotchkiss 1991, Agler et al. 1994, Klosiewski and Laing 1994, Patten 1995 and Patten et al. 1995) reveal little about sex and age composition. Lack of information makes it difficult to predict future population trends or compare the sex and age structure and breeding propensity of different populations.

From early spring to fall populations are dynamic. Numbers decline in early spring as breeding birds move to mountain streams and up river systems to nest. Numbers increase from late June through September as birds return to coastal areas to molt (Isleib and Kessel 1973). Post-spill surveys (Patten 1995, Patten et al. 1995) were not designed to account for this population flux. In 1994 sexing and aging criteria were developed (Rosenberg 1995) and repeat surveys were tested as a method to detect within season changes in population structure and numbers.

Additionally, little pre-spill productivity data (brood surveys) from western PWS makes comparisons with post-spill populations difficult. Prior to the spill no systematic brood surveys were conducted, however, incidental brood observations are common (Isleib and Kessel 1973, Sangster et al. 1978, Oakley and Kuletz 1979). After the spill, only 14 harlequin duck broods were observed in areas surveyed from 1989 - 1993 (Patten 1995, Patten et al. 1995), suggesting that reproduction declined in oiled areas. We believe it is necessary to revisit areas where pre-spill observations of broods were made to determine whether productivity has increased since the initial decline.

OBJECTIVES

1. Compare population structure (number of breeding pairs, subadult males, adult males, and females) between oiled and unoiled areas in spring.

2. Estimate density for oiled and unoiled survey sites in spring and fall.

3. Compare annual changes in density and population structure for oiled and unoiled survey sites in spring.

4. Compare sex structure of molting flocks in oiled and unoiled areas.

5. Compare annual changes in density and sex structure for oiled and unoiled survey sites during the molt.

6. Compare production between oiled and unoiled areas.

The goal of this study is to determine the status and recovery potential of harlequin ducks. By comparing the population structure between oiled and unoiled areas we will test whether low reproductive success in oiled areas has resulted in changes in age and sex ratios and proportions of paired birds. Within season population changes are compared to detect whether populations in oiled and unoiled areas change similarly during the course of the breeding season and again during the molt. Number of broods are used to indicate current reproductive success and compared for oiled and unoiled areas. In future years we will compare annual changes in density and population structure to test whether the two populations are exhibiting a similar direction and rate of change or the oiled population is responding differently.

STUDY AREA AND METHODS

The study was conducted in Prince William Sound (PWS), Alaska (Fig. 1). A general description of the physiography, climate, oceanography, and avian habitats of PWS is described by Isleib and Kessel (1973). Two separate study areas were selected, one in western PWS (WPWS) in waters affected by the *T/V Exxon Valdez* oil spill and one in eastern PWS (EPWS) in waters geographically distant and unaffected by the spill. The western PWS study area included shoreline segments and offshore rocks from the north end of Culross Island, south to Jackpot Bay and east to Green Island (Fig. 1) (Rosenberg 1995). The eastern PWS study area includes shoreline segments from Shoup Bay in Valdez Arm to Simpson Bay, and portions of Hinchinbrook Island (Fig. 1). Transects followed shorelines of mainland and island sites, and included offshore rocks (Fig. 2). Transects in both study areas were established in areas previously surveyed by Patten (1995) and Patten et al. (1995) and known to support harlequin ducks.

We surveyed near-shore habitats from May through September, 1995 (Fig. 2, Fig. 3). Surveys were conducted simultaneously in EPWS and WPWS during three spring and three fall survey periods (Table 1, Table 2). Spring surveys were timed to monitor harlequin ducks during the breeding season, while fall surveys coincided with molting and brood-rearing. Additional transects were surveyed in fall to include potential brood-rearing areas (e.g. stream mouths and estuaries) (Table 1, Table 2). With the exception of the second spring survey in WPWS (Table 1) a sufficient number of transects were surveyed to ensure meaningful comparisons among survey periods. On average, each completed survey period lasted for about eight days. Incomplete surveys resulted from prolonged periods of inclement weather.

Survey methods followed Rosenberg (1995). Surveys were conducted from open skiffs (ca. 6m long) traveling at 2-20 km/hr within 100 meters of shore at a pace, course and distance that assured complete coverage of the survey area and maximized the opportunity to observe ducks. Distance from shore depended on light, weather and tide conditions. One full-time observer and a observer/boat operator continuously surveyed near shore habitats using 10X binoculars. No surveys were conducted when wave height, weather, or light conditions compromised accuracy. The location and number of ducks in each flock were recorded on nautical charts (National Ocean and Atmospheric Administration).

Three spring surveys were conducted between 10 May and 16 June, 1995. Birds were categorized as paired or single. Single birds were classified by sex and males further segregated into one of three age classes based on plumage patterns (Rosenberg 1995). Collectively, first and second year males were considered subadults (Terres 1980). No unobtrusive method exists for determining age classes of females under our survey conditions. Paired females were considered adults.

Three fall survey periods were conducted from 23 July through 14 September, 1995. Molting birds were categorized as males or females. Progression to basic plumage during molt prevented aging males. Ducks were considered flightless when they consistently dove or swam away upon our approach rather than fly away. Broods were identified by the presence of down on ducklings, or if the adult female exhibited protective behavior. Ducklings were aged according to Wallen's (1987) application of Gollop and Marshall's (1954) stages of plumage development. Chronology of nesting and onset of incubation was estimated by backdating from age-classes of broods using methods and assumptions described by Crowley (1996). Fledging dates were estimated by forward dating.

Transect length (km) and length of streams (km) intersecting each transect were calculated from The Alaska Department of Natural Resources PWS_ESI Arc Info GIS database. Shoreline length of small islands not included in the PWS_ESI Arc Info GIS database was calculated using the U.S. Forest Service CNFSHORE Arc Info GIS database. Anadromous and non-anadromous stream classification and lengths were derived from The Alaska Department of Fish and Game Anadromous Waters Catalog and Atlas (ADF&G 1994a, ADF&G 1994b). Total stream length, rather than number of streams, was used as an index to compare available nesting habitat between WPWS and EPWS survey areas. Shoreline classification was derived from Gibeaut (1990).

Statistical Methods

We used a generalized logit model (Agresti 1990) to test for differences between EPWS and WPWS in the ratio of males to females during the spring and fall, the ratio of adult males to subadult males during the spring, the ratio of paired to non-paired females during the spring, the ratio of paired to non-paired ducks during the spring, and the ratio of flightless to flight capable females during the fall. A test of the hypothesis of no interaction between main effects (i.e. location and survey) was based on a likelihood ratio test (Stokes et al. 1995). The interaction term was excluded from the model when it was non-significant, and a reduced model was used to test for significant location or survey effects. We used individual flocks (cluster sample) to calculate a pooled variance when comparing ratios between EPWS and WPWS for a specific survey period (Cochran 1977).

We used a Poisson Regression model with shoreline length as an offset variable (Agresti 1990, Stokes et al. 1995) to test for differences in density of harlequin ducks between WPWS and EPWS during the spring and fall.

We compared the number of harlequin ducks counted during fall surveys in WPWS in 1994 (Rosenberg 1995) and 1995; fall surveys in EPWS in 1991, 1993 and 1995 (Crowley 1996), spring surveys in EPWS in 1992 and 1995 (Crowley 1996). Data were only used when the location of the survey and the date the survey was conducted were similar among years. The change in the number of harlequin ducks for all comparisons was calculated as:

$$\text{change} = \text{count 1995} - \text{comparable historical count}$$

For each comparison, we used a nonparametric Wilcoxon sign rank test (Conover 1980) to test for significant variation in harlequin numbers among time periods. We used a Wilcoxon sign rank test (Conover 1980) to test for significant variation in harlequin numbers between locations.

RESULTS

Survey Area

Transects and Shoreline

We surveyed 24 and 33 transects during the spring, and 28 and 41 transects during the fall for the presence of harlequin ducks in WPWS and EPWS, respectively (Table 1, Table 2, Appendix A). Additional transects were added to fall surveys to increase coverage in potential brood-rearing areas. A substantial decrease in survey coverage occurred during the second spring survey in WPWS when severe weather prevented us from completing the survey and limited our survey coverage to only 4 transects (Table 1). For similar reasons, a slight decrease in survey coverage occurred during the third fall survey in EPWS when 34 transects were surveyed (Table 2). Overall, transect length was extremely variable (Table 1 Table 2), averaging 16.3 km in WPWS (n = 136; s.d. = 15.9 km) and 7.7 km in EPWS (n = 215; s.d. = 7.0 km). Individual transects varied in length among survey periods because weather conditions deteriorated suddenly, preventing completion of the transect; transect length was increased to incorporate potential brood-rearing areas; transects were started or ended at slightly different locations.

We surveyed substantially more shoreline in WPWS than EPWS during all completed surveys (Table 1, Table 2). Because we could not complete the second spring survey in WPWS, only 61 km of shoreline were surveyed during this period (Table 1). Shoreline length, for completed surveys, averaged 355 km in WPWS and 259 km in EPWS in the spring, and 481 km in WPWS and 296 km in EPWS in the fall.

Habitat

Shoreline on transects in EPWS was primarily composed of mixed sand/gravel beaches (ca. 36%) followed by gravel/cobble/boulder beaches (ca. 17%) and sheltered rocky shores (ca. 17%) (Table 3). These three shoreline types were also dominant in WPWS. Mixed sand/gravel beaches were relatively less abundant and sheltered rocky shore were relatively more abundant in WPWS than EPWS (Table 3). Exposed rocky shores also comprised a large proportion of shoreline in WPWS (ca. 14%); much greater than this shoreline type was represented in EPWS (ca. 3%) (Table 3). Although sheltered tidal flats and marshy areas comprised a relatively small proportion of the total shoreline, these areas were more prevalent in EPWS than in WPWS (Table 3).

Total length of streams intersecting our transects was much greater in EPWS than WPWS (Table 4, Fig. 4, Fig. 5). For every kilometer of shoreline surveyed in EPWS (total = 1664.1 km) their existed 2.44 km of stream, compared to 0.62 km in WPWS (total = 2212.8 km of shoreline). Anadromous streams accounted for 92% (2.25 km) of the total stream length in EPWS, but only 63% (0.39 km) in WPWS. More kilometers of non-anadromous streams were present in WPWS (0.23 km) than in EPWS (0.19 km) for each kilometer of shoreline surveyed (Table 4).

Harlequin Duck Distribution

Harlequin ducks were observed (during at least one survey period) on all but 2 transects, both in EPWS (Snug Corner Cove and Fish Bay). For all survey periods combined, harlequin ducks were absent on 15% of the transects surveyed in WPWS (Table 5) and 16% in EPWS (Table 6). The number of harlequin ducks varied considerably among transects, and within transects among survey periods (Table 5, Table 6, Appendix A). Within transect variability was lower in EPWS, especially during the fall survey period when the coefficient of variation for the average transect was 66% in EPWS and about 83% in WPWS (Table 7, Table 8). Transects which consistently supported large numbers of harlequin ducks included Green Island, Foul Bay, Channel Island, Falls Bay, Culross Island, Crafton Island and Totemoff Creek in WPWS (Table 5), and Hell's Hole, Olsen Bay, Port Etches, Port Gravina (SE), and Sheep Bay (east) in EPWS (Table 6) (Appendix A). Thirty five percent of the total ducks counted in WPWS were located on Green Island.

Seasonal Variation in Harlequin Ducks

Density

The number (Table 6) and density (Table 9) of harlequin ducks in EPWS declined significantly (χ^2=6.8837, df=1, p=0.0087) from early May through late June, then increased significantly (χ^2=237.6401, df=1,p=0.0001) from late-July through mid-September. Because survey coverage was identical among spring surveys in EPWS, the relative change in density (Fig. 6) and in total harlequin ducks (Fig. 7) are identical. Densities of harlequin ducks are not directly comparable between spring and fall surveys, however, because survey coverage differed between survey periods (Table 2). Densities were low on transects added during the fall, therefore, densities in the fall are higher than we report (Table 9) when only compared to areas surveyed in the spring.

Even though we lack data for the second spring survey in WPWS (Table 5), it appears harlequin ducks progressively increased during our spring surveys. We observed larger numbers of ducks during the third spring survey than the first (Table 5). Density, however, was significantly lower during the last spring survey (χ^2=6.8837, df=1, p=0.0087) (Table 10) suggesting a decrease in harlequin numbers during the spring. Because the lower density for the third spring survey can, for the most part, be attributed to an increase in survey coverage on Naked Island, and few ducks were located there during the spring (Table 5), we believe the number of harlequin ducks, rather than density, more closely represents the relative change in harlequin ducks in WPWS during the spring. As in EPWS, the density (Fig. 6) of harlequin ducks in WPWS increased significantly during the fall (χ^2=237.6401, df=1, p=0.0001). Densities of harlequin ducks are higher than we report for the fall in WPWS (Table 10) when only comparable areas surveyed in the spring are considered.

The net decline in harlequin numbers during the spring in EPWS can be attributed to decreasing numbers of females because the number of males increased during this time period (Table 11). The inverse relationship between the number of female and male harlequin ducks was also observed in WPWS as the breeding season progressed (Table 11). A general pattern of increasing flock size with an associated decrease in the number of flocks was apparent during the spring for harlequin ducks in both locations (Fig. 8).

The rate of increase in duck numbers during the period from our last spring survey (mid-June) to our first fall survey (end of July) was much greater in EWPS (49.3%) than WPWS (11.2%) (Fig. 7). Densities during this period also increased at a higher rate in EPWS (24%) than WPWS, where it decreased by 18% (Fig. 6) because transects added during the fall survey period contained relatively few ducks. The progressive increase in harlequin ducks in WPWS and EPWS during the fall resulted from an increase in both males and females (Table 12). Flock size was negatively correlated with the number of flocks from late July through mid-August. From mid-August through early September, however, the number of flocks increased in WPWS and decreased in EPWS, with an associated increase in flock size in both locations (Fig. 8).

When we ignore the second spring survey in WPWS, densities of harlequin ducks were significantly higher in EPWS than WPWS (χ^2=65.330, df=1, p=0.0001) during the spring and for all surveys during the fall (χ2=776.3960, df=1, p=0.0001) (Table 9, Table 10). Greater difference in harlequin densities occurred between EPWS and WPWS during the fall (Fig. 9). Larger differences existed between EPWS and WPWS when comparing densities of harlequin ducks as opposed to total harlequin numbers (Fig. 9) because of differences in survey coverage between locations (Table 1, Table 2).

Sex Ratios

Male harlequin ducks were more abundant than females during the spring (Table 11) and fall (Table 12) survey periods in WPWS and EPWS. In both locations the proportion of males increased steadily during the spring and decreased during the fall (Fig. 10). The ratio of male to female harlequin ducks varied between EPWS and WPWS among spring (χ^2=14.72, df=4, p=0.0053) and fall surveys (χ^2=11.81, df=4, p=0.0188) (Fig. 11). During the first spring survey, female harlequin ducks comprised a significantly greater proportion of the harlequin duck population in EPWS (39.3%) than in WPWS (35.1%) (t=8.18, df=298, p<0.001). By the third spring survey, female harlequin ducks were relatively more abundant in WPWS (21.3%) than in EPWS (18.7%).

During the first fall survey in late July, the ratio of males to female was 2 times larger in WPWS (6.42:1) than in EPWS (3.24:1) (Fig. 11). The disparity in sex ratios between locations declined during the fall, but the proportion of females was still significantly lower in WPWS (34.1%) than in EPWS (40.8%) by the end of the third fall survey (t=17.632, df=284, p<0.001).

Breeding Pairs

We counted more breeding pairs in EPWS than WPWS during the spring (Table 11). The number of pairs declined in both locations from May through June with the progression of nest initiation (Fig. 12). As the total number of females and the number of pairs declined, non-paired females composed a significantly larger proportion of the female population (χ^2=204.27, df=2, p<0.001) (Fig. 13). The ratio of paired to non-paired females was significantly lower in WPWS (χ^2=81.09, df=1, p<0.001). By the last spring survey in mid-June, there were 20 non-paired females for every paired female in WPWS, as opposed to a 2.5:1 ratio in EPWS (Fig. 13).

Male Age Ratios

The male segment of the harlequin duck population was composed of primarily adults during the spring (Fig. 14). Subadult males were equally represented in WPWS and EPWS (χ^2=2.94, df=1, p=0.0866). The proportion of subadult males, however, varied among spring surveys (χ^2=21.94, df=2, p<0.001). Our analysis suggests that the proportion of subadult males was lowest and highest during the first and second spring surveys, respectively. Meaningful interpretation of subadult age classes (Fig. 15) is difficult because of the large proportion of unknown-aged subadults in EPWS and the lack of data for the second spring survey in WPWS.

Molt

Male harlequin ducks exhibited a more synchronous molting period than did females (Fig. 16). The ratio of flightless to flight capable males varied between EPWS and WPWS among fall surveys (χ^2=32.90, df=2, p<0.001). The proportion of flightless males was similar between locations during the first and second fall surveys, however, flightless males were relatively more abundant in EPWS (17.3%) than WPWS (1.0%) by the third fall survey (Fig. 16). By the third fall survey in mid-September, over 80% of males were flight capable (Fig. 16).

The molting period for females was more extensive and more variable between locations than it was for males (Fig. 16). The ratio of flightless to flight capable females varied between EPWS and WPWS among fall surveys (χ^2=38.20, df=2, p<0.001). A larger proportion of flightless females were observed in WPWS (75.4%) than EPWS (46.7%) during the first fall survey in late July (Fig. 16). From the mid-August to mid-September, however, the proportion of flightless females was more similar, but slightly higher in EPWS (Fig. 16).

Broods

Harlequin duck broods were only observed in EPWS (Fig. 17). Ten broods, totaling 26 ducklings (mean = 2.6, s.d. = 1.35) were observed at 7 locations (Table 13). Most (60%) broods were observed during the second fall survey (Table 13). All broods were observed at the mouth of streams (Fig. 17). We estimate that nest initiation, for the broods we observed, occurred in late May through early July. Fledging was estimated to occur from late August through late September.

Annual Changes in Harlequin Numbers

We did not detect variation in harlequin duck counts when comparing fall surveys in 1994 and 1995 for WPWS, fall surveys in 1991, 1993 and 1995 for EPWS, and spring surveys in 1992 and 1995 for EPWS. The mean sign rank for duck counts in the fall for WPWS was -6.24, while not significant (p = 0.10, n = 33), it does show greater (or more) decreases than increases in counts. The mean sign rank for duck counts in the fall for EPWS was -1.42 which was also not significantly different from 0 (p = 0.81, n=77). We found no significant difference in direction or magnitude of change in harlequin numbers (p = 0.34) when fall surveys were compared between EPWS and WPWS. There was no significant variation in harlequin counts in EPWS for our only spring comparisson (p = 0.49, n=17).

DISCUSSION

Population Structure, Distribution, and Abundance

The number of harlequin ducks we observed in Prince William Sound was correlated with seasonal movements in and out of the study area (Fig. 7). These movements were associated with annual life history events (i.e. breeding, molting, brood-rearing) that ultimately influence the viability of the population. The general pattern of seasonal movements was similar between EPWS and WPWS. We did, however, observe differences between locations in the magnitude and timing of these movements that can represent differences in the population's growth potential.

A redistribution of ducks occurred within the WPWS study area. For most transects located to the west of Green Island, densities declined throughout spring and continued to decline between the last spring and first fall survey. From the first fall to last fall surveys they increased. At Green and Channel islands the inverse was true: densities increased throughout spring and into late July and then declined (Table 10). We believe birds are moving to Green and Channel islands to molt and then once flight capable departing, perhaps to pre-molt sites. No such pattern of movement was detected for EPWS.

Factors Supporting Low Productivity in WPWS

No broods were observed in WPWS. Comparisons of temporal changes in nesting chronology and population structure between oiled and unoiled areas are useful to determine if low reproductive success in oiled areas has resulted in changes in age and sex ratios and proportions of paired birds. We have identified some significant differences between EPWS and WPWS populations that may result from low productivity in WPWS. These are:

1). Males comprised a significantly greater proportion of the WPWS population during the first spring survey.

2). The ratio of paired to non-paired females was significantly lower in WPWS.

3). Males comprised a significantly greater proportion of the WPWS population during the fall.

4). A greater proportion of flightless females was observed in WPWS in late July.

5). The return of postbreeding males was earlier and more condensed in EPWS and;

6). The return of postbreeding females began later in WPWS.

Although sex ratios are male biased in harlequin ducks, the significantly higher ratio in WPWS during the first spring survey (Fig. 11), implies greater female mortality and therefore less reproductive potential. Breeding females were also less abundant and comprised a smaller proportion of the total female population in WPWS in spring (Fig. 13). Number of breeding pairs declined in spring with the progression of nest initiation (Fig. 12). As breeding pairs declined, relatively more females remained in the WPWS study area (Fig. 13). This suggests pair separation rather than departure for breeding areas.

In EPWS, declines in breeding pairs and females were more commensurate. Non-paired females were twenty times more abundant than paired females in WPWS late in the breeding season, versus only three times more abundant in EPWS (Fig. 13). The greater proportion of non-breeding females cannot be explained by a greater number of subadult females. Proportions of subadult males were similar between sites and we expect the same of subadult females (Fig. 14). A surplus of adult males in both locations indicates availability of potential mates (Table 11).

Fewer breeding pairs and a lower proportion of females departing the study area in spring suggests lower breeding propensity in the WPWS population.

In fall, we again find significantly higher proportion of males in WPWS (Fig. 11) further supporting arguments for greater female mortality and less reproductive potential. Less breeding propensity in WPWS populations is further supported by the much higher proportion of flightless (molting) females in WPWS (Fig. 16) in late July. Among waterfowl, non-breeding females molt earlier than breeding females and we suspect the higher proportion of flightless birds in the WPWS population represents a greater percentage of non-breeding females. Fewer breeding females, a higher proportion of males, and no observations of harlequin duck broods leads us to conclude that productivity is lower in WPWS than EPWS.

Potential Explanations for Lower Productivity in WPWS

Several factors may explain lower productivity of harlequin ducks in WPWS. Higher densities of harlequin ducks in EPWS (Table 9, Fig. 9) suggests variation exists in quantity or quality of preferred habitat between locations. Less breeding habitat may explain lower productivity in WPWS, but not complete reproductive failure. Perhaps, lack of brood observations suggests that nesting habitat is restricted in WPWS, and our survey methods may be insufficient to detect low production.

Substantially fewer kilometers of streams in WPWS (Table 4) implies less availability of nesting streams and ultimately less production. Further, individual streams in the spill area may not be as desirable for nesting. Crowley (1994) reported that harlequin ducks prefer to nest on streams with a relatively high volume discharge and low gradients. Unfortunately, little stream flow data are available for most of the oiled portions of Prince William Sound. Overall, stream gradients in WPWS may be of shorter length and higher gradient than those in EPWS.

Another potential source of variation in habitat quality between EPWS and WPWS can be the availability of food sources necessary for achieving breeding condition or for brood rearing. Lower availability of high quality foods may preclude females in WPWS from nesting. The inability to attain sufficient weight or obtain critical nutrients may explain the larger proportion of non-breeding females observed in WPWS late in the breeding season (Fig. 13). Coastal nesting females rear broods in estuaries. Lack of sufficient quantity or quality of foods in estuarine areas may nullify the use of the entire stream as a nesting area. Harlequin ducks that nest and rear broods to fledging on inland waterways are thought to forego nesting in years when freshwater aquatic food resources are low. (Bengtson 1972).

Recruitment

The number and proportion of subadult birds in a population should be used cautiously when measuring recruitment and assesing rates of productivity (Chadwick 1992). Based on the proportion of sub-adult males, we found no evidence of lower recruitment rates in WPWS (Table 11, Fig. 14), yet there has been little to no indication of coastal nesting (coastal streams or small islands) in oiled areas of WPWS from 1991 through 1995 (Patten 1995, Patten et al. 1995, Rosenberg 1995). This indicates reproductive success and recruitment in WPWS in 1994 and 1993 (Fig. 14, Fig. 15).

We are not certain why the proportion of sub-adult birds are similar between areas. Because most non-breeding males are thought to remain on coastal areas until their third spring (Dement'ev and Gladkov 1967, Kuchel 1977, Wallen 1987, Cassirer and Groves 1992, Diamond and Finnegan 1993, Bengtson 1972), we expected the number of subadult males to remain constant throughout the breeding season. Thus, as more post-breeding adult males return to coastal areas the proportion of subadult males should decline. However, densities of subadult males increased at a greater rate than densities of adult males in both study areas suggesting some immigration. Subadults, therefore, may be more transient than adults (at least on the coast) limiting their use as indicators of recruitment. Alternatively, the occurance of sub-adults in WPWS may represent production by breeding pairs off the study area, and the fleged young return to PWS after our surveys are completed. Preliminary evidence (see below) suggests that a greater proportion of the WPWS population may nest inland, where a relatively larger majority of young may be produced.

Significance of Coastal Versus Inland Nesting Populations

Between the spring and fall survey periods the number of ducks increased as post breeding birds returned to the coast to molt (Table 5, Table 6, Fig. 7). During early incubation pair-bonds weaken and males return to coastal areas (Isleib and Kessel 1973). Non-breeding birds which remain in PWS molt first, followed by males immigrating from breeding areas. Post-breeding females are the last birds to become flightless (Palmer 1976). The return rate of females depends on their success nesting and brood rearing, local phenology, and the distance from the coast to the breeding area. In July, males and females returned to EPWS at a greater rate than WPWS. As the numbers of females almost doubled in EPWS, numbers declined in WPWS (Table 11, Table 12). This earlier influx of post- breeding males and females into EPWS may signify a return of birds that nest in close proximity to the coast. As no females and fewer males returned to WPWS during this time we believe this signifies a much smaller coastal breeding population.

As in British Columbia (Breault and Savard 1991) the relative importance of coastal and interior breeding components of the population is unknown. The lack of broods, presence of subadults, and delayed return of post-breeding birds to WPWS suggests a greater percent of nesting occurs at more distant locations. Our first spring survey began May 10, after a portion of the winter population departed for breeding areas (Crowley 1996) (Fig. 12). This is confirmed by our September counts which greatly exceeded counts from early May (Table 5, Table 6, Fig. 7). We expect that more inland than coastal breeding pairs departed for nesting sites by the time surveys began. If inland nesters indeed represent a higher proportion of the WPWS breeding population, a higher percentage of breeding pairs may have departed from WPWS than from EPWS before our first survey.

Annual Changes

If reproduction is continually low or absent, populations will decline if no immigration occurs. Harlequin ducks exhibit fidelity to molt sites (Patten 1995). Molting birds are relatively stationary, therefore, molting populations may serve as the best measure of population trends. We compared numbers of ducks observed in identical shoreline segments from similar time periods in the fall of 1994 and 1995 in WPWS. Although there was a slight decline, we did not detect a significant change between years. Therefore, between 1994 and 1995, the population appeared to be stable. Thus, barring immigration, recruitment compensated for mortality.

Power Analysis

With the addition of 1996 data we will analyze population trends to determine whether the rate of change in duck numbers is the same for EPWS and WPWS. For illustrative purposes, we compared similar surveys conducted in 1991, 1993, and 1995 for 25 locations in EPWS. Linear regression was used to estimate the rate of change in duck populations for each survey location. The average of the 25 slopes was then used to estimate the overall rate of change for EPWS. Because comparable coverge (>2 years data) is not available for WPWS, we assumed that the slope estimates would have the same variability as in EPWS. The power of the test to determine whether the rate of change in duck populations is the same between EPWS and WPWS was then calculated for different levels of variation in slope between EPWS and WPWS and is presented below and in Figure 18.

Difference in Slope	0.25	0.5	0.75	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0
Power (α=0.10)	0.14	0.18	0.24	0.31	0.37	0.43	0.49	0.56	0.62	0.68	0.73	0.78	0.83	0.87
Power (α=0.05)	0.07	0.10	0.14	0.19	0.24	0.29	0.35	0.41	0.47	0.53	0.60	0.66	0.71	0.77

For example, we would correctly reject the null hypothesis that there is no difference in the rate of change between EPWS and WPWS (α=0.10) 68% of the time if the slopes differed by 2.2. We expect the power of our ability to detect changes will increase with the addition of future survey data.

The level of sampling in 1995 was sufficient to critically test for variation in demographic parameters (sex and age ratios) of harlequin ducks between EPWS and WPWS. The sampling effort planned for 1996 is the same as 1995 and should be adequate to detect similar changes.

CONCLUSIONS

The number of harlequin ducks we observed in Prince William Sound was correlated with seasonal movements associated with annual life history events (i.e. breeding, molting, brood-rearing). The general pattern in seasonal movements was similar between EPWS and WPWS. We did, however, observe differences between locations in the magnitude and timing of these movements that may explain why we observed no broods in WPWS, but did observe ten broods in EPWS.

Important differences between EPWS and WPWS populations that may result from low productivity in WPWS are: 1) Males comprised a significantly greater proportion of the WPWS population during the first spring survey; 2) The ratio of paired to non-paired females was significantly lower in WPWS; 3) Males comprised a significantly greater proportion of the WPWS population during the fall; 4) A greater proportion of flightless females was observed in WPWS in late July; 5) The return of postbreeding males was earlier and more condensed in EPWS; and 6) The return of postbreeding females began later in WPWS.

We interpreted significantly higher male:female ratios in WPWS during spring and fall to signify greater female mortality and less reproductive potential. Fewer breeding females in WPWS and more females remaining in WPWS as the numbers of breeding pairs declined suggested pair separation (rather than departure for breeding areas) and a lower breeding propensity. Less breeding propensity in WPWS populations is further supported by the much higher proportion of flightless (molting) females in late July. A surplus of adult males in both locations indicates potential mates are not limiting. Fewer breeding females, a higher proportion of males, and no observations of harlequin duck broods lead us to conclude that productivity has been and remains lower in WPWS than EPWS.

The density of harlequin ducks was consistently greater in EPWS. Habitat differences between EPWS and WPWS may explain higher densities in EPWS and lower productivity of harlequin ducks in WPWS. Substantially fewer kilometers of streams in WPWS implied less availability of nesting streams and ultimately less production. Further, we speculated that individual streams in the spill area may not be as desirable for nesting due to their length, gradient, or volume of discharge, and differences in availability of food sources necessary for achieving breeding condition or brood rearing may also inhibit nesting in WPWS.

In spite of low productivity in WPWS, we observed similar recruitment in EPWS and WPWS. This indicated reproductive success and recruitment in 1994 and 1993. Because subadults movements appeared independent of adult movements, subadults may be more transient than adults, limiting their use as comparative indicators of recruitment. However, a greater proportion of the WPWS population may nest inland.

Males and females returned to EPWS at a greater rate than WPWS. This earlier influx of post-breeding males and females into EPWS may signify a return of birds that nest in close proximity to the coast. As no females and fewer males returned to WPWS during this time we believe this signifies a smaller coastal breeding population. The lack of broods, presence of subadults, and delayed return of post-breeding birds to WPWS suggests a greater percent of nesting occurred at more distant locations.

Finally, we compared the number of harlequin ducks observed in identical shoreline segments from similar time periods in WPWS and EPWS. We did not detect significant variation among time periods for both locations. Thus, harlequin duck numbers appear to have remained stable during our observation period.

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Table 1. Kilometers of shoreline surveyed for harlequin ducks in western Prince William Sound, Alaska in 1995.

		Spring Survey Dates			Fall Survey Dates		
Transect Location	No.	10 May- 20 May	26 May- 27 May[a]	9 June- 16 June	25 July- 1 Aug.	10 Aug.- 18 Aug.	5 Sept.- 14 Sept.
Aguliak Island	26	9.02	dns[b]	*	*	*	*
Applegate Island	1	3.96	*	*	5.90	*	*
Bay of Isles	5	44.51	dns	42.82	41.87	42.82	*
Channel Island	7	1.60	dns	*	*	*	*
Clam Island	20	dns	dns	dns	1.62	*	*
Crafton Island	11	6.82	dns	*	*	*	*
Culross Island	2	33.41	27.46	*	33.41	*	*
Drier Bay	24	6.58	dns	9.91	14.79	*	*
Eshamy Bay	3	28.43	dns	*	45.36	42.55	*
Eleanor Island	27	14.19	dns	*	*	*	*
Ewan Bay	14	dns	dns	dns	25.00	14.37	7.04
Falls Bay	4	15.07	dns	*	11.80	15.07	*
Foul Bay	10	11.68	dns	*	*	*	*
Foul Pass	6	5.46	dns	*	*	*	*
Green Island	8	51.52	dns	*	*	*	*
Herring Bay	12	13.21	dns	15.47	25.68	29.20	30.73
Jackpot Bay	13	dns	dns	dns	27.46	26.09	12.21
Johnson Bay	23	0.37	dns	*	17.84	*	16.13
Junction Island	17	2.72	dns	*	*	*	*
Lower Herring Bay	25	3.26	dns	4.24	25.05	12.06	8.79
Masked Bay	16	6.01	dns	2.76	7.70	9.27	3.49
Mummy Island	18	10.83	10.40	*	10.08	10.40	10.83
Naked Island	9	23.10	dns	73.24	*	*	42.61
New Years Island	19	dns	dns	dns	2.13	*	*
Squire Island	22	18.77	*	*	20.58	18.77	19.49
Squirrel Island	21	4.46	dns	*	*	*	*
Storey Island	28	2.75	dns	*	*	*	*
Totemoff Creek	15	14.41	dns	*	*	*	*
Total		332.14	60.59	377.55	514.14	494.16	434.24

[a] Incomplete survey coverage because of poor weather.
[b] dns = did not survey

* indicates no change in shoreline length from previous completed survey.

Table 2. Kilometers of shoreline surveyed for harlequin ducks in eastern Prince William Sound, Alaska in 1995.

		Spring Survey Dates			Fall Survey Dates		
Transect Location	No.	10 May-17 May	23 May-31 May	10 June-16 June	25 July-30 July	11 Aug.-17 Aug.	6 Sept.-12 Sept.
Beartrap Bay	5	4.84	*	*	*	*	*
Black Creek	27	2.63	*	*	*	*	*
Busby Island (south)	25	6.16	*	*	*	*	*
Busby Island (north)	26	6.18	*	*	*	*	*
Close Island	10	4.75	*	*	*	*	*
Constantine Harbor	19	19.71	*	*	*	*	*
Fish Bay	42	dns[a]	dns	dns	7.92	*	dns
Galena Bay	21	12.63	*	*	*	*	*
Galena Island	29	0.29	*	*	*	*	*
Galena Rocks	30	2.47	*	*	*	*	*
Gravina Island	2	0.61	*	*	*	*	*
Gravina Rocks	1	0.33	*	*	*	*	*
Gull Island	17	0.51	*	*	*	*	*
Hell's Hole	13	6.44	*	*	*	*	*
Irish Cove	40	dns	dns	dns	3.93	*	dns
Jack Bay	22	5.70	*	*	*	*	*
Landlocked Bay	34	13.33	*	*	*	*	*
Olsen Bay	7	14.15	*	*	*	*	*
Parshas Point	6	0.69	*	*	*	*	*
Port Etches	20	17.03	*	*	*	*	*
Port Gravina (SE)	3	16.42	*	*	*	*	*
Port Gravina (NE)	4	20.62	*	*	*	*	*
Porcupine Bay	16	6.85	*	*	*	*	*
Redhead	14	6.99	*	*	*	*	*
Redhead Point	15	1.78	*	*	*	*	*
Reef/Red Sector	24	7.13	*	*	*	*	*
Rocky Point	28	5.79	*	*	*	*	*
Sawmill Bay	31	7.40	*	*	*	*	*
Sheep Bay (east)	9	33.68	*	*	*	*	*
Sheep Bay (SW)	12	8.77	*	*	*	*	*
Sheep Point	8	1.26	*	*	*	*	*
Shelter Bay	18	9.01	*	*	*	*	*

Table 2. (cont.)

Shoup Bay	32	9.47	*	*	*	*	dns
Simpson Bay	35	dns	dns	dns	12.10	*	*
Snug Corner Cove	37	dns	dns	dns	5.43	*	dns
St. Matthew's Bay	36	dns	dns	dns	4.99	*	*
Surf Creek	11	0.98	*	*	*	*	*
Two Moon Bay (west)	38	dns	dns	dns	5.08	*	dns
Two Moon Bay (east)	39	dns	dns	dns	5.85	*	dns
Vladnoff River	23	3.95	*	*	*	*	*
Whalen Bay	41	dns	dns	dns	7.36	*	dns
Total		258.55	258.55	258.55	311.21	311.21	266.17

[a] dns = did not survey

* indicates no change in shoreline length from previous completed survey.

Table 3. Shoreline classification for transects surveyed in western (WPWS) and eastern (EPWS) Prince William Sound in 1995. Proportions of each shoreline type are averaged for spring and fall survey periods within locations.

		Shoreline Composition (%)										
Location	Survey Period	Exposed Rocky Shore	Exposed Wave-cut Platform	Fine Grained Beaches	Coarse Grained Beaches	Mixed Sand/Gravel Beaches	Gravel Cobble Boulder Beaches	Exposed Tidal Flat	Sheltered Rocky Shore	Sheltered Tidal Flat	Marsh	Not Classified
WPWS	Spring	15.2	8.2	0.6	0.1	23.9	19.9	0.0	24.8	1.8	1.3	4.2
WPWS	Fall	12.8	7.7	0.9	0.1	29.0	16.9	0.0	24.8	1.8	1.5	4.5
EPWS	Spring	3.3	7.9	0.8	0.1	34.9	17.6	0.9	18.1	7.4	5.5	3.5
EPWS	Fall	2.9	6.9	0.7	0.1	37.2	17.3	0.8	16.5	8.3	6.4	3.0

Table 4. Length of coastal streams located on near-shore transects surveyed for harlequin ducks in eastern (EPWS) and western (WPWS) Prince William Sound, Alaska in 1995.

			Stream Length (km)			
Location	Survey period	Survey number	Anadromous	Non-Anadromous	Total	Stream length: Shoreline length ratio
WPWS	Spring	1	86.1	63.4	149.5	0.45 : 1
WPWS	Spring	2	7.6	3.9	11.5	0.19 : 1
WPWS	Spring	3	89.8	72.9	162.7	0.43 : 1
EPWS	Spring	1	567.8	39.5	607.2	2.35 : 1
EPWS	Spring	2	*	*	*	*
EPWS	Spring	3	*	*	*	*
WPWS	Fall	1	233.3	129.4	362.7	0.71 : 1
WPWS	Fall	2	231.2	122.6	353.8	0.72 : 1
WPWS	Fall	3	216.1	109.3	325.4	0.75 : 1
EPWS	Fall	1	722.5	66.6	789.4	2.54 : 1
EPWS	Fall	2	*	*	*	*
EPWS	Fall	3	609.1	42.5	651.6	2.45 : 1

* indicates no change from previous survey.

Table 5. Number of harlequin ducks observed during boat surveys of near-shore transects in western Prince William Sound, Alaska in 1995.

		Spring Survey Dates			Fall Survey Dates		
Transect Location	No.	10 May-20 May	26 May-27 May[b]	9 June-16 June	25 July-1 Aug.	10 Aug.-18 Aug.	5 Sept.-14 Sept.
Aguliak Island	26	35	dns[a]	43	8	20	8
Applegate Island	1	67	21	40	10	24	12
Bay of Isles	5	38	dns	24	10	59	77
Channel Island	7	16	dns	59	88	86	29
Clam Island	20	dns	dns	dns	0	6	0
Crafton Island	11	68	dns	88	33	46	122
Culross Island	2	57	9	31	48	45	137
Drier Bay	24	4	dns	0	0	18	52
Eshamy Bay	3	0	dns	6	1	4	47
Eleanor Island	27	12	dns	0	0	0	0
Ewan Bay	14	dns	dns	dns	11	15	25
Falls Bay	4	74	dns	12	28	52	140
Foul Bay	10	89	dns	76	61	77	164
Foul Pass	6	22	dns	41	21	27	24
Green Island	8	242	dns	329	517	484	323
Herring Bay	12	12	dns	0	8	5	24
Jackpot Bay	13	dns	dns	dns	10	3	5
Johnson Bay	23	4	dns	1	19	0	0
Junction Island	17	12	dns	8	2	3	10
Lower Herring Bay	25	1	dns	0	4	27	16
Masked Bay	16	5	dns	0	0	16	11
Mummy Island	18	26	13	21	11	10	8
Naked Island	9	2	dns	16	0	16	124
New Years Island	19	dns	dns	dns	0	2	0
Squire Island	22	32	6	0	15	41	6
Squirrel Island	21	7	dns	0	21	11	85
Storey Island	28	4	dns	11	0	30	3
Totemoff Creek	15	46	dns	85	65	33	91
Total		875	49	891	991	1160	1543

[a] dns = did not survey

[b] Incomplete survey coverage because of poor weather.

Table 6. Numbers of harlequin ducks observed during boat surveys of near-shore transects in eastern Prince William Sound, Alaska in 1995.

		Spring Survey Dates			Fall Survey Dates		
Transect Location	No.	10 May- 17 May	23 May- 31 May	10 June- 16 June	25 July- 30 July	11 Aug.- 17 Aug.	6 Sept.- 12 Sept.
Beartrap Bay	5	10	11	6	4	6	7
Black Creek	27	0	0	0	0	0	63
Busby Island (south)	25	25	21	9	35	24	35
Busby Island (north)	26	24	11	0	36	41	37
Close Island	10	8	22	15	34	42	73
Constantine Harbor	19	33	37	41	5	11	38
Fish Bay	42	dns[a]	dns	dns	5	1	dns
Galena Bay	21	36	20	12	4	11	7
Galena Island	29	6	0	0	9	21	0
Galena Rocks	30	20	10	12	50	20	40
Gravina Island	2	7	6	0	45	75	0
Gravina Rocks	1	2	5	75	2	0	0
Gull Island	17	14	20	81	63	31	21
Hell's Hole	13	130	168	66	99	125	55
Irish Cove	40	dns	dns	dns	0	0	dns
Jack Bay	22	31	16	21	7	10	25
Landlocked Bay	34	27	25	7	45	71	88
Olsen Bay	7	14	41	93	100	113	180
Parshas Point	6	2	0	1	0	0	15
Port Etches	20	13	58	28	96	75	156
Port Gravina (SE)	3	69	57	163	110	104	210
Port Gravina (NE)	4	43	13	3	26	57	82
Porcupine Bay	16	24	33	24	29	64	79
Redhead	14	29	50	0	61	6	4
Redhead Point	15	7	2	0	6	19	12
Reef/Red Sector	24	11	11	1	20	77	74
Rocky Point	28	43	11	0	24	23	42
Sawmill Bay	31	16	28	18	10	8	8
Sheep Bay (east)	9	44	26	102	108	113	149
Sheep Bay (SW)	12	38	19	0	39	39	68
Sheep Point	8	52	22	0	42	46	31
Shelter Bay	18	44	29	38	80	48	11
Shoup Bay	32	32	60	0	0	0	dns

Table 6. (cont.)

Simpson Bay	35	dns	dns	dns	3	0	19
Snug Corner Cove	37	dns	dns	dns	0	0	dns
St. Matthew's Bay	36	dns	dns	dns	0	11	33
Surf Creek	11	17	3	0	17	25	44
Two Moon Bay (west)	38	dns	dns	dns	0	3	dns
Two Moon Bay (east)	39	dns	dns	dns	5	8	dns
Vladnoff River	23	7	8	4	4	0	0
Whalen Bay	41	dns	dns	dns	1	0	dns
Total		878	843	820	1224	1328	1706

[a] dns = did not survey

Table 7. Average density and number of harlequin ducks, and coefficient of variation for transects surveyed in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995.

		Spring Surveys				Fall Surveys				All Surveys			
Transect Location	No.	Ducks	C.V.	Density	C.V.	Ducks	C.V.	Density	C.V.	Ducks	C.V.	Density	C.V
Aguliak Island	26	39.0	14.5	4.33	14.5	12.0	57.5	1.33	57.9	22.8	69.3	2.53	69.2
Applegate Island	1	42.7	54.1	10.78	54.2	15.3	49.7	2.60	49.2	29.0	74.1	6.69	87.7
Bay of Isles	5	31.0	31.9	0.71	29.6	48.7	71.3	1.14	71.1	41.6	64.4	0.97	64.9
Channel Island	7	37.5	81.1	23.44	81.1	67.7	49.5	42.29	49.5	55.6	58.6	34.75	58.7
Clam Island	20	dns	dns	dns	dns	2.0	175.0	1.24	172.6	2.0	175.0	1.24	172.6
Crafton Island	11	78.0	18.1	11.44	18.1	67.0	71.8	9.82	71.7	71.4	49.3	10.47	49.3
Culross Island	2	32.3	74.3	1.06	65.1	76.7	68.2	2.30	67.8	54.5	80.2	1.68	76.2
Drier Bay	24	2.0	140.0	0.31	138.7	23.3	113.3	1.58	113.3	14.8	149.3	1.07	136.4
Eshamy Bay	3	3.0	141.3	0.11	136.4	17.3	148.6	0.40	150.0	11.6	171.5	0.28	164.3
Eleanor Island	27	6.0	141.7	0.43	139.5	0.0	0.0	0.0	0.0	2.4	225.0	0.17	223.5
Ewan Bay	14	dns	dns	dns	dns	17.0	42.4	1.68	98.2	17.0	42.3	1.68	98.2
Falls Bay	4	43.0	101.9	2.86	101.7	73.3	80.4	5.04	73.8	61.2	81.5	4.16	77.9
Foul Bay	10	82.5	11.2	7.07	11.0	100.7	55.0	8.62	55.1	93.4	43.6	7.99	43.6
Foul Pass	6	31.5	42.5	5.77	42.6	24.0	12.5	4.38	13.2	27.0	30.4	4.95	30.1
Green Island	8	285.5	21.5	5.80	26.9	441.3	23.5	8.57	23.6	379.0	30.8	7.36	30.7
Herring Bay	12	6.0	141.7	0.46	139.1	12.3	82.9	0.42	76.2	9.8	92.9	0.43	90.7
Jackpot Bay	13	dns	dns	dns	dns	6.0	60.0	0.30	53.3	6.0	60.0	0.30	53.3
Johnson Bay	23	2.5	84.0	6.8	84.6	6.3	173.0	0.36	172.2	4.8	168.7	2.92	156.2
Junction Island	17	10.0	28.0	3.68	28.3	5.0	87.2	1.83	87.4	7.0	62.3	2.57	62.3
Lower Herring Bay	25	0.5	140.0	0.16	137.5	15.7	73.2	1.41	78.6	9.6	120.8	0.91	114.3
Masked Bay	16	2.5	140.0	0.42	140.5	9.0	90.9	1.63	96.9	6.4	109.7	1.14	116.7
Mummy Island	18	20.0	33.0	1.89	31.2	9.7	15.5	0.93	19.4	14.8	47.9	1.41	46.1
Naked Island	9	9.0	110.0	0.16	56.3	46.7	144.3	1.04	155.8	31.6	165.2	0.69	181.2

Table 7. (cont.)

New Years Island	19	dns	dns	dns	dns	0.7	171.4	0.31	174.2	0.7	179.1	0.31	174.2
Squire Island	22	12.7	133.9	0.68	133.8	20.7	87.9	1.07	91.6	16.7	97.6	0.88	98.9
Squirrel Island	21	3.5	140.0	0.79	140.5	39.0	102.8	8.74	102.9	24.8	139.1	5.56	139.0
Storey Island	28	7.5	65.3	2.73	65.9	11.0	150.0	4.00	150.3	9.6	126.0	3.49	136.1
Totemoff Creek	15	65.5	42.1	4.55	42.2	63.0	46.2	4.37	46.2	64.0	38.7	4.44	38.7
Average			80.5		77.5		82.3		84.7		96.5		99.6

[a] dns = did not survey

Table 8. Average density and number of harlequin ducks, and coefficient of variation for transects surveyed in eastern Prince William Sound, Alaska in 1995.

		Spring Surveys				Fall Surveys				All Surveys			
Transect Location	No.	Ducks	C.V.	Density	C.V.	Ducks	C.V.	Density	C.V.	Ducks	C.V.	Density	C.V
Beartrap Bay	5	9.0	29.4	1.86	29.6	5.7	26.3	1.17	27.4	7.3	37.0	1.52	36.2
Black Creek	27	0.0	0.0	0.0	0.0	21.0	173.3	7.99	173.5	10.5	244.8	3.99	245.4
Busby Island (south)	25	18.3	45.5	2.98	45.3	31.3	20.4	5.08	20.3	24.8	39.1	4.03	39.2
Busby Island (north)	26	11.7	102.5	1.89	102.6	38.0	6.8	6.15	6.9	24.8	66.1	4.02	65.9
Close Island	10	15.0	46.7	3.16	46.8	49.7	41.4	10.46	41.5	32.3	72.4	6.81	72.5
Constantine Harbor	19	37.0	10.8	1.88	11.2	18.0	97.8	0.91	97.8	27.5	56.0	1.40	55.7
Fish Bay	42	dns	dns	dns	dns	3.0	93.3	0.38	92.1	3.0	93.3	0.38	92.1
Galena Bay	21	22.7	53.7	1.79	54.2	7.3	47.9	0.58	48.3	15.0	77.3	1.19	77.3
Galena Island	29	2.0	175.0	6.80	173.5	10.0	105.0	34.0	105.4	6.0	138.3	20.40	137.7
Galena Rocks	30	14.0	37.9	5.67	37.7	36.7	41.7	14.85	41.7	25.3	63.6	10.30	63.2
Gravina Island	2	4.3	87.9	7.10	87.5	40.0	94.3	65.68	94.4	22.2	139.2	36.40	139.6
Gravina Rocks	1	27.3	151.3	83.80	151.2	0.67	179.1	2.05	172.7	14.0	213.6	42.90	213.9
Gull Island	17	38.3	96.6	75.76	96.8	38.3	57.2	75.76	57.2	38.3	71.0	75.76	71.1
Hell's Hole	13	121.3	42.5	18.84	42.5	93.0	38.1	14.44	38.0	107.2	39.6	16.64	39.7
Irish Cove	40	dns	dns	dns	dns	0.0	0.0	0.00	0.0	0.0	0.0	0.00	0.0
Jack Bay	22	22.7	33.5	3.98	33.7	14.0	68.6	2.45	68.9	18.3	49.7	3.20	50.0
Landlocked Bay	34	19.7	55.8	1.48	56.1	68.0	31.9	5.10	31.8	43.8	69.7	3.29	69.6
Olsen Bay	7	49.3	81.5	3.49	81.4	131.0	32.7	9.26	32.7	90.2	64.5	6.37	64.4
Parshas Point	6	1.0	100.0	1.46	100.0	7.5	141.3	7.30	173.2	3.0	196.7	4.38	197.7
Port Etches	20	33.0	69.4	1.94	69.6	109.0	38.5	6.40	38.6	71.0	72.5	4.17	72.4
Port Gravina (SE)	3	96.3	60.2	5.87	60.3	141.3	42.1	8.61	42.0	118.8	48.9	7.24	48.9
Port Gravina (NE)	18	19.7	105.6	0.96	105.2	55.0	51.1	2.67	50.9	37.3	78.8	1.81	79.0
Porcupine Bay	16	27.0	19.3	3.94	19.3	57.3	44.9	8.37	44.8	42.1	55.6	6.15	55.6

Table 8. (cont.)

Redhead	14	26.3	95.4	3.77	95.2	23.7	136.3	3.38	136.1	25.0	103.6	3.58	103.6
Redhead Point	15	3.0	120.0	1.68	120.2	12.3	52.8	6.92	52.7	7.7	89.6	4.30	90.7
Reef/Red Sector	24	7.7	75.3	1.07	75.7	57.0	56.3	7.99	56.3	32.3	104.9	4.54	105.1
Rocky Point	28	18.0	123.9	3.11	123.8	29.7	36.0	5.12	36.1	23.8	71.0	4.11	71.0
Sawmill Bay	31	20.7	30.9	2.79	31.2	8.7	13.8	1.17	13.7	14.7	52.3	1.98	53.0
Sheep Bay (east)	9	57.3	69.3	1.70	69.4	123.3	18.2	3.66	18.0	90.3	51.2	2.68	51.1
Sheep Bay (SW)	12	19.0	100.0	2.17	100.0	48.7	34.3	5.55	34.4	33.8	67.5	3.86	67.4
Sheep Point	8	24.7	105.7	19.61	105.8	39.7	19.4	31.53	19.6	32.2	59.3	25.57	59.3
Shelter Bay	18	37.0	20.3	4.11	20.4	46.3	74.5	5.14	74.5	41.7	54.9	4.63	55.1
Shoup Bay	32	30.7	97.7	3.24	97.8	0.0	0.0	0.00	0.0	18.4	147.3	1.94	147.4
Simpson Bay	35	dns	dns	dns	dns	7.3	139.7	0.61	137.7	7.3	139.7	0.61	1377.7
Snug Corner Cove	37	dns	dns	dns	dns	0.0	0.0	0.00	0.0	0.0	0.0	0.00	0.0
St. Matthew's Bay	36	dns	dns	dns	dns	14.7	114.3	2.94	114.6	14.7	114.3	2.94	114.6
Surf Creek	11	6.7	135.8	6.84	136.1	28.7	48.4	29.4	48.3	17.7	90.4	18.12	90.4
Two Moon Bay (west)	38	dns	dns	dns	dns	1.5	140.0	0.30	140.0	1.5	140.0	0.30	140.0
Two Moon Bay (east)	39	dns	dns	dns	dns	6.5	32.3	1.12	32.1	6.5	32.3	1.12	32.1
Vladnoff River	23	6.3	33.3	1.60	33.1	1.3	176.9	0.34	170.6	3.8	89.5	0.97	87.6
Whalen Bay	41	dns	dns	dns	dns	0.5	140.0	0.07	128.6	0.5	140.0	0.07	128.6
Average			73.1		73.1						66.0		

[a] dns = did not survey

Table 9. Relative density (ducks/km shoreline) of harlequin ducks along near-shore transects in eastern Prince William Sound, Alaska in 1995.

		Spring Survey Dates			Fall Survey Dates		
Transect Location	No.	10 May-17 May	23 May-31 May	10 June-16 June	25 July-30 July	11 Aug.-17 Aug.	6 Sept.-12 Sept.
Beartrap Bay	5	2.07	2.27	1.24	0.83	1.24	1.45
Black Creek	27	0.00	0.00	0.00	0.00	0.00	23.99
Busby Island (south)	25	4.06	3.41	1.46	5.68	3.89	5.68
Busby Island (north)	26	3.88	1.78	0.00	5.83	6.64	5.99
Close Island	10	1.68	4.63	3.16	7.16	8.84	15.37
Constantine Harbor	19	1.67	1.88	2.08	0.25	0.56	1.93
Fish Bay	42	dns[a]	dns	dns	0.63	0.13	dns
Galena Bay	21	2.85	1.58	0.95	0.32	0.87	0.55
Galena Island	29	20.41	0.00	0.00	30.61	71.43	0.00
Galena Rocks	30	8.10	4.05	4.86	20.25	8.10	16.20
Gravina Island	2	11.49	9.85	0.00	73.89	123.15	0.00
Gravina Rocks	1	6.14	15.34	230.06	6.14	0.00	0.00
Gull Island	17	27.67	39.53	160.08	124.51	61.27	41.50
Hell's Hole	13	20.19	26.09	10.25	15.37	19.41	8.54
Irish Cove	40	dns	dns	dns	0.00	0.00	dns
Jack Bay	22	5.44	2.81	3.68	1.23	1.75	4.38
Landlocked Bay	34	2.03	1.88	0.53	3.38	5.33	6.60
Olsen Bay	7	0.99	2.90	6.57	7.07	7.99	12.72
Parshas Point	6	2.92	0.00	1.46	0.00	0.00	21.90
Port Etches	20	0.76	3.41	1.64	5.64	4.40	9.16
Port Gravina (SE)	3	4.20	3.47	9.93	6.70	6.34	12.79
Port Gravina (NE)	4	2.09	0.63	0.15	1.26	2.77	3.98
Porcupine Bay	16	3.50	4.82	3.50	4.23	9.34	11.53
Redhead	14	4.15	7.15	0.00	8.72	0.86	0.57
Redhead Point	15	3.93	1.12	0.00	3.37	10.66	6.73
Reef/Red Sector	24	1.54	1.54	0.14	2.81	10.80	10.38
Rocky Point	28	7.42	1.90	0.00	4.14	3.97	7.25
Sawmill Bay	31	2.16	3.79	2.43	1.35	1.08	1.08
Sheep Bay (east)	9	1.31	0.77	3.03	3.21	3.36	4.42
Sheep Bay (SW)	12	4.33	2.17	0.00	4.45	4.45	7.75
Sheep Point	8	41.34	17.49	0.00	33.39	36.57	24.64
Shelter Bay	18	4.89	3.22	4.22	8.88	5.33	1.22
Shoup Bay	32	3.38	6.34	0.00	0.00	0.00	dns

Table 9. (cont.)

Simpson Bay	35	dns	dns	dns	0.25	0.00	1.57
Snug Corner Cove	37	dns	dns	dns	0.00	0.00	dns
St. Matthew's Bay	36	dns	dns	dns	0.00	2.21	6.62
Surf Creek	11	17.44	3.08	0.00	17.44	25.64	45.13
Two Moon Bay (west)	38	dns	dns	dns	0.00	0.59	dns
Two Moon Bay (east)	39	dns	dns	dns	0.86	1.37	dns
Vladnoff River	23	1.77	2.03	1.01	1.01	0.00	0.00
Whalen Bay	41	dns	dns	dns	0.14	0.00	dns
Total[b]		3.40	3.26	3.17	3.93	4.27	6.41
Average		6.84	5.48	13.71	10.02	10.98	9.46
Standard Error		1.56	1.43	8.30	3.53	3.68	1.88

[a] dns = did not survey

[b] total harlequin ducks/total shoreline surveyed

Table 10. Relative density (ducks/km shoreline) of harlequin ducks along near-shore transects in western Prince William Sound, Alaska in 1995.

		Spring Survey Dates			Fall Survey Dates		
Transect Location	No.	10 May- 20 May	26 May- 27 May[a]	9 June- 16 June	25 July- 1 Aug.	10 Aug.- 18 Aug.	5 Sept.- 14 Sept.
Aguliak Island	26	3.88	dns[b]	4.77	0.89	2.22	0.89
Applegate Island	1	16.94	5.31	10.11	1.70	4.07	2.03
Bay of Isles	5	0.85	dns	0.56	0.24	1.38	1.80
Channel Island	7	10.00	dns	36.88	55.00	53.75	18.13
Clam Island	20	dns	dns	dns	0.00	3.71	0.00
Crafton Island	11	9.97	dns	12.90	4.84	6.74	17.88
Culross Island	2	1.71	0.33	1.13	1.44	1.35	4.10
Drier Bay	24	0.61	dns	0.00	0.00	1.22	3.52
Eshamy Bay	3	0.00	dns	0.21	0.02	0.09	1.10
Eleanor Island	27	0.85	dns	0.00	0.00	0.00	0.00
Ewan Bay	14	dns	dns	dns	0.44	1.04	3.55
Falls Bay	4	4.91	dns	0.80	2.37	3.45	9.29
Foul Bay	10	7.62	dns	6.51	5.22	6.59	14.04
Foul Pass	6	4.03	dns	7.51	3.85	4.95	4.40
Green Island	8	4.70	dns	6.39	10.04	9.39	6.27
Herring Bay	12	0.91	dns	0.00	0.31	0.17	0.78
Jackpot Bay	13	dns	dns	dns	0.36	0.12	0.41
Johnson Bay	23	10.84	dns	2.71	1.07	0.00	0.00
Junction Island	17	4.41	dns	2.94	0.73	1.10	3.67
Lower Herring Bay	25	0.31	dns	0.00	0.16	2.24	1.82
Masked Bay	16	0.83	dns	0.00	0.00	1.73	3.15
Mummy Island	18	2.40	1.25	2.02	1.09	0.96	0.74
Naked Island	9	0.09	dns	0.22	0.00	0.22	2.91
New Years Island	19	dns	dns	dns	0.00	0.94	0.00
Squire Island	22	1.71	0.32	0.00	0.73	2.18	0.31
Squirrel Island	21	1.57	dns	0.00	4.71	2.47	19.05
Storey Island	28	1.45	dns	4.00	0.00	10.91	1.09
Totemoff Creek	15	3.19	dns	5.90	4.51	2.29	6.32
Total[c]		2.63	0.81	2.36	1.93	2.35	3.55
Average		3.91	1.80	4.40	3.56	4.62	4.54
Standard Error		0.87	1.19	1.59	1.96	1.90	1.09

[a] Incomplete survey coverage because of poor weather.
[b] dns = did not survey
[c] total harlequin ducks/total shoreline surveyed

Table 11. Composition of harlequin ducks observed during spring surveys of near-shore transects in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995.

Location	Spring Survey	Number						
		Adult Males	Subadult Males	Unk.[a] Males	Females	Unclassified	Total	Breeding Pairs[b]
WPWS	1	395	129	2	284	65	875	163
WPWS[c]	2	22	6	0	21	0	49	8
WPWS	3	455	172	2	170	92	891	8
EPWS	1	390	84	4	309	91	878	258
EPWS	2	336	157	2	239	109	843	166
EPWS	3	428	153	33	141	65	820	40

[a] Age of males unknown.
[b] Not included in totals.

[c] Incomplete survey coverage because of poor weather.

Table 12. Composition of harlequin ducks, and number of broods observed during fall surveys of near-shore transects in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995.

		Number				
Location	Fall Survey	Males	Females	Unclassified	Total	Broods[a]
WPWS	1	841	133	17	991	0
WPWS	2	845	300	15	1160	0
WPWS	3	939	486	119	1543	0
EPWS	1	915	282	27	1224	1
EPWS	2	883	415	30	1328	6
EPWS	3	865	596	245	1706	3

[a] Not included in total.

Table 13. Location, date, and composition of harlequin duck broods observed in eastern Prince William Sound, Alaska in 1995.

Transect	Location	Date	Brood Size	Age
Sawmill Bay	Stellar Creek	30 July	1	IC
Port Etches	Etches Creek	14 Aug.	3	IIB
Constantine Harbor	Constantine Harbor	14 Aug.	2	IIB
Constantine Harbor	Constantine Harbor	14 Aug.	4	IIC
Hell's Hole	Hell's Hole	15 Aug.	2	IIC
Galena Bay	Millard Creek	17 Aug.	1	IIC
Sawmill Bay	Stellar Creek	17 Aug.	2	IIC
Beartrap Bay	Beartrap Creek	6 Sep.	5	IIC
Constantine Harbor	Constantine Harbor	9 Sep.	4	IIC
Landlocked Bay	Banzer Creek	11 Sep.	2	IIC

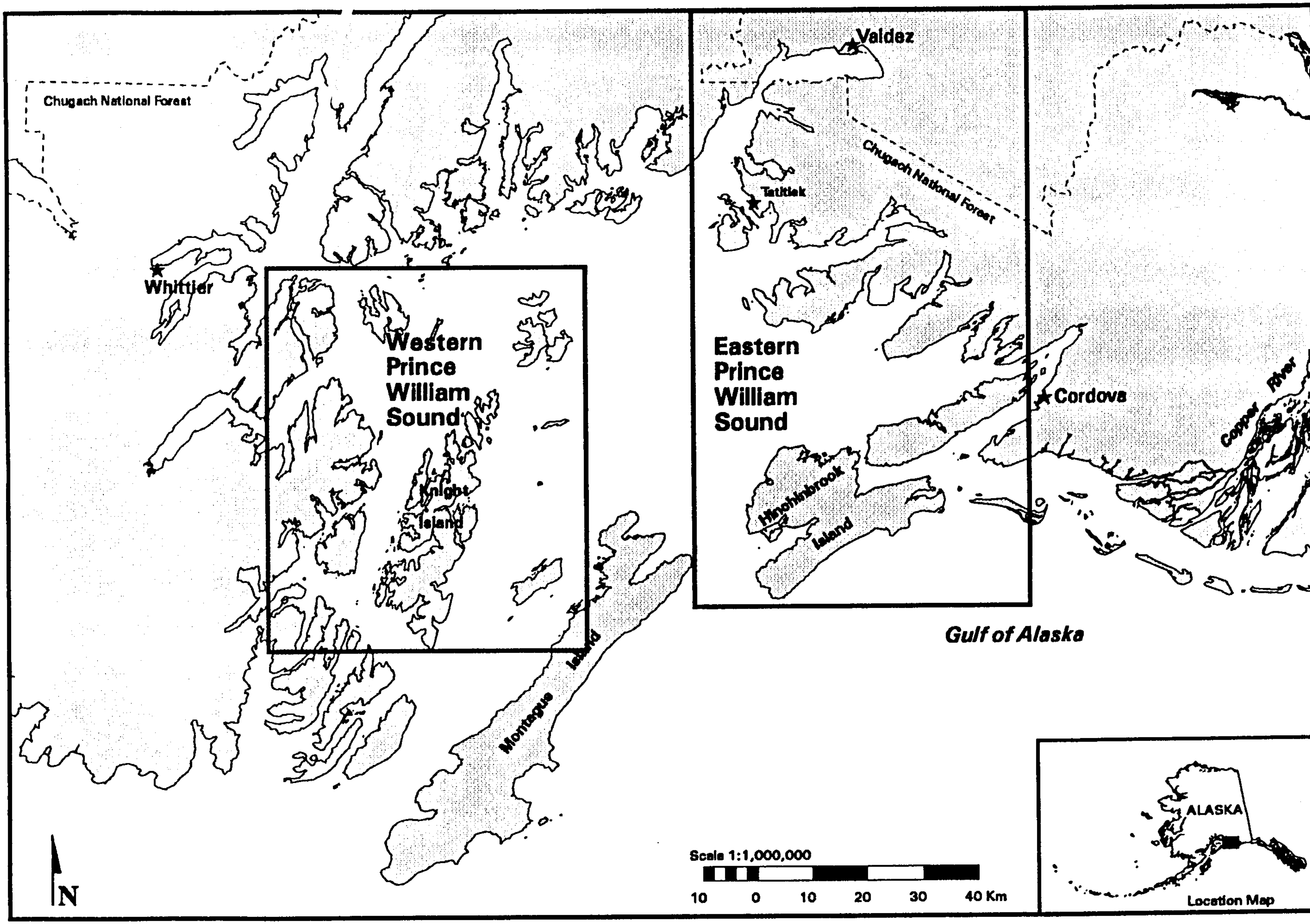


Figure 1. Map of Prince William Sound, Alaska showing the location of western and eastern study areas used to monitor harlequin ducks during surveys in 1995.

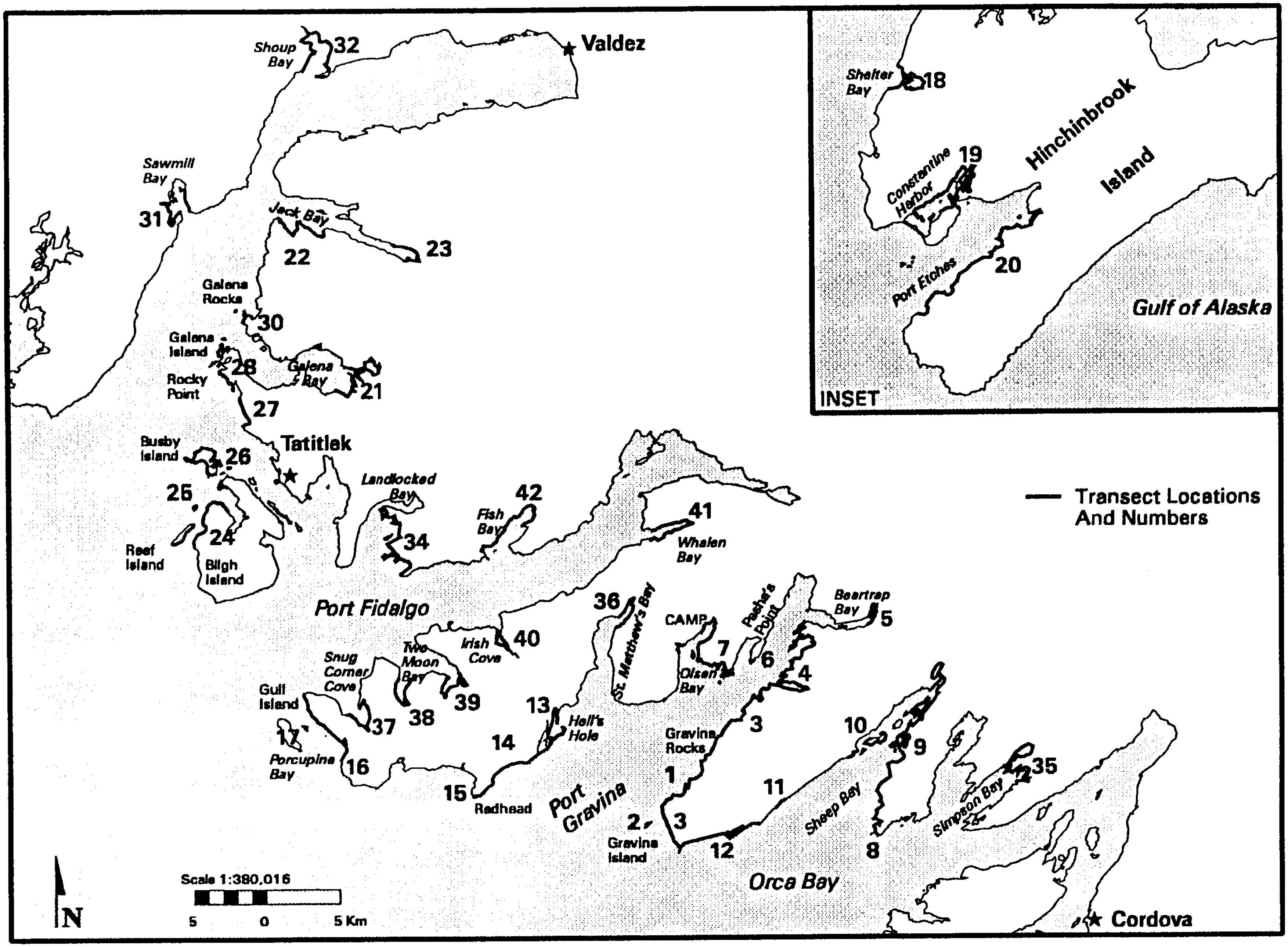


Figure 2. Map of eastern Prince William Sound study area showing the location of transects used during surveys of harlequin ducks in 1995. Numbers refer to transect numbers listed in tables.

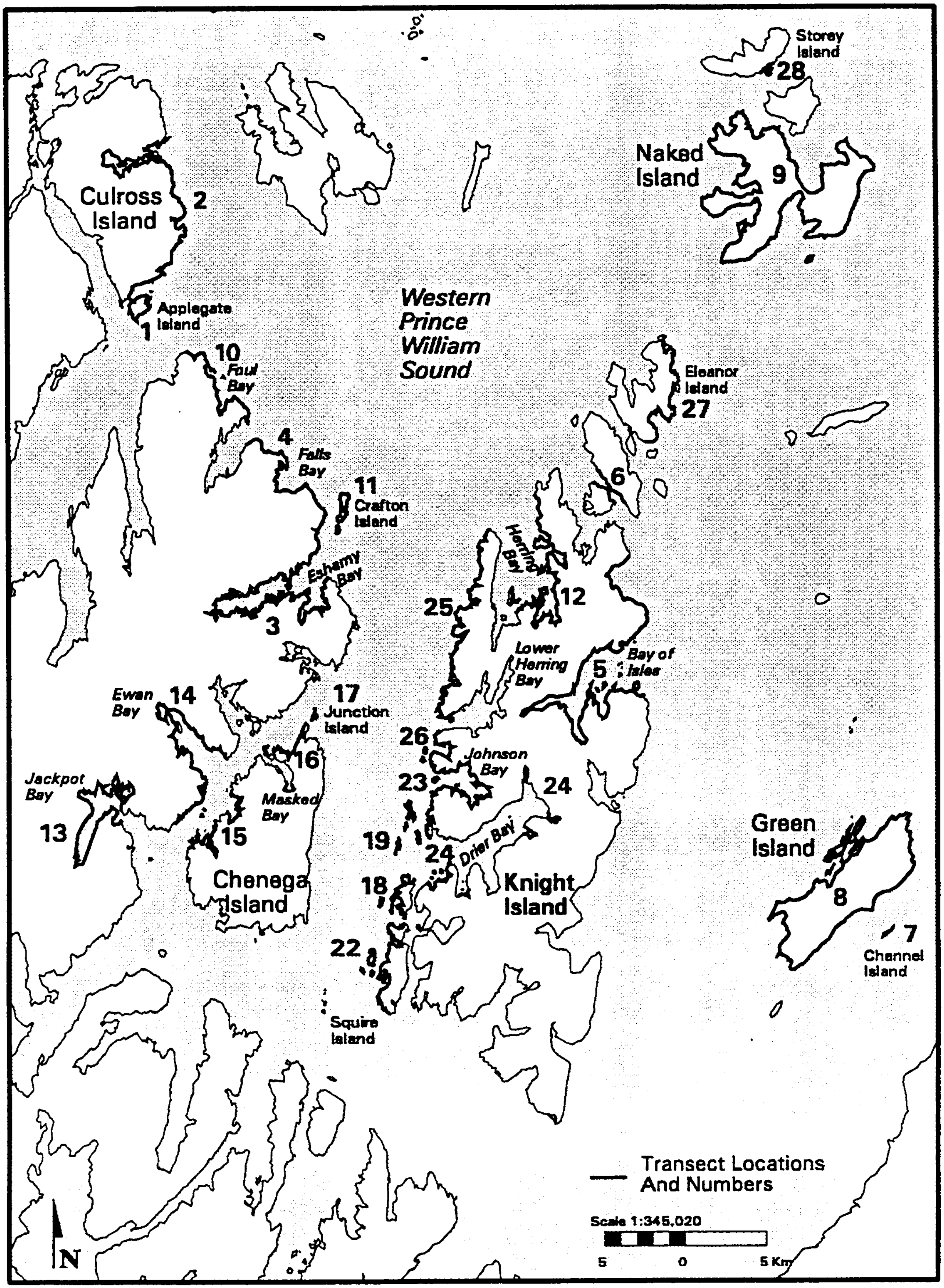


Figure 3. Map of western Prince William Sound study area showing the location of transects used during surveys of harlequin ducks in 1995. Numbers refer to transect numbers listed in tables.

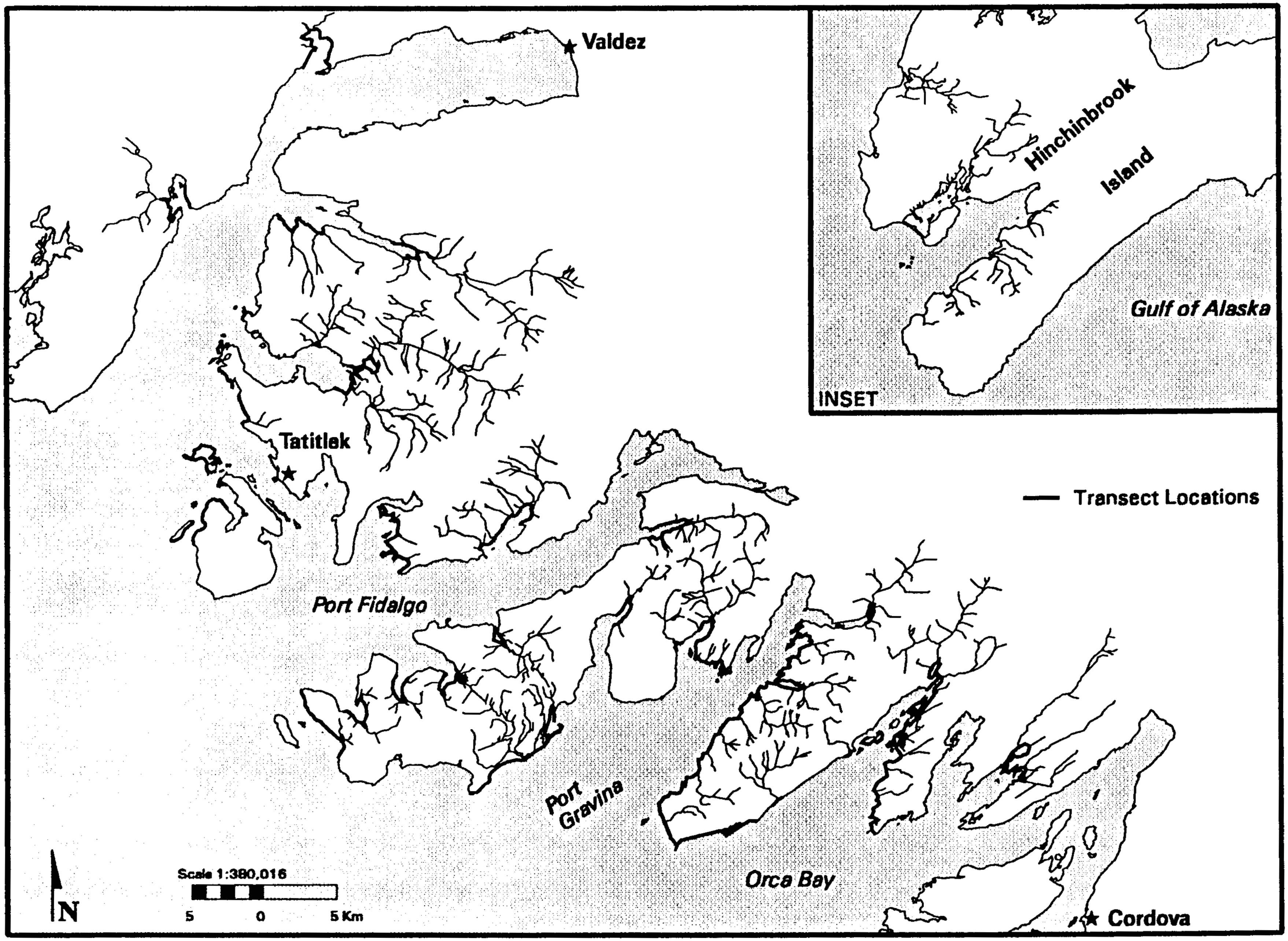


Figure 4. Location of streams on the eastern Prince William Sound study area.

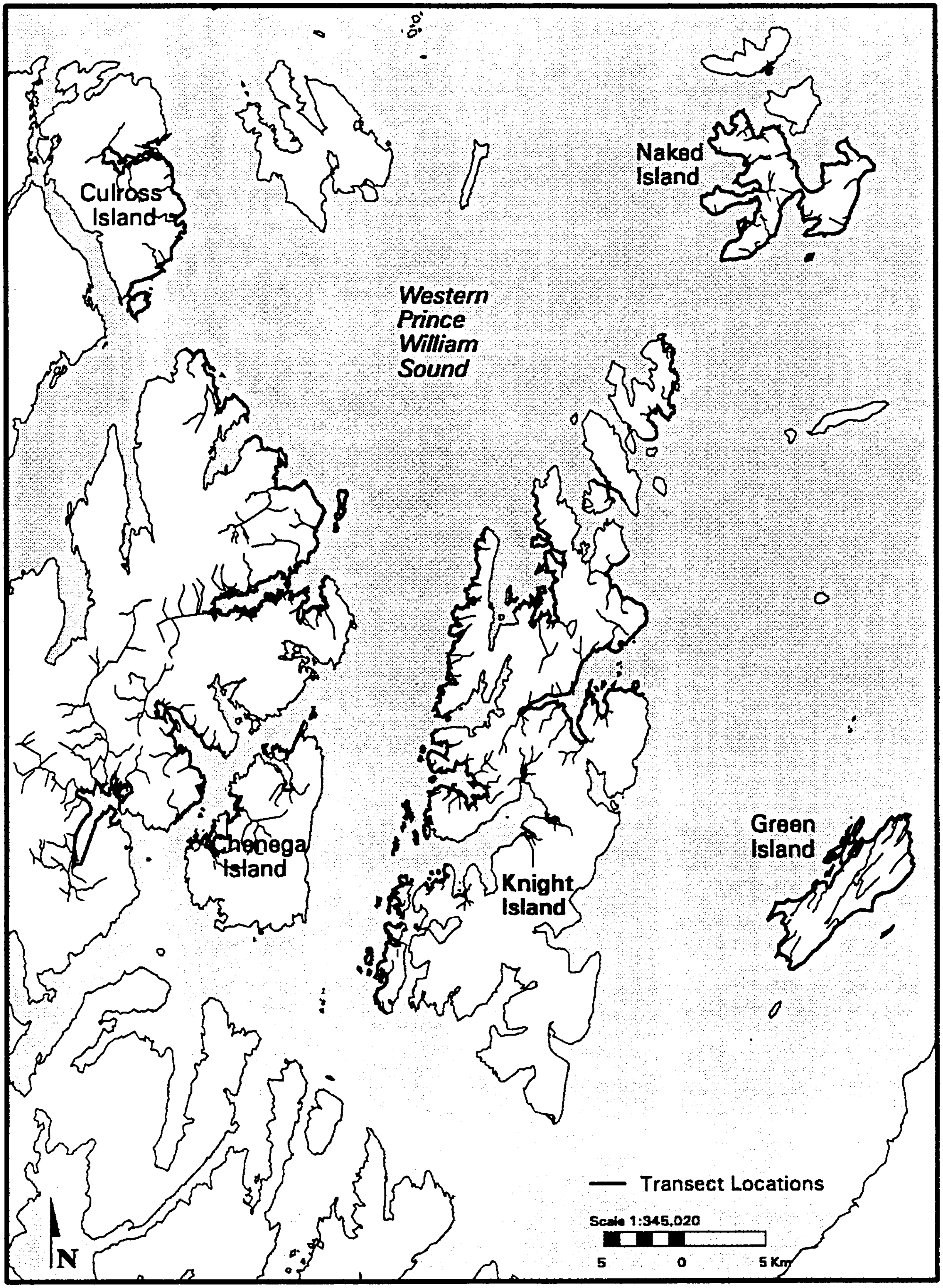


Figure 5. Location of streams on the western Prince William Sound study area.

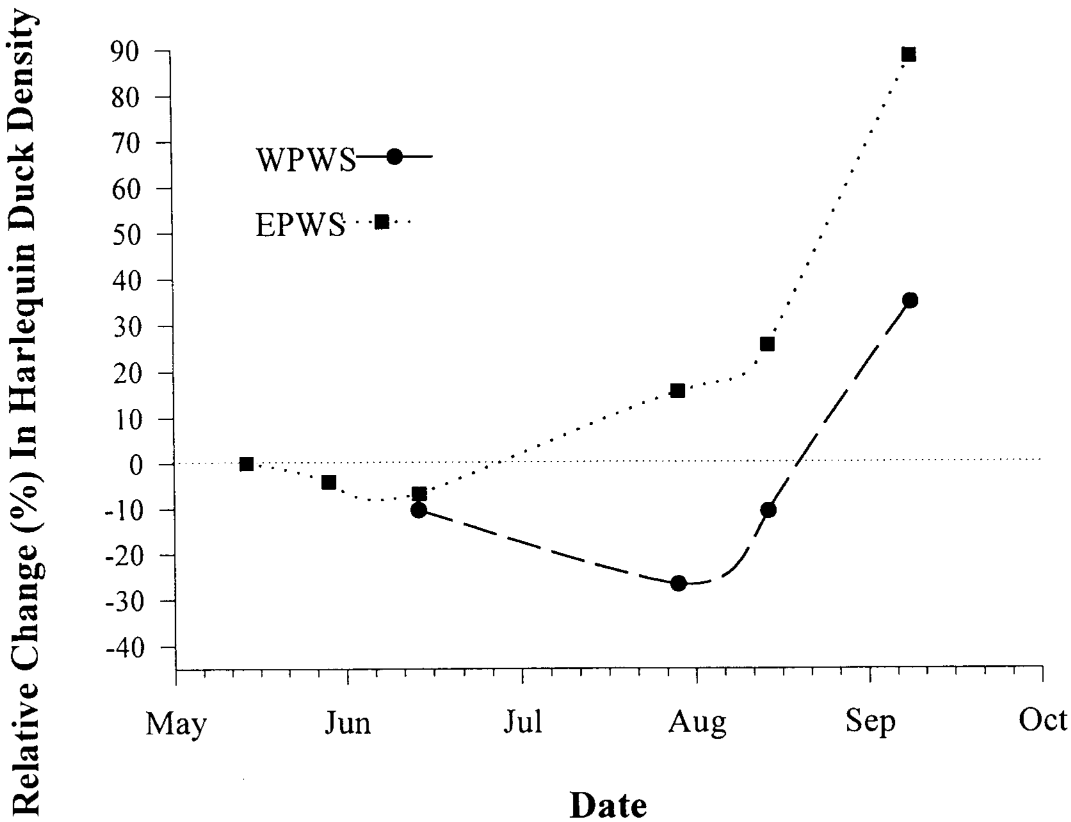


Figure 6. Relative change in density of harlequin ducks observed during boat surveys of near-shore transects in eastern (EPWS) and western (WPWS) Prince William Sound, Alaska in 1995. Because the second spring survey was not completed in WPWS, we can not estimate the relative change in density during the spring.

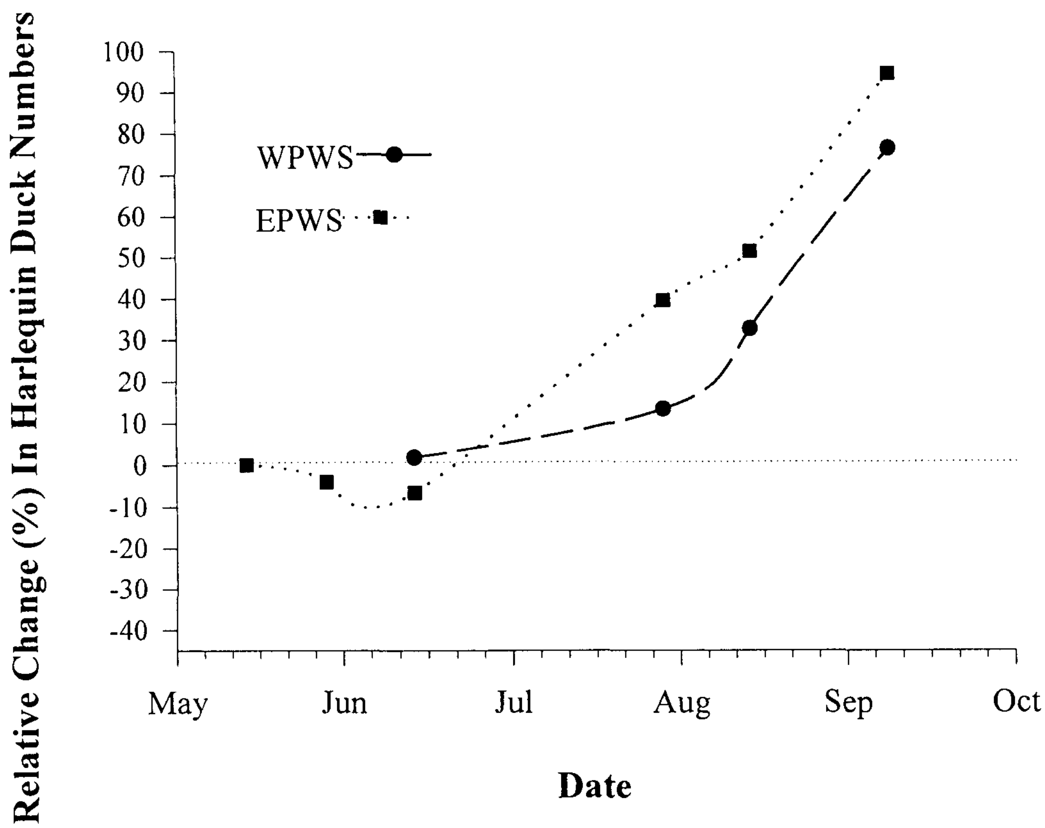


Figure 7. Relative change (%) in the number of harlequin ducks observed during boat surveys of near-shore transects in eastern (EPWS) and western (WPWS) Prince William Sound, Alaska in 1995. Because the second spring survey was not completed in WPWS, we can not estimate the relative change in harlequin numbers during the spring.

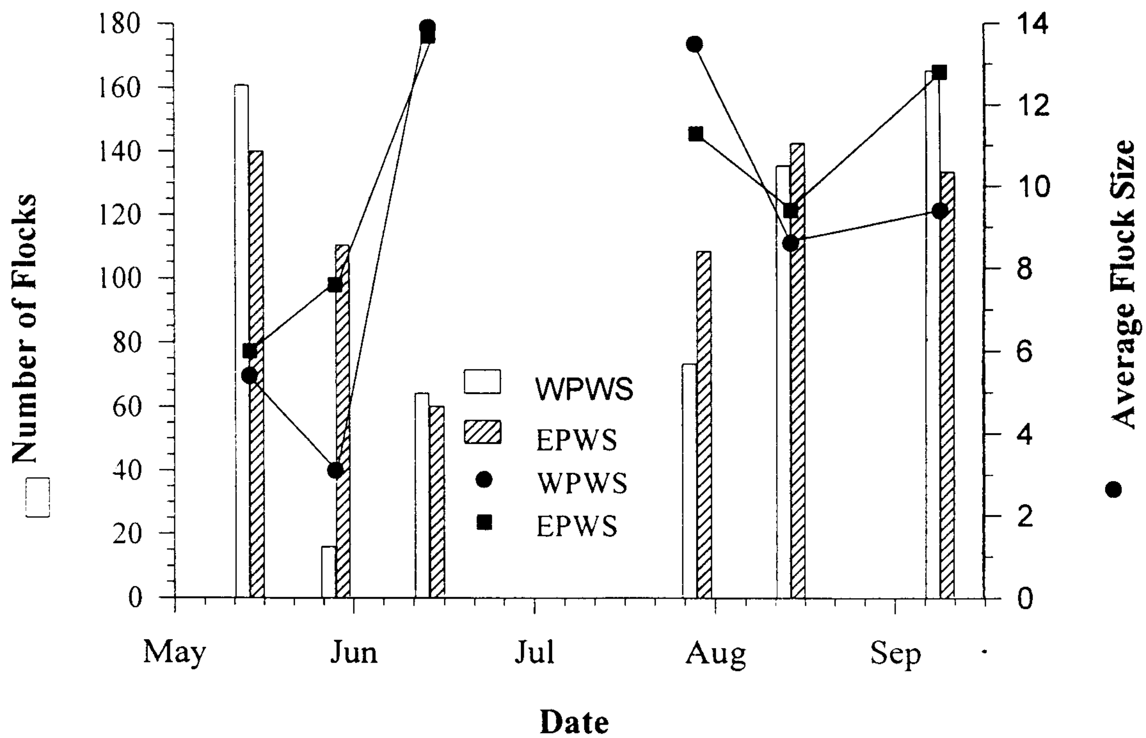


Figure 8. Average flock size and number of flocks of harlequin ducks observed during surveys of near-shore transects in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995. Few data were collected during the second spring survey in WPWS because of poor weather.

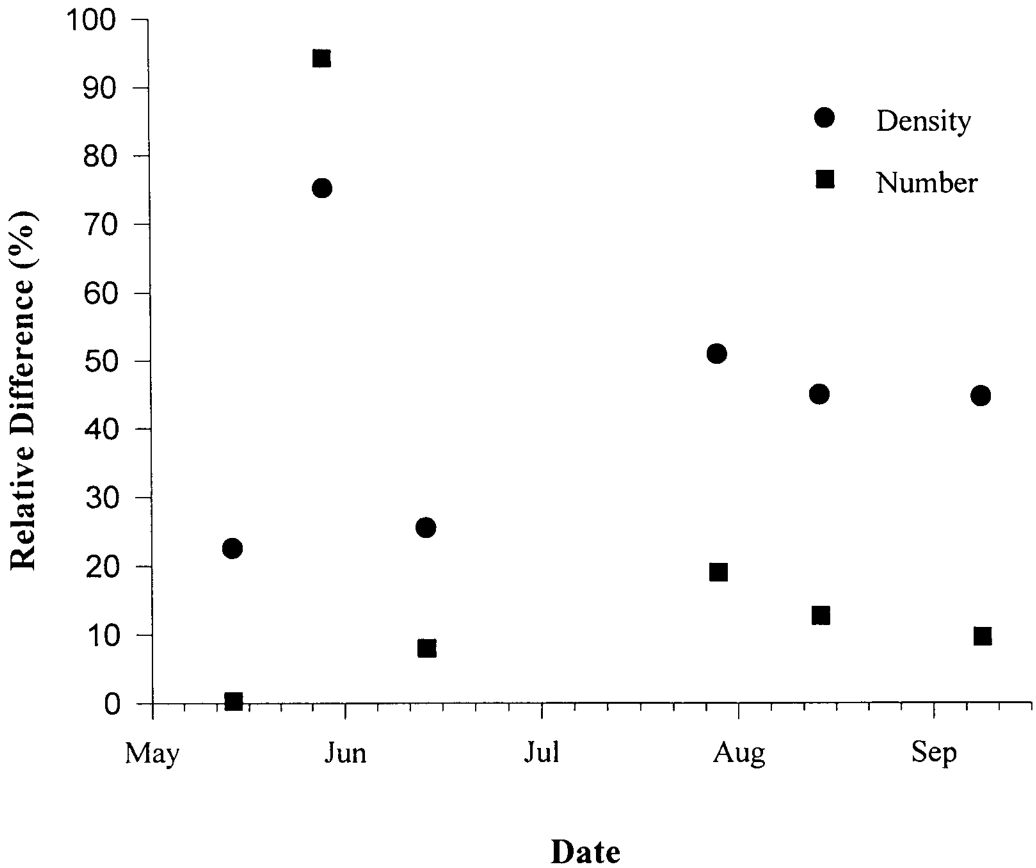


Figure 9. Relative difference in density and total harlequin ducks between eastern (EPWS) and western (WPWS) Prince William Sound, Alaska in 1995. The large differences between EPWS and WPWS during the second spring survey reflects the few data collected in WPWS during that period.

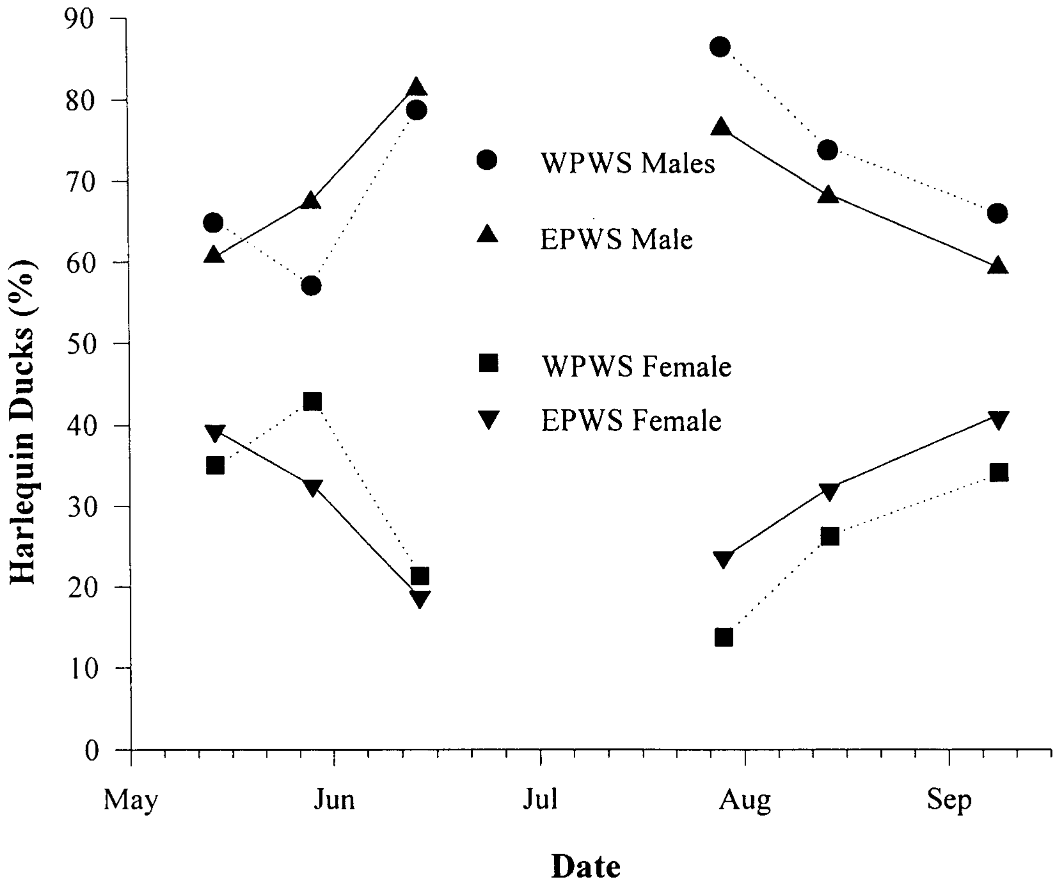


Figure 10. Proportion of male and female harlequin ducks observed during boat surveys of near-shore transects in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995. An incomplete second spring survey in WPWS resulted in limited data for that time period.

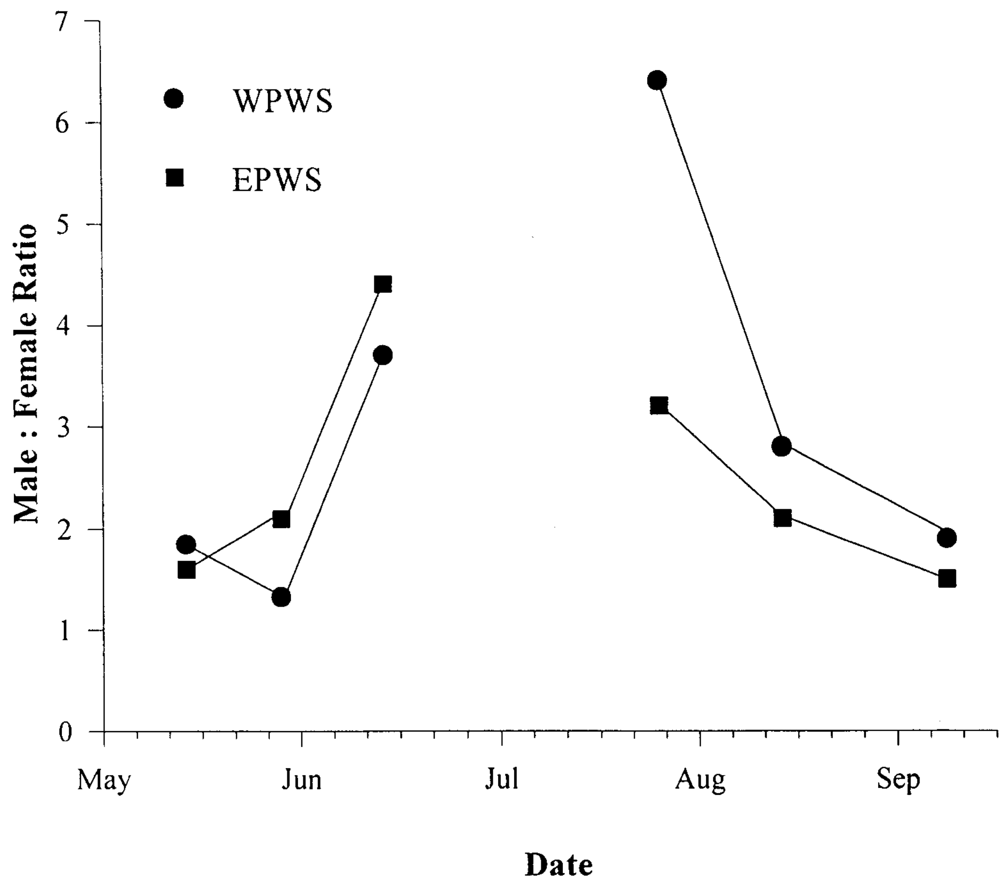


Figure 11. Ratio of male to female harlequin ducks in eastern (EPWS) and western (WPWS) Prince William Sound, Alaska in 1995. Few data were collected during the second spring survey in WPWS because of poor weather.

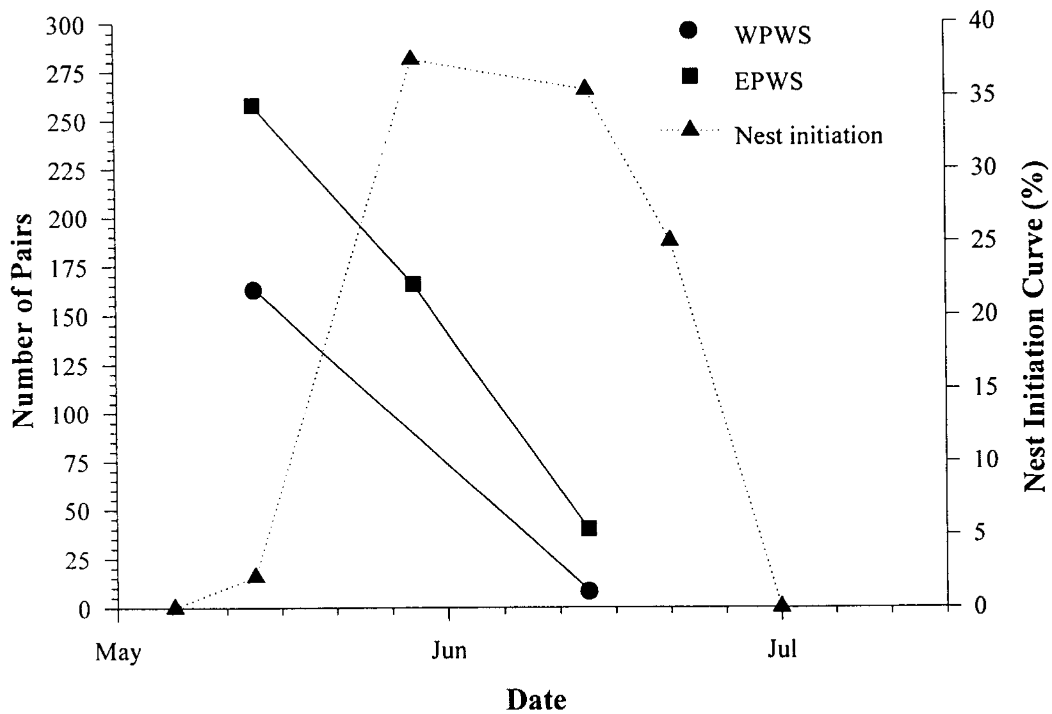


Figure 12. Relationship between the decline in breeding pairs with the progression of nest initiation by harlequin ducks in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995. Nest initiation curve was derived by back-dating from nest and brood ages (Crowley 1996).

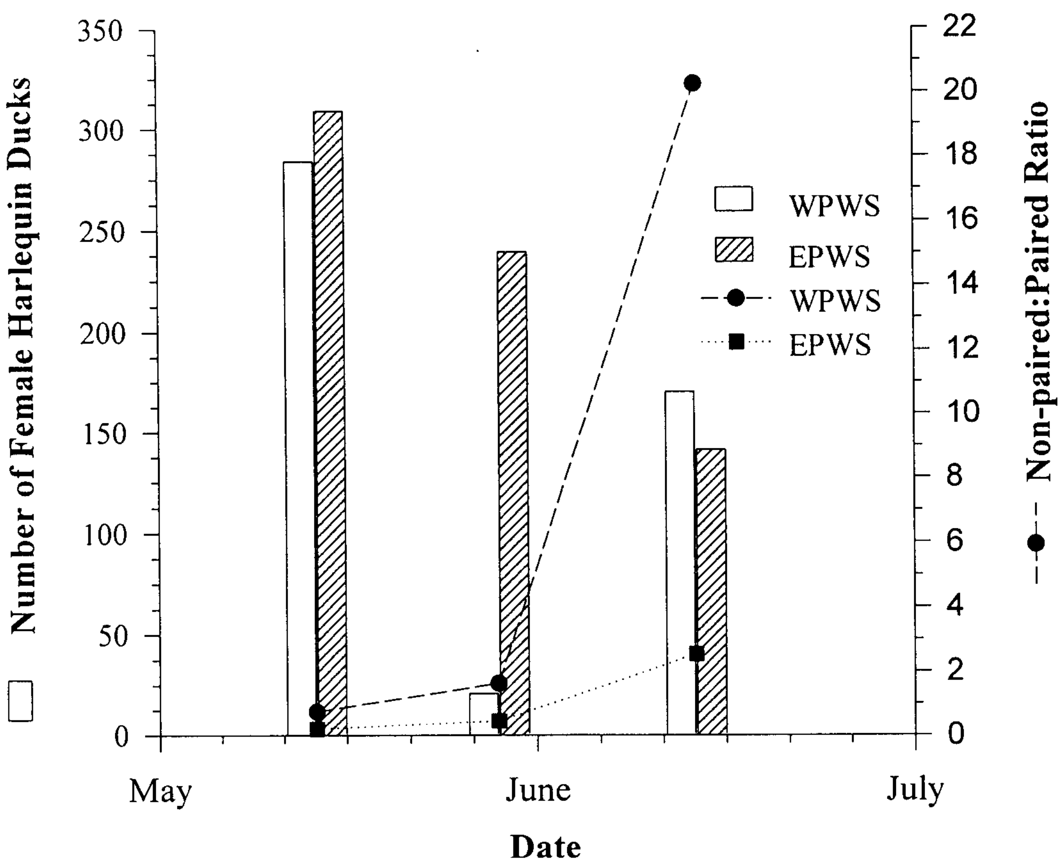


Figure 13. The number of female harlequin ducks and the ratio of non-paired to paired females observed during spring surveys in eastern (EPWS) and western (WPWS) Prince William Sound, Alaska in 1995. Few data were collected in WPWS during the second spring survey because of poor weather.

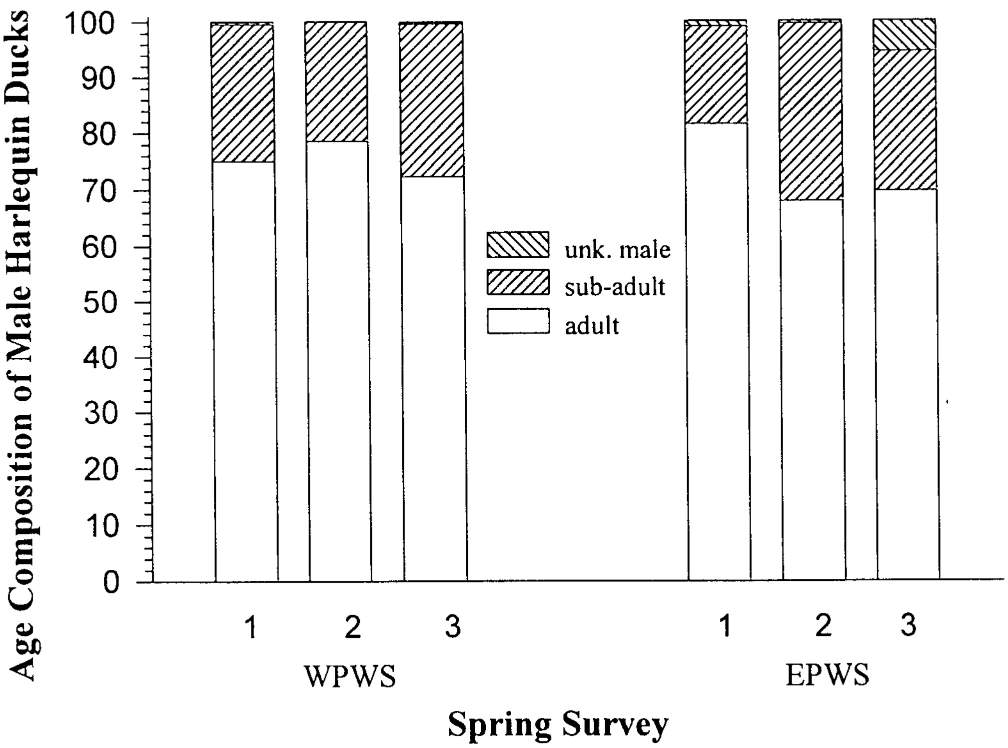


Figure 14. Age ratios of male harlequin ducks during spring surveys in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995. Few data were collected during the second spring survey in WPWS because of poor weather.

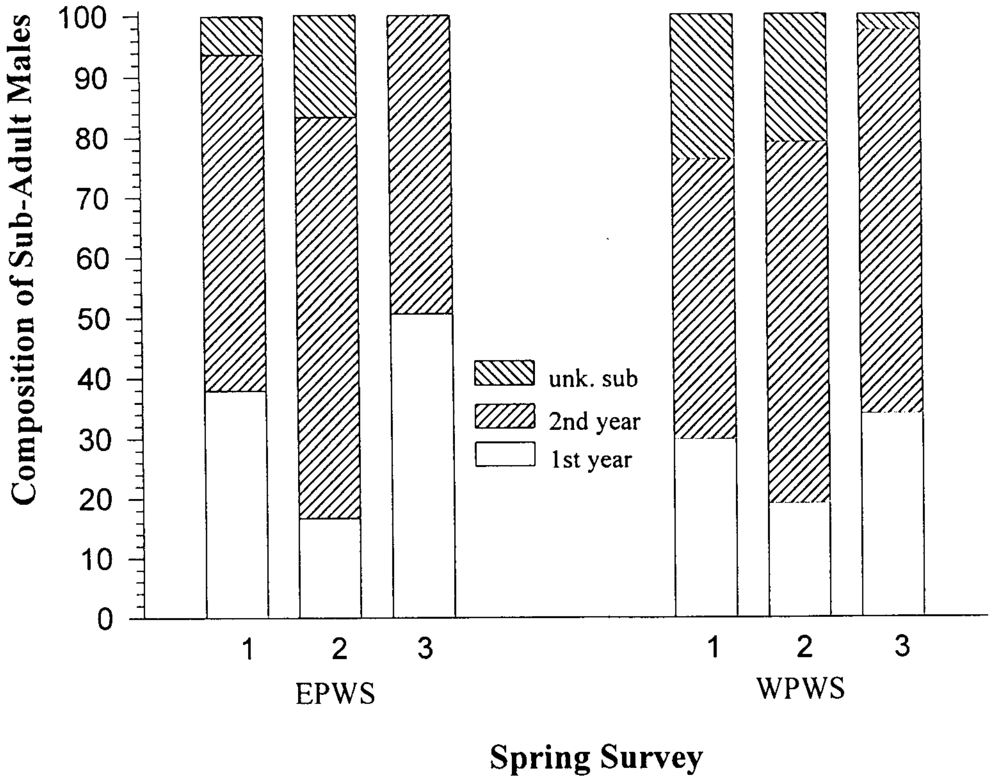


Figure 15. Age ratios of subadult, male harlequin ducks during the spring in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995. Few data were collected during the second spring survey in WPWS because of poor weather.

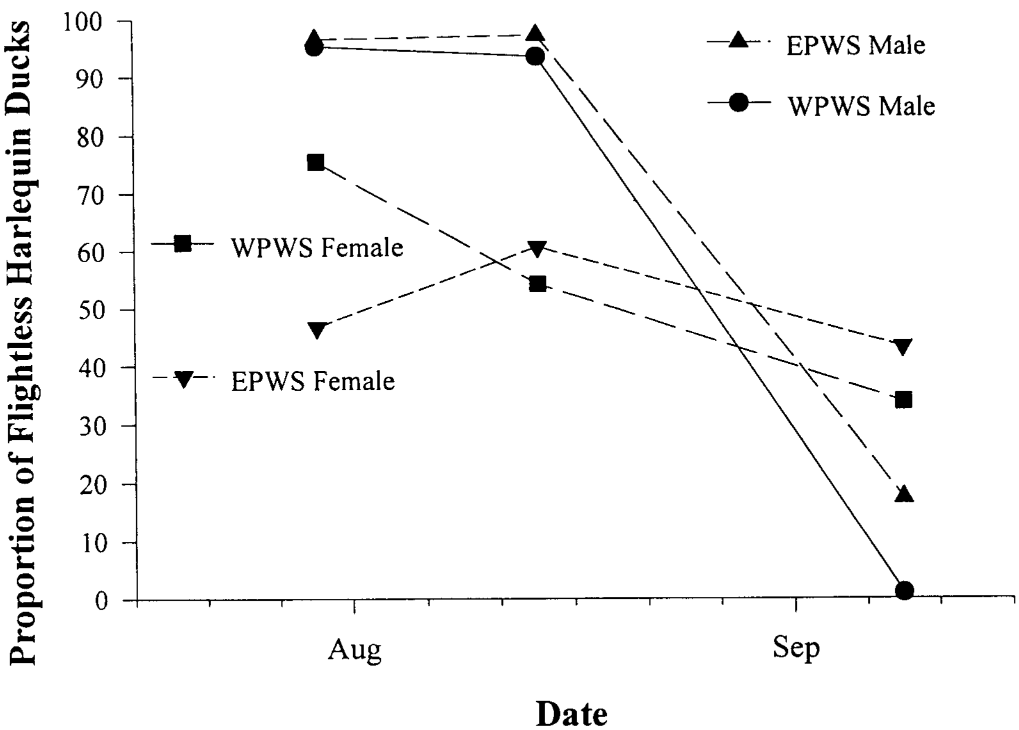


Figure 16. Proportion of flightless harlequin ducks observed during boat surveys of near-shore transects in western (WPWS) and eastern (EPWS) Prince William Sound, Alaska in 1995.

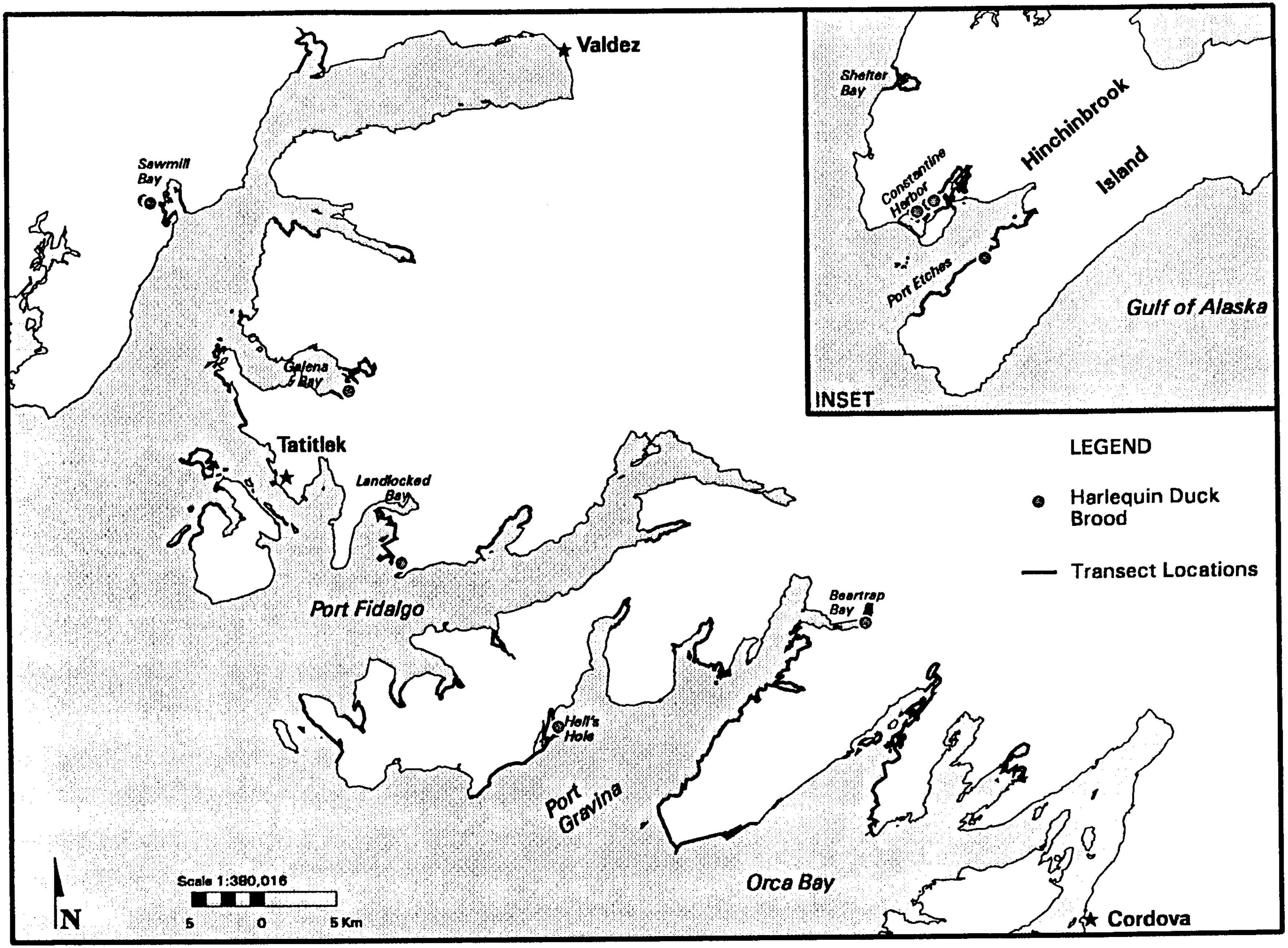


Figure 17 Location of harlequin duck broods observed in eastern Prince William Sound, Alaska in 1995.

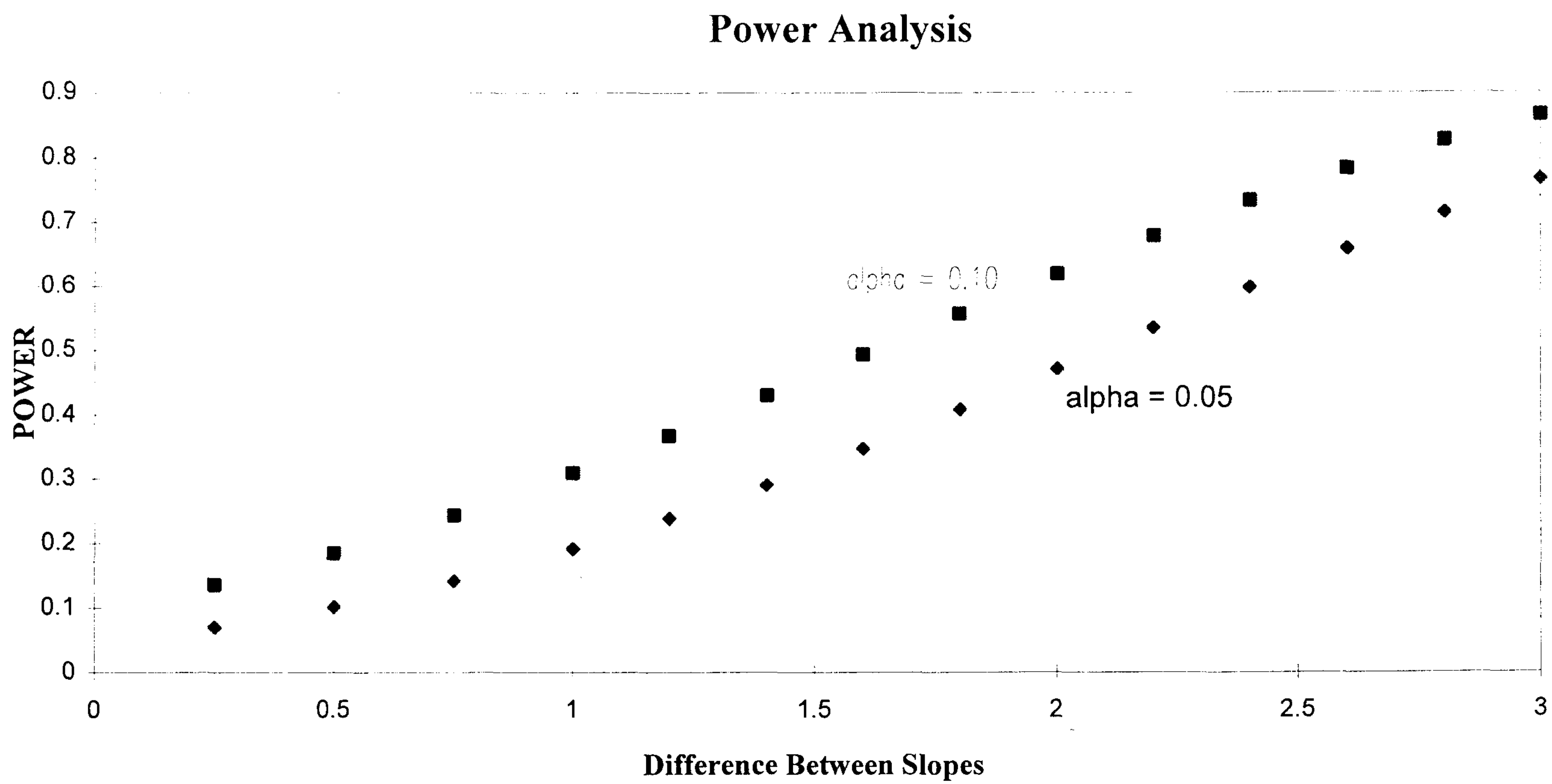
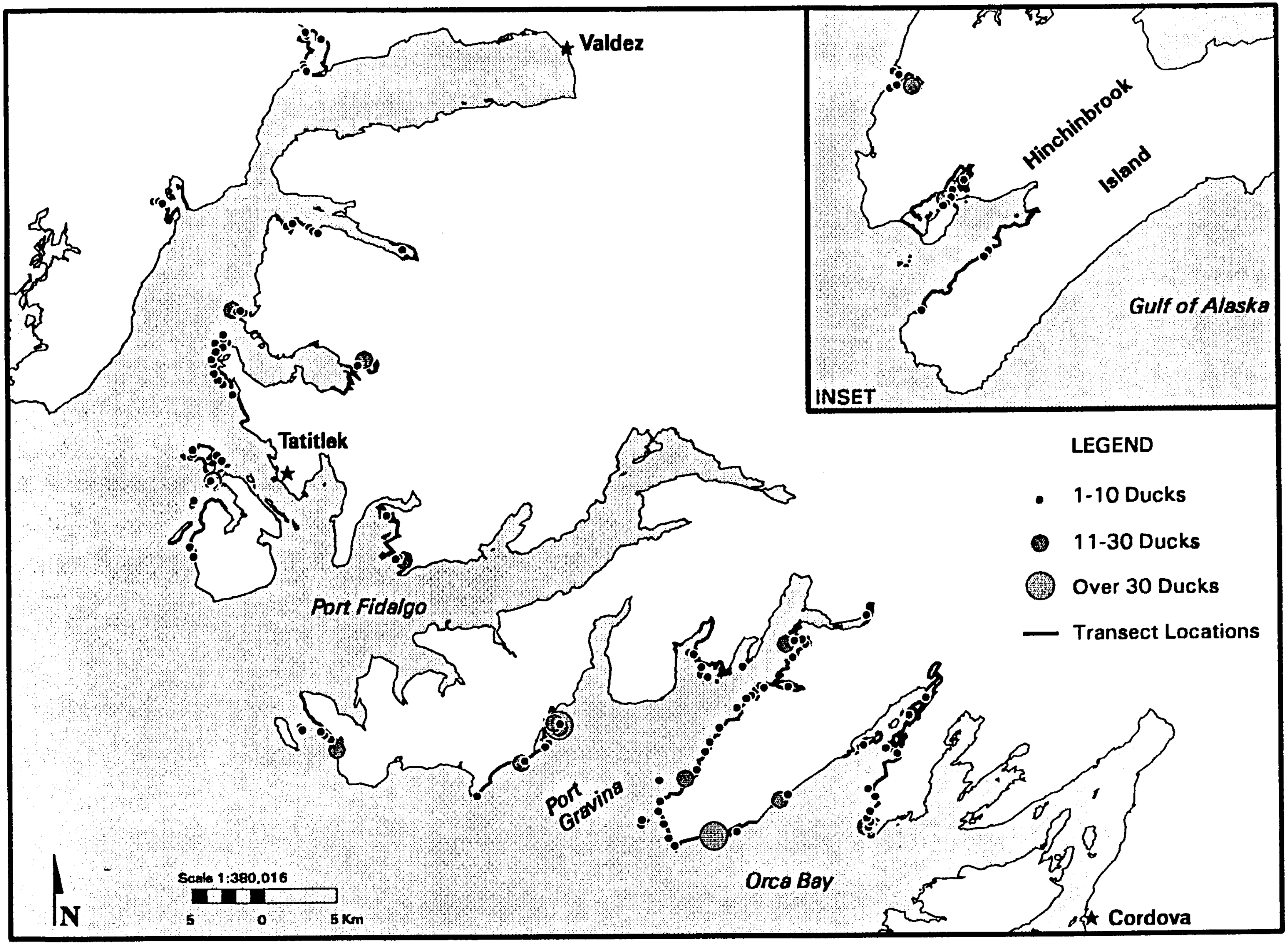


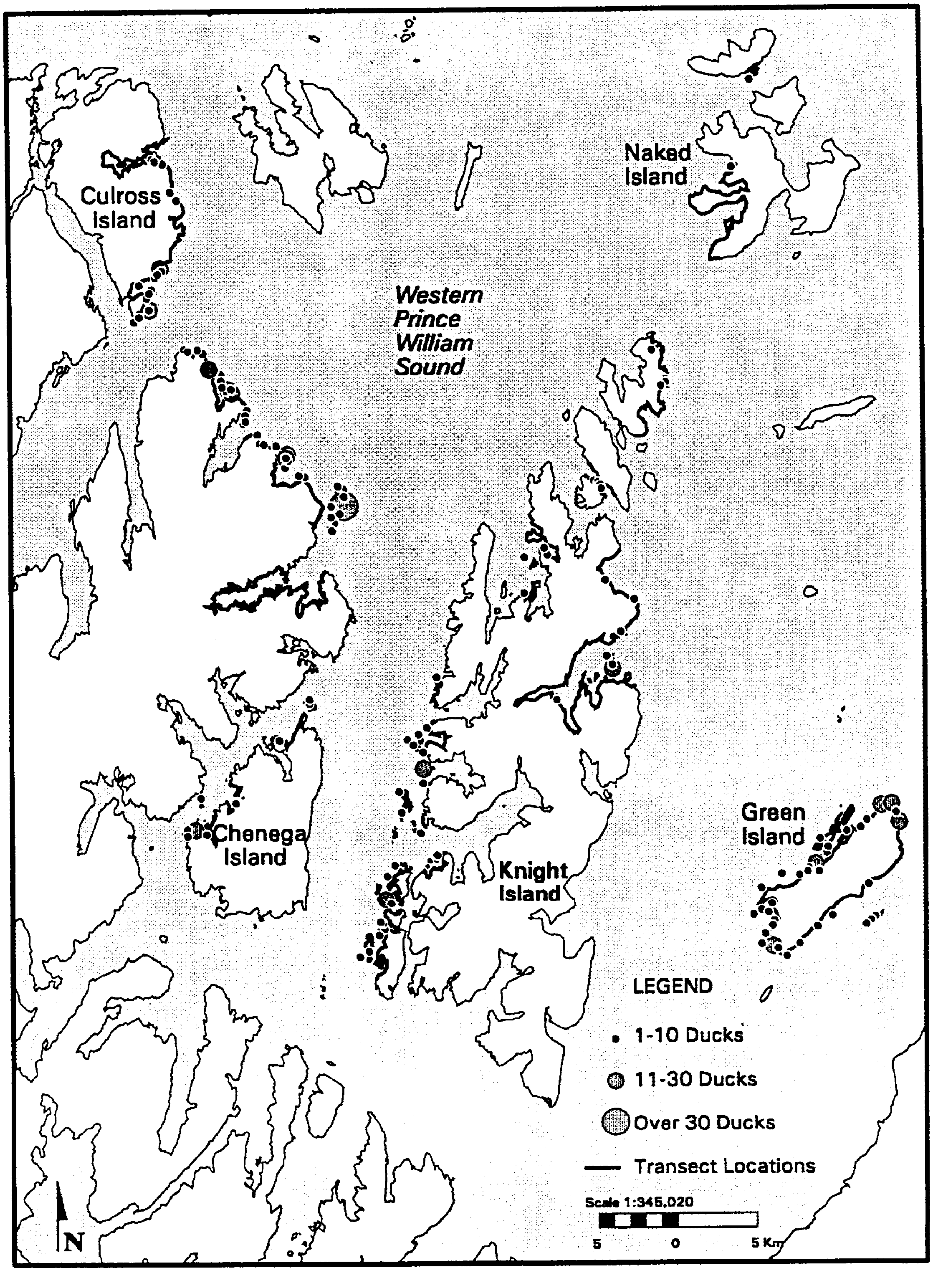
Figure 18. Power of the test to determine if the rate of change in eastern Prince William Sound and western Prince William Sound harlequin duck populations is the same.

APPENDIX A

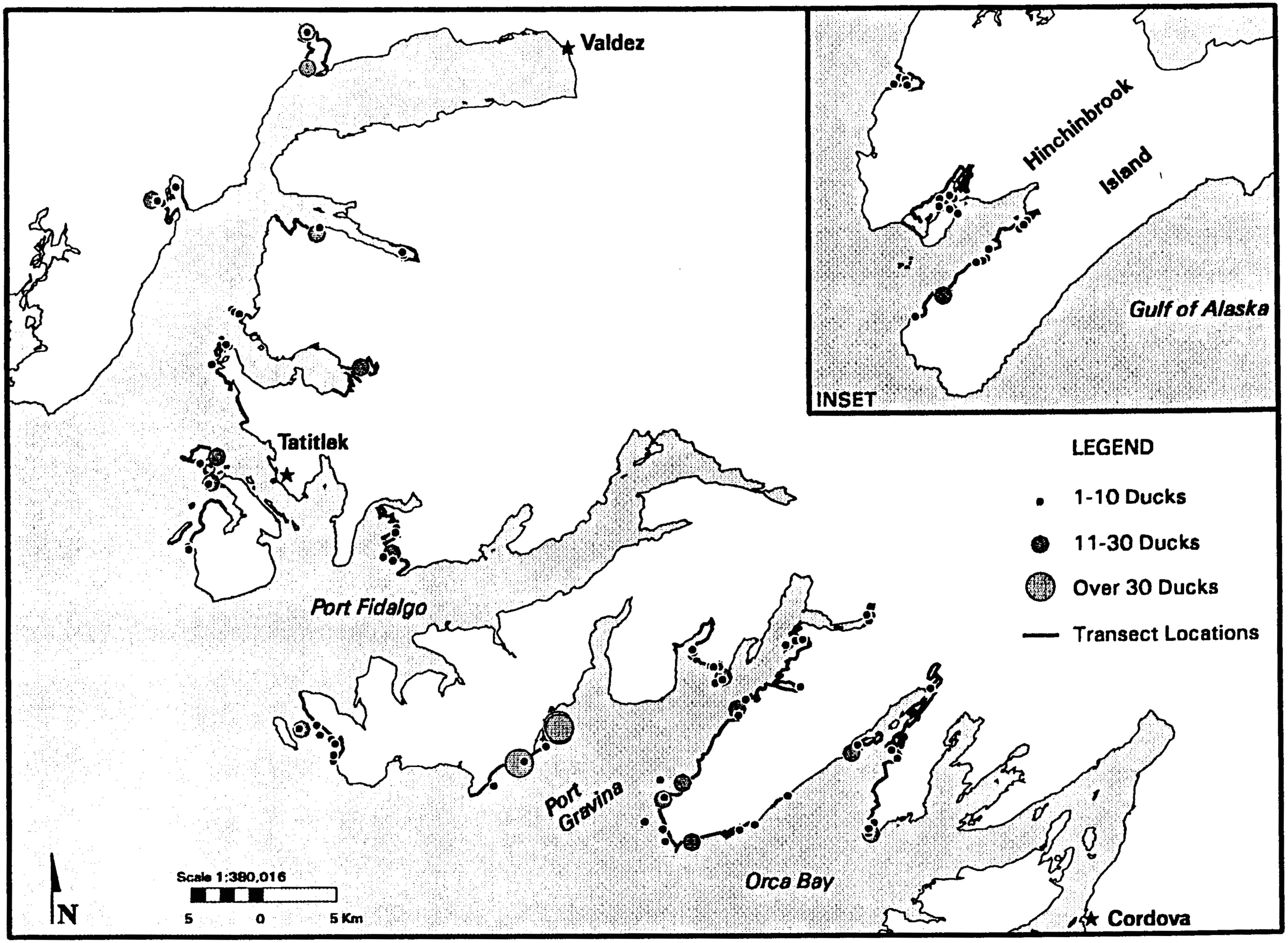
Locations of harlequin duck observations and relative abundance for three spring and three fall surveys in eastern and western Prince William Sound, Alaska in 1995.



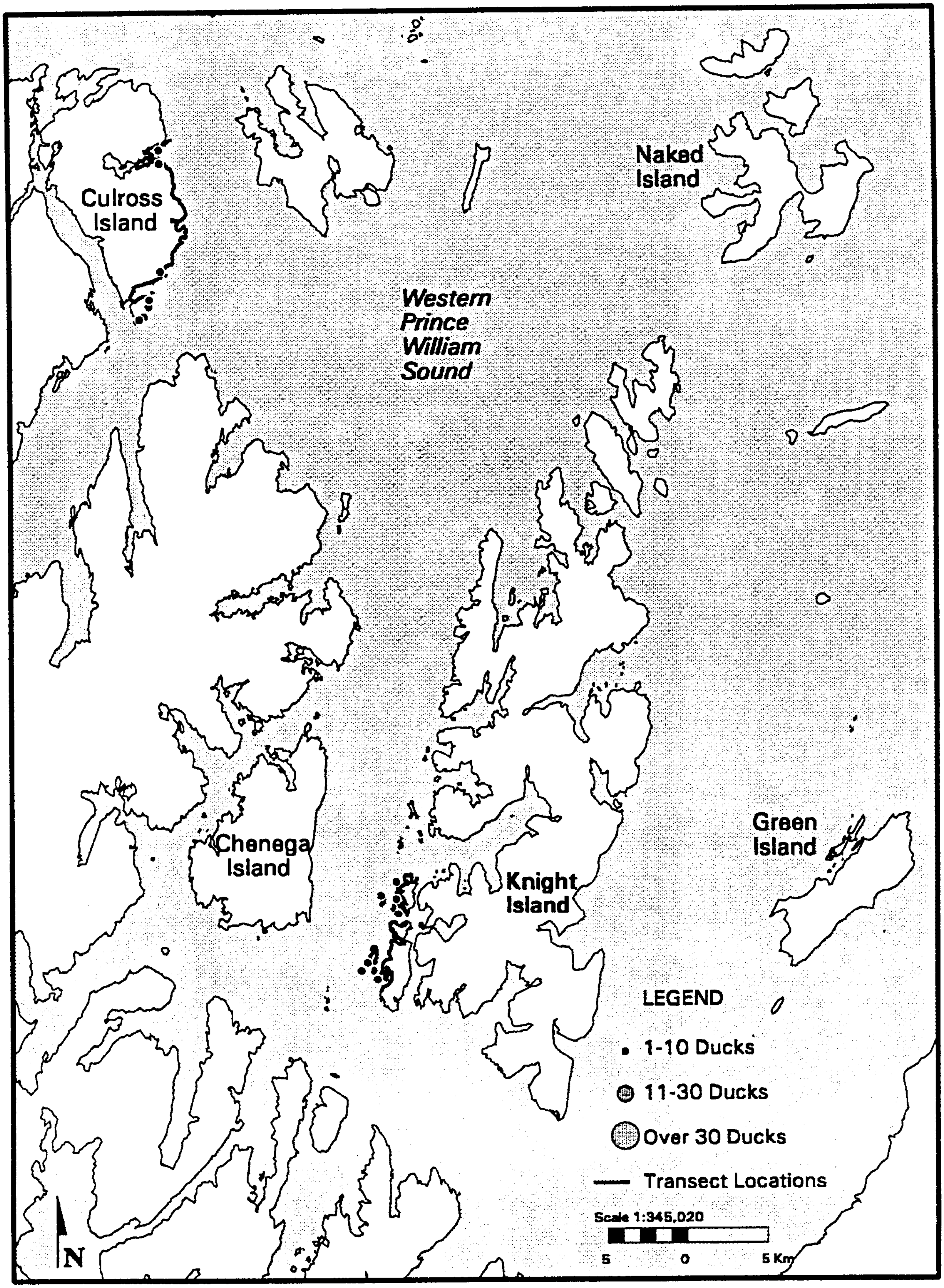
Appendix A1. Location of harlequin ducks observed in eastern Prince William Sound during the first spring survey (10 May-17 May) in 1995.



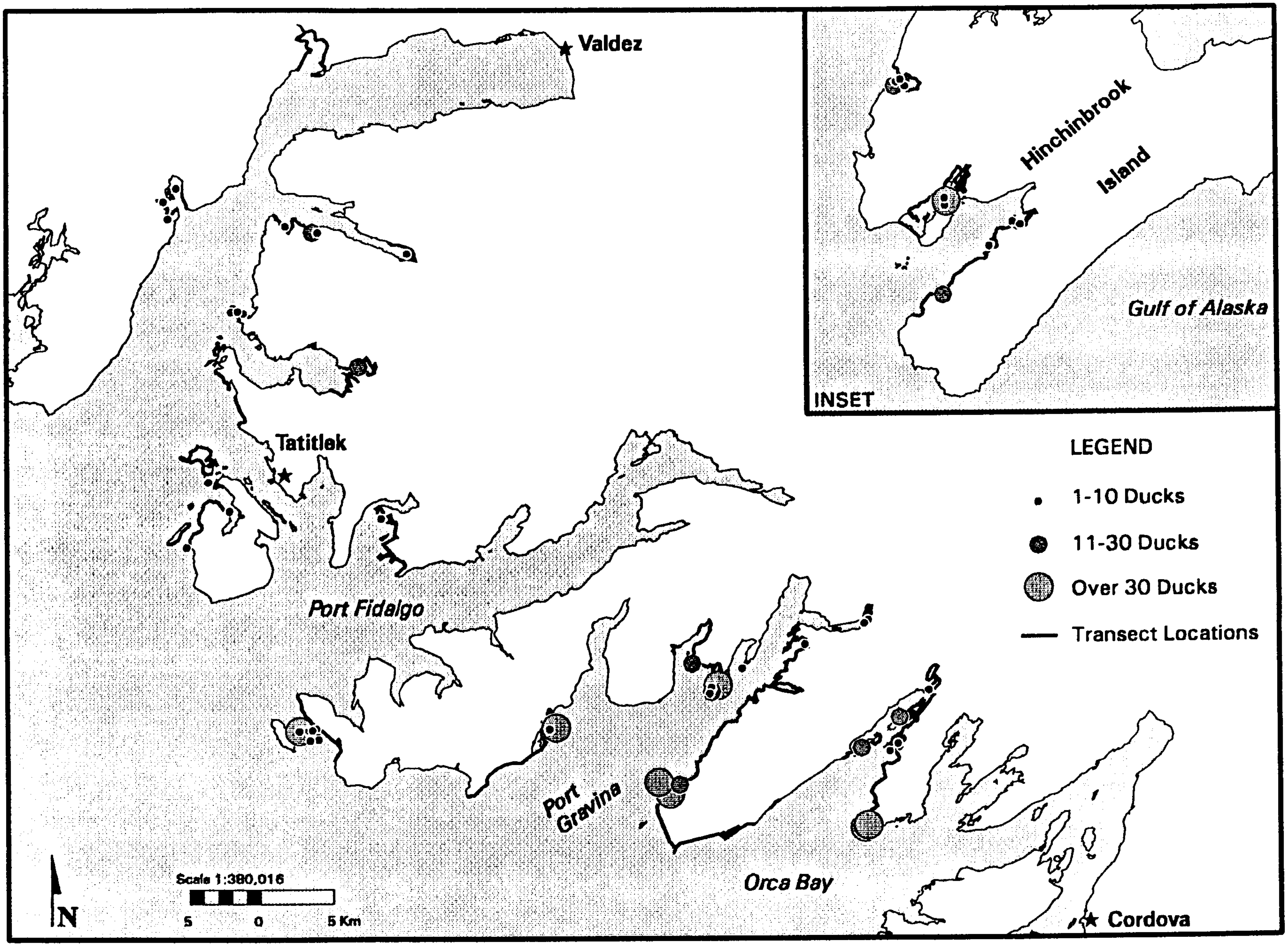
Appendix A2. Location of harlequin ducks observed in western Prince William Sound during the first spring survey (10 May-20 May) in 1995.



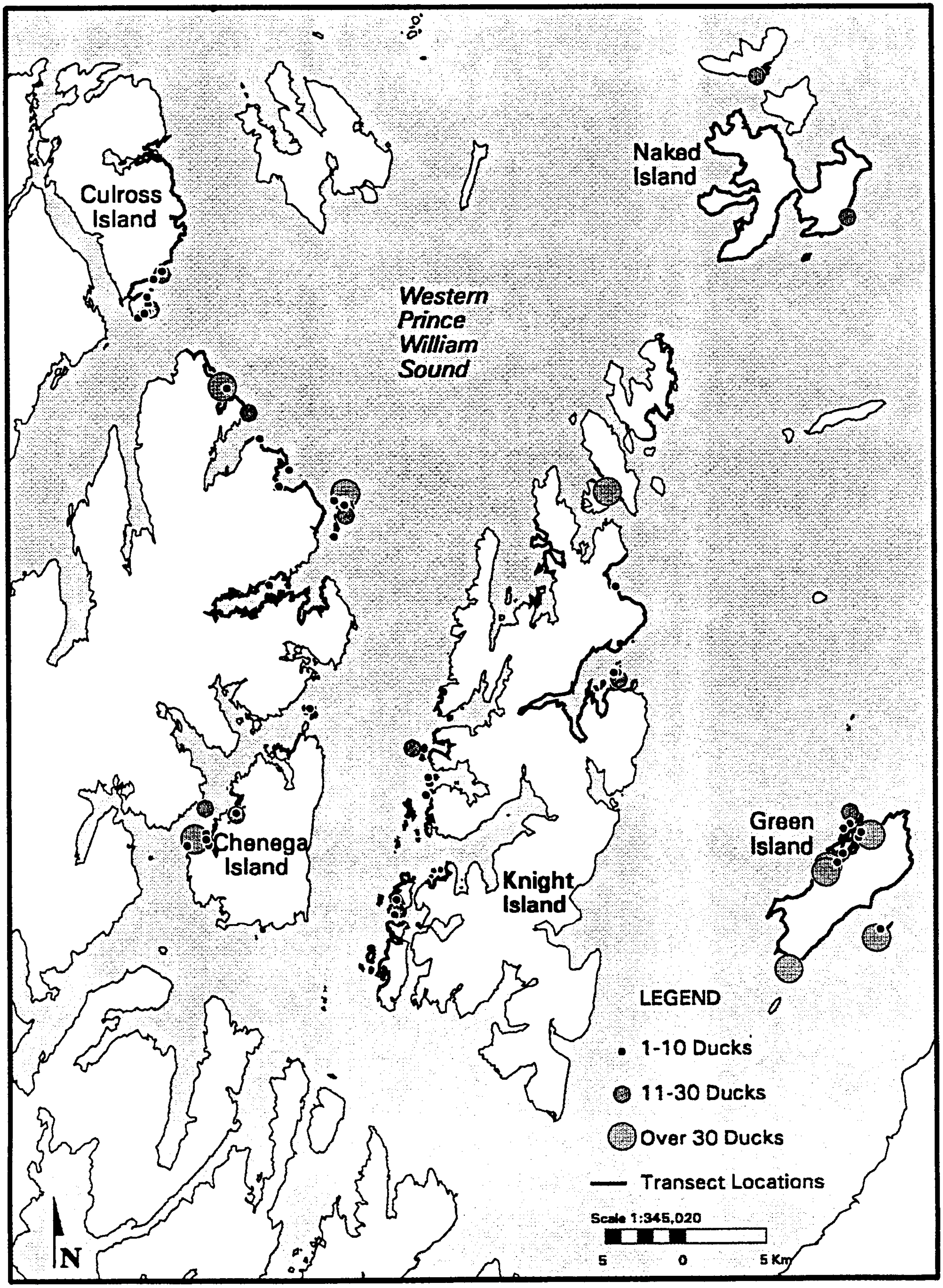
Appendix A3. Location of harlequin ducks observed in eastern Prince William Sound during the second spring survey (23 May-31 May) in 1995.



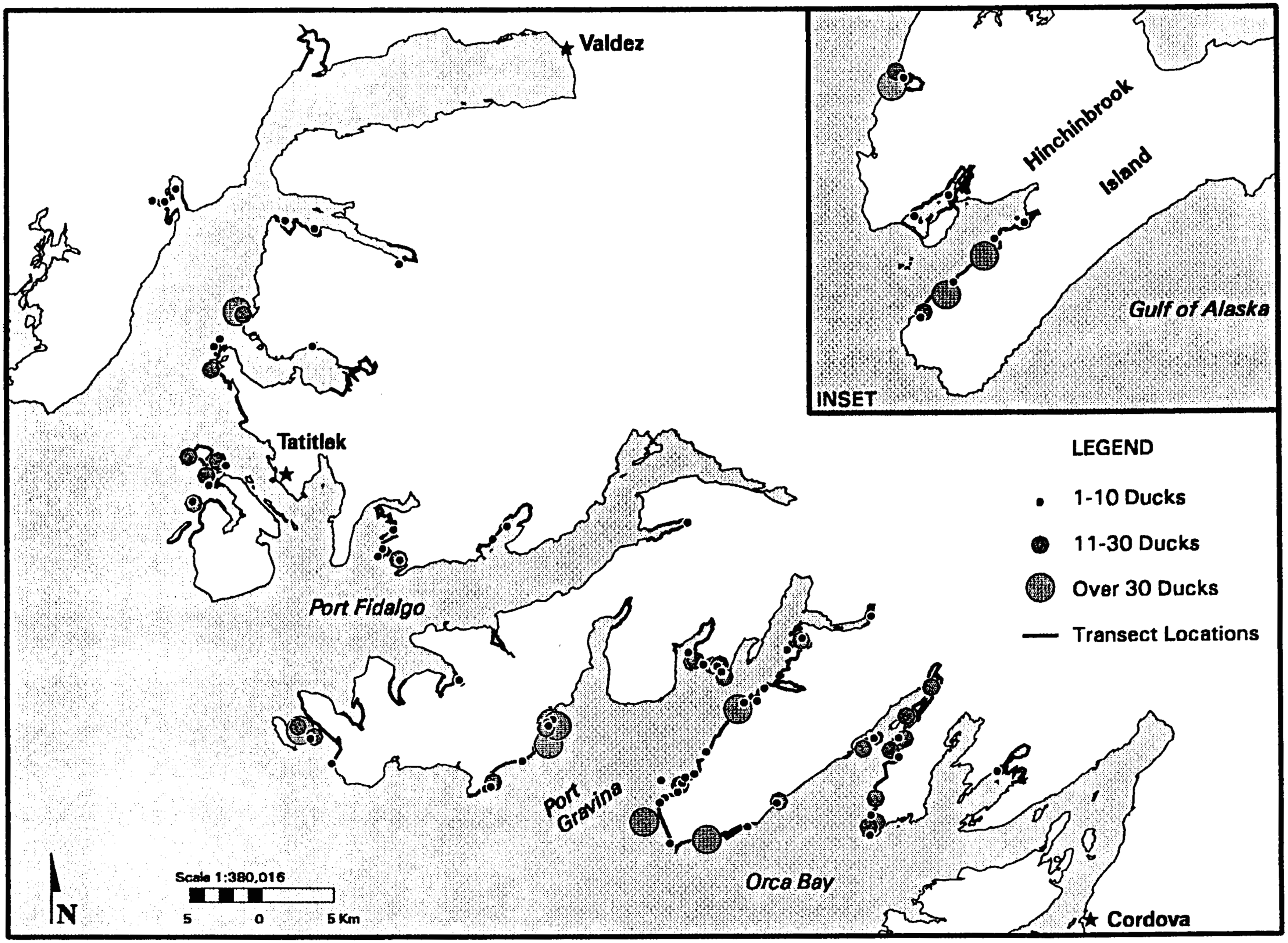
Appendix A4. Location of harlequin ducks observed in western Prince William Sound during the second spring survey (26 May-29 May) in 1995. Survey coverage was not completed because of poor weather.



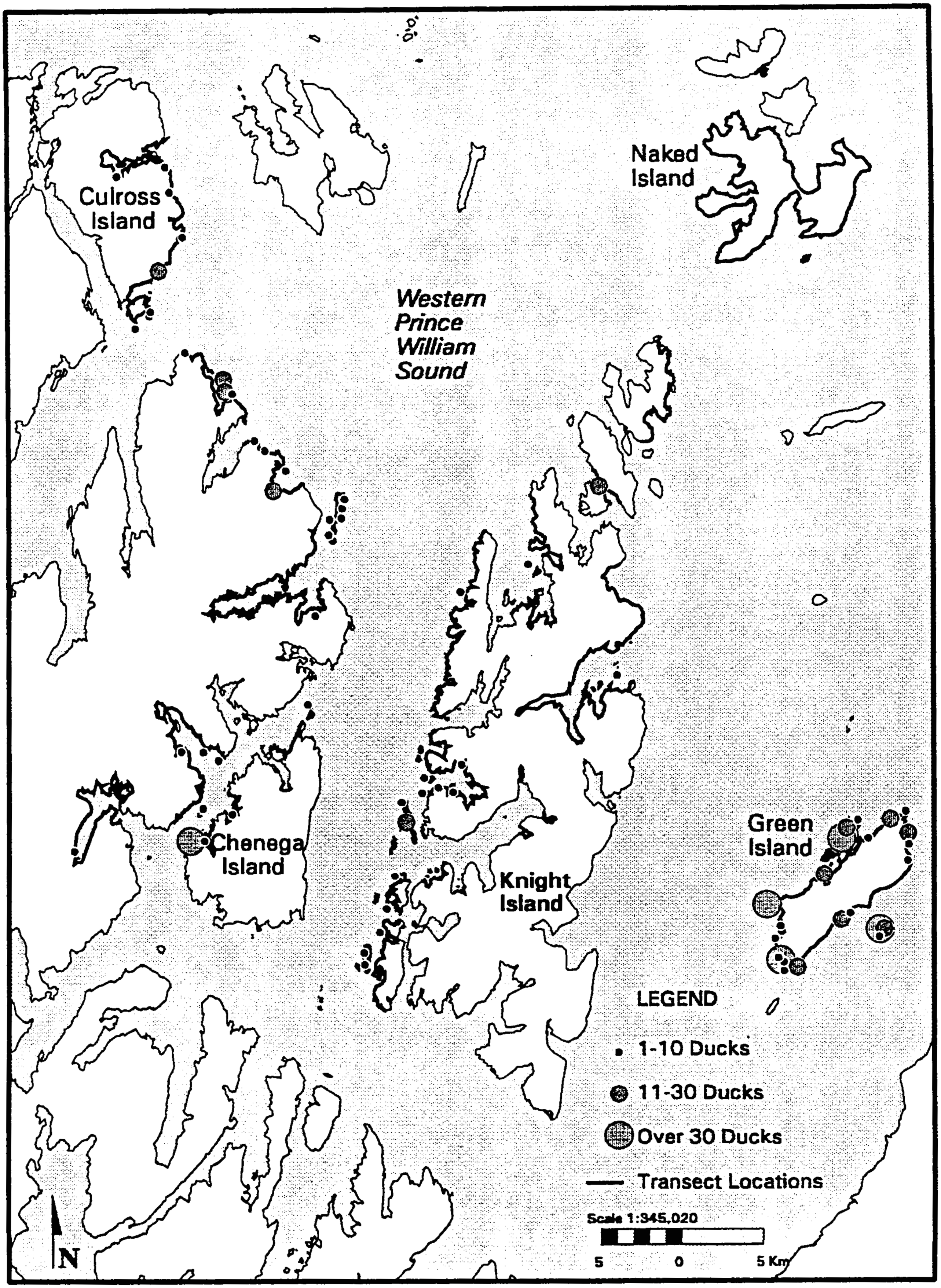
Appendix A5. Location of harlequin ducks observed in eastern Prince William Sound during the third spring survey (10 June-16 June) in 1995.



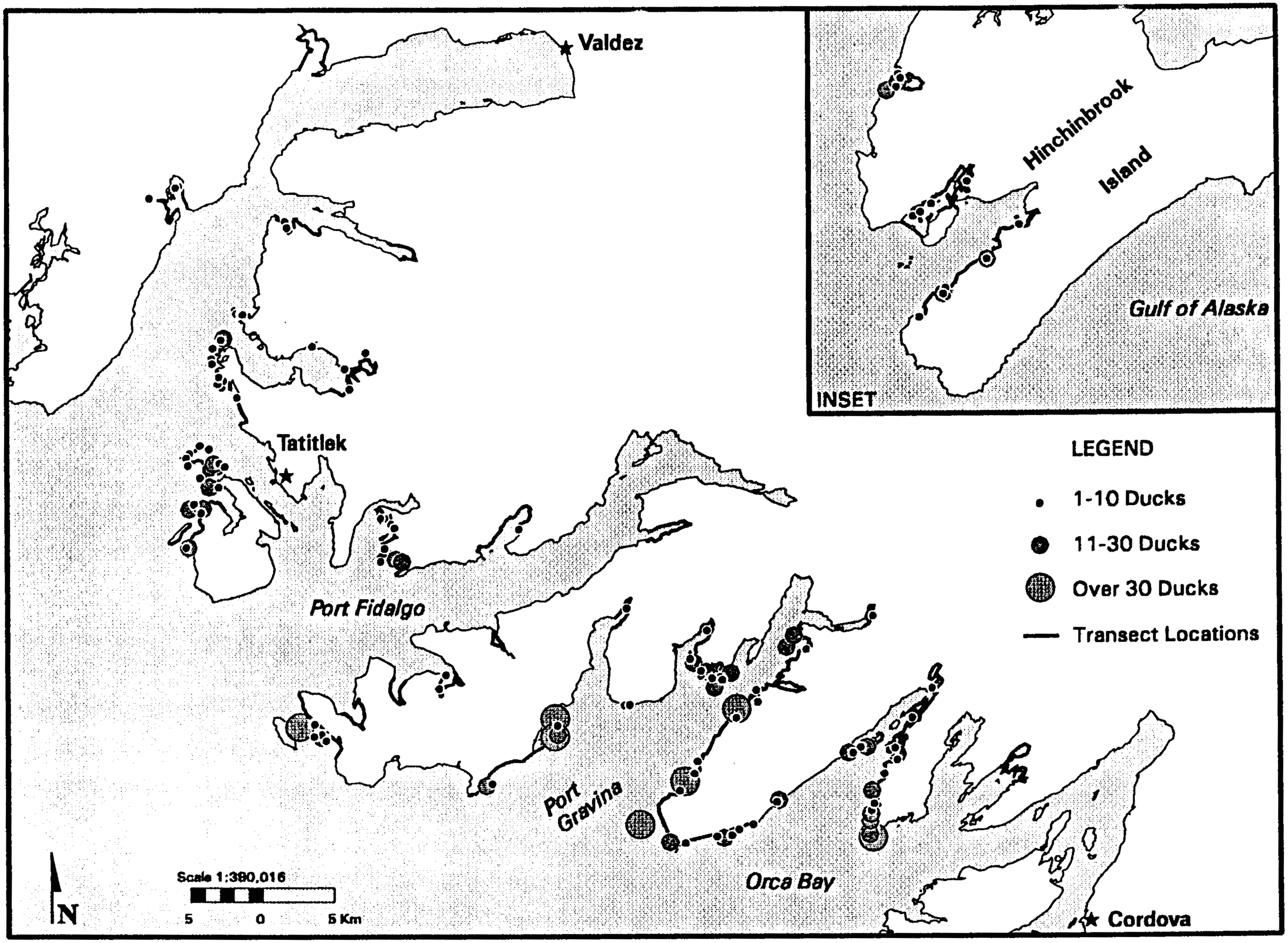
Appendix A6. Location of harlequin ducks observed in western Prince William Sound during the third spring survey (9 June-16 June) in 1995.



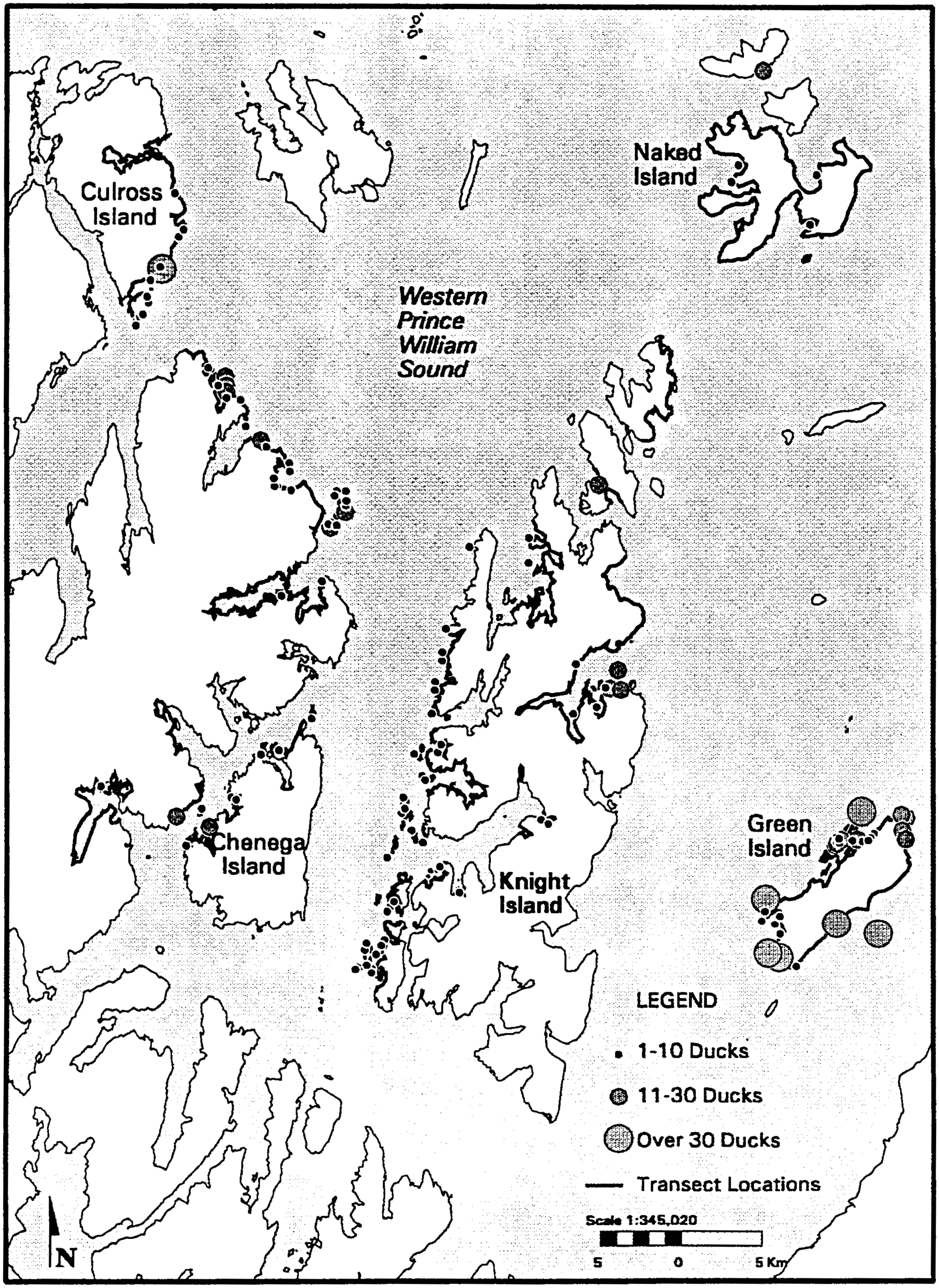
Appendix A7. Location of harlequin ducks observed in eastern Prince William Sound during the first fall survey (25 July-30 July) in 1995.



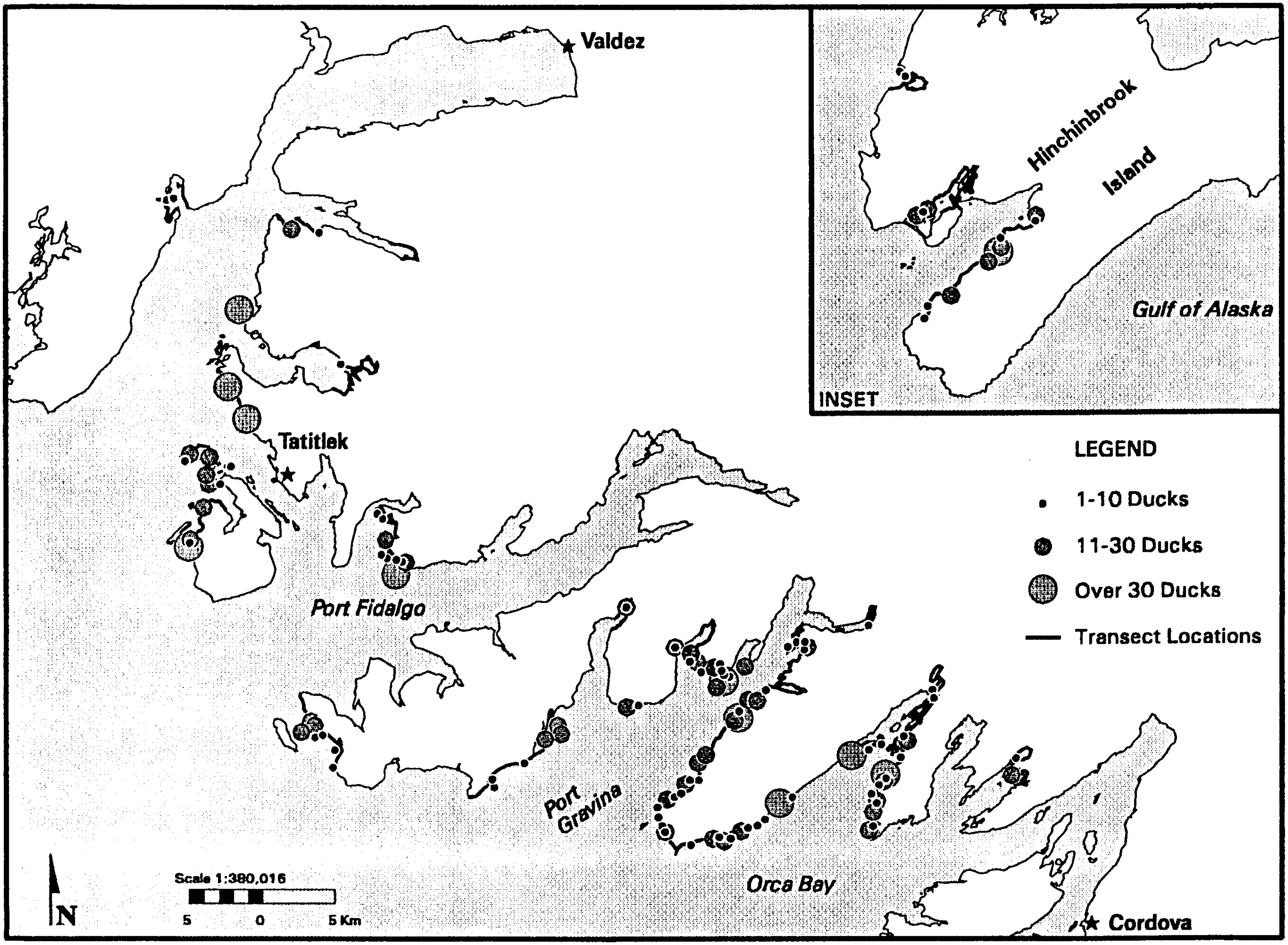
Appendix A8. Location of harlequin ducks observed in western Prince William Sound during the first fall survey (25 July-1 Aug.) in 1995.



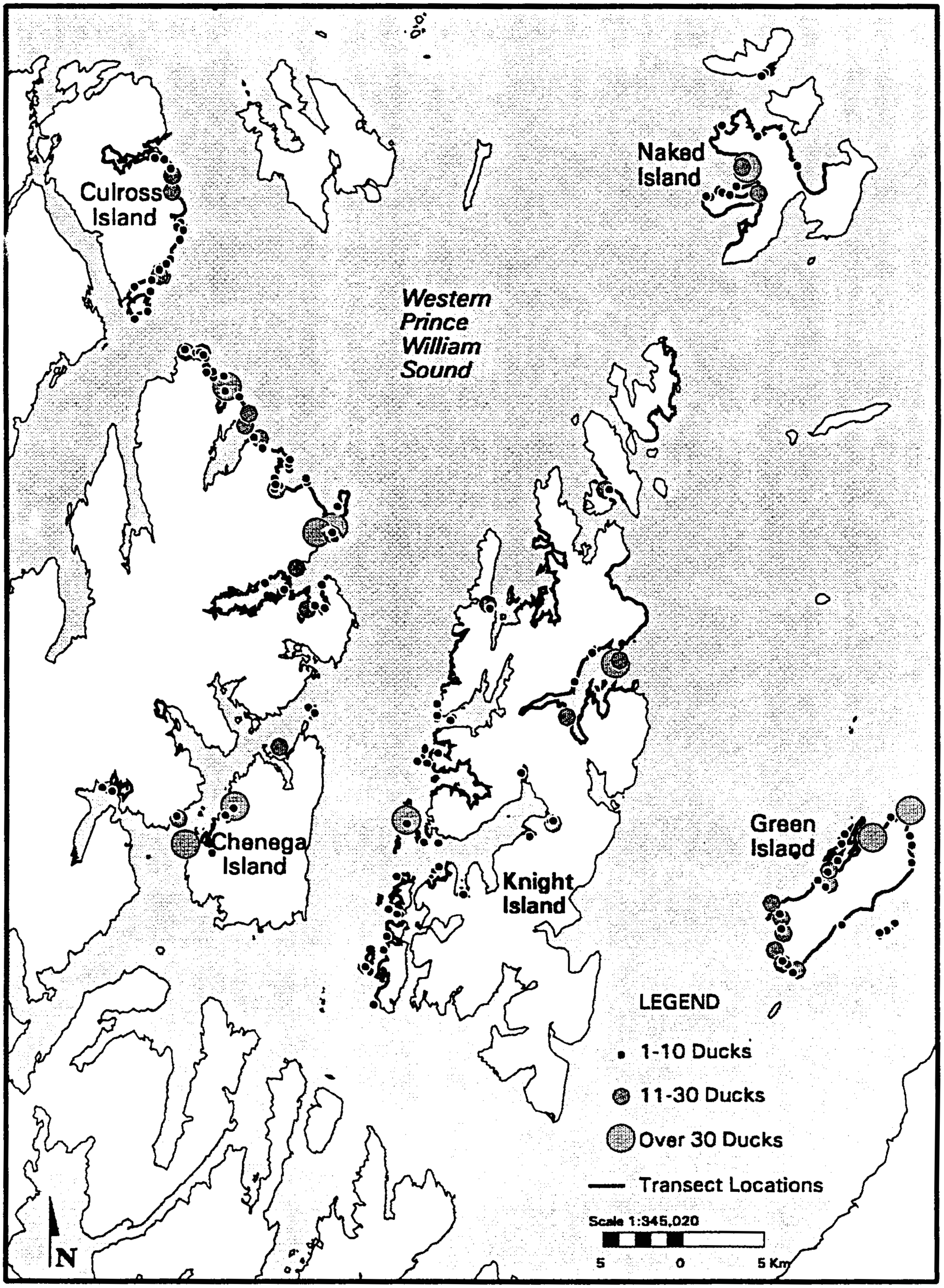
Appendix A9. Location of harlequin ducks observed in eastern Prince William Sound during the second fall survey (11 Aug.-17 Aug.) in 1995.



Appendix A10. Location of harlequin ducks observed in western Prince William Sound during the second fall survey (10 Aug.-18 Aug.) in 1995.



Appendix A11. Location of harlequin ducks observed in eastern Prince William Sound during the third fall survey (6 Sept.-12 Sept.) in 1995.



Appendix A12. Location of harlequin ducks observed in western Prince William Sound during the third fall survey (5 Sept.-14 Sept.) in 1995.